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Effect of strength training on bone growth and development in children and adolescents

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Abstract

Strength training is very common in adults and it has become more and more popular in children and adolescents. Strength training is designed to improve physical strength and endurance and it's often associated with the use of weights. There has been a concern that strength training could potentially stunt youth's growth by damaging their growth plate and putting too much stress on the growing body. This systematic review is to summarize previous and current studies on the effects, both positive and negative, of strength training on growth in children and adolescents. The effects of strength training were defined as its impact on bone growth, which is affected by growth hormone and sex hormones, including testosterone and estrogen. In this review the correlation between strength training in adolescents and potential risks/benefits to their height was explored. While there are both risks and benefits associated with strength training, the results suggest that properly designed and supervised strength training increases bone strength and decreases sports-related injuries and bone fracture risks, by increasing growth hormones, testosterone and bone density. Therefore, strength training has more benefits than harms to growth. In conclusion, strength training in a safe and well-supervised environment can positively improve body development as well as the height growth of adolescents with no negative effect on youth body growth.

Keywords: height growth, strength training, children, adolescents, bone density

Introduction

Strength training exercises are not only for adult trainers but also have become increasingly popular in youth and adolescents for sports training, fitness programs, and physical activities (Stricker et al., 2020). Specifically in competitive sports, strength training is a popular practice to gain competitive advantage since it builds muscular strength and promote muscle formation. Even those who do not participate in sports have found interest in using forms of strength training to procure muscularity (American Academy of Pediatrics Council on Sports Medicine and Fitness et al., 2008). Due to the recent popularity in strength training among youth athletes and adolescents, it has been a controversial topic whether strength training can be beneficial or harmful to height growth of children.

Height growth is an important part of youth development. It is generally accepted that height is mostly determined by genetics, but environmental factors play important roles as well. Studies in twins have shown that approximately 80% of height is heritability, leaving the remaining 20% to be dependent on environmental factors like nutrition and exercise (McEvoy et al., 2009). In children and adolescents, bones grow in length because growth plates in the bones are not closed. At the end of puberty, growth plates fuse and bone growth slow down and stop growing. Normal bone growth is controlled by a number of hormones, including growth hormone, thyroid hormone and sex hormones. Growth hormone is the most important factor and sex hormones,

testosterone or estrogen, are important for pubertal growth.

Strength training including weightlifting has been perceived by some researchers to have negative effects on the growing body, especially height growth of a child. Therefore, some researchers have reached the concord that strength training is harmful to adolescents and would stunt height growth. Therefore, the ongoing myth has pushed back many of those who wanted to gain muscle strength to achieve their desired muscle mass whether it is for their self-esteem, or to stimulate athletic development (Granacher et al., 2016). Studies on negative effect of strength training show that potential injuries induced by improper use of weights can stunt growth. Growth plates are highly susceptible to injury in children because they are the last segment of the bone to solidify and tend to be weak. Fractures to growth plates (that are not treated properly) may cause the bone to grow abnormally since growth plates are crucial in determining length of the mature bone; the ramification could be a crooked arm or even a leg that is shorter than the other (AAOS, 2014. Otherwise, no direct investigation to prove that strength training will hinder the heights of pubescents has been performed.

On the contrary, other studies have shown positive impact of strength training on growth development. The majority of the fitness community has reached a consensus that, as long as the child is using the weights properly and taking the right precautions, strength training will not limit a child's height but might even increase it; medical and fitness expertise now encourage children to train strength as it strengthens bone density, tendons, and ligaments while also drastically reducing risk of future injuries (Imbo, 2015). Although it may be proved that height will not be hindered, the possible increases in height is still in question. There is a correlation between strength training and higher production of growth hormones, testosterone, and bone mineral density, which are all crucial in regulating the growing body and even impelling height growth (Richmond & Rogol, 2016).

By systematic review of conflicting reports on the correlation of strength training and bone growth and development, his study shows that, under proper supervision, strength training can successfully improve body growth and development of children and adolescents by collectively increasing bone density, growth hormones, and testosterone and by strengthening skeletal muscles.

