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ORIGINAL ARTICLE

A new age-based equation for predicting maximum heart rate in endurance-trained runners

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KEYWORDS
Cardiovascular system;
Exercise test;
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Running

Abstract This study aimed to generate an age-based maximum heart rate (HR_{max}) equation for endurance-trained runners. Thirty-four male runners performed three tests on a motorized treadmill, starting at 8 km h^{-1} with increments of 1 km h^{-1} every 1, 2 or, 3 min. HR_{max} was defined as the highest heart rate value recorded during each test. *Post hoc* analyses indicated that the HR_{max} derived from each test was significantly lower than the highest HR_{max} value, for each participant. HR_{max} predicted by ''$206 - 0.7 \times$ age'' underestimated the highest HR_{max} by 8.6 beats min^{-1}. Thus, the generated age-based ''$218 - 0.8 \times$ age'' equation should be used to predict HR_{max} in endurance-trained runners.

PALAVRAS-CHAVE
Sistema cardiovascular;
Teste físico;
Resistência física;
Corrida

Uma nova equação baseada em idade para predição da frequência cardíaca máxima em corredores aerobiamente treinados

Resumo Esse estudo objetivou gerar uma equação de frequência cardíaca máxima (FC_{max}) baseada na idade para corredores aerobiamente treinados. Trinta e quatro corredores homens realizaram três testes incrementais em esteira motorizada, com início a 8 km·h^{-1} e incrementos de 1 km·h^{-1} a cada um, dois ou, três minutos. A FC_{max} foi definida como o valor mais alto de frequência cardíaca registrado em cada teste. As análises de *post hoc* indicaram que a FC_{max} de cada teste foi significativamente menor que o valor mais elevado de FC_{max} para cada

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participante. A FC_{max} predita pela equação ''206 − 0,7 x idade'' subestimou a mais alta FC_{max} em 8,6 batimentos·min^{-1}. Logo, a equação gerada baseada em idade ''218 − 0,8 x idade'' deveria ser usada para predizer a FC_{max} em corredores aerobiamente treinados.

PALABRAS CLAVE
Sistema cardiovascular;
Prueba física;
Resistencia física;
Carrera

Una nueva ecuación basada en la edad para pronosticar la frecuencia cardíaca máxima en corredores entrenados en resistencia

Resumen El objetivo de este estudio fue generar una ecuación de la frecuencia cardíaca máxima ($FC_{máx}$) basada en la edad en corredores entrenados en resistencia. Treinta y cuatro corredores de sexo masculino realizaron 3 pruebas en una cinta ergométrica motorizada, comenzando con la velocidad de 8 km/h^{-1} con incrementos de 1 km/h^{-1} cada uno, 2 o 3 min. La $FC_{máx}$ fue definida como el valor de la frecuencia cardíaca más elevada registrada durante cada prueba. Los análisis posteriores indicaron que la $FC_{máx}$ derivada de las pruebas fue considerablemente más baja que el valor más alto de la $FC_{máx}$ de cada participante. La $FC_{máx}$ pronosticada por la ecuación «206-0,7 × edad», subestimada la más alta $FC_{más}$ por 8,6 lat/min^{-1}. Así, la ecuación generada basada en la edad «218-0,8 × edad» debería utilizarse para pronosticar la $FC_{máx}$ en corredores entrenados en resistencia.

Introduction

Maximal heart rate (HR_{max}) is one of the most commonly used values in clinical medicine and physiology (Tanaka et al., 2001) where it is used as a criterion for assessing maximal effort during graded exercise testing (Duncan et al., 1997; Howley et al., 1995) and can be used to prescribe appropriate exercise intensity (ACSM, 2006; Robergs and Landwehr, 2002). For these purposes, exercise and fitness professionals often use age-based equations to estimate HR_{max} (Engels et al., 1998; Sporis et al., 2011; Tanaka et al., 2001). However, several equations are available to estimate this value (Engels et al., 1998; Gellish et al., 2007; Graettinger et al., 1995; Inbar et al., 1994; Jones et al., 1985; Lester et al., 1968; Miller et al., 1993; Schiller et al., 2001; Sheffield et al., 1978; Tanaka et al., 1997; Whaley et al., 1992), including meta-analyses of published equations (Londeree and Moeschberger, 1982; Tanaka et al., 2001) and most of them differ widely in their estimates of HR_{max} (Londeree and Moeschberger, 1982). Additionally, these equations were derived from different populations and testing protocols, which can also affect the determination of this value.

HR_{max} is a protocol-dependent physiological variable that is expected to be higher in long-duration tests as compared to short-duration tests (Bishop et al., 1998; Roffey et al., 2007). Nevertheless, some age-based HR_{max} equations were generated using short protocols (Graettinger et al., 1995; Inbar et al., 1994; Schiller et al., 2001; Tanaka et al., 1997), following the suggestion of Buchfuhrer et al. (1983) to bring the subject to the limit of tolerance in 10 ± 2 min. In fact, Buchfuhrer et al. (1983) suggested that short duration protocols were best to obtain the highest maximal oxygen uptake (VO_{2max}) value, but not for attaining the highest HR_{max} value. This group also reported higher HR_{max} values in long (∼26 min) tests than in short (∼11 min) tests. These reports, therefore, suggest that age-based HR_{max} equations were generated using testing protocols that might not have been the most appropriate for attaining the highest value for HR_{max}. Additionally, one other shortcoming of the currently available age-based equations is that none of the previous studies derived a predictive equation by using the highest HR_{max} value obtained from two or more testing protocols, using the same individuals. Such a method could provide higher values for each subject and, consequently, higher values for the derived HR_{max} equation.

The incorrect prediction of HR_{max} may cause systematic errors in exercise prescriptions (Cleary et al., 2011). When HR_{max} is overestimated, the prescribed exercise intensity will be greater than needed to improve cardiovascular fitness. On the other hand, the underestimation of HR_{max} leads to lower stimulus that may not improve aerobic parameters. Thus, reducing the error associated with estimating HR_{max} would improve the accuracy of exercise prescriptions (Cleary et al., 2011), and improved estimates require the development and use of new equations designed for specific populations and modes of exercise (Robergs and Landwehr, 2002). Thus, the purpose of this study was threefold: (a) to compare three age-based HR_{max} equations derived for the same participants from each incremental test of different duration, (b) to derive an age-based HR_{max} equation for recreational endurance-trained runners from the highest HR_{max} value, for each participant, attained from the three incremental tests, and (c) to compare the generated equations with the well-known ''206 − 0.7 × age'' equation proposed by Tanaka et al. (2001) for recreational endurance-trained individuals. We hypothesized that the

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