Does physical exercise increase or compromise children's and adolescent's linear growth? Is it a myth or truth?*

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ABSTRACT

Modern society has given a lot of value to being slim and tall. This physical structure has been reinforced since childhood and has been affecting the adolescents desire to fit in this stereotype, especially the ones shown in the media. Because of this, health professionals are frequently questioned about the positive effects that physical exercises perform on children and adolescent's linear growth. Through the specialized literature, this article intended to illustrate the main effects that physical exercise would perform on the secretion of growth hormone (GH) in the several body tissues during childhood and adolescence. Through this reviewing, it was possible to verify that physical exercises induce the stimulation of the GH/IGF-1 axis. Although much is speculated with regard to physical exercise and bone growth, no well-developed studies were found in the specific scientific literature to corroborate this statement. The adverse physical practicing effects during childhood and adolescence, apparently, were independent of the type of the exercise practice, but else a result of the intensity. The high training intensity seems to cause an important metabolic modulation with raise of the inflammatory markers and the suppression of the GH/IGF-1 axis. However, it is important to emphasize that the sportive modality itself selects children and/or adolescents with lower stature as strategy for the attainment of better results in function of the mechanical facility of movements. Through this research, the performance of linear studies is evident, where individuals are followed before, during, and after exercise, with the determination of the training volume and intensity in order to reach definitive conclusions with regard to the effects on the final stature.

Key words: Physical growth. Physical exercise. Children. Adolescents.

INTRODUCTION

Modern society has given a lot of value to being slim and tall. The search for a body image, many times idealized by parents, media, social groups and the adolescents themselves, many times unchain harmful behaviors for health. Among the several existing stereotypes, the search for slim and tall appearance is usually reinforced since childhood.

With regard to the adult final stature, the concern of parents when observing that their children are smaller that their cousins or their schoolmates of same age and gender is quite common. In this context, health professionals are frequently questioned about the positive effects that physical exercises perform on children and adolescent's linear growth. The phrase: *"Do some sport to grow more"* is commonly heard, even though it is not clear if this statement contains a scientific truth.

Among the sportive modalities, the swimming is emphasized that, according to the common sense, is the most adequate sport modality to increase the linear growth, probably due to the fact that this sportive modality presents active load with low impact[1], followed by stretching activities equally "famous" for the same effects.

According to Georgopoulos *et al.*[2], while moderate physical exercise stimulates growth, the exhausting physical training represents stress able to attenuate the physical growth and this effect is rather a result of the training intensity and duration than the type of physical exercise itself. If on the one hand, there are doubts about the true effect of these exercises on the individual's final stature, on the other, it is clear that the physical exercise may induce significant increases on the growth hormones (GH) in the circulation[3-5], event also detected in children and adolescents[6].

GH have several biological effects during life, leading to the stimulus of the somatic growth during childhood and adolescence and contributing significantly to the energetic supply that acts on the glycidic, protein and lipidic metabolisms[5,7], besides contributing for a healthy body composition in the adult life.

From these indicatives, a deep and organized reading was conducted, especially about the potential effects on the linear growth of children and adolescents enrolled in systematized physical exercise programs. In this context, the specialized literature with regard to the main effects of the physical exercise on the GH secretion and actuation in the body tissues during this period of life was reviewed. To do so, the perspective will be to respond to the following question: Does physical exercise increase or compromise children's and adolescent's bone linear growth?

HORMONAL ACTIONS ON GROWTH DURING CHILDHOOD AND ADOLESCENCE

Physical growth is characterized by the sum of cellular, biological, biochemical and morphological phenomena, which interaction is performed through a scheme genetically preestablished and influenced by the environment[8,9].

Among the environmental aspects, the nourishment is emphasized, that associated with hormonal and genetic factors promotes the growth cartilage proliferation and the bone linear stretching[9].

