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Literature Review

Neuromuscular Adaptations to Strength Training in Children and Adults

Anastasia Athanasiou*

Department of Orthopaedics, Al Malaki Specialist Hospital, Bahrain

***Corresponding Author:** Anastasia Athanasiou, Department of Orthopaedics, Al Malaki Specialist Hospital, Bahrain.

Received: November 08, 2022; **Published:** Novemver 18, 2022

Abstract

The neuromuscular performance of preadolescent children differs significantly from that of adults. It is generally documented that mechanical loading, cumulatively with the effect of maturation, improves muscle strength in childhood. This improvement is mainly considered the result of neuromuscular adaptations, although there is evidence of morphological adaptations too. In addition, children have less ability to mobilize type II muscle fibers, but this ability improves greatly under the influence of training. The size and architecture of muscles and tendons differ between children and adults, affecting the macodynamic and tachodynamic relationship. Athletic performance depends on two key areas. Neuromuscular adaptations and hypertrophy of physical abilities. Through the improvement of physical abilities, the best performance is achieved in all sports. Towards this direction, we study the neuromuscular adaptations to strength training in children, in order to efficiently consult athletes and trainers on how increased strength, power, speed and muscle hypertrophy can lead to improved performance.

Keywords: *Neuromuscular Adaptations; Strength Training; Children; Adults*

Introduction

The neuromuscular performance of preadolescent children differs significantly from that of adults. It is generally documented that mechanical loading (e.g. resistance exercise), cumulatively with the effect of maturation, improves muscle strength in childhood. This improvement is mainly considered the result of neuromuscular adaptations, because there is a lack of androgens for muscle hypertrophy, although there is evidence of morphological adaptations (e.g. muscle hypertrophy). In addition, children have less ability to mobilize type II muscle fibers, but this ability improves greatly under the influence of training. For example, artistic gymnasts (9.5 ± 1.2 years) were compared with untrained, peer children (10.1 ± 1.3 years) and untrained adult men (22.9 ± 4.4 years) and found that young athletes had a similar level of torque development when bending elbows with adult untrained men and an 11 - 20% higher rate of torque development than their untrained peers, despite the absence of greater muscle hypertrophy. The researchers attributed this finding to the higher levels of motor unit stimulation and the increased mobilization of type II muscle fibers in young athletes due to chronic artistic training.

Due to the limitation of taking muscle biopsies in children, data on muscle composition in children are scarce and come from previous studies. In these studies, it is shown that children have a higher percentage of oxidative fibers (type I) compared to adults. Also, type II muscle fibers in children appear to be smaller in cross-sectional area than type I fibers, which probably indicates reduced activation and/or use of type II motor units in childhood. It is alleged that children may not be able to use type II muscle fibers as adults, that children's type I muscle fibers are more tolerant of fatigue and/or that children have a higher rate of type I muscle fibers, which is reduced gradually from the age of 5 to the age of 20 (from 65 to 50%). However, differences in muscle composition between children and adults need to be further explored in the future using new, non-invasive methods.

The size and architecture of muscles and tendons differ between children and adults, affecting the macodynamic and tachodynamic relationship. For example, tendons have less stiffness in childhood boys than in adolescent boys and adults. A possible cause of this phenomenon is that the myototendin tissue of athletes during adolescence is more flexible than that of older athletes. Resistance training (10 weeks, 2 times/week) increases tendon stiffness, but does not affect the rate of force application. The development of tendons during childhood and adolescence brings about adjustments both in their dimensions (length, cross section) as well as in their properties.

First it has to get explained how the development of athletic performance as a derivative of biological evolution and the development of athletic and physical abilities, takes place. Athletic performance depends on two key areas. Neuromuscular adaptations and hypertrophy of physical abilities. Neuromuscular adaptations be.g.in at the age of about 10 years and peak at the age of 16 - 17 years. In order to play football, children between the ages of 10 and 15 must have completed their neuromuscular adjustments. Such adjustments are all those that concern the technique of football which are the pass, the shooting technique, the head, the stopping of the ball, the possession, the dribbling, etc. All this can be completed by the age of 15 of the child. So, at this age the young footballer will have learned as best he can the secrets of the ball.

