

Impact of Resistance Training Protocols on Muscular Fitness in Preadolescents: A Narrative Review

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ABSTRACT

Objectives: The aim of the present review is to critically assess the effect of resistance training (RT) protocols on muscular fitness in preadolescents (6-12 years old). This study examines the physiological, neuromuscular, psychological, and developmental outcomes of structured RT in this age group to dispel current myths and offer supportive evidence-based practices. It also focuses on RT's contribution to physical literacy and long-term athletic development.

News Recent studies emphasise that preadolescents respond positively to RT through predominantly neural adaptations that lead to improved motor unit recruitment, coordination, and strength, but not significant hypertrophy. RT has been proven to increase muscular endurance, power, and prevent injury. It's also important for psychological well-being to increase self-esteem, emotional regulation, and social connectedness.

Prospects and Projects Future research should examine individualised and developmentally appropriate RT protocols, examine long-term outcomes, and include a variety of training modalities (e.g., bodyweight, resistance bands, and machines). Investigating combined neuromuscular and psychological effects can result in more comprehensive intervention designs that can be implemented in schools and communities.

Conclusion: RT is a safe, effective, and holistic intervention for preadolescents that promotes physical competence, supports psychological growth, and encourages a lifelong habit of physical activity and health. It must be part of youth fitness and educational programmes.

Keywords: Resistance training, adolescents, muscular strength, low repetition, high repetition

INTRODUCTION:

Muscle fitness means having muscles that can pick up heavier objects or muscles which will work longer before getting tired [1]. In the preadolescent period (ages 9–12), neuromuscular maturity has been reported to be parallel to the improvements and coordination between muscle groups, and proficiency in physical activities [2]. According to the Centres for Disease Control and Prevention (CDC), strength building exercises can help to improve bone density, body composition, and cardiovascular function for children and adolescents [3]. It is estimated that about 24% of children ages 6-17 engage in the recommended guideline of muscle strengthening three or more times a week [4]. The importance of muscular fitness in preadolescents is even more striking when considering the great changes that occur physically and neurologically during this stage [5]. In addition, increased strength is associated with increased self-esteem and reduced levels of anxiety and depression in youth.

Physical activity is important for holistic development of children, which not only affects physical health, but also cognitive and emotional well-being [6]. At the preadolescence phase regular physical activity increases the strength of the muscular and skeletal systems, improves motor coordination and contributes to cardiovascular health [7]. The World Health Organisation

(WHO) emphasises that children aged 5-17 should do at least 60 minutes of moderate to vigorous physical activity every day to ensure optimal development [8]. The National Strength and Conditioning Association (NSCA) says that children can gain 30-50% in muscular strength after 8-12 weeks of consistent training [9]. Research has shown that children who engage in structured physical activities, a lower risk of obesity and improved academic performance due to an increase in cognitive function [10].

Resistance Training in Youth

Resistance training in preadolescents has long been a controversial topic with shifting history, misconception and scientific knowledge [11]. Historically, there was a large concern that resistance training would stunt growth, damage growth plates or risk injury with children [12]. For decades, resistance exercise for youth was discouraged with an assumption that children did not have the hormonal environment to develop muscular strength or hypertrophy [13]. However, it became evident that properly supervised RT was not only fairly safe for preadolescents, but beneficial for their general health and development [14]. Current guidelines and recommendations from organisations like the American College of Sports Medicine (ACSM) now recommend the use of resistance training in youth fitness programmes [15]. In addition, RT is known as a preventative measure against sports-related injuries, obesity, and poor bone

health and contributes to life-long habits of physical activity.

From a physiological response adaptability standpoint, preadolescents respond remarkably well to resistance training even with their immature hormonal profile [16]. Unlike adolescents or adults, their muscular improvements are not primarily due to hypertrophy, but rather neural adaptations improvements in motor unit recruitment, coordination and efficiency of firing rather than improved muscle size [17]. While significant increases in muscle size before puberty are limited by lower levels of testosterone, there may be significant improvements in strength, endurance and power [18]. Additionally, RT has a positive effect on bone mineral density and joint stability as well as metabolic health in children [12]. Under structured guidance, children can develop muscular fitness, enhance quality of movement and form healthy behaviours that contribute to athletic performance and long-term wellness

Resistance Training Protocols

Resistance training in preadolescents has received considerable attention in recent years, particularly, as part of early interventions for the promotion of muscular fitness, strength, and general health [14]. There are different types of resistance training that are age appropriate to use with this age group that provide unique benefits if implemented correctly. Bodyweight exercises like push-ups, squats and lunges are generally recommended because they are simple and low-risk for injury [19]. These exercises enhance the functional strength and Free weights (e.g., dumbbells, barbells) are capable of more complex movement patterns, and facilitate neuromuscular development when appropriately supervised [20]. Meanwhile, machine-based training provides controlled movements and may be helpful for beginners to assure correct form, but is less commonly used in younger populations because of the size and cost of the equipment [21]. Research has shown that when these conditions are met, RT will be not only safe, but beneficial for children, without negative effects on their growth and development.

