17 - COMPARISON OF MAXIMAL HEART RATE OBTAINED IN THREE DIFFERENT SITUATIONS

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INTRODUCTION

The maximal heart rate (HR_{max}) is defined as the highest heart rate (HR) reached during a maximal oxygen uptake (VO_{2max}) progressive test (ASTRAND *et al.*, 1973; ENGELS *et al.*, 1998; HAWKINS *et al.,* 2001; MILLER *et al.*, 1993; TANAKA *et al.*, 2001). However, Boudet *et al.* (2002) argue that there is not a consensus in relation to the definition of HR_{max} and also points out the lack of a reliable measurement protocol (BOUDET *et al.,* 2002; ROBERGS; LANDWEHR, 2002).

The HR_{max} is an important physiological variable commonly used as a reference of maximal effort intensity (FERNAHALL *et al.*, 2001; TANAKA *et al.*, 2001) as there is a linear relationship between HR and oxygen uptake (VO_2) under continuous activity with progressive intensity (ACSM 2003; JOHNSON *et al.*, 1991). Due to this relationship, it is admitted that at a given exercise intensity, the percentage of HR_{max} (%HR_{max}) corresponds to a certain VO_{2max} percentage (LONDEREE *et al.*, 1995).

Therefore, based on this linear relationship between HR and VO_2, we can use HR calculated as a %HR_{max} to control the intensity of a given physical activity, as well as for individualized prescription of physical training (COLLINS *et al.*, 1991; ENGELS *et al.,* 1998; LONDEREE *et al.*, 1995, TANAKA *et al.*, 2001, WHALEY *et al.*, 1992).

In several environments where physical activities are performed, such as in gyms, the application of maximal effort tests prove unfeasible for safety reasons (FERNAHALL *et al.,* 2001; TANAKA *et al.*, 2001). In these cases, submaximal exercise tests and equations to predict HR_{max} are safer and valuable in the prescription of physical activities (FERNAHALL *et al.,* 2001). However, such equations have a high error rate in predicting HR_{max} as it varies greatly from individual to individual (ROBERGS *et al.,* 2002). Among the equations to predict HR_{max}, the 220age equation is the most used to estimate HR_{max} (BOUDET *et al.,* 2002; ENGELS *et al.,*1998; FERNAHALL *et al.*, 2001; MILLER *et al.*, 1993; RICARD *et al.,* 1990; ROBERGS *et al.*, 2002; TANAKA *et al.,* 2001; WHALEY *et al.,* 1992) and is often presented in textbooks without scientific references to support its utilization (ROBERGS *et al.,* 2002). HR_{max} obtained through this equation can be either maximal for some individuals, unattainable for others or submaximal for the rest (WHALEY *et al.,* 1992), and an error range of 10 to 12 bpm is suggested for this estimative (ACSM, 2003; BOUDET *et al.*, 2002; HOWLEY *et al.*, 1995; JOHNSON *et al.,* 1991; ROBERGS *et al.*, 2002).

As this variable depends on each individual, maximal and specific tests are recommended for a reliable measurement of HR_{max} (BOUDET *et al.*, 2002; LONDEREE *et al.*, 1982; TANAKA *et al.,* 2001; ZAVORSKY *et al.*, 2000) or even recording the highest HR during an actual competition, as performed by Deutsch *et al.* (1998) e Mohr *et al.* (2004).

The above-mentioned studies show some disagreement on the ideal situation to determine HR_{max}. Therefore, the goal of the present study is to compare the HR_{max} of Futsal players obtained in three different situations: competition (HR1), 220age equation (HR2), and maximal subjective effort test (HR3).

METHODS

Subjects

The study was conducted during the 2002 Minas Gerais State Championship. The subjects of this study were ten adult female futsal athletes (TABLE 1) belonging to the team that had won the Metropolitan Championship title the same year.

TABLE 1. Age, body mass (BM), height (H), body fat percentage (%fat), and aerobic capacity (VO_{2max}) of volunteers. Values given as average and standard deviation.

n	Age (years)	BM (kg)	H (cm)	%fat	VO_{2max} ($mL.kg^{-1}.min^{-1}$)
10	19.5	57.1	161.0	23.7	40.0
	± 1.6	± 6.5	± 3.8	± 4.4	± 3.8

This study respected all standards established by the National Health Council (Res. 196/96) involving research with human beings. Federação Mineira de Futsal (Minas Gerais State Futsal Federation), the institution in charge of organizing Minas Gerais' Women's Futsal Championship, and the athletes' team agreed with the use of heart rate monitors during the matches. Either the volunteer athletes or their legal tutors signed a Free and Informed Consent Agreement and acknowledged to be aware of the goals and the methods used and of the possibility of quitting the study at any time without further justification.

Procedures

In order to measure HR_{max} during matches and maximal test, the volunteers used a Polar Vantage® heart rate monitor. It consists of a pulse monitor and a transmitter strip. HR was recorded and stored every five seconds and the data were transferred to a computer through a Polar interface and treated later.

The maximal progressive test on a bicycle ergometer (ACSM, 1995) consisted in 2-minute stages starting with a load of 50W in the first stage and an increase of 25W at each subsequent stage until exhaustion. Verbal stimulus was given during the whole test so that the athletes could really reach their maximal performances, which was evaluated with the Borg scale (BORG,1982). This test was used to estimate the aerobic capacity and determine the volunteers' HR_{max}.

HR1 was taken as the highest HR reached by each athlete during the two official matches played.

HR2 was estimated using the equation HR_{max} = (220 age).

HR3 was taken as the highest HR measured during the maximal progressive test (ACSM, 1995), as previously described.

The HR_{max} values obtained in the three conditions were compared.

Statistical Analysis

Wilcoxon Rank Sum non-parametric test was used to compare the three variables (HR1, HR2 and HR3) with the help of MINITAB software. Pearson's correlation between the three variables was also performed by using SPSS® software, version 10.0. Significance level of $p<0.05$ was adopted for all statistical analyses. The data are given as average and standard deviation.

RESULTS

TABLE 2 shows the results of comparisons between the three variables (HR1, HR2, HR3). Although no difference was found between HR1 and HR3, we observed that HR_{max} at competition presented higher absolute values for 8 out of the 10 athletes evaluated when compared with their respective test HR_{max} values.

TABLE 2 - HR_{max} (bpm) of a group of 10 volunteer athletes obtained in three different conditions.

VOLUNTEER	FC1	FC2	FC3
1	190	200	164
2	209	201	202
3	188	201	176
4	198	196	178
5	204	200	187
6	185	198	195
7	203	200	172
8	213	201	204
9	183	199	198
10	205	201	192
AVERAGE	**198**	**200**	**187***
SD	**11**	**2**	**14**

** Significant difference (p0.05) in relation to HR2.*

No significant correlation ($p>0.05$) was found between variables HR1 and HR2 ($r=0.40$), HR2 and HR3 ($r=0.17$), and HR1 and HR3 ($r=0.31$).

DISCUSSION

Several methods are proposed to determine HR_{max}. Maximal tests, estimates with equations, and in minor proportion measurements during practice are used for the determination of HR_{max}. The variety of methods used evidence a certain methodological inconsistency.

This inconsistency in the determination of HR_{max} is reinforced by findings such as those of Deutsch *et al.* (1998), Gleim *et al.* (1981) and Reilly & Keane (2002) who found values of HR_{max} at competition higher than results of maximal exercise stress tests performed in the laboratory with rugby, american football, and soccer athletes, respectively. This is partly consistent with the findings of the present study, in which 8 out of the 10 evaluated athletes (80%) presented higher HR1 values as compared to HR3. Thus, although the results of this comparison have not shown a significant general difference ($p=0.06$), we can infer that if a larger number of athletes had been evaluated, a difference between HR_{max} at competition and the test HR_{max} might have been found.

