

## Maximal Heart Rate: Influence of Sport Practice during Childhood and Adolescence

Débora Helena Balassiano and Claudio Gil Soares de Araújo

Clínica de Medicina do Exercício - CLINIMEX; Programa de Pós-Graduação em Ciências do Exercício e do Esporte - Universidade Gama Filho - Rio de Janeiro, RJ, Brazil

### Abstract

**Background:** The heart rate (HR) achieved at the end of an exercise test (ET) is called maximal HR and is known to have clinical and epidemiological relevance. For its correct measurement, it is necessary that the ET be truly maximal.

**Objective:** To evaluate the influence of a history of intense physical activity and/or participation in sports competitions during youth on the maximal HR (% of age-predicted HR) on a clinical cardiopulmonary exercise test (CPET).

**Methods:** A total of 600 non-athlete individuals (65.8% males) with a mean age of  $46 \pm 13.7$  years, under primary prevention of cardiovascular diseases and who underwent maximal CPET, were retrospectively selected. Their physical activity profile during childhood/adolescence (PAPCA) was classified in scores growing from 0 to 4, with value 2 corresponding to their respective age-predicted levels.

**Results:** None of the 20 individuals with maximal HR values equal to or greater than 200 bpm had been inactive or somewhat active during childhood /adolescence. A significant association was observed between PAPCA scores and maximal HR (% of age-predicted HR) ( $p = 0.02$ ), with a 7-bpm higher value for PAPCA scores 3-4 (32.9% of the sample) in comparison to PAPCA 0-2.

**Conclusion:** Two hypotheses exist to explain these results in individuals who had been more active during youth: a) persistence of chronic adaptations to training on the cardiac chronotropism, or b) higher ability and/or motivation to achieve a truly maximal CPET. Information on the physical activity profile during childhood / adolescence may contribute to the interpretation of maximal HR on ET (Arq Bras Cardiol. 2013;100(4):333-338).

**Keywords:** Heart Failure; Exercise; Sports; Physical Exertion; Ergometry; Adolescents; Child.

### Introduction

Practicing physical exercises regularly is widely known to be one of the major components of a healthy lifestyle, and it seems to contribute to the reduction of cardiovascular mortality<sup>1,2</sup>. A recent analysis of more than 600 thousand cases found that middle-aged individuals may earn up to four years of survival when physically active<sup>3</sup>. Briefly, the habit of practicing physical exercises should be stimulated from childhood and, ideally, be maintained until the end of life. Some studies suggest that physically active children and adolescents have a higher probability of maintaining the habit of practicing physical exercises regularly in adulthood<sup>4-7</sup>. Theoretically, we can presume that adult individuals who practiced high-intensity physical exercises when young would be more prone to perform an effectively maximal effort if necessary.

The exercise test (ET), also known as ergometric test<sup>8,9</sup>, is one of the ancillary tests most frequently used in cardiology<sup>8</sup>. During an ET, cardiopulmonary and electrocardiographic responses to a progressive and programmed exertion leading the individual to exhaustion are analyzed. The aerobic performance on an ET or CPET is closely related to the individual's usual physical exercise level, and considerably higher in those who keep themselves physically active. On the other hand, the maximal HR is inversely related to age and seems not to depend on the individual's current aerobic training degree<sup>10</sup>. Actually, high maximal HR levels on ET or CPET have proven to be indicators of a favorable clinical prognosis in middle-aged individuals<sup>11,12</sup>.

In a clinical context, it is possible that the individual's past experience with maximal effort will have an influence on their motivation to complete a truly maximal ET. Thus, we hypothesized that, when undergoing a clinical CPET, individuals with a history of practicing intense physical exercises and/or of participation in sports competitions during childhood/adolescence would tend to achieve a higher maximal HR, as expressed as a percentage of the maximal age-predicted value.

