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Review

Strength Training for Children and Adolescents: Benefits and Risks

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A B S T R A C T

Physical activity has proved to be an effective means of preventing several diseases and improving general health. In most cases, though, light to moderate efforts are suggested, for both youngsters and adults. Common sense advices call for late inception of intense, strength training-related activities, like weight lifting and plyometrics, which are usually postponed at the end of the growth age, even among sport practitioners. However, such advices seem to have a mainly anecdotal nature. The purpose of this review is to evaluate risks and benefits of early inception of strength training, at adolescence or even earlier, and to verify whether concerns can be grounded scientifically. Current literature does not seem to have any particular aversion against the practice of strength training by children and adolescents, provided that some safety rules are followed, like medical clearance, proper instruction from a qualified professional and progressive overload. At the same time, several studies provide consistent findings supporting the benefits of repeated, intense physical efforts in young subjects. Improved motor skills and body composition, in terms of increased fat free mass, reduced fat mass and enhanced bone health, have been extensively documented, especially if sport practice began early, when the subjects were pubescent. It can be therefore concluded that strength training is a relatively safe and healthy practice for children and adolescents.

Key words: *strength training, weight lifting, adolescents, growth, body composition*

Introduction

Modern Western societies imply increasingly sedentary life styles and reduced physical exercise. Technological progress, limited outdoor activities and economic improvement have modified dietary habits and reduced the amount of exercise performed by children and adolescents[1]. It is well known that regular moderate intensity physical activity – such as walking, cycling, or participating in sports – has significant benefits for health. According to the 2008 guidelines of the European Commission[2], school-aged youth should participate in moderate to vigorous daily physical activity for 60 minutes or more. Obesity, sedentary lifestyle and poor cardio-respiratory fitness in childhood and adolescence may increase the risk of health problems later in life. The teenage years bring many physical, social and psychological changes for the individual. From infancy to adulthood, growth, maturation and development occur simultaneously and interact: growth consists in the increase of the size of the body as a whole and of its parts, maturation refers to progress towards the biologically mature state and development refers to the acquisition of behavioral competence[3].

Changes in body dimensions and composition during growth and maturation are factors affecting strength and motor performance[4]. Some changes in anthropometric traits and strength in a sample of Italian adolescents studied by Gualdi-Russo and Toselli[5] are reported in Figures 1–4.

The strength and motor performance varies during childhood and adolescence in relation to biological and environmental factors. Among biological factors the specific contribution of maturity status is apparent: the strength advantage of early-maturing subjects is related to their larger body size in comparison to late-maturing ones. These differences are more marked in boys than in girls. Regular physical activity is an important factor during growth and maturation, regulating body weight and, particularly, fatness.

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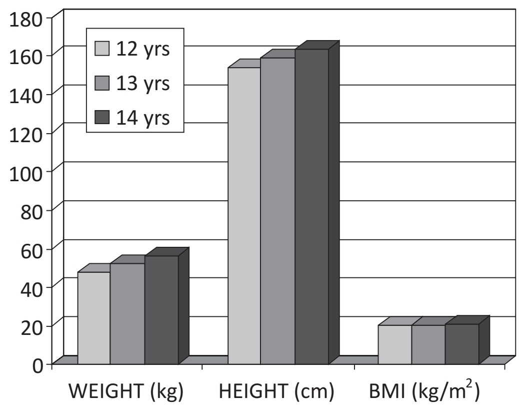

Fig. 1. Anthropometric traits in a sample of Italian adolescent males[5] by age.

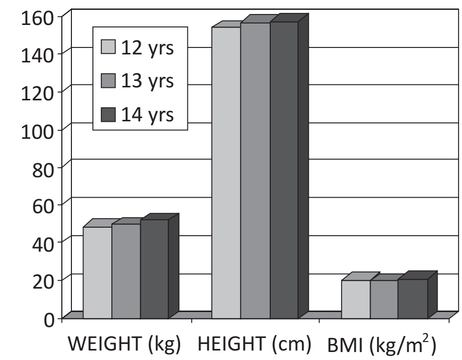

Fig. 2. Anthropometric traits in a sample of Italian adolescent females[5] by age.