Additionally, Palmer *et al.* (1994) found that 85% of their subjects showed a higher HR_{max} at competition than in the test; however, their results, as well as those of the present study, are not sufficient to identify statistical differences. According to the same author, such values can be physiologically significant, and therefore may cause a training load error if HR_{max} is measured in laboratory. Following this supposition, Mohr *et al*. (2004) adopted the largest HR value found in matches when evaluating the intensity of a football match through HR relativized as $\%HR_{max}$ as HR_{max}.

Possibly, the higher HR_{max} reached at competition comparatively to laboratory test results arose from either motivation, or the stress involved in the activity, and/or from the competitiveness of sports (BOUDET *et al*., 2002). The lack of motivation of the athletes in maximal incremental tests can also prevent them from reaching their maximum possible effort, leading to HR_{max} erroneous measurements (LONDEREE *et al*., 1982). Thus, HR_{max} in test may be underestimated in relation to competition measurements.

The previously mentioned studies leave room for doubt on possibly overestimated effort intensity in some sports. Therefore, if test HR_{max} is lower than the real HR_{max} reached during an activity, its average intensity determined as $\%HR_{max}$ will be overestimated. Such overestimation could lead to an error in the athlete's training load (ACSM, 2003).

Another conflicting factor when determining HR_{max} is the low applicability in large-scale of maximal tests to evaluate physical aptitude, which can bring risks to the tested individuals (TANAKA *et al.*, 2001; FERNAHALL *et al.*, 2001). Aiming at improving the safe prescription of physical activities for individuals with different levels of aptitude, usually HR_{max} is determined by a submaximal test or equations (ENGELS *et al.*, 1998, FERNAHALL *et al.*, 2001).

Based on the present study, in which HR2 was higher than HR3, and the study by Parson *et al*. (2005), which compared HR_{max} in women estimated by the 220age equation with the value measured by bicycle ergometer maximal test, it can be said that the 220age equation overestimates the test HR_{max}. Therefore, it would be more recommendable to use maximal tests to measure instead of estimating HR_{max} (ACSM, 2003; BOUDET *et al.*, 2002; RICARD *et al.,* 1990; TANAKA *et al.*, 2001; ZAVORSKY *et al.*, 2000).

Concerning the 220age equation, it can also be said that it is not a reliable predictor of HR_{max} at competition (BOUDET *et al.*, 2002). No statistical difference was observed between HR1 and HR2 in the present study, which would make HR2 a good predictor of HR_{max} at competition. However, as the age of the experimental subjects is relatively homogeneous (SD 2), HR1 presented a variability (SD 11) deemed high in studies with similar variation values (ACSM, 2003; BOUDET *et al.*, 2002; HOWLEY *et al.*, 1995; JOHNSON *et al.*, 1991; ROBERGS *et al.*, 2002; WHALEY *et al.*, 1992). There was no correlation between HR1 and HR2 either, suggesting that the use of this equation to estimate HR_{max} is questionable and should be considered on an individual basis.

CONCLUSIONS

- Due to the high individual variation of $HR_{max,}$ it would be preferable to measure HR_{max} either in laboratory tests or at competitions instead of estimating it with the 220age equation.
- Measurement by standardized laboratory tests may underestimated HR_{max} in relation to competition values

possibly due to the poor motivation of the athletes in artificial laboratory test conditions.