The relevant linear growth during puberty includes three distinct phenomena that are sequentially revealed: the **growth spurt**, with approximate duration of two or three years, being characterized by a reduced growth speed during the pre-pubertal phase, a growth with high growth speed, also known as growth speed maximum peak (PHV) and a growth ceasing phase, which contributes with over than 20% on the adult final stature; the **quick acquisition of the bone mineral content**, recognized as bone mass peak, where the bone formation process overcomes the bone reabsorption process, which is presented as a linear increment during childhood and exponential during the second decade of the life with the high-

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est intensity between ages of 13 and 17 and the years considered as critical for the event are those between 14 and 15 years of age, and the **skeletal maturation process**, which ends with the epiphyseal closing[1,8,10-12].

GH, also known as somatotropin, is the peptide produced in high amounts by the anterior hypophysis, playing important role in the growth of bones and soft tissues[13,14]. This hormone is secreted in pulsatile way and controlled by complex mechanism involving hypothalamic proteins and the GH release hormone (GHRH) that acts by stimulating its secretion and the inhibitory somatostatin. The peaks of highest secretion are observed during fast asleep and although it is produced during lifetime, the highest peaks occur during puberty[5,12,14,15].

In the growth promotion, GH acts both direct and indirectly. It acts directly through the binding of GH to its receptors in the growth plate and indirectly acting on growth in the cell differentiation process and in the synthesis of type-I collagen. These GH biological effects are mostly mediated by growth promotion factors similar to the insulin, known as IGFs (insulin-like growth factors), and the main factor is the IGF-1[5,7,13,14,16].

IGF-1 is a polypeptide present in the blood stream mainly produced in the liver, being mediated by GH hepatic receptors and in other tissues such as bone tissue[5,11]. In skeleton, IGF-1 plays important role such as the differentiation maturation and recruitment of osteoblasts[16]. In the blood stream, IGF-1 is associated to binding proteins, being known as IGFBPs (binding protein). Remarkably, IGFBP-3 is the main binding protein and has its production stimulated by GH[4,5,13,14].

The regulatory system of the GH/IGF-1 axis does not involve only endocrine actions, but also paracrine and autocrine IGF-1 actions[16]. The IGF-1 acts singularly for both genders, being the main mediator of the growth linear speed up involved in the determination of the bone thickness, length, density and skeletal structure, increasing the body proportions during childhood and adolescence[8,16].

It is clear that the linear growth potential is genetically determined, but as already mentioned, there are several hormonal factors of local action or intervenient systemic. In this context, puberty is specially characterized by the activation of the GH/IGF-1 axis and its interactions with gonadal steroids promote the PHV[8,11].

In this period of intense growth, the GH secretion ratio is strongly influenced by age and pubertal development and at the pre-pubertal period, its secretion is reduced with no differences between genders, presenting the highest concentrations at the end of puberty, approximately from 15 to 19 years of age and decreasing after the age of 20[14,15]. Phillip and Lazar[11] reported the sexual dimorphism in the GH secretion, showing that adolescent girls presented significant increase on the surrounding GH levels at the beginning of the mammary development (M2 by the Tanner criterion) while boys indicate the highest levels between the third and fourth stages (G3 and G4) for genitals.

It is important emphasizing the action of the sexual hormones with regard to the pubertal growth, presenting a relevant increase on the GH secretion at a first moment, and later an increment on the IGF-1 production, which direct effects fall upon the bone cartilage[15]. Phillip and Lazar[11] reported a progressive increase on the serum levels of testosterone and estrogens during puberty for both genders. These are the main regulatory agents of the PHV and the maturation of the growth plate until the epiphyseal fusion is finished[11].

Traditionally, the GH increment was attributed to the testosterone effect on the male gander and to supra-renal estrogens and androgens in the female gender. Studies developed in the last decade revealed that the estrogens must be the main hormones that stimulate GH secretion in both genders and its action is mediated by receptors of the hypophysis. According to Velduhis *et al.*[17], the effect of androgens on the GH/IGF-1 axis would only be real when these hormones were flavored into estrogens, corroborating that these non-flavored androgens would not present effect on the GH secretion.