**Mailing Address:** Claudio Gil Soares de Araújo •

CLINIMEX - Rua Siqueira Campos, 93/101. Postal Code 22031-070, Rio de Janeiro, RJ- Brazil

E-mail: cgaraujo@iis.com.br

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## Methods

### Sample

All individuals undergoing evaluation which included a maximal Cardiopulmonary Exercise Test (CPET) in a private Exercise Medicine Clinic for the first time in the period from January 2012 to March 2012 were retrospectively analyzed. Those using negative chronotropic medication regularly or who had a cardiac pacemaker, and those whose CPET had been interrupted before the physiological maximum more commonly due to clinical reasons such as angina or relevant dyspnea and/or due to hemodynamic or electrocardiographic abnormalities (supraventricular or ventricular tachyarrhythmias and/or horizontal or downsloping segment depression greater than 3 mm) were excluded. All individuals participating in sports competitions at the time of the evaluation were also excluded. After the exclusion criteria had been applied, 600 individuals (65.8% males) with ages between 11 and 87 years ( $46.3 \pm 13.6$ ) were identified.

As part of this clinic's routine since 1994, all individuals were evaluated by indication of their attending physicians, or, in a few cases, by decision of the performing physician within a clinical perspective as part of an evaluation preceding the individual's participation in sports and/or physical exercise guidance. All participants gave written informed consent after having their occasional questions clarified, and a formal authorization was made to allow the use of their data for scientific and statistical purposes provided that the anonymity of the individuals was protected. The present evaluation protocol and the retrospective data analysis were duly approved by the Research Ethics Committee according to the terms of resolution 196/96 of the National Health Council.

## Protocols

### Classification of the Physical Activity Profile during Childhood/Adolescence (PAPCA)

By means of a detailed and guided history taking, information on the physical exercises practiced by the individuals during childhood and adolescence was collected and classified in a Likert-like ordinal increasing scale of five possibilities. For the purpose of PAPCA classification, data were pooled in scores from 0 to 4, where: 0 – sedentary or very little active; 1 – somewhat active, with a physical activity pattern below the recommended for the age range; 2 – active or moderately active, with a physical activity pattern within the expected or compatible with the age range; 3 – more active or very active, with a usual physical activity pattern above the typically expected for the age range; 4 – competitive or extremely active, with a regular physical activity pattern characterized by high intensity and/or large amount (frequency vs. duration) or participation in competitive sports. Examples for each of the scores are presented in Table 1. When a wide variation in the regular physical activity profile was observed, the final score corresponded to a weighing of the corresponding periods of time. For the retrospective analysis of the present study, information described in the standardized medical history

was independently classified by the two authors. The rare discordance cases (less than 4%) were further jointly reassessed and a final decision was made as regards the PAPCA score. In no case was the discordance greater than one level.

### Maximal Cardiopulmonary Exercise Test (CPET)

After a medical visit which included history taking, physical examination and a more encompassing evaluation, the individuals underwent CPET with direct analysis of expired gases during exercise ( $\text{VO}_2$ 000; Medgraphics, USA) in a leg cycle ergometer (CG-04; Inbrasport, Brazil) (76.5%) and/or treadmill (ATL; Inbrasport, Brazil) (23.5%), according to the individual's previous experience and/or objective of the procedure, in a customized ramp protocol aiming at a duration of approximately 10 minutes. During and especially at the end of CPET, the individuals were verbally stimulated to persist in the exercise with the purpose of obtaining a truly maximal result<sup>13-15</sup>. No CPET was interrupted based on maximal HR predicted values. The maximal nature of the exercise, more easily evaluated by CPET, in addition to being confirmed by the individual undergoing the test and by the report of the physician who supervised the procedure, was corroborated in all tests by simultaneously obtaining a Borg result of 10, identification of an anaerobic threshold and by the U-shape pattern of the ventilation equivalents<sup>13,14,16</sup>.