Designing an effective training plan means that manipulation of important protocol variables such as intensity, volume, frequency and duration. Intensity refers to load / resistance applied that should be light to moderate for beginners to ensure proper form and safety [20]. Volume-the total amount of sets and reps to be completed-should be moderate, i.e., 1-3 sets of 8-15 reps per exercise with a progressive increase depending on individual capacity [22]. Frequency is also critical; the American Academy of Pediatrics (AAP) have recommended resistance training 2 - 3 times per week on non-consecutive days for optimal recovery and adaptation [23]. The length of time of each session can vary from 20 to 45 minutes depending on the complexity of the exercises and attention span of the child [24]. Supervision by a qualified adult or coach is critical to ensure the technique is correct, to prevent injury and to encourage motivation and discipline. Warm up and cool down routines need to be included to prepare the muscles and decrease the risk of strains [25].

This study addresses the ongoing misconceptions regarding RT in preadolescents. By reviewing resistance training protocols systematically and their effect on muscular fitness, the research is providing novel, evidence-based insights into safe, effective practices tailored for children. Understanding how preadolescents respond physiologically and psychologically to structured training is paramount to facilitate life-long physical activity, improve athletic performance, and help prevent early onset of obesity and musculoskeletal problems. The aim of this study was to critically analyse the effect of RT protocols on muscular fitness in preadolescents. The key objectives are to review the existing literature concerning RT protocols specifically applied to preadolescents and establish a comprehensive understanding of current knowledge. It examines the physiological, musculoskeletal, and performance-related consequences of different training approaches to evaluate their effectiveness and safety. The purpose of this study is to identify areas of research and propose evidence-based recommendations for the development of age-appropriate guidelines for RT.

Methodology

Research Design

This review was conducted to systematically search and analyse relevant and published literature on the effects of RT in preadolescents. For that, different electronic databases including PubMed, Google Scholar, ScienceDirect, and ResearchGate were used to locate studies using keywords such as “resistance training,” “strength training,” “preadolescents,” “children,” “neural adaptations,” “muscle strength,” “physical activity,” and “psychosocial outcomes.” The literature published in English between 2015 and 2024 was considered eligible if it focused on children aged 6 to 12 and reported the RT's physiological, psychological, or developmental outcomes. Articles that included individuals outside the intended age range, exclusively focused on athletes or special populations unrelated to the review topic, or lacked quantifiable results were disqualified. Peer-reviewed experimental research, reviews, and position statements were included. After an initial screening of titles and abstracts, full texts of the relevant articles were assessed, and data were synthesised qualitatively to identify key findings and trends related to the review's objectives.

Results

Physiological Adaptability in Preadolescent

Preadolescence is a critical period of growth and is characterised by dynamic physiological changes that affects the way body reacts to physical training, especially resistance exercise [26]. Unlike adults, preadolescents experience major neurological development as they grow, and this has major implications for muscular fitness. Tumkur Anil Kumar et al. (2021) discussed that most distinguishing characteristics in this age group is that strength gains from resistance training are to a large degree neuromuscular rather than muscle hypertrophy [17]. This is mostly because the concentrations of circulating androgens such as testosterone, which promote muscle gain, are relatively low before hitting puberty. As a result, preadolescents find themselves coordinating,

recruiting motor units, increasing and synchronising their firing frequency with RT [27]. Studies like those by Multani et al. (2019) have demonstrated repeatedly that children are able to make significant strength gains without any measurable growth in muscle size [28]. Therefore the neural factors are the most important mechanism by which performance is enhanced during this stage of development.

Mascia et al. (2023) research also supports the notion that preadolescents have an outstanding ability to adapt to a wide range of training stimuli, provided the programmes designed support this [29]. These adaptations include improvement in muscular strength, endurance, power and efficiency of movements, with relatively low training intensities. Gao et al. (2023) commented that when resistance training is implemented with proper technique and supervision, it can improve muscle activation patterns, better motor skill acquisition, and improved dynamic stability which are important for both athletics development and injury prevention [30]. In addition, regular training also improves proprioception and balance, both important components of muscular fitness and of overall physical literacy in children as they grow [31]. However, Ketelhut and Ketelhut (2020) study implies that well designed RT programmes can be effective in stimulating the adaptations without the need for excessive amounts of volume and intensity which poses the risk of overtraining or injury [32].

Moreover, the neuromuscular, but also the metabolic, adaptability of preadolescents to RT. While their anaerobic energy systems are not as developed as in adolescents or adults, children show an improved ability to recover quickly between sets and training sessions [33]. This is due in part to their more efficient re-synthesis of phosphocreatine and to a lower buildup of blood lactate making them well-suited to short bursts of activity, with adequate rest. This metabolic profile implies that resistance training programmes can be safely applied even in young populations, as long as rest intervals and recovery strategies are appropriate for the age [34]. Furthermore, longitudinal studies such as the ones mentioned above in the *Journal of Strength and Conditioning*. Kramer (2020) study have pointed to the role such training, plays in developing increased muscular endurance and work capacity benefits that transfer over into a variety of sports and physical tasks [35]. These studies highlight the importance of progressive training of exercises to meet the maturing physiology of preadolescents.

Perhaps one of the most persuasive aspects of preadolescent adaptability is the plasