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Athlete's heart in children and adolescents

Abstract

Physical activity through play is a form of expression and development for children and it is defined as any movement produced by skeletal muscles that results in energy expenditure. Physical Exercise is a planned physical activity, structured within a sporting and social context, with an aim to maintain physical conditioning. A competitive athlete is someone who participates in an organized team or individual sport that requires systematic training and regular competitions aimed at a goal, namely a prize or excellence in the sport. There are important physiological particularities in relation to movement and physical conditioning in this stage of the human being's physical growth and development, with an impact on the cardiovascular system. Currently it is considered that all athletes, regardless of the type of sport practiced, develop a combination of cardiac alterations that simultaneously include dilation and increased thickness of the left ventricular wall. The difference in the intensity of these alterations vary according to factors such as the type of sport practiced, gender, age and body surface area of the athlete. In the adolescent population, especially athletes, it is extremely important to differentiate echocardiographic alterations resulting from intense training with those ones that show some type of cardiac pathology.

Keywords: physical activity, physical exercise, physical conditioning, athletes, athlete's heart, children, adolescents

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Exercise physiology in children and adolescents

Physical activity through play is a form of expression and development for children. Fun through this activity is the biggest factor of implementing and maintaining the execution of movements. The physical, physiological, psychological, and social benefits that physical activity brings to children and adolescents are unequivocal.

Physical Activity, Physical Exercise and Physical Conditioning are interconnected terms that define different concepts.

Physical Activity is defined as any movement produced by skeletal muscles that results in energy expenditure. It can be categorized as occupational, sportive, daily care or any other activity.

Physical Exercise is a planned physical activity, structured within a sporting and social context, with logical and organized repetitions with an aim to maintain physical conditioning, the latter being a set of abilities and attributes related with the improvement in skills associated to health and performance, and it can be measured through specific physical tests carried out by qualified professionals.[1]

In the dynamic of physical activity and exercise, the muscles can produce concentric contractions or can be exposed to external resistance and strength training, eccentric contractions. When muscular force does not emanate a movement, the contraction is denominated static or isometric. Static exercises (e.g. weight lifting) inflict a pressure load greater than a volume load on the heart. On the other hand, dynamic exercises, for example running, result in an increase on the volume load. The cardiovascular response is proportional to the intensity of the exercise up to its maximum level. Most exercises combine dynamic and static components.[2]

A competitive athlete is someone who participates in an organized team or individual sport that requires systematic training and regular competitions aimed at a goal, namely a prize or excellence in the sport.[3]

In the journey of reaching athletic goals, improving performance consists of acquiring motor abilities, improving cardiorespiratory capacity, muscular strengthening with consequent changes in body composition and dimensions, psychological motivation and adequate maintenance of metabolism and nutritional concepts.[4]

The first major issue to be consider in terms of sports physiology in pediatrics is that children are not miniature adults. With the increasing understanding of issues related to the benefit of exercise and physical conditioning in this population, it is crucial to analyze cardiac physiology through clinical evaluation and interpretation of test results of these patients. We are discussing individuals who are under a constant process of growth and development of musculoskeletal, endocrine and nervous systems under the maturation process and cardiorespiratory function, which limits some physical effort of physiological and metabolic processes.[5]

Regarding muscle fibers, there is predominance of type I fibers, with oxidative characteristics more specialized in anaerobic alactic metabolism than type II fibers, responsible for glycolytic metabolism. Therefore, children have a lower efficiency of glycolytic activity than adults. In issues related to the bioenergetic profile, studies show a low anaerobic capacity to produce adenosine-5-triphosphate, ATP, during exercise. This immature glycolytic system can be explained by the low concentration of muscle glycogen, around 50 to 60% of the glycogen found in adult muscle cells, besides the lower enzymatic activity of enzymes involved in glycogen mobilization such as lactate dehydrogenase and phosphofructokinae-1, that being so, physical capacity is based on the oxidative system that proves to be more efficient. During the maturation process in adolescence, the action of hormones such as insulin, somatotropin, insulin-like growth factors and steroid hormones will provide changes in the concentration of the muscle fiber types and metabolic maturation which will direct the individual towards the body composition characteristics and physical capabilities of an adult. It is up to us to evaluate the cardiovascular physiological parameters such as Heart Rate, Stroke Volume, Cardiac Output and Arteriovenous Oxygen Difference in order to understand the clinical exercise of the individuals in pubertal development. These parameters are influenced by some factors such as: smaller heart size and lower blood volume; greater stimulation of peripheral

chemoreceptors, lower amount of circulating catecholamines, and difference in adjustments in peripheral thermoregulation mechanisms.[5,6]