During CPET, the HR was obtained from a one-lead electrocardiographic record (CM5 or CC5) (Elite Ergo PC 3.1.2.5 or 3.3.4.3 Micromed, Brazil), starting in the resting period immediately pre-test and continuing every minute during exertion up to at least five minutes after the end of the exercise. HR was measured from this electrocardiographic tracing, with a software program in the same leads. The maximal HR obtained in the last seconds of the CPET was then expressed as a percentage of the maximal predicted HR, as calculated by the equation derived from a meta-analysis<sup>17</sup>, which is exactly the same obtained in a sample of one thousand healthy Brazilians<sup>18</sup> - maximal HR =  $208 - 0.7 \times (\text{age})$ . The 600 CPET included in the present study (period of 27 months) were performed by only four physicians experienced in the procedure.

### Statistical analysis

The main data obtained from the 600 individuals were submitted to descriptive analysis. For comparison of the results between the five PAPCA scores, two analyses were carried out: a) linear regression between the score results and the percentage obtained from the maximal predicted HR; and b) comparison between the results of the percentages obtained from the maximal predicted HR among PAPCA score subgroups using the t test or analysis of variance, depending on the number of means involved. We also compared and analyzed results obtained by the four physicians and with the two ergometers for these sets of pooled scores. The chi square test was used for comparisons in the frequency distribution in the scores alone or pooled. In addendum, the percentage of the total sample individuals who achieved a maximal HR lower than 90% and higher than 100% of the maximal predicted HR according to the formula was also calculated. The level of statistical significance was set at 5%, with a 95% confidence interval. The Prism 5.04 software program (Graphpad, USA) was used for all calculations and construction of figures.

**Table 1 – Examples of classification of Physical Activity Profile during Childhood/Adolescence (PAPCA)**

Score	Definition	Example
0	sedentary or very little active	(a) occasional pedaling; (b) physical education at school with frequent leaves.
1	somewhat active	(a) physical education with regular attendance; (physical activity below the age-recommended level). (b) ballet and other for a short period.
2	active or moderately active	(a) swimming; (with physical activity within the expected or compatible with the age range). (b) soccer with satisfactory attendance.
3	more active or very active	(a) surf; (b) water polo; and/or (with physical activity above the typically expected for the age range) associated activities.
4	competitive or extremely active	(a) swimming competition (high-intensity physical activity and/or large amount or competitive). (b) long-distance cycling.

## Results

Half of the individuals were aged between 36 and 56 years. Their height was (mean  $\pm$  standard deviation)  $171.7 \pm 9.2$  cm, and their body weight was  $77.5 \pm 16.0$  kg. Based on the exclusion criteria, notably the exclusion of individuals using negative chronotropic medications, especially betablockers, the sample had a clinical profile of primary prevention, with many cases of arterial hypertension, obesity and dyslipidemia, and only 3.54% of individuals with known coronary artery disease. Only 192 (32%) sample individuals were apparently healthy. The sample clinical profile was quite varied, as shown in details in Table 2.

Data on the PAPCA classification show that 20% of the individuals had had few or no sports experience during childhood/adolescence, in contrast with only 13% with sports competition experience or highly significant engagement in regular physical activities – score 4. Individuals classified as PAPCA score 4 were also younger than those who had had a sedentary lifestyle in youth – 44 vs. 50 years of age. Maximal HR on CPET ranged between 113 and 214 bpm, corresponding to 75% and 119% of the maximal age-predicted HR. In only 12.5% of CPET was the maximal HR lower than 90% of the predicted value, and in 40% the predicted value according to the age equation was surpassed. Among the 16 individuals with maximal HR values (% of age-predicted HR) higher than 110% of the age-predicted percentage, 11 had PAPCA 0-2; the other 5 had PAPCA 3-4. Only 20 individuals (3.3%) showed a HR equal to or greater than 200 bpm on CPET; none of them had a PAPCA scores 0 or 1. The results of maximal HR expressed as a percentage of the maximal age-predicted HR obtained for the five PAPCA scores ranged between 96% and 99%, with a positive association ( $p = 0.02$ ). When the scores were pooled, the results of maximal HR obtained (% of the maximal predicted HR) were slightly lower for 0-1 – 97.2% and 2 – 97.7% than for 3-4 – 98.9%. When the results are analyzed by the extremes of pooled scores (0-2 and 3-4), a tendency to higher percentages of maximal HR ( $p = 0.034\%$ ) is observed, as shown in Figure 1. The peak  $VO_2$  obtained on CPET ranged between 34% and 217% of the age/gender-predicted value, with a mean value very close to the predicted value – 99.3%. Concomitantly, a progressive increase in peak  $VO_2$  following the magnitude of the pooled scores can be observed ( $p < 0.001$ ).