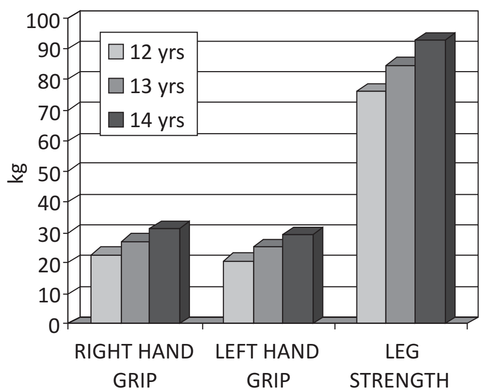

Fig. 3. Strength values in a sample of Italian adolescent males[5] by age.

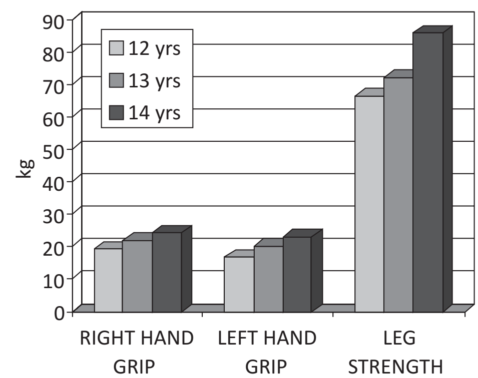

Fig. 4. Strength values in a sample of Italian adolescent females[5] by age.

Information on the characteristics of elite young athletes in a variety of sports is rather limited. The evaluation of the maturity status is essential when working with young athletes because individual differences in the timing and tempo of biological maturation, particularly during adolescence, influence body size and composition, muscular strength and behavior. Inter-individual variability has important implications for performance, age-group competitions and talent identification, selection and development. Albeit BMI is widely used in surveys of health and nutritional status, its interpretation in young adults, especially athletes, as an indicator of fatness should be taken with caution. Therefore, in kinanthropometry, in order to evaluate the positive effects of physical activity on body composition, the athlete's body fat percentage, fat mass and fat free mass are assessed. Changes in body composition from early to late adolescence can be summarized as follows: males gain almost twice as much fat free mass as females, and females gain about twice as much fat mass as males.

Large fat free mass is important in performances that require force to be exerted against an object, as in shot put or weight lifting, but can be a limiting factor in tasks in which the body must be projected as in vertical jump or moved across space, as in running. Fat free mass is significantly related to strength in male adolescents[3].

In sport practice, strength training was usually introduced at the end of the somatic growth, that is when the athlete was 18 years old or so. In particular, to avoid weight lifting before and during adolescence was a common suggestion in many different contexts connected to physical activity, from commercial gyms to physical education courses. This conservative approach has a mainly anecdotal origin, since usually no scientific evidence is given in order to support it. Most of the concerns are related to the possibility of injuries or diminished growth potential. Still, many of the young athletes who regularly compete in various sport disciplines begin their training very early, when they are pubescent or even pre-pubescent. Beside the fact that students begin physical education at primary school in many countries, early inception of sport practice is often suggested in order to take advantage of the ease and quickness with which children and adolescents improve their motor control and acquire new sport skills.

Furthermore, adolescents can be observed while lifting weights during their usual daily activities, outside a sport or training facility: carrying a schoolbag, a suitcase, a shopping bag or other items, lifting them from the floor. Without proper training, they may do it rounding their back or using any other improper technique, while the correct one could be learnt under supervision from a weight lifting instructor, inside a gym.

It is therefore necessary to evaluate whether the advice to postpone strength training in general and weight lifting in particular at the end of adolescence is sound and can be substantiated scientifically. The main purposes of the present review are the following: to find any evidence in current literature of benefits or dangers for the health of the adolescents related to early inception of strength training, and to compare the relative stress of this kind of physical activity to other common sport practices.

Strength Training: Concepts and Objectives

Strength training is a form of physical activity, usually structured and planned, involving intense efforts against a resistance. Its main aim is to increase muscular strength, in order to improve performance, at least in case a sport is practiced. It is extensively adopted in power-oriented sports, like sprinting[6] and soccer[7], even if its benefits are recognized also in endurance sports, like long distance running[8,9] and cross country skiing[10,11]. In a non-competitive environment instead, strength training is adopted for many different purposes. For example, strength training may be used to improve overall fitness, increasing muscle hypertrophy and reducing body fatness at the same time. In fact, strength training can be an effective means to improve body composition[12]. In other cases, some individuals may adopt it in order to accomplish some professional goal, like achieving the degree of physical fitness which is required in the military or to join the fire brigade.