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ABSTRACT

Comparison of maximal heart rate obtained in three different situations. Purpose: Compare Futsal players' HR_{max} obtained in three different situations: competition (HR1), 220age equation (HR2), and maximal incremental test (HR3). **Methods:** Ten female athletes (161.0 3.8 cm height; 17.20 19.5 years; 23.7 4.4% body fat; 40.0 3.8 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ VO_{2max}) belonging to a futsal team from Belo Horizonte that had won the 2002 Metropolitan Championship were evaluated. To measure HR_{max} during the matches and during the maximal incremental test, the volunteers used a Polar Vantage® heart rate monitor. HR1 was taken as the highest HR of each player during matches. HR2 was estimated using the following equation: HR_{max} = (220 age). HR3 was determined as the highest HR recorded during a maximal incremental test until fatigue performed on a bicycle ergometer. Wilcoxon Rank Sum and Pearson Chi-Square tests were used in statistical analysis with significance level of $p<0.05$. **Results:** HR2 (200 2 bpm) was higher than HR3 (187 14 bpm), $p<0.05$. HR1 (198 11 bpm) was not different from either HR2 or HR3. There was no significant correlation between variables HR1, HR2, and HR3. We observed that competition HR_{max} presented higher absolute values for 8 of the 10 athletes evaluated when compared to test HR_{max}. **Conclusion:** HR_{max} measurements during standardized tests performed in laboratory may be underestimated in relation to competition values. This may be due to the fact that the tests represent an artificial situation for the athletes, who do not feel as motivated as during competitions. Due to the high individual variation of HR_{max}, it would be preferable to measure it either in laboratory tests or during competition instead of estimating it using the (220 - age) equation. **Keywords**: Maximal Heart Rate,

Intensity, Futsal.

RESUME

Comparaison de la fréquence cardiaque maximale obtenue dans trois situations différentes. L'objectif : Comparer le FC_{max} des joueurs de futsal qui ont été obtenus dans trois situations différentes : compétition (FC1), équation (FC2) et test d'effort maximal (FC3). **Les méthodes** : Elle concerne dix sportives (161,0 3,8 cm de hauteur ; 17,20 19,5 années ; 23,7 4,4% de graisse et VO_{2max} de 40,0 3,8 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$) qui appartiennent à l'équipe de futsal de Belo Horizonte (Brésil). Le cardio-fréquencemètre Polar Vantage® a été utilisé pour mesurer le FC_{max} pendant les entraînements et aussi durant le test d'effort physique maximal. Le FC1 représente la valeur maximum enregistrée de chaque joueuse pendant les compétitions ; le FC2 représente la valeur calculée en fonction de l'âge $FC_{máx}$= (220-l'âge) et le FC3 représente la valeur la plus grande enregistrée pendant le test d'effort progressif et maximum, sur un vélo ergonomique. Les tests statistiques de Wilcoxon et de corrélation de Pearson ont été utilisés pour l'interprétation des fréquences, en acceptant le degré de signification $p<0,05$. **Les résultats** : La différence entre FC2 (200 2 bpm) et FC3 (187 14 bpm) a été significative, $p<0,05$. Le FC1 (198 11 bpm) n'a été pas différent des FC2 et FC3. Il n'y a pas une corrélation significative parmi les variables FC1, FC2 et FC3 ($p>0,05$). On a observé que les $FC_{máx}$ de compétition présentaient des valeurs absolues plus grandes que les $FC_{máx}$ d'effort pour 8 sur 10 sportives contrôlées. **La conclusion:** Le FC_{max} mesuré pendant les tests standardisés qui sont réalisés dans les laboratoires peut être sous-estimé par rapport à celui obtenu pendant les compétitions, peut-être parce que les tests représentent une situation artificielle pour les athlètes, lesquelles ne sentent pas autant motivées. Comme le FC_{max} individuel est très variable on peut faire l'hypothèse que les évaluations obtenues pendant les compétitions ou les tests d'effort seront plus valables qui celles estimées par la formule 220 l'âge.

Mots-clefs : Fréquence cardiaque maximale, intensité, futsal.