Hypertrophy of physical ability, i.e. the development of muscle strength with all that entails, begins at the age of 12 - 13 with a small increase. From the age of 14, the increase shows a jump till the age of 18 and then follows a course that the development cannot exceed 5%. This small percentage, in combination with the technique but also the "construction" of the body of each athlete, is what makes the difference. Through the improvement of physical abilities, the best performance is achieved in all sports. Towards this direction, we study the neuromuscular adaptations to strength training applying the findings to consult athletes and trainers on how increased strength, power, speed and muscle hypertrophy can lead to improved performance. Through this work, we analyze the muscle function during the exercise and the results of the training on the muscle performance and function. It also describes the function of the nervous system in controlling movement and how these affect neuromuscular adaptations in relation to aerobic/anaerobic and resistance training.

Muscle fibers, motor units, and motoneurons

Types of muscle fibers

The two types of muscle fibers are slow-twitch (type I) and fast-twitch (type II). The difference is that slow-twitch muscle fibers support long-distance endurance activities such as marathons, while fast-twitch muscle fibers support fast, powerful movements such as sprinting or weightlifting. Slow contraction fibers, type i (types of muscle fibers) have a high concentration of mitochondria and myoglobin. They are also shorter than fast-twitch fibers and are surrounded by many capillaries. This combination supports their ability for aerobic metabolism and resistance to fatigue, particularly important elements for prolonged exercise activities. Type I fibers produce less strength, have a slower production of maximum intensity (lower myosin ATPase activity) compared to type II fibers, but are able to maintain long-term contractions. It is the key to stabilizing and controlling posture. Type II rapid contraction muscle fibers are divided into type IIx and IIa. Typically, they have a lower concentration of mitochondria, myoglobin, and capillaries than slow-twitch fibers and have a lower fatigue tolerance. They are larger in size and also produce more power faster, an important issue for power activities:

- **Type IIx**: These fibers produce the most power, but are incredibly inefficient due to their high myosin ATP activity, low oxidative capacity and heavy dependence on anaerobic metabolism.

- **Type IIa**: These fibers are known as intermediate fibers, they could be considered to be a mixture of type I and type IIx, with comparable strength. They can be used equally by the aerobic and anaerobic energy system. These fibers have a higher oxidative capacity and have increased fatigue strength compared with type IIx fibers.

Muscles and their motor units

This term refers to the sequential activation of kinetic units that takes place when an increase in contraction force is required. The increase in muscle contractility is achieved in two ways, the increase in the number of active motor units (spatial mobilization) and the increase in the frequency of activation of the motor units (temporal mobilization). The kinetic units are divided into 2 types. Slow motor units consisting of slow motor neurons and slow muscle fibers, because the rate of contraction of the above muscle fibers is slow. Because of the fact that morphologically speaking the size of the neuron and the muscle fibers is small (smaller vertical cross section), the above kinetic units are called small. The other category is the Rapid motor units which consist of rapid motor neurons and rapid muscle fibers, because the speed of contraction of the above muscle fibers is faster. The above motor units are called large motor units because morphologically the size of the neuron and the muscle fibers, but also the number of muscle fibers per motor unit are relatively larger than the slow ones.

A muscle consists of many motor units, each of which is innervated by a different nerve ending with a different level of excitability. Other motor units require strong stimuli to be stimulated while others do not. Regardless of whether the level of excitability is low or high, when the irritation exceeds it, then all the fiber that constitutes the motor unit is stimulated. In other words, the principle of “all or nothing” is followed. The mobilization of the kinetic units follows the “principle of size”, according to which the small kinetic units are the first to be stimulated and the larger ones follow. For this reason, high-precision movements can only be performed with low power output, whereas movements that do not require high precision have a high level of power output resulting from the stimulation of large kinetic units. All motor units are stimulated and receive nerve impulses at maximum frequency during voluntary contraction. The decrease of the voltage inside the muscle follows a reverse course. First the frequency and the function of the larger kinetic units are reduced and the smaller ones follow in the same way.