To train strength, muscular force is applied against some kind of resistance. In most cases, especially when the individual is healthy, resistance is provided by free weights, like barbells, dumbbells or the athlete's own body weight, or by weight machines, like the leg press, the lat machine etc. This kind of training is usually adopted in sport conditioning, because the load can be increased progressively according to the athlete's strength, which can be considerable. Athletes employ gravity also in other ways in order to improve their performances, like in plyometrics or high-impact training, where body mass is accelerated dropping from a pre-determined height, according to the athlete's ability and conditioning level. This kind of strength training is usually considered the most dangerous, because the real impact forces applied to the athlete's body (bones, muscles, tendons, ligaments etc.) are not easily measured, as in weight lifting. Since force is defined as mass times acceleration, we can say that weights mainly focus on the first factor, while plyometrics relies on the second to increase force. Nonetheless, also weights can be accelerated, in order to increase force production without adding kilograms, and advanced plyometrics may imply added weight by means of weighted belts or vests.

It must be considered, though, that similar strength training effects can be found in sport practices other than weight lifting or plyometrics, like sprinting, gymnastics and other kinds of power-oriented sports, or team sports involving leaping and bouncing, like volleyball and basketball. These types of physical efforts produce great acceleration, which, applied to the athlete's body mass, produce great force. Nonetheless, these intense efforts are usually practiced by children, even outside a sport environment, simply while playing with their peers.

Strength training has in important role in rehabilitation after injuries, especially those which involve surgery and/or a long period of immobilization, in order to re-gain the physiological muscle hypertrophy and joint range of motion[13–18]. In case of injuries to lower limbs, when the patient is still lying in bed, body weight can be excessive and not suitable for post-surgery rehabilitation. Therefore, non-bodyweight bearing exercises can be used, by means of cables and/or small weights, attached to the ankles of the patient, like in leg raises and knee extensions.

Body weight can be excessive also for healthy individuals who have a low relative strength, that is a low strength-to-body weight ratio. A push up, a pull up or even a body weight squat can be a demanding task for people who are too young, elderly, overweight or out of shape. Free weights or machines can provide a controlled and adjustable source of resistance. For example, a push up can be effectively substituted by a bench press, a pull up by a lat pull down using a lat machine, a body weight squat by a leg press, involving more or less the same muscle groups. Weights can be adapted to the individuals' actual strength, which may be relatively low compared to their own body weight.

Other kinds of resistance than weights may be applied in order to increase muscular strength, like elastic bands, or friction, as in water or on a steady bike. In fact, gravity is not necessarily present (e.g. astronauts during space missions are at risk of losing considerable amounts of muscle mass[19,20]) or not fully applicable. Orthopedics patients may have access to a swimming pool, where the weight-bearing effort of an injured knee, ankle or hip can be reduced. At the same time, also competitive swimmers may use swim paddles to increase the resistance provided by water.

Exercises are usually performed in sets of several repetitions (i.e. consecutive lifts). If heavy loads are employed, providing stimulus for maximal strength, then repetitions are necessarily low in numbers. When the load is moderate, in order to improve body composition and cardiovascular fitness, then the overall number of repetitions can be considerably high. The main training parameters are intensity and volume. Intensity is given as percentage of the maximal load which can be lifted for the prescribed number of repetitions: 1 repetition-maximum (RM) is the load which can be lifted just once, 10 RM is the load which can be lifted 10 times within one set. Strength training implies relatively heavy loads, between 60% and 100% of 1 RM, the so-called »strength training zone«[21]. For example, the 90% of 1 RM is a quasi maximal load, allowing for small volume (i.e. low repetitions). Volume is the total number of repetitions per exercise. For example, performing 3 sets of 10 repetitions in one given exercise determines a volume of 30 repetitions.

The most common strength training exercises are listed in Table 1, with the discipline in which they are usually practiced, even if in most cases athletes involved in different sports may use a blend of them. This is especially true in body building, where the overall balanced development of muscle mass is of great importance. Therefore, body builders use most of the listed exercises (and even more than those), while strength training for athletes usually comprises a small set of exercises, like the clean, the squat and the bench press, involving most skeletal muscles in a coordinated fashion.