In this context, puberty is the development stage in which the GH secretion is more sensible to stimulus produced by many factors including the secretion of sexual gonadal hormones. However, many are the mediator factors of the GH release and regulation including the hypothalamic GHRH, the GH-inhibitory (somatostatin), cerebral neurotransmitters, the IGF-1 production and its binding proteins and nutritional and physical exercise factors[15].

The exact, sequential and progressive mechanism of this growth spurt period remains doubting, even though it is known that the neuroendocrine mechanism that regulates growth during childhood and adolescence years are unique and of high complexity.

DO PHYSICAL EXERCISES INCREASE OR COMPROMISE BONE GROWTH?

In the last years, health professionals have been questioned about the adverse effects of the physical training in children and adolescents on bone growth[18], and not much is known with regard to the trainability of adolescents. The modifications on the maturational status during adolescence period hinder significantly the interpretations of the researches conducted with this group of individuals[15].

Researchers have questioned some sportive practices such as gymnastics, long-duration runnings and ballet as activities that might jeopardize the linear growth and/or the bone mineral density in function of the large training volume, the low body weight requirements and the severe dietary control[19-23]. However, not much is known about the participation of children and adolescents in competitive sports and the true repercussions of the training that they are submitted to on growth. Generally, much is speculated and not many results are conclusive.

If on the one hand it has been previously reported that physical exercise may induce significant increases of GH in circulation, on the other, Guy and Micheli[24] support that during puberty, intense physical exercises not always bring benefits for adolescents, particularly in relation to the skeletal growth. Damsgaard *et al.*[25] reported that the intense strength training in adolescents seems to cause decrease on the IGF-1 levels, suggesting that this training may reduce growth and hinder the final stature.

Theintz *et al.*[26] demonstrated reduction on stature and low IGF-1 levels in young gymnasts submitted to intense training and low dietetic ingestion with the objective of maintaining a more suitable body image with influence on the competition judgment. However, dietetic restrictions and intense physical training are not only observed in gymnastics, once modality wrestling usually depends on the body weight for category classification and the low weight assures advantages in competitions. Roemmich and Sinning[27] observed significant reduction on IGF-1 in a group of wrestler adolescents submitted to intense training associated to restrictive diet with the perspective of reaching low weight and reclassification to lower weigh categories in competition.

Scheett *et al.* verified important reduction on the IGF-1 levels in pre-pubertal from 9 to 11 years of age submitted to aerobic training for five weeks when compared with the control group. The results indicated that the aerobic physical exercise (90 minutes) practiced for five times during the week stimulated pro-inflammatory cytokines and contributed for the suppression of the GH/IGF-1 axis[28]. The authors explained this phenomenon through the hypothesis that the mechanism that caused reduction on IGF-1 was the exercise intensity that induced the stimulation of pro-inflammatory cytokines, interleukin I (IL-1β), interleukin 6 (IL-6) and the tumoral necrosis factor (TNF-α). The authors concluded that an elevation on the pro-inflammatory factors through the performance of exercises could inhibit GH/IGF-1 axis elements.

Nemet *et al.*[29] studied the acute effect of the practice of water polo on the GH/IGF-1, the pro-inflammatory cytokines and white blood cells subpopulations in female athletes from 14 to 16 years of age. The researchers collected blood samples before and after a 1-hour and 50 minutes training session. The results indicated decreases on IGF-1 and insulin with concomitant increases on the blood lactate levels, on IL-6 (pro-inflammatory) and $IL1_{ra}$ (antiinflammatory). The IGFBP-1 responded quite well to the water polo acute training with elevation on the basal levels up to 14 times. For the researchers, the results found indicated an intense catabolic state with depression on the IGF-1 values[29]. Similarly, a study conducted with pre-pubertal females demonstrated elevation of cytokines and strong reduction on the IGF-1 values as result of aerobic training of 45 minutes a day during five weeks[4].

