EC CARDIOLOGY
Mini Review

The Equation for Maximal Heart Rate ”220-Age” Revisited: Is it Still Useful?

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Abstract

Introduction: The assessment of maximal heart rate (HRmax) based on the equation HRmax = 220-age has been a central parameter of exercise physiology and applied clinical sciences for almost a century. This equation is often presented without referencing the original research.

Objectives: Cardiorespiratory fitness (CRF) is an important clinical variable and can be associated with morbidity, mortality, reduced health-related quality of life, dysfunction, and loss of independence. CRF decreases with age, but the relationship between aging in years and CRF parameters is not so clear-cut. The problem with using the HRmax = 220-age equation is one of accuracy. Underestimating the maximal heart rate by just six beats per minute (bpm) results in an error of 350 mL/min in the estimated V02max. In other words, for a 75-kg person, this translates to an error of -8.3% or -4.7 mL/kg/min.

Methods: A literary review using keywords “maximum heart rate” in PubMed and Google Scholar studying the most cited and cross referenced articles.

Results: The HRMax = 220 is not based on original research.

Conclusion: Individualized testing prevents the errors of the old HRmax = 220-age equation both in clinical and athletic medicine.

Keywords: *Maximal Heart Rate; Cardiorespiratory Fitness; VO_2 Max; Maximal Oxygen Consumption; Wireless Heart Monitors*

Introduction

The assessment of maximal heart rate (HRmax) based on the equation HRmax = 220-age has been a central parameter of exercise physiology and applied clinical sciences for almost a century. This equation is often presented without referencing the original research, which is understandable because there was in fact no original research. The equation HRmax = 220-age has severe limitations and deserves to be revisited [1-6]. In the literature, HRmax = 220-age is frequently used with Heart Rate Reserve (HRR), devised by Karvonen [1]. However, the study of Karvonen did not assess HRmax. The modern origin for the HRmax = 220-age equation is Fox., *et al*. in 1971 [2]. However, Fox and colleagues admit that a simplistic formula such as 220-age cannot adequately capture the nuanced changes in cardiac maximal rate that occur with age. While this formula is handy and succinct, even those who proposed it admitted it did not accurately reflect the data points [2]. Robergs and Landwehr calculated and plotted data from the Fox manuscript, and in their linear regression not even then did HRmax = 220-age does not support the Fox equation [3]. Even now, 50 years later, there is still no equation that achieves the precision required for reliable clinical assessments.

Clinical implications

Cardiorespiratory fitness (CRF) is an important clinical variable and can be associated with morbidity, mortality, reduced health-related quality of life, dysfunction, and loss of independence. CRF decreases with age, but the relationship between aging in years and CRF parameters is not so clear-cut. In fact, the CRF declines with age, but not in a linear fashion and deterioration of this value accelerates after about the age of 45 years [4]. In the Aerobics Center Longitudinal Study (ACLS), 3,429 women and 16,889 men ranging in age from 20 to 96 years were asked to completed two to 33 different health examinations from 1974 to 2006 [4]. These data along with data from other epidemiologic sources have suggested that low CRF can be associated with hypertension, diabetes mellitus, metabolic syndrome, potentially life-threatening cardiovascular events, and cancer. In fact, a poor CRF score is associated with all-cause morality as well. Maximal oxygen consumption (VO_2max) is considered an important metric for health and fitness [4]. In fact, the U.S. Social Security Administration has defined disability, in part, by saying it occurs in anyone whose VO_2max < 18 mL/kg/min. $V0_2max$ can be assessed fairly easily and with good accuracy in both the general population as well as in a clinical or rehabilitation setting using the submaximal step test [5]. The Young Men's Christian Association (YMCA) method uses the HRmax = 220-age equation to estimate VO_2max but results were not always reliable. The problem with using the HRmax = 220-age equation is one of accuracy. Underestimating the maximal heart rate by just six beats per minute (bpm) results in an error of 350 mL/min in the estimated $V0_2max$. In other words, for a 75-kg person, this translates to an error of -8.3% or -4.7 mL/kg/min. Although the CRF declines non-linearly with age, much can be done to preserve and improve CRF with age including maintaining an appropriate body weight, physical activity, and not smoking, thus, many factors-and not just age-affect CRF. An objective criterion for HRmax in children could have practical value because HRmax is often used as a surrogate for VO_2max in graded exercise testing but only a subset of children achieves VO_2 plateau at maximal exercise using such secondary criteria, such as HRmax [7].

