Upper normal values of blood pressure response to exercise in Olympic athletes

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Background Exercise test is widespread performed in athletes to assess cardiovascular adaptations during effort; however, scarce information exists relative to the behavior of blood pressure during exercise in athletes. We sought to define the normal values and upper limits of blood pressure response to exercise in a large population of elite, healthy athletes.

Methods A total of 1,876 healthy, normotensive elite athletes (aged 25 ± 6 years, 64% male) underwent a comprehensive clinical evaluation including maximal bicycle exercise test.

Results At maximum exercise, the systolic blood pressure increased significantly (Δ = +69 ± 18 mm Hg; $P < .001$), whereas diastolic blood pressure showed minimal change (Δ = +1 ± 7 mm Hg; $P = .001$). The upper reference values were 220 mm Hg in male and 200 mm Hg in female athletes for systolic blood pressure, and 85 mm Hg in male and 80 mm Hg in female for diastolic blood pressure. A subgroup of 142 athletes (7.5%) showed high blood pressure response to exercise, that is, increase in systolic and/or diastolic blood pressure above the 95th percentile. Multivariate logistic regression analysis showed that endurance and mixed sport disciplines, body mass index, and baseline systolic blood pressure were the strongest determinants for high blood pressure response to exercise.

Conclusion The gender-specific reference values for systolic and diastolic blood pressure at maximum exercise in athletes were defined. A small subset (7.5%) of athletes showed higher blood pressure response, in the absence of target organ disease or metabolic abnormalities, and associated with superior physical performance and larger cardiac remodeling. (Am Heart J 2016;177:120-8.)

Olympic athletes represent a subset of highly trained individuals achieving extraordinary physical performance. They are enduring intensive and long-term training schedule, which is eventually responsible for cardiovascular (CV) adaptations referred to as the "athlete's heart".[1,2] In the context of the CV evaluation of athletes, exercise testing is indicated to detect rhythm or hemodynamic disorders,[3,4] but it is also widely performed to assess the athlete's performance and to derive information deemed relevant to the athlete's training schedule.[5,6]

Currently, conflicting opinions exist among physicians regarding the clinical relevance of assessing the blood pressure (BP) during exercise, and the normal values and upper limits of BP response to exercise are not well defined, both in the general population and even less in highly trained athletes.[7–11] The European Society of Cardiology (ESC) guidelines reported no consensus on BP response during exercise; only reference values for systolic BP of <210 mm Hg for men and of <190 mm Hg for women are stated.[12] In a similar fashion, the American College of Cardiology/American Heart Association (ACC/AHA) guidelines reported that peak systolic BP >214 mm Hg can predict future occurrence of clinical hypertension.[4] These reference values, derived from aged and sedentary population, cannot be wisely applied to the athletic population.

In the present study, we sought, therefore, to assess the behavior of BP during exercise in a large cohort of highly trained athletes, members of the Italian Olympic Team, in order to define the normal values and upper limits of BP response to exercise.

Methods

Study population

The Institute of Sports Medicine and Science is the medical division of the Italian National Olympic

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Committee and is responsible for the physiologic and medical evaluation of all national team members before participation in the Olympic Games or other major international events. Within this program, in the period 2008 to 2014, 1,937 consecutive athletes were evaluated prior to the 2008 Beijing Olympic Games, 2009 Pescara Pan-Mediterranean Games, 2009 FINA World Championship, 2012 London Summer Olympic, or 2014 Sochi Winter Olympic Games.

Of the athletes considered for inclusion, 61 showing either CV abnormalities (n = 3) or BP consistently >140 and/or 90 mm Hg on repeated measurements were excluded; therefore, the final study population comprised 1,876 normotensive and healthy athletes.[12] None was taking CV or vasoactive medications.

Athletes were 25 ± 6 years of age (range 15-45 years); 1,245 were male (64%). All have been competing for ≥3 years (average 11 ± 5 years) prior to entering our program and were training regularly at the time of our evaluation. Based on the predominant characteristics of training, athletes were classified in 4 subgroups[13]: (1) skill (ie, primarily technical activities; n = 462) including golf, table tennis, equestrian, rhythmic gymnastic, shooting, karate, taekwondo, and sailing; (2) power (ie, primarily isometric activities; n = 331) including weightlifting, artistic gymnastics, wrestling, and short-distance running (100-200 m); (3) mixed (eg, disciplines with both isometric and isotonic components; n = 531), including soccer, basketball, volleyball, handball, water polo, tennis, and fencing; (4) endurance (eg, primarily isotonic activities; n = 552) including rowing, canoeing, swimming, long-distance running and marathon, cycling, triathlon, and pentathlon.

Written informed consent was waived for all athletes undergoing a standard clinical evaluation pursuant to Italian law and Institute policy. The study design was approved by the Review Board of the Institute and funded by the Italian National Olympic Committee. No extramural funding was used to support this work.

The authors are solely responsible for the design and conduct of this study, all study analyses, and the drafting and editing of the manuscript and its final contents.

Clinical evaluation

Cardiovascular evaluation included clinical history, physical examination, and resting 12-lead electrocardiogram. Office basal BP was measured at morning time in a quiet room by an experienced cardiologist; athlete was in the sitting position, after a few minutes of rest and before the exercise test. The cuff was positioned at the upper arm (heart level) with cuff size and bladder dimension adjusted to the arm circumference. Auscultatory technique was used and phases I and V of the Korotkoff sounds were used to define the systolic and diastolic BP, respectively.[12]

Body height and weight were obtained in each subject before exercise testing. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters, and body surface area (BSA) was derived by the Mosteller formula.[14,15] Body composition and fat percentage were measured using Bioelectric Impedance Analysis (BIA 101 Quantum; Akern, Pontassieve , Italy) using constant sinusoidal current, at an intensity of 50 kHz and 400 μA. The athlete was advised to withdraw training 12 hours prior to this investigation.[16]

As a part of the medical program, all athletes underwent ophthalmic examination including fundus oculi. Blood sample was collected at the time of clinical evaluation in order to measure fasting glucose levels, lipid profile, and renal function.

Exercise test

The exercise testing was performed on bicycle ergometer (Cubestress XR400; Cardioline SpA, Milan, Italy). The starting load was 0.5 W/kg, with subsequent increase of 0.5 W/kg every 2 minutes until exhaustion, identified as the time when athlete was unable to maintain the power output despite encouragement. Digital 12-lead electrocardiogram was monitored before, continuously during exercise, and for at least 5 minutes during the recovery.[4,17]

To reliably and consistently measure the BP over the test, the patient was asked to put the left arm in an extended and relaxed position with the hand over the doctor's shoulder. Both systolic and diastolic BPs were manually measured just before starting exercise, every incremental step until stop and after 5 minutes of recovery. Maximal BP was defined as the measurement at the last stage of exercise just before interruption.

Echocardiography

Two-dimensional and Doppler echocardiography was performed using iE33 (Philips Medical System, Andover, MA), equipped with an S5-1 probe (5 MHz). Two-dimensional measurements of left ventricular (LV) cavity, wall thickness, left atrium, and aortic root diameters were performed according to the European Association of Cardiovascular Imaging and American Society of Echocardiography.[18] Left ventricular ejection fraction was measured by the biplane Simpson rule from the apical 4- and 2-chamber views.[18] Left ventricular mass was measured by Devereux formula and normalized to BSA.[18] Patterns of LV geometry were defined according to ESC recommendations. Left ventricular hypertrophy was defined as LV mass index >95 g/m^2 in women or >115 g/m^2 in men.[18] Left ventricular inflow velocities were recorded by pulsed-wave Doppler from the apical 4-chamber view with a 2-mm sample volume positioned at the tip of the mitral leaflets; early (E) and late (A) diastolic peak