Methodology

A systematic literature review methodology was performed following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009), enabling for various differing perspectives surrounding the common myth to be taken into account and analyzed. This study was conducted by using a specific set of search terms (i.e., “strength training” AND “adolescents”) that were inputted into academic databases PubMed and Googe Scholar (few academically reputable websites, which included information from databases and professionals, were also tracked by the same search terms). Any article that included the growth of a youth was included in order to broaden understanding of research while still sustaining the relevancy of the question. Additional research based on references was also performed to find relevant search terms (such as “growth hormones”) that may have an indirect impact to height.

Out of the yielded results from the search, relevant papers (n=71) were screened. Papers excluded from the research are the ones that did not discuss the specified age range (children and adolescents ages 8-20) of the subjects in topic, talked about a specific group of people not targeted in the investigation (ex. strength training impact on people of obesity or cerebral palsy), or was irrelevant (focus on a different aspect of the effects of strength training other than growth). Articles (n = 27) were traced on a document where they were thoroughly evaluated for their quality, application, and creditability. A PRISMA 2020 checklist was implemented to help guide the

process and document reference information (Page et al., 2021).

Of the full text articles that were evaluated, articles (n=6) were excluded because they discussed more towards growth of pubescents in maturation/ weight or discussed of the psychological stress-related injuries to the distal radius in female height growth. Other articles that were not directly focused on the correlation of strength training and height but included factors of height that may be insightful (ex. Study of growth hormones, testosterone, and bone density), were included in the study. Authors that had differing viewpoints were both used as it brings diversifying information of the potential benefits and risks of strength training. Figure 1 depicts the method of research in further simplicity.

Results

This systematic review has provided four different aspects to be considered: risks of injuries in strength training, bone density, growth hormones, and testosterone. Skeletal injuries to the bone are incredibly prone to have a negative impact on height as well as the bone density, which is why they were included. Growth hormone and testosterone were considered as major hormones known to have anabolic effect on bone growth during puberty. Testosterone possesses strong androgenic and anabolic effects that are important for both women and men, although men produce significantly more testosterone than women.

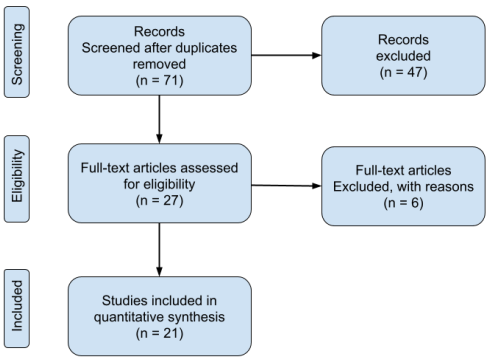

FIGURE 1: PRISMA flow diagram.

Risks of Injuries in Strength Training

The common myth that the use of strength training by adolescents and children will be detrimental to their height originated from the misconception that injuries are frequent potential injuries to growth plates that may be deleterious to linear growth. Starting from the 1970s and 1980s, resistance training (a type of strength training mainly to increase the size and strength of skeletal muscles) was not advocated for youth due to the postulated "high risk" imminent when performed; data from the National Electronic Injury Surveillance System (NEISS), stated the increasing trends of growth plate injuries within youth lifers (Bubnis, 2018; Faigenbaum et al., 2011). While the NEISS did not specify the cause of injury that is most prevalent from strength training, data suggests that 40% to 70% of all strength-training injuries derived from muscle strains, most commonly in the hand, low back, and upper trunk (American Academy of Pediatrics Council on Sports Medicine and Fitness et al., 2008).

However, studies have shown that most injuries resulting from strength training are due to improper usage of weights or the absence of professional supervision of the child. One incidence of a 16-year-old football player indicates that he attempted to bench press 48 kg of weight without any assistance, resulting in a fracture of the left distal radius with dorsal displacement (Faigenbaum et al., 2011). Improper usage of weights is only subject to cause injuries. Injuries to back and trunk are commonly demonstrated because of adolescents' impulse to build "mirror muscles". This focus on building muscle mass brings about the principle of improper training because the child is using weights the that is neglecting other important muscles like the core and trunk when training, leading to the persistent soft tissue injuries (Myers et al., 2017). According to surveyed study on UK students ages 13-16, practice of Olympic weight lifting and weight training reported an injury rate of 0.0012 per 100 participation hours (Barbieri & Zaccagni, 2013). Similarly, strength training

experimental programs were studied and out of 10 studies, 3 reported injuries; injury rates of 0.176, 0.053, and 0.055 per 100 participant-hours, respectively (Myers et al., 2017).