TABLE 1
COMMON STRENGTH TRAINING EXERCISES

Olympic weightlifting	Powerlifting	Body building	Body weight training
Snatch Clean and jerk	Squat Bench press Deadlift	Overhead presses Biceps curls Leg extensions Leg curls Rowers	Push ups Pull ups Parallel dips Body weight squats One-leg squats Sit ups

Benefits and Risks of Strength Training for Children and Adolescents

For reasons which have been mainly reported anecdotally, strength training, especially if involving weight lifting, has been considered dangerous for children and adolescents, and at risk of limiting their growth. However, the American College of Sports Medicine highlights that there is no current scientific evidence of the fact that strength training and weight lifting are inherently dangerous or can restrain the growth of children and adolescents. Like any other kind of sport practice, there are some risks which can be considerably diminished following a small set of suggestions: proper supervision form an expert adult, warm up and stretching before lifting, focus on proper form rather than load, gradual resistance increases as technique, strength and control improve[22].

The American Academy of Pediatrics gives comparable guidelines, implying that strength training can be safe and effective for children and adolescents, provided that medical clearance is granted. At the same time, it discourages them from practicing sports, like Olympic weightlifting and powerlifting, which involve maximal lifts[23–25].

A similar position has been taken by the National Strength and Conditioning Association, which is in favor of supervised and appropriately prescribed strength training for both pre-adolescents and adolescents[26].

In strength training, the gains in muscular strength are often associated with improvements in body composition. In a study by Faigenbuam et al.[27] a group of boys and girls aged between 8 and 12 followed a twice-a-week resistance training program for 8 weeks. After warm up and stretching, the training group performed the following 5 exercises: leg extension, leg curl, bench press, overhead press and biceps curl. Both training and control groups continued physical education at school. As expected, strength gains in the training group were significant compared to both pre-training and control. Also improvements in body composition were significant: skinfold thickness decreased of 2.3% on average, compared to an increase of 1.7% in control group. It is interesting to note that upper arm, chest and hip girths did not change significantly. The only exception was the thigh girth, which anyway increased relatively less than control (+2.4% *vs.* +3.9%).

The volume-intensity schema adopted was the popular Delorme method: 3 sets of 10 repetitions each, the first one with 50% of 10 RM, the second one with 75% of 10 RM and the third one with 100% of 10 RM. Delorme was among the first physicians who realized the importance of strength training – and weight lifting in particular – in rehabilitation after injuries[28].

A similar pyramiding method was adopted in a study by Schwingshandl et al.[29]. Obese children and adolescents were prescribed a diet with caloric restriction. Unfortunately, diet alone may reduce both fat and fat free mass. Subjects were therefore divided into 2 groups: training and control. After some light aerobics and stretching as a warm up, the training group performed 3 to 4 sets, 10 repetitions each, of the prescribed exercises, which were chosen to involve all major muscle groups. The first set was performed using the 50% of 10 RM. Load was increased progressively in each set, until muscle failure because of fatigue. When the child was able to complete more than the prescribed 10 repetitions in the last set, the load was increased in the following training session. After 12 weeks, weight change was not significant in both groups, while the increase in fat free mass was significantly higher in the training group than in control, implying that resistance training may have a positive effect on body composition in fat reduction programs for obese children and adolescents.

Supervised strength training, involving weight lifting (bench press, leg extension, lat pull down etc.) and stretching, after an adequate warm up, has proved to be effective in a group of children, males and females, increasing strength, reducing skinfold thickness, improving body composition, motor skills and flexibility[30].

In a study by Watts et al.[31] obese adolescents were involved for 8 weeks in a strength training program consisting in 1 hour of circuit training, 3 times per week, including both cycle ergometer and resistance training. Since the program was primarily designed to treat obesity rather than improving strength, exercise intensity was kept between 55–70% of pre-training 1 RM. Training reduced abdominal and trunk fat, thus diminishing cardiovascular and metabolic risks, and increased strength, body composition and overall fitness at the same time.

Even if the main purpose of strength training is to increase muscle strength, it seems to have a positive carry over also in bone density and therefore it qualifies as an interesting means for preventing and reducing osteoporosis. This is particularly true for children: if strength training is adopted early, bone mass gains last longer. Skeletal exposure to mechanical loading during growth seems to be an effective strategy to increase bone mass and density, according to Khan et al.[32]. In a study by Fuchs et al.[33], high impact training is used to verify its efficacy in improving skeletal mass in a group of elementary school children. Bone mineral content, bone area and bone mineral density were adopted as indices of bone health. The training protocol consisted in 100 drop jumps form a 61 cm box, 3 times per week for 7 months, implying ground reaction forces up to 8 times body weight. However, the adopted method proved to be safe and effective in improving the above mentioned parameters at the femoral neck and lumbar spine. Actually, in a popular sport like gymnastics, impact forces in drop landings range from 8.2 to 11.6 times body weight, according to a study by Ozguven and Berme[34].

Even if the authors say that the program could be introduced in physical education classes, its main limitation may be in the fact that high-impact training may result in an excessive effort for overweight children. Still, in the training group no injuries occurred during the whole duration of the study. Actually, selected children had to be within the 20% of the recommended weight for height and age. The benefits at the femoral neck persisted even after several months of detraining, when the same bone health parameters were re-assessed in both exercise and control group[35].

Significant positive effects of impact training on bone mineral content at the hip was also found by Gunter et al.[36] in a longitudinal study. The benefits of 7 months of impact training on a group of school children were partially maintained up to 8 years later.

Osteoporosis is a major problem especially for adult women. Even if considerable improvements in terms of bone health can be assessed in adults engaging in some form of strength training, the benefits do not seem to persist as long as in children or adolescents, suggesting that early inception of intense physical exercise may be prescribed for long-lasting improvements. A study by Winters and Snow[37] assessed bone mineral density in a group of females aged 30–45, before and after a 12 month training period. The training program included both high impact and resistance training (squats, lunges and calf raises). Drop jumps off a box generated ground reaction forces of 4 to 5 times body weight. Intensity was gradually increased using weighted vests. After the training period, exercisers improved their bone mineral density and strength significantly, with respect to both baseline (pre-training) and control values. Unfortunately though, after 6 months of detraining, values decreased significantly towards baseline values.

A study by Kannus et al.[38] evaluated the effects of playing starting age on bone mineral content of the dominant arm in a group of female tennis players. Athletes had a significantly higher difference in bone mineral content between dominant and non-dominant arm compared to control. The difference was 2 to 4 times greater in individuals who had started playing tennis before or at menarche, compared to those who had started 15 years after menarche. Tennis resembles strength training and may carry over similar effects on the bones since it consists of ballistic and explosive movements, handling a light implement. Even if the involved masses are small (ball and racquet), the acceleration produced during the impact may be very large, producing great force against the dominant arm.

Similar positive effects on bone mineral density of female gymnasts were found by Proctor et al.[39] in the whole body and in particular in the upper limbs, without any significant bilateral differences, which is a major advantage compared to tennis. Gymnastics exercises, like pull ups and ring or parallel dips, are often employed in body weight strength training, for their carry over to upper body muscle strength.

Swimming and cycling are among the most popular sports and bring several health benefits. However, bones seem to be less directly addressed by these activities, because of their non-weight-bearing nature, which limits the loading on the skeleton. A group of well trained adolescent females (track and field athletes, gymnasts and water polo players) were assessed by Greene et al.[40]. Although all the selected sports require intense physical work, gymnastics involves weight-bearing in both the upper and lower body, track-and-field (sprints and jumps) only in the lower body, and water polo has no weight-bearing component. Water polo players did not show greater bone strength or muscle size in the lower leg compared to controls. On the contrary, gymnasts showed significantly greater bone strength than non active females. Also track-and-field athletes displayed greater bone strength in the lower leg, compared to controls. The gymnasts showed the greatest musculoskeletal benefits in the upper body. Despite intense training, water polo players showed no significant benefits in musculoskeletal health in the lower body and only limited benefits in the upper body when compared with non active girls.

Ferry et al.[41] investigated bone mineral density in female adolescent soccer players, swimmers and control group. Bone mineral density was significantly higher in soccer players compared with swimmers. In contrast, swimmers had weaker bones than controls, despite the fact that female swimmers cannot be considered sedentary subjects.