RESUMEN

Comparación de la frecuencia cardíaca máxima obtenida en tres situaciones diferentes. Objetivo: Comparar la $FC_{máx}$ de jugadoras de Futsal obtenida en tres situaciones diferentes: en competición (FC1), con la ecuación (FC2) y con la prueba de esfuerzo máximo subjetivo (FC3). **Métodos**: Se evaluaron 10 atletas de sexo femenino (estatura de 161,0 3,8 cm; 17,20 19,5 años; 23,7 4,4% de grasa; $VO_{2máx}$ de 40,0 3,8 $mLO_2 \cdot kg^{-1} \cdot mín^{-1}$) de un equipo de futsal de Belo Horizonte. Para medir la $FC_{máx}$ durante los partidos y la prueba de esfuerzo máximo, las voluntarias usaron un cardiofrecuencímetro. La FC1 fue considerada como el valor mayor de FC para cada jugadora durante los partidos. La FC2 se calculó resolviendo la ecuación $FC_{máx}$= (220 edad). La FC3 se determinó como el valor mayor de FC registrada durante una prueba de esfuerzo máximo y progresivo, realizado en cicloergómetro. Para el análisis estadístico se empleó la prueba de Wilcoxon y la correlación de Pearson. El nivel de significancia adoptado fue de $p<0,05$. **Resultados**: La FC2 (200 2 bpm) fue superior a FC3 (187 14 bpm), $p<0,05$. La FC1 (198 11 bpm) fue igual a la de la FC2 y la FC3. No hubo correlación significativa entre las variables FC1, FC2 y FC3 ($P>0,05$). Se observó que la $FC_{máx}$ de competición presentó valores absolutos mayores en 8 de las 10 atletas evaluadas cuando se compara a la $FC_{máx}$ de prueba. **Conclusión**: La $FC_{máx}$ medida durante pruebas estandarizadas realizadas en laboratorio puede ser subestimada si se la compara a la que se midió durante actividades competitivas. Quizás se deba a que, para los atletas, las pruebas representen una situación artificial y no se sientan tan motivados como durante las competiciones. Debido a la alta variabilidad individual de la $FC_{máx,}$ sería preferible medirla en una prueba o durante un partido en lugar de calcularla resolviendo la ecuación 220 edad.

Palabras clave: Frecuencia Cardíaca Máxima, Intensidad, Futsal.

RESUMO

Comparação da freqüência cardíaca máxima obtida em três diferentes situações. Objetivo: Comparar a $FC_{máx}$ de jogadoras de Futsal obtida em três diferentes situações: Competição (FC1), equação (220 idade) (FC2) e teste de esforço máximo subjetivo (FC3). **Métodos:** Foram avaliadas 10 atletas do sexo feminino (estatura de 161,0 3,8 cm; 17,20 19,5 anos; 23,7 4,4% de gordura; $VO_{2máx}$ de 40,0 3,8 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$) pertencentes a um time de futsal de Belo Horizonte, que conquistou o título de Campeão Metropolitano de 2002. Para medir a $FC_{máx}$ durante os jogos e o teste de esforço máximo, as voluntárias utilizaram um cardiofreqüencímetro Polar Vantage®. A FC1 foi considerada como o maior valor de FC para cada jogadora durante os jogos. A FC2 foi estimada utilizando-se a equação $FC_{máx}$= (220 idade). A FC3 foi determinada como o maior valor de FC registrada durante um teste de esforço máximo e progressivo até a fadiga, realizado em cicloergômetro. Para a análise estatística foi utilizado o teste Soma de Postos Wilcoxon e correlação de Pearson. O nível de significância adotado foi de $p<0,05$. **Resultados:** A FC2 (200 2 bpm) foi maior que FC3 (187 14 bpm), $p<0,05$. A FC1 (198 11 bpm) não foi diferente da FC2 e da FC3. Não houve correlação significativa entre as variáveis FC1, FC2 e FC3. Foi observado que a $FC_{máx}$ de competição apresentou maiores valores absolutos em 8 das 10 atletas avaliadas quando comparada a $FC_{máx}$ de teste. **Conclusão:** A $FC_{máx}$ medida durante testes padronizados realizados em laboratório pode ser subestimada em relação àquela medida durante atividades competitivas, talvez porque os testes representem uma situação artificial para os atletas, que não se sentem tão motivados quanto durante competições. Devido à alta variabilidade individual da $FC_{máx,}$ seria preferível medi-la em teste ou competição ao invés de estimá-la pela equação 220 idade.

Palavras-chave: Freqüência Cardíaca Máxima, Intensidade, Futsal.