Strength training isn't the only exercise that holds a probability of injury to the growth plate. While growth plate injuries are usually caused by a sudden event, they can also occur gradually; repeated stress inflicted on the bone through participation in competitive or recreational sports can intensify the likelihood of injury (AAOS, 2014).

It is reported that approximately 15 to 30 % of childhood fractures are injuries to the growth plate (Bubnis, 2018). Lastly, a study done on Canadian and Belgian boys have shown that there is no difference in stature and growth rate between those who participated in trainings and those who did not participate in trainings (Malina, 1994).

Bone density

Strength training has been shown to have a positive impact on the bone, including bone mineral density; strength training in youth is able to strengthen bone mineralization and be beneficial to bone density (American Academy of Pediatrics Council on Sports Medicine and Fitness et al., 2008). Similarly, GH and IGF-1 are found to have essential interventions in bone growth through the promotion of chondrocyte proliferation and differentiation. GH and IGF-1 appear to act interdependently, in which together they regulate the bone growth and remodeling, to influence longitudinal growth and bone strength. The cartilage growth plates are made up of three layers: the resting zone, proliferative zone and hypertrophic zone. Within the resting zone, GH performs to induce chondrocytes that differentiate and proliferate, and in both the proliferative and hypertrophic zones, IGF-1 induces differentiation and an increase in height within the columns of cells. (Blum et al., 2018). Additionally, physical exercises induce improvements in bone density, mass, and size. A study done on prepubertal boys required 10 jumping intervention 3 times per week for 7 months and results displayed a significant improvement in bone mineral at several bone regions (Richmond & Rogol, 2016). Similarly, to the adolescent wrestler mentioned above, deficit energy intake through excessive or over training may be detrimental to the bone. Still ample levels physical activity has shown to enhance optimal bone strength and is therefore recommended for children and adolescents.

Growth hormones

The fundamental endocrine system that regulates linear growth in children is known as the growth hormone (GH)–insulin-like growth factor (IGF)-1 axis, which is made up of hormones, growth factors, and amino acids; the GH being a strong regulator of the IGF-1 secretion. GH-IGF-1 axis function disorders can severely influence growth potential. While GH is the predominant hormone responsible for somatic growth, most of the effects of GH are moderated through IGF-1, including long bone growth. For example, secretion of IGF-1 in cartilage cells of the growth plates have shown to have direct effect. (Blum et al., 2018; Roemmich et al., 2001). Growth hormone deficiency patients have lower concentrations of IGF-1, approximately 70% compared with age matched norms, linking short stature to the level of IGF-1 in children (Ranke et al., 2004). Furthermore, physical activity in children has shown to be critical to tissue growth and anabolism and has also demonstrated the increase of GH and IGF-1, as well as rapid growth. Exercise has shown to induce an increase of IGF-1; IGF-1 is believed to perform a big role in building muscle mass through strength training. Pubertal status has shown to be a determinant in GH response to acute exercise where the children more advanced in his or her pubertal stage is shown to respond with a greater GH concentration (Richmond & Rogol, 2016).

With the heightened participation in competitive sports and physical activity, concerns regarding the aftermath of excessive training potentially stunting growth, due to the negative impact on the GH-IGF axis, have risen. In a study

on in prepubescent female gymnasts, following 3 days of intensive training (3.5-5.5 hours daily), the concentrations of IGF-1 had decreased by 25% while there was no change in GH levels. (Richmond & Rogol, 2016). Moreover, it has been stated that participation in competitive sports that do not use weights have not appeared to have delayed puberty or change in growth. Conversely, there have been very few cases of slow of growth and maturation among some sports that have weights integrated in their training. Sports like gymnastics and wrestling have demonstrated this risk by the experience of energy depletion to the extent that there is a combination of extreme energy expenditure and restricted energy intake; greater output of energy than intake. On average, adolescent wrestlers expends about 800 kcals per practice, practicing about 2.5 hours a day for 5-6 days a week. With this in mind, it has been found that wrestlers actually intake 50% less than recommended. This under-nutrition taken by youth wrestlers may cause disruptions in the GH-IGF-1 axis, vital in determining rate of growth and pubertal maturation (Roemmich et al., 2001).