Effects of strength training on connective tissues (ligaments and tendons in particular) have not been as widely assessed as those on bones. However, a recent study[42] has found a positive correlation between resistance training (in particular Olympic weightlifting) and cruciate ligaments' cross sectional areas. The authors conclusions are that the benefits were induced by early inception of heavy training at the age of puberty.

Discussion and Conclusions

An meaningful distinction should be made between weight lifting for strength training and Olympic weightlifting. The latter implies competitions in which maximal or even supra-maximal (when the lift fails) loads are employed, as in powerlifting. In strength training instead, sub-maximal weights, which can be lifted more than once, are used. This distinction may account for a different risk factor between the aforementioned disciplines. In general, whenever a maximal effort is required, as in competitive sport, it is believed that risks tend to be present in a higher percentage than in recreational activities. More specifically, even if strength training may be strenuous and intense, if no maximal loads are employed, than it can be considered a safe and effective form of physical activity for most individuals, including children and adolescents, provided that proper instruction and supervision are given.

However, a study by Hamill[43] questions the common belief that resistance training is safer than Olympic weightlifting, since both appear to be relatively safe according to his findings, especially if compared to other sports. The surveyed subjects were UK students, aged 13 to 16. Practicing both Olympic weightlifting and weight training had an injury rate of only 0.0012 per 100 participation hours. Individually, both disciplines scored well below other popular British sports, like soccer, rugby or even athletics.

In a study by Risser et al.[44] muscle strain, a non-disabling injury, was reported to be the most common accident among high school American football players practicing weight lifting as a form of strength training. The cumulative percentage of injuries among all athletes was a reasonable 7.6%, corresponding to 0.082 injuries per person/year. Much higher rates can be found in adolescent[45] or amateur[46] soccer players. However, the study did not specify whether injuries were caused by maximal lifts (i.e. excessive load) or poor form, as it may happen in a competitive environment, where fatigue and strive for performance may lead to an excessive demand on the athlete's physical capabilities.

The topic of growth and strength training could be further assessed from an endocrine point of view, considering the relationship between exercise and hormonal responses. A review by Kraemer and Ratamess[47] highlights the well established finding that resistance training and growth hormone are positively correlated, but further research is needed in order to verify whether strength training could induce positive endocrine responses in adolescents.

In conclusion, early inception of strength training, at adolescence or even earlier, does not seem to imply higher risks than other popular sport disciplines, provided that the young athletes follow the aforementioned guidelines. In particular, supervision by an expert instructor, focus on proper technique and cautious progression in increasing loads are the most common advices which must be adhered to. On the positive side, resistance training has proved to increase basic motor skills, like muscle strength, coordination and flexibility, but also body composition, in terms of improved fat free to fat mass ratio and increased bone health.

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TRENING SNAGE ZA DJECU I ADOLESCENTE: KORISTI I RIZICI

S A Ž E T A K

Pokazalo se da je tjelesna aktivnost efektivno sredstvo u prevenciji bolesti i poboljšanju općeg zdravlja. No, u većini slučajeva se ipak preporuča laka ili umjerena tjelovježba, kako za djecu tako i za odrasle. Nekad se znaju preporučati i intenzivni treninzi snage, poput dizanja utega ili pliometrije, koji se čak i kod sportaša prakticiraju tek pri kraju razvojne dobi. Takve preporuke mogu biti dvojake prirode i cilj je ovog rada procijeniti rizike i koristi ranog uvođenja treninga snage, u adolescenciji ili čak ranije, kako bismo potvrdili postoji li znanstveno opravdana zabrinutost. Iz aktualne literature se čini da ne postoji averzija prema treninzima snage kod djece i adolescenata, ukoliko se primijenjuju određena sigurnosna pravila poput liječničke dozvole, točnih i detaljnih instrukcija od strane kvalificiranog profesionalca i progresivno opterećenje. U isto su vrijeme neke studije utvrdile korist od ponavljajućeg, intenzivnog tjelesnog napora kod mladih. Zabilježene su poboljšane motoričke sposobnosti, manja količina tjelesne masnoće i zdravije kosti, pogotovo ako se s treniranjem započne rano, u pubertetu. Iz navedenog se može zaključiti da su treninzi snage sigurni i zdravi za djecu i adolescente.