The pro-inflammatory cytokines reduce the IGF-1 systemic levels through several paths, being able to attenuate their effects by increasing the IGF binding protein levels that inhibit their bioactivity, for example the IGFBP-1[4,6,28]. The anabolic effects of physical exercises on the metabolic profile go beyond the classic view of the hormonal control, where gland secrets the hormone that will produce its biological effect in some specific organ and many other interactions probably will also occur.

Other researchers proposed to investigate the variations on the stature measures among athletes from different sportive modalities in the perspective of observing a body composition standard and those involving sports and/or the involvement generated by the impact of the exercise on the growth of the young athlete.

With this objective, Damsgaard *et al.* evaluated the growth of children and adolescents in different sportive modalities[18]. The authors observed, in study conducted with 184 children and adolescents from 9 to 13 years of age that several factors were emphasized in the attainment of the athletes' stature, among them they considered the genetic and nutritional aspects, the maturational level and the stature prior to the sportive practice, as the most important determinant factors. No differences between the sportive modality and the training duration on the stature obtained were observed in the investigation. This suggests, according to the authors, that the selection of children involved in sports depends on constitutional factors and the sport itself does not influence much the results. The female gymnasts of this study presented lower stature when compared with swimmers; however, this evidence preceded the beginning of the sportive training. In short, the results suggest that the pre-pubertal growth was not affected by the competitive sport and that constitutional factors are of great relevance in the selection and inclusion of children in the sportive modality.

These indicatives are in agreement with those verified by Peltenburg *et al.*[30] who observed in their study that the female gymnasts in early age already demonstrated lower stature if compared to swimmers and schoolmates. These results supported the sportive selection theory related to the size of children and corroborate that the small body provides gymnasts advantages on the performance of movements related to sports[21,22,31].

Eisenmann and Malina[31] believe that the sportive selection is a factor that assures weigh and stature below percentile 50 in both genders for long-distance runners and followed the growth rate of professional runners between 8 and 15 years of age during five years. The results indicated lower weight and stature in all age ranges and both genders when athletes were compared with the national reference. However, the authors did not believe that a negative impact of the training on the linear growth has occurred; once data suggest the important role the sportive selection plays through the body dimensions.

It is worthy mentioning that the authors did not perform the nutritional and the psychological stress evaluations, once athletes are frequently encouraged to reduce body weight with high weekly running volume.

Caine *et al.*[22] performed a literature review about the topic and the main results indicate lower stature of gymnasts before the beginning of the physical training followed by high training volume of approximately 36 weekly hours between 5 and 10 years of age with negative energetic balance. The authors concluded that high competitive level athletes certainly experienced growth attenuation; however, there is a set of factors that also contribute, among them the genetic aspects, the nourishment and the psychological stress, thus the total responsibility for the low stature among gymnasts should not be attributed to the physical training.

According to Georgopoulos *et al.*, the intensity and duration of the physical training are factors more relevant than the sportive modality[2]. However, not many researchers reported and controlled that training intensity (overload, number of repetitions, biomechanical aspects and difficulty level of the abilities), what makes the comprehension of the training cause-effect relation on growth difficult[22].

Thus, it has been suggested that the maximum weekly physical training load is of 15 to 18 hours, when working with pre-pubertal and pubertal individuals in order to avoid growth involvements[31].

In the study of Theintz *et al.*, the gymnastics and swimming groups presented higher training weekly average load if compared with groups of tennis and handball players. In none of the four sportive modalities the negative effect of the training load on growth speed and on body mass index was observed[26].

Unlike the profile observed in female Olympic gymnasts, study performed with 255 athletes with average age of 13 years who practiced rhythmic gymnastics, Georgopoulos *et al.* demonstrated that the athletes were taller, average of 160.04 cm and slimmer, average of 42.0 kg, with body mass index of (BMI) of 16.26 kg/m^2 and relative fat of 16.1% if compared with non-athletes individuals who composed the control group. The verification that the female gymnasts were taller and slimmer when compared with their controls with late menarche and delayed puberty development did not take the authors by surprise, once these adolescents are submitted to high training intensity regimen (average of 29.14 hours/week) since childhood and pre-adolescence, always being encouraged to keep low body weight. The taller and low body weigh profile seems to occur more frequently among rhythmic gymnastics athletes, also being part of the selection of these young athletes for this sportive modality[2]. In this study, the delayed puberty development and the observation of the PHV occurring at a behindhand moment was not associated to the lower predicted adult stature, once an adequate recovery on the growth potential was observed in posterior age[2], even after athletes have been submitted to high training intensity regimen (average of 29.14 hours/week) since childhood and pre-adolescence.

Similar verification was performed Klentrou and Pyley[32] when investigated Greek and Canadian female rhythmic gymnasts compared to the control group and emphasized that the Canadian gymnasts were taller than their control group, while the Greek gymnasts were shorter than their control group. The authors attributed these differences to the number of hours and days of training weekly performed by both groups. Thus, they verified that the menarche event was delayed in 32 out of the 45 gymnasts from the elite group composed of Greek and Canadian gymnasts with age average of 14.5 and 14.7 years, respectively, and when divided into two groups considering those without menarche and those with menarche, they verified that those without menarche presented higher number of hours and training frequency per week with difference statistically significant in the evaluation of the body fat percentage and stature, and stature of 167 cm for athletes with menarche and 156 cm for the pre-menarche athletes was verified. The authors emphasize, with the results presented, the importance of the training frequency and duration on the body composition and final stature.

For the American Academy of Pediatrics[33], the high intensity training and the early sportive specialization generate risks, but its

members emphasize that: "Although much concern is related to the interest in competition sports for children and adolescents, not much scientific information is available to support or to refute the risks".

In the attempt of attributing the effects of the exercise on the catabolic and anabolic mediators, it has been lately possible to determine the limits between the effects of the physical exercise aimed at the health promotion, relating its action to the activation of the GH/IGF-1 axis and the harmful effects, characterized by the excess of cytokines and the suppression of the GH/IGF-1 axis.

FINAL CONSIDERATIONS

Although much has been speculated with regard to the fact that the bone growth is increased by the practice of physical exercises, well-developed studies that could support this paradigm were not found in the specific scientific literature. What one can assert with wide scientific support is that the supervised and adequately programmed sportive activities increase the bone mineral density[1,10,34-36], particularly during adolescence[8], when the bone mass peak is about to be reached[1,10]. Studies present the combination, calcium-rich diet associated to physical exercise during adolescence as adequate resource for the maximization of the bone mass peak and hence reductions of the future osteoporosis risk[1,8,10,36,37].

With regard to the adverse effects generated by the physical training during childhood and adolescence, the sportive modality practiced is apparently regardless, once the training intensity is emphasized, being generally admitted as of large daily and/or weekly volume, high number of repetitions and high overload imposed to the skeleton. The high training intensity of several sportive modalities here mentioned, indicated an important metabolic modulation with the elevation of inflammatory markers and the suppression of the GH/IGF-1 axis. However, it must be emphasized that many times, the sportive selection itself recruits children and/or adolescents with smaller profiles[20] as strategy to obtain better results in function of the mechanical facility of movements.

Once the scientific bases in the determination of the "optimum" levels of sportive activity for children and adolescents are not yet established, it is wise to be careful in the prescription of exercises for young individuals, once the two first decades of life are unique and important for the bone growth and biological maturation.

Apparently, the type of sport does not generate restrictions of its practice for children and adolescents, but the efforts intensity should be based on the trainability previously acquired, on the body dimensions, on the maturational level and especially on the objective to be reached.

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