Testosterone

Injections in testosterone have proved to improve first year height velocity of young children with constitutional delay of growth and puberty, without affecting the final height (Giri et al., 2017). Although testosterone has not been proved to increase (or decrease) the height of adolescents, it enhances muscle hypertrophy, strength, endurance, and power. In a study of male junior elite weight lifters ages 16 to 18, following a normal session of intensive weight lifting, there was a 32% increase in testosterone concentration. Another study in male triathletes with an average age of 15, displayed significantly higher concentrations of testosterone after 16 training sessions in a 2-week period. Young athletes after a session of strength training resulted in a lower increase in testosterone concentration (Richmond & Rogol, 2016). One study tested the hormonal response to high power resistance exercise by taking the serum samples of testosterone (as well as cortisol and lactate) before and after lifting sessions of "10 × 5 speed squats at 70% of system mass (1 RM + BW) with 2 min inter-set rest intervals". Results showed a very large effect size for testosterone; high power resistance exercise produces acute increases in testosterone (Fry & Lohnes., 2010). However, there have been no studies that have linked the higher production of testosterone and growth height but is something to consider in further studies as it may prove to have an indirect positive effect.

Discussion

These results indicate the fallacy of the negative relation associated between strength training and growth of children and adolescents, indicating that this training may not stunt height growth. Numerous studies have shown that strength training holds minimal risk and under the proper conditions (adult supervision, proper amount of weight and techniques taught by professional trainer, etc.), it would be safe and may not disturb the growth of height in adolescents and pubescent kids (Dahab & McCambridge, 2009; Malina, 2006; Bubnis, 2018; Malina, 1994; Roemmich et al., 2001). Health benefits that are yet to be found to have direct influence to height (testosterone and bone density) demonstrate the positive impact strength training has on the entire body, not limited to just height growth.

TABLE 1: Summary of benefits, plausible risks, and ways to reduce risks of strength training.

Benefits	Plausible Risks	Ways to reduce risks
• No found negative impact to height • Low risk of injury (proper form) • Higher production of GH/ IGF-1 • Improvement in bone density • Increases in muscle strength, mass, and growth • Boosts in self esteem	• injury to growth plates • Muscle strains • Soft tissue injuries • energy expenditure and restricted energy intake: potential slow of growth	• Use proper form and weights • Seek guided training from professional • Increase nutritional intake • Build all core muscles; do not focus just on "mirror muscles"

Some limitations of this systematic review involve the lack of literature revolving around the direct consequences that strength training holds on the height of the growing body, although much data was found about risk of injuries, GH, and IGF-1. More research targeted towards the stress that weight lifting puts on the bones or growing body should be investigated since gradual skeletal risks were not included very much in this study. Further studies may include the application of strength training on those with skeletal or growth diseases such as osteoporosis and growth hormone deficiency. In addition, while testosterone was not proven to hold direct consequences to height, the correlation between height and higher testosterone production is a subject to be studied and may prove to be very important to this review.

To conclude, this study has shown that the benefits of strength training, including increased production of growth hormones, improvements in bone density, increases in muscle strength, and boosts in self-esteem, outweighs the plausible risks like injury to growth plates, etc. Moreover, these risks can be avoided most of the times by using the appropriate amounts of weights, proper technique, and professional supervision to train.

Table 1 summarizes the benefits and risks, as well as the specific conditions to follow in order to reduce the risk of injury. Although genetics is the primary determinant in the peak stature of a child, the conditioning of the growing body during this crucial period is just as important as one fault physical activity, such as strength training, could potentially alter their linear growth curve and final height. However, following the listed conditions suggested in this study, any concerns of strength training negatively impacting children and adolescents should be dispelled. Any possible injuries or negative effects observed by exercise should be anticipated and one should take full responsibility regarding the plausible risks that may be pertinent to physical growth.

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