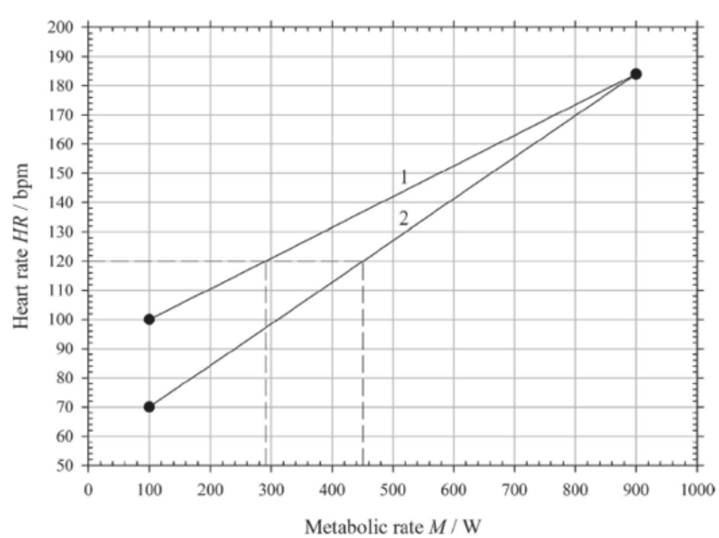

Fig. 2. Comparison of the (M vs. HR) relationships on 2 hypothetical occasions for the same subject.

Illustration 1: *With permission J Malchaire., et al. Industrial Health 2017:55;219-232 [8].*

Malcharie., *et al*. noted that the most precise expression is that in Roberg’s paper recommending the Inbar equation (HRmax = 205.8 - 0.685 × age). In this connection, it is important to realize that the estimation error is very large: SD = 6.4 bpm, based on a study (n = 1424) with a correlation coefficient of 0.67. A similar study led to the expression (207 - 0.64 × age) with a lower correlation coefficient (r = 0.42). The Inbar correlation coefficient may be larger because the cohort used in that study was more homogeneous and, therefore, less likely to have other factors that could have affected the HRmax. But this does not mean or even suggest that the Inbar formulation was the more accurate. For example, the differences between HRmax as one might calculate it using the Inbar method and the general formula of 208 - 0.7 x age results in findings that are 2 bpm lower for individuals over the age of 20. Thus, the more general formula was utilized, but it was not very precise.

When these formulas were reviewed no statistically significant differences emerged between many groups: between 80-year-old men and 80-year-old women, between sedentary and physically trained subjects; between Hispanics and Caucasians; and between those in robust health and those with health issues, including those with hypertension but excluding those with heart disease [3]. Multivariate analysis models could explain 86% (at most) of the total variance while simple linear regression could explain 72%. In this context it is important to recognize that in practical terms, the attributes of the group analyzed play a major role and results are scarcely reproducible across other samples; in other words, better multivariate models are unlikely to emerge. Based on these considerations, it was concluded that the simple equation stated above is the best way to predict HRmax: .

This is a simple, succinct, and elegant equation, but it is very imprecise. The standard deviation for HRmax is 11 bpm [8].

HRmax in fitness and athletic medicine

Wireless heart rate monitors were pioneered in 1977 by Electro for the Finnish national cross-country ski team and became popular retail items in the 1980s [9]. In fact, new technological innovations have greatly expanded the wearable market, offering improved accuracy and user-friendliness [10]. The publication by Fox., *et al*. in the 1970s of the HRmax = 220-age and the introduction of wearable heart rate monitors in the 1980s contributed to paradigm shifts in the endurance athletic community. The work with maximum aerobic function was introduced by Maffertone in the 80s to endurance runners, based on the training heart rate that would improve their capacity and avoid overtraining and injuries [11]. High-intensity interval training has become popular among adolescents and adults around the world, because it allows for CRF improvements that compare to moderate-level continuous exercise [12,13]. The work of O’Keefe., *et al*. showed that there is an age-related increased risk for atrial fibrillation related to training intensity/volume [14].

Conclusion

It is prudent to consider this information about maximum heart rate when in dialog with clients and/or patients about their biometrics, goals, and risk factors in relation to their overall workload. Individualized testing prevents the errors of the old HRmax = 220-age equation both in clinical and athletic medicine.

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