Heart Rate, which is originally one of the parameters utilized to control exercise intensity in physical training, has an exacerbated response in children due to high metabolic demands and smaller Heart Volume and Blood Volume with consequent lower stroke volume. The role of thermoregulation, according to Bar-Or Oded,[7] is a consequence of the reduced heat evaporation capacity for heat dissipation in children, causing a dependence in the convention and irradiation mechanisms, which results in an increase in the redistribution of the blood flow to the body surface area with greater vasodilation, hypotension and exacerbated chronotropic effect to balance.[5,7]

Stroke Volume, is defined as the amount of blood ejected from the left ventricle during systole, usually behaves as a plateau during increasing exercise intensity, due to peripheral vasodilation, Heart Rate and a combination of Preload, Myocardial Contraction and After Load. According to Rowland et al, Stroke Volume is lower in children with morphological aspects (smaller volume and lower blood flow) and a lower contractility that will continue to change as maturation occurs.[5]

Another parameter to be considered is Cardiac Output, a constant product of Stroke Volume and Heart Rate, thus characterizing the Volume Ejected by the Left Ventricle per minute. In addition, it presents lower values comparing to values found in adults, reflecting the smaller cardiac volumes before the end of the maturation process and which presents constant increases throughout this process.[5,6]

The Arteriovenous Oxygen Difference is defined as the difference in oxygen between the arterial blood and venous blood, it reflects the efficiency in the extraction of peripheral oxygen by active metabolic tissues. This parameter will be greater in children than adults to compensate the different in lower Cardiac Output and it relates beyond tissual metabolism, to heat production and thermoregulation. Children require a greater energy expenditure to perform movements compared to adults, which results in a greater heat production, causing a greater release of oxygen by hemoglobin and greater peripheral perfusion.[5]

All the differences in the integrated cardiological parameters are extremely important to interpret functional test results, as well as to interpreting autonomic alterations that are pertinent to the development of the cardiac electrical control and which can occur both in symptoms assessment and assessment of morpho functional electrocardiographic alterations in Athlete's Heart.

Athlete's Heart

Currently it is considered that all athletes, regardless of the type of sport practiced, develop a combination of cardiac alterations that simultaneously include dilation and increased thickness of the left ventricular wall. The difference in the intensity of these alterations vary according to factors such as the type of sport practiced, gender, age and body surface area of the athlete.

Athlete's Heart is a physiological process defined by a set of clinical alterations, electrocardiographic and echocardiographic alterations resulting from intense and prolonged practice of physical exercise, which resulted in an increase in efficiency of cardiovascular function, being reversible with the interruption of sports practice. The most relevant alterations are myocardial hypertrophy, enlargement of cardiac cavities, and the increase in cardiac mass, which may have different intensities between various athletes. In most cases, the values found remain within normal limits, however in extreme ways of adaptation the physiological process reaches borderline values with some similarities to certain pathological processes.[8]

In the adolescent population, especially athletes, it is extremely important to differentiate echocardiographic alterations resulting from intense training with those ones that show some type of cardiac pathology. So much so that for Brazilian Societies of Cardiology and Sports Medicine, the ECG has become the routine exam in the preparatory evaluation for this population, while the transthoracic echocardiogram is indicated for the evaluation of possible morpho functional alterations. Nonetheless, due to immaturity and shorter training time, heart alterations in adolescent athletes are less evident than in adults. Paradoxically, the reference values for assessment of these alterations, nowadays, are derived from studies with adults or small pediatric studies with various methodologies.[9,10]