The main data for each of the five PAPCA scores are shown in Table 3. We can observe that the CPET of individuals classified in scores 0 and 4 tended to be respectively, less and more often performed in a treadmill ( $p = 0.01$ ). However, when the scores were pooled in 0-2 and 3-4, this difference between ergometers was no longer observed ( $p = 0.18$ ). No difference was observed in the results of maximal HR obtained (% of the maximal predicted HR) between the CPET supervised by the four different physicians ( $p = 0.62$ ).

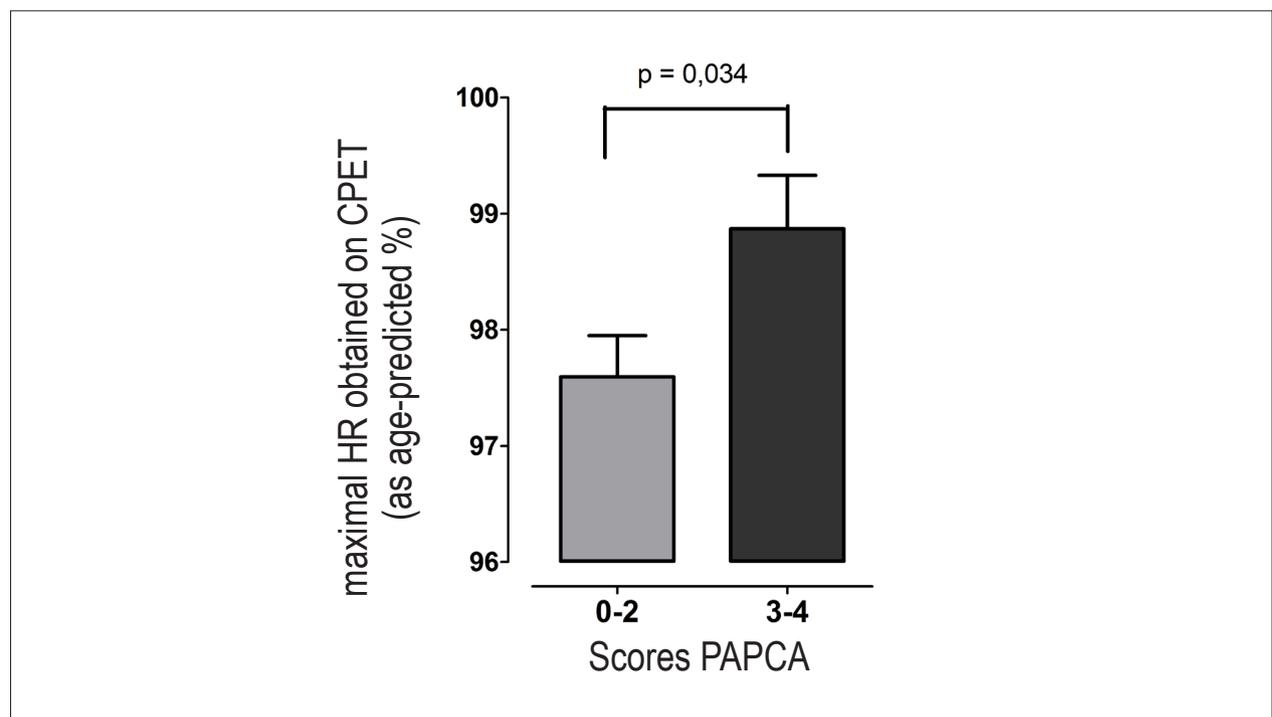
## Discussion

To date, the physiological and/or perceptive mechanisms that define the limit of maximal effort<sup>19-21</sup> remain not fully understood or consensually accepted, and the analysis of the different theories or possibilities is beyond the scope of the present article. However, for practical purposes and for almost all clinical applications, ET should be truly maximal so that it is possible to increase the probability of identifying abnormalities in body systems functioning, which are more frequently observed at higher levels and/or peak effort. This is probably even more relevant, with the significant increase in the number of middle-aged individuals (corresponding to approximately 50% of our sample) who are starting to participate in mass aerobic events such as half-marathons, marathons, road cycling competitions, open water competitions, triathlons and cross-country or adventure racing competitions<sup>22,23</sup>.

Notwithstanding, performing a truly maximal ET is not a simple task and implicates that both the observer and the patient make a good alliance, with proper mutual confidence and a high degree of motivation and cooperation, conditions which are not always easily obtained or observed in the daily clinical practice. As a matter of fact, both physicians and patients may, for different reasons, avoid the discomfort and stress of the truly maximal effort. In this context, the competence and experience of the physician (observer) supervising the ET seem to be very important for ensuring that the maximal effort is achieved. For instance, although very wrongly, it is not uncommon that ET are interrupted when the HR reaches levels close to or equal to the maximal age-predicted values, thus probably jeopardizing the clinical interpretation of results. When ET is performed along with the collection and analysis of expired gases – the so called Cardiopulmonary Exercise Test (CPET), it may be easier to identify and characterize a maximal effort<sup>24</sup>, although some degree of subjectivity always persists in this regard.