As the number of motor units that a person can use increases, so does its ability to produce muscle strength and to increase its maximum strength. At the same time, this maximum power can be achieved in a much shorter period of time, where, in combination with the above, it allows this person to be able to produce more power. This is a crucial point, in which a coach should emphasize in order to give the necessary stimulus for the body of the trainee-athlete to mobilize, or to “force” into mobilizing, more and more kinetic units. Unfortunately, this cannot be achieved with slow and single-joint movements, but with multi-joint and dynamic ones. The low-intensity activities, such as jogging, makes the body employing only a few motor units, which in fact activate mainly only type I muscle fibers. On the contrary, as the intensity and the requirement of the exercise for strength increase, so does the number of mobilized motor units, which also lead to the activation of the type IIa and IIx fibers. For this reason, especially intermediate people and above, and definitely athletes should be included in a training program with exercises mostly high-intensity or explosive-ballistic, in order to get this adaptation which will lead them to better functionality, physical performance and athletic performance.

Types of neurons

The most important types of neurons, depending on their function, are: 1) Afferent neurons convey information from tissues and organs into the central nervous system and are also called sensory neurons, 2) interneurons or connective neurons are located exclusively inside the central nervous system, they integrate the information provided by sensory neurons and transmit it to motor neurons and 3) efferent neurons (motor neurons) transmit signals from the central nervous system to the effector cells. According to the number, the length and the branches that they have, there are: 1) Unipolar or better Pseudo-monopolar neurons with a branch that is very short and divided into two branches, one of which will function as a dendritic. (they are found in the Spinal Ganglia), 2) Bipolar neurons with a body from which an axis and a dendrite emerge from opposite poles (they are found in the bipolar cells of the retina) and 3) Multipolar neurons with a single axis and many dendrites (most neurons) A special class of these neurons are the pyramidal neurons.

Development of muscular strength in pre-adolescent and adolescent age - Measurements and risks

In children, muscular strength develops in parallel with normal development and is a result of maturation of the central nervous system [1]. In the past, there were doubts as to whether children could actually improve their muscular strength, and early studies failed to show an improvement in muscular strength in pre-adolescent and adolescent boys. The potential for the poor improvement in muscular strength at these ages was attributed to hormonal factors, because testosterone levels are low [2]. Contrary to the above views, studies reported increases in upper limb muscular strength with the hand grip test in 13-year-old girls and boys after the implementation of the isometric training program, while Hettinger [3] reported increases of 1.6 to 4.1% per week in the isometric strength of the extensor and flexor muscles of the arm in girls and boys aged 12.6 years after an isometric training program. Improvements in the isometric strength of the knee extensor and flexor muscles in preadolescent boys and girls were also found after an isometric workout program.

Corresponding improvements were also reported in performance tests requiring upper body and arm strength in pre-adolescent boys and girls after the implementation of cycling training which included muscular empowerment exercises. The results of newer studies with better experimental design also prove the effectiveness of muscular strength training in improving muscular strength in adolescence. Isometric training caused a significant increase in isometric muscular strength in the knee area in a group consisting of pre-adolescent girls and pre-adolescent twins [4]. Pfeiffer and Francis [5] found greater improvements in pre-adolescents in dynamic upper and lower limb muscular strength than in adolescents at relative values, applying 9-week training to boys of the pre-adolescent, adolescent and post- adolescent age. Improvements in upper and lower extremity muscular strength have also been reported by Sewall and Micheli [6] applying vigorous resistance training at 9 and 14 weeks, respectively, to pre-adolescent boys on specially designed resistance instruments for children.

Falk and Tenenbaum [7] in a review of their literature on investigating the effectiveness of resistance training in children, report that resistance training may be effective in increasing strength in pre-adolescents and adolescents. Analyzing the existing literature of 28 studies describing resistance training programs for girls and boys under 12 and 13 years of age, they found that only 9 of these studies provided the necessary data to calculate the magnitude of the effect these training programs could have. The majority of studies, however, showed gains in muscular strength between 13 and 30%. In general, recent studies seem to contradict the older ones on the effectiveness of resistance training in children. The conflicting views on improving muscular strength in pre-adolescent boys appear to be due to experimental study design, as the effectiveness of resistance training in pre-adolescent children can be influenced by a variety of factors, such as age, bio maturing, gender, as well as the frequency, duration and intensity of the training program. So far the majority of surveys examined participants of various ages, without recording biological maturity or having a control group.

Measurements of muscular strength in isokinetic dynamics

With the use of isokinetic dynamics after the 1960s, research has made it possible to investigate the types of muscular strength and endurance, such as dynamic (isokinetic) muscular force at low and high angular velocities, isometric muscular strength and isometric-isokinetic endurance, as the dynamometers provided this possibility. Coyle., *et al*. [8] reported that training at low angular velocities improves muscular strength only in tests of low angular velocities, while Colliander and Tesh [9] found improvements in muscular strength only at high angular velocities, which were training speeds. It was reported that training in high angular velocity ($240^{o}s^{-1}$) improves the muscular power at the same angular velocity and at higher angles, while training at low angular velocities ($30^{o}s^{-1}$) improves maximum muscular strength in the low velocities as well as the maximum isometric. Maximum torque improvements at both the highest and lowest angular velocities than the training speed reported [10]. Muscular strength training with classic weights and tests on isokinetic power was applied by Weir., *et al*. [11] who found improvements in muscular strength only at high angular velocities.

Interactions in the types of muscular power

For the development of muscular strength and the investigation of the effectiveness of the muscular strength training, the majority of the researches use the training instrument itself as a measuring instrument. As a result, the interactions that may result from strength training should not be adequately investigated. It is accepted that during the development of a capacity or a type of muscular strength there is a partial improvement of other abilities or types of muscular strength, due to the interaction of stimuli. Although irritant interactions are of particular interest and offer important information for athletes and coaches, they have not been adequately investigated by researchers. A limited number of studies provide information on the interactions of muscular strength stimuli in adults and a minimum in children of developmental age.

Mandroukas., *et al*. [12] reported significant increases in maximal isokinetic strength at low angular velocities, maximal isometric strength and isokinetic muscular endurance after 12 weeks of cycle-ergometer in obese adult women. Corresponding interactions in adult women are reported by Ferketich., *et al*. [13], after a dynamic training program in the cycle-ergometer and corresponding measurements in the isokinetic dynamometer. Seaborne and Taylor [14] applied protocols for training in isokinetic energy at low ($36^{o}\cdot s^{-1}$) and high ($108^{o}\cdot s^{-1}$) angular velocities and measurements at the same dynamometer in 20-year-old untrained women. The above researchers observed interactions at the corresponding high angular velocity, but also isometric energy, as well as isometric endurance (20%), after 6 weeks of training in the protocol performed at high angular velocity. A dynamic training program with increasing resistance lasting 20 weeks in pre-adolescent boys was implemented by Ramsay., *et al*. [15]. The above reported increases in dynamic muscular strength at various angular velocities, as well as in isometric muscular strength.

Risks from the use of training tools during the training of muscular empowerment of children of developmental ages

Strength training is an integral part of any training program that aims to improve performance. Sports that involve throwing, jumping and short distances running, where high strength is required in a short period of time, also require specialized strength training. There are several training methods to improve muscle strength, such as weight training with high (80 - 100% of 1 maximum repetition [1-MR]), medium (-60% of 1-MR) or low (-30% of 1-MR) load, plyometric training, ballistic training as well as a combination of the above methods [16]. In addition, the opposite training method is used in order to improve muscle strength. This method is based on the use of alternating sets with heavy load and sets with light load or body weight either in the same exercise or combining similar exercises [17]. High, medium and low weight training is one of the most popular training methods to improve muscle strength. Some studies recommend performing medium to high loads (60 - 100% of 1-MR) with slow execution speed while other studies suggest training with light to moderate loads (30 - 60% of 1-MR) and explosive execution rate [18]. The effect of different weight training loads on performance improvement as well as the different adjustments they cause, have been extensively studied.

Hakkinen [19] examined the effect of high-load strength training on the electrical and mechanical behavior of the extensor leg muscles. The test subjects, 11 men who had experience in strength training, trained with an intensity of 70 - 120% of 1 MR in the full seat exercise for a period of 24 weeks. After the end of the training, an increase of the maximum force was observed by 30.2% while the height of the jump from a half seat improved by 7.3% with a simultaneous increase of the electromyographic activity of the vastus lateralis and medialis. In addition, the improvement in maximum force caused a change in the load-power ratio in both the half-seat jump and the swing jump. On the contrary, when training with jumping and ballistic exercises was applied for the same period of time (depth jumps of 30 - 60 cm height, swing jumps with load 0 - 60% of 1-MR) a significant improvement of 21.2% in the jump height from the half-seat was observed, while the corresponding improvement in strength was only by 6.8% with a simultaneous increase in the electromyographic activity of the vastus lateralis and medialis. In addition, the improvement in travel speed caused a change in the power-load ratio in both the half-seat jump and the swing jump. In other words, it was observed that, according to the training principle of the specialization, that depending on the training content (weight training, ballistic exercises, plyometric exercises) and the intensity of the load (high, medium, low load) there is a corresponding increase in neuromuscular activity as well as an improving efficiency by simultaneously changing the load-power and load-speed ratio.

It was also observed that weight training using both low and high loads improves athletic performance but it is not known yet which of the loads brings the greatest improvement. In a study by Harris., *et al*. [20] the effect of high- and low-load strength training (9 weeks, 4 times a week) on various performance factors was examined. The subjects were divided into two experimental groups where the high load group performed training with a load of 80 - 85% of 1-MR while the low load group performed training with a load of 30% of the maximum isometric force. After the end of the training period the high load team significantly improved in maximum strength and power through the evaluation of the Margaria-Kalamen test while the low load team significantly improved in strength and in vertical and momentum jump.

Weight training with low to high loads (35 - 100% of 1-ME) can improve both maximum strength and jumping ability. Also, the improvement of maximum power is greater with the use of high loads while the improvement of jumping ability is greater with the use of low to medium loads. In addition to the load, the pace of exercise seems to play an important role. Ballistic training with weights from 30 to 90% of 1-MR brings improvement of both maximum strength and jumping ability while it seems to prevail over weight training in improving jumping ability. Finally, ballistic training with 30% of either the maximum isometric or 1-MR seems to prevail over high-load training (80% of 1-MR or 6-10 MR) in improving jumping ability. A comparison between weight training and ballistic training over a wide range of loads will lead to useful conclusions about the most appropriate training program design.

Methodology

Research statement

The aim of the study is to investigate the neuromuscular adaptations to strength training in children and adolescence and apply the findings to advise and guide athletes and trainers on how increased strength, power, speed and muscle hypertrophy can lead to improved performance.

Review of literature/critical analysis

Several studies have been critically analyse the efficacy of resistance training regarding neuromuscular adaptations in youth sports [21]. All of these studies highlighted the efficacy of resistance training since this training type offers the opportunity for a young athlete to change in physical performance. Under this perspective, the work Kumar., *et al*. [22] describe the neuromuscular changes after 4 - 20 weeks of resistance training regarding the muscle thickness, and motor unit. The authors also described how different neuromuscular mechanisms adapt in response to growth can optimize the training responsiveness in youths. In adults, the factors that determine muscle strength as well as the adjustments that come with training are known. On the contrary, there is little information related to the increase in muscle strength in children. A study by Rochongar., *et al*. [23] found that young French high-level footballers had greater isokinetic strength in the lower extremities than high school students, which means that football training affects improving muscle strength. In contrast, Maffulli., *et al*. [24] reported that boys who exercised until the age of 15 had the same values of isometric strength in the quadriceps as boys who were not involved in any sporting activity. After this age, people who exercised had significantly higher values compared to non-athletes.

It is obvious that the adjustments that a beginner has, let alone a teenager, are great. In order for a coach to have the best possible result for himself and his athlete, he must know the appropriate program that he must follow. From all the studies that have been done, valuable conclusions have been drawn regarding the safety and weight training, the benefits of weight training and the immediate adjustments that a young athlete has after a well-structured and designed program. From the first research conducted in the field according to Ramsay., *et al*. [15] was reported that after the implementation of a weight training program for beginners (9 - 11 years old) lasting 20 weeks with a gradual increase in loads (70 - 85% of MR) and frequency 3 times a week, there was an improvement in strength due to neuromuscular factors. No change in the cross-section of the muscle fibers was observed and no significant change in the time-contraction ratio was observed to improve the time to reach maximum torque. Also, the cross section of the muscle fibers in both groups did not change, as it was checked by magnetic resonance imaging.

Similar results are reported by Ozmun., *et al*. [25] after the implementation of a program with weights lasting 8 weeks and frequency 3 times a week, in boys and girls aged (9 - 12 years). An increase in electromyographic activity by 16.8% (IEMG) was observed, while no change in muscle mass was found. In another study by Gorostiaga., *et al*. [26], which was performed on handball athletes aged 14 - 16 years, reported that the significant improvement in strength was mainly due to the improvement of specific neural factors and not to muscular hypertrophy. The improvement of the muscular strength of children of developmental ages occurs progressively with the evolution of their biological maturity, while its further improvement is achieved through the training of mental strengthening with their body weight or with external resistances. To date, the majority of researchers have used external resistances to improve muscular strength and methods applied to adults. These training tools, however, are dangerous to be used by children because their muscular and skeletal systems are constantly evolving. This is a deterrent to scientific research because it places moral constraints on researchers.

Restrictions on research have been reinforced by corresponding directives from responsible bodies and by scientific research. The American Academy of Pediatrics (1982) issued guidelines to its members on the practice of children with external resistance and recently returned to the same subject in collaboration with the National Electronic Injury Surveillance System (2001). The instructions indicate the danger of the training equipment and the implementation of muscular strengthening programs with sub-maximum intensities, provided that the health of the participants is ensured. The danger of muscular strength training in resistance to developmental age is shown by the results of research conducted by the Consumer Product Safety Commission and the National Electronic Injury Surveillance System (1979), where in 35,512 injuries recorded during muscular strength training, 50% of the injuries were suffered by children aged 10 - 19 years. Epiphyseal disc fracture in pre-adolescents who have participated in weight training has also been reported by Gumbs., *et al*. [27].

Despite the remarks made so far about the danger posed by the use of external resistors with the classic training instruments for children of developmental age, the same instruments seem to be used in the future by the coaches, as they contribute to the improvement of children's muscular strength. Given that cycle-ergometer, is a safe training tool for trainee health and helps to improve muscular strength in adult women [13] and in pre-adolescents and adolescents. It would be useful for researchers to apply it for further investigation of other advantages than those mentioned so far in the literature. At this point, it has to be mentioned that the rate of development of strength in childhood is so intense that any improvement during training, disappears quickly if the training is not continuous and regular. In a related study by Faigenbaum., *et al*. [28] the increase in strength after an 8-week program, disappears after 8 weeks and returns to baseline, with a decrease of 3% per week. After the period of abstinence from training, the advantage of strength is lost. The strength of these children is now at the same level as that of children who did not exercise at all. This is due on the one hand to the increase in the strength of children who did not exercise due to maturation, and on the other hand to the loss of strength of the trained children due to abstinence from exercise. So, continuous training is therefore probably necessary to improve strength in pre-adolescents.

The same results are reported in other studies, that after 8 weeks of interruption of the program (lasting 12 weeks), the strength of children who exercised returned to the same levels as children who did not exercise. In a more recent and contrasting study, [29] it was reported that after an 8-week strength program, strength levels remained almost the same as the last measurement taken. In a recent study by Ingle., *et al*. [30] a combined weight training program and pleiometric exercises was studied in 54 adolescents and young adolescents aged 12.3 years. The sample consisted of the experimental group (n = 33) and the control group (n = 21) and followed the program for 12 weeks with a frequency of 3 times a week. It is reported that although the experimental team improved significantly in strength, in the vertical jump and in the chest (basketball) after 12 weeks of the measurement to maintain the adjustments, almost all reached their initial levels. This fact agrees with the above research.

A study by DeRenne., *et al*. [31] analysed how the benefits of training can be maintained. The program had a frequency of 1 and 2 times a week and was a program of maintenance of maximum strength and muscle endurance, lasting a total of 12 weeks. The results showed an improvement in strength for both groups compared to the control group, however no differences were observed between the two experimental groups and the control group, after 12 weeks of interruption of the intervention program. The research that has been done to investigate this issue is very limited and much more so when it comes to young athletes.

Discussion and Conclusion

The necessity of strength training at a young age is one of the key components of functional training with a central focus and the goal of improving performance in sports. The first contact and acquaintance of the little ones is not only with each sport, but mainly with the recognition and sense of weight and body function in space and time. There are many exercises that improve and initially develop neuromuscular fitting due to the involvement of many muscle groups that work together for the ideal body position in space and organs. An important condition is to learn the correct technique and body position before we start planning the load based on time (sooner or later) and repetitions. Much of the planning in strength training should include exercises to stabilize the core - torso as the most important part of the body's function on the organs. For each organ, those special neuromuscular adaptations should be developed that will help the athlete in the escalating difficult execution of movements and positions based on the specific characteristics of the organ.

Strength training plays the most important role for an athlete to stand out and reach optimal athletic performance. Many athletes and coaches are unaware of how important strength is in all sports, team or non-team. We will focus more on teamwork because there are different points of view. Several teams stop strength training during the competition period, with the result that the athletes have performed some strength training units only during the preparation. Most of the research that has been done clearly shows that strength training during the competition season helps to maintain the high level of athletic readiness of athletes and to prevent injuries. Some research has shown that there may be a reduction in the chances of injury, but again this alone is not enough. Without strength training, the chances of injury are high. Training on unstable surfaces can, for example, reduce a young player's chances of a sprain by balancing on the bosu or by doing some more specific exercises in the physical area of the sport. Sure you can have some neuromuscular adjustments with exercises on unstable surfaces but the athlete does not play football on balloons with air, so we should also take into account the sport that the young athlete does. closing for unstable surfaces, adjustments will be available to healthy and non-athletes, but there should also be a combination and more specific training that responds to the realism of each sport.

Our work concludes that young athletes should follow modern training methods to maximize neuromuscular adaptations. Young people who play sports need to understand the neuromuscular mechanisms associated with improving athletic performance but also with preventing sports injuries, as well as the importance of training to maximize neuromuscular adaptations. In particular, both young athletes and their coaches should be aware of i) the function of the neuromuscular system in athletic movements, ii) methods of evaluating neuromuscular function, iii) methods of improving neuromuscular function to improve the quality of movements, iv) methods of improving neuromuscular performance to maximize strength and power, v) mechanisms of neuromuscular fatigue and ways of handling them; vibration training, etc.

In conclusion, in the recent literature there is a lot of research related to neuromuscular adaptations of strength-related sports involving young people. The development of strength with known methods of resistance training can positively affect her athletic movements with a typical example being weightlifting that through this sport improves the muscular endurance of the athlete. There is remarkable progress in Neuromuscular adaptations to strength training in children and adolescents, however we need more studies to focus in youth athletes to offer a framework for better knowledge of both athletes and coaches, so that they can improve in their sport skills while staying healthy and safe from injuries and other various problems.

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