Most of the adaptations the cardiovascular system suffers can be explained by the need to supply the oxygenated blood more effectively to the muscles and the Fick principle, thus developing a thicker and more efficient cardiac wall, larger left ventricle and consequently a lower heart rate.[11]Other adaptations are better explained by the type of exercise and environmental conditions, as well as duration of training. All those changes have already been thoroughly explained in adults, but some aspects of it are still unclear when it comes to the pediatric athlete. Current literature seems to suggest that the androgenic hormones are related to the thickening of the cardiac wall, while the vagotomy, typical of the adolescent heart (which is transitioning from the children's pattern to the one seen in adults,) is an important factor to explain some of the electrical adaptation found in ECG tests. The resting ECG of pediatric athletes seems not to predominantly reflect exercise-induced morphological remodeling but maturation, Incomplete Right Bundle Branch Block (RBBB), Repolarization Changes, and Bradycardia can be observed more commonly in pediatric athletes rather than in sedentary children.[12] The hormonal theory also explains why there are differences in heart adaptation between male and female athletes. In short, the appearance of between-sex differences in LV parameters in adolescent athletes may not only reflect, as generally thought sex-related different responses of LV to training, but also the physiological age-dependent divergence in LV parameters in early adolescence. Furthermore, in the 12–14 years age interval, sex-related differences in body size are much less pronounced than in 16-year-old people, thus limiting the specific influence of anthropometric characteristics on LV. It may be thus of interest to study LV parameters in adolescent athletes of both sexes within their trans-pubertal age.[13]

To provide more consistent data with the pediatric population and provide to attending doctors a more accurate tool to evaluate cardiac condition of these athletes, Cavarreta conducted in 2018 a study with more than 2000 pediatric boy athletes. The results of this study motivated D'ascenzi, which expanded this analysis as means to achieve an appropriate Z-score (estudoCHILD).[14,15] Having an adapted tool by age group is essential, in the meta-analysis conducted by Rowland, it was concluded that, unlike what is found in adults, in the pre-pubertal pediatric population there is no difference in the alterations found between male and female sex, which corroborates with the theory that androgenic hormones have an important role in the formation of findings about Athlete's Heart. This same theory is also supported by a study by Pelà et al. Rowland, however, it does not rule out the possibility that the less evident findings in this age group are due to the immaturity of system and shorter training time in comparison to adult athletes.[13,16]

Among the available data for the pediatric and adolescent population, most studies also refer to Caucasian and male populations. Ozo and Sharma published a review in 2020 on the impact of ethnicity on athlete's cardiac adaptation, which found that the current parameters of assessment settings often put black and afro descendent athletes at risk for participation, once that the parameters utilized for assessment were developed based on data for predominantly Caucasian populations.[17]

The sports pre-participation assessment is the clinical examination of the athlete or those who practice physical activity that aims to detect possible clinical and cardiac abnormalities, many of them silent, which can lead to temporary or permanent withdraw from the sport, and in some cases, even sudden death. It is of huge importance in competitive athletes to identify whether the alterations found are structural or functional adaptations due to training.

Up to 90% of the time, it is possible to recognize situations with a risk of sudden death in cases of detectable cardiac alterations through systematic examination applied to the inherent risks of each age group. This data was mainly identified from Italian studies such as Classic Coorte by Corrado and collaborators and the introduction of mandatory complementary examinations as a form law for high-performance athletes.[18,19]

It is a set of medical measures that involve a physical examination and relevant complementary exams, aimed to diagnosing potential clinical situations that may pose a risk to the practice of high-intensity and high-performance competitive physical exercises.

People with cardiovascular and metabolic diseases who wish to engage in exercise under these conditions must undergo specific care and assessments according to specificities in each pathology.

This systematic clinic is recommended by The American Heart Association, (AHA), The European Society of Cardiology (ESC), and by The International Olympic Committee (COI).[18] Around the world there are several protocols referring to the pediatric age group and the great discussion is based on the cost effectiveness of examinations in a population in which there are 2,5x greater risks of sudden death in young athletes following the findings demonstrated by Corrado and cols. [19,20]

Whether in Brazil or Italy, it is recommended to carry out a mandatory clinical examination including a physical examination, anamneses, and electrocardiogram. The other examinations have their relevance according to pathological alterations found in the initial examinations.

Exercise and physical conditioning are essential in childhood and adolescence to develop physical abilities that will last throughout their whole lives. It is up to the attending doctors to consider the cardiovascular peculiarities and the safety of The Sports Pre-Participation Assessment so as to exclude situations with a risk of sudden death and make necessary referrals to other specialists, when applicable, avoiding overdiagnosis and unwarranted disqualification from sports practice and in this way promote safe and healthy engagement in an active lifestyle with unequivocal benefits for the quality of life and longevity of their patients.

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Conflicts of interest

Authors declare that there is no conflicts of interest.

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