**Table 2 – Main data and sample clinical profile (N = 600)**

Variable	Result
Gender	Male (65.8%)
Age (years)	46.3 ± 13.6
Height (cm)	171.7 ± 9.2
Weight (kg)	77.5 ± 16.0
VO <sub>2</sub> peak (mL.kg <sup>-1</sup> .min <sup>-1</sup> )	33.8 ± 12.1
Arterial hypertension	17.9%
Significant smoking habit (past or current)	34.3%
Obesity (BMI > 30 kg.m <sup>-2</sup> )	11.0%
Dyslipidemia	29.9%
Diabetes mellitus	6.2%



**Figure 1 – Comparison of the maximal HR obtained on the maximal Cardiopulmonary Exercise Test (CPET) (as age-predicted %) between individuals with low or moderate (scores 0 to 2) and high or very high (scores 3 and 4) physical exercise profile in childhood /adolescence (scores 3 and 4).**

To the best of our knowledge, the hypothesis tested in the present study is original, and has not been the object of previous studies. The careful data collection and further PAPCA classification, the small number of specialized physicians supervising CPET performance and the sample characteristics, both as regards its size and clinical and demographic profiles, are strong points of the present study. It is worth pointing out that, in accordance with the exclusion criteria applied, none of the 600 sample individuals was regularly engaged in competitive sports at the time the CPET was performed.

From the results found, we observed a tendency to a higher HR (% of the age predicted HR) with the increase in the amount of exercise and sport practiced in youth. The mean

maximal HR was approximately 9 bpm higher on CPET for those who had a history of competitive sports during childhood or adolescence or who practiced physical exercises at a level above that predicted for their age range in comparison to the remaining individuals with the PAPCA of a sedentary person, i.e., score 0 in the physical activity classification – 175 vs. 166 bpm. However, we should point out that there was considerable data overlap between all the subgroups, so that inactivity during childhood should not be considered as a regular physiological explanation for a relatively low maximal HR on ET or CPET. We also observed that peak VO<sub>2</sub> was higher in the group that practiced competitive or high-intensity exercises during childhood and adolescence.

**Table 3 – Comparison between the five physical activity profiles during childhood/adolescence scores (N = 600)\***

Score (N)	Age (years)	VO <sub>2</sub> peak (mL.kg <sup>-1</sup> .min <sup>-1</sup> )	Maximal HR (% of the age-predicted HR)	Cycloergometer (%)	Treadmill (%)
0 (26)	51.7 ± 13.6	29.1 ± 13.8	96.7 ± 7.3	91	9
1 (94)	50.2 ± 14.4	26.3 ± 8.7	97.3 ± 7.0	74	26
2 (283)	45.4 ± 13.7	34.7 ± 12.1	97.8 ± 7.1	74	26
3 (118)	46.0 ± 13.1	34.6 ± 11.2	98.7 ± 6.5	70	30
4 (79)	43.7 ± 11.8	39.1 ± 12.0	99.1 ± 6.4	75	25

\* values expressed as mean ± standard deviation.

Interestingly, no difference was observed between maximal HR values (% of age predicted HR) when the CPET performed by the four different physicians were compared, thus suggesting that the way the procedures were conducted might have been similar and did not cause any intervening factor in the results analysis. Since the choice of the ergometer in which CPET is performed depends on clinical conditions and on the objectives of the assessment, it is natural that an occasional statistical difference between determined subgroups may occur. Nonetheless, when the PAPCA scores were analyzed between subgroups 0-2 vs. 3-4, this difference caused by the ergometers disappeared. In fact, data previously published by our laboratory suggest that, despite the known physiological differences, it is usually possible to obtain maximal HR values in CPET both performed in leg cycle ergometers and in treadmills when a customized and adequate choice is made<sup>15</sup>. Another recent evidence<sup>18</sup> corroborating the validity of mixing the results of maximal CPET in the two ergometers was obtained in a study which determined the regression between maximal HR and age in one thousand individuals, of whom 613 performed the test in a cycle ergometer and 387 in a treadmill. The equation found was exactly like that of the literature (HR max = 208 – 0.7 x age (years)). This would not have occurred if the data obtained in CPET in cycle ergometer had systematically underestimated the maximal HR.

There are several ways to measure or estimate the physical activity profile. The PAPCA classification system used in the present study was developed and has been applied in our laboratory for approximately two years, and this article is the first in which its data are analyzed. Considering the slight discordance identified between the two observers – only 4% of the cases and never by more than one score point –, this classification system of physical activity profiles can be considered promising. However, further specific studies are required to validate a wider and generic use.

Nonetheless, the study design causes some limitations. The retrospective analysis and based in self-responses of the individuals tested may have introduced some biases which could not be controlled or identified. Also, we should point out that the application of the results was not formally tested in samples or populations with characteristics different from those of the present study sample. The study was not mechanistic.

Thus it was not possible to characterize whether this slightly higher maximal HR found in individuals who had been more active during youth is a result of some real chronic effect on the cardiac chronotropism that persists in adulthood or whether it simply reflects the motivation and ability to tolerate a truly maximal effort, something that these individuals had already experienced in the past. On the other hand, the present study opens perspectives for further studies to improve the analysis of the influence of remote or recent past physical activity and/or sports practice profile data on cardiovascular and respiratory variables obtained during ET and CPET.

## Conclusion

The results of the present study contribute to the body of knowledge and to the clinical use of ergometry by evidencing that the history of practice of sports and/or more intense physical activity during youth may influence the final maximal HR value (% of age-predicted HR) on CPET, thus suggesting that information on this profile may be useful in the performance of the procedure and interpretation of the results obtained.

## Author contributions

Conception and design of the research, Acquisition of data, Analysis and interpretation of the data, Statistical analysis, Writing of the manuscript and Critical revision of the manuscript for intellectual content: Balassiano DH, Araújo CGS; Obtaining funding: Araújo CGS.

## Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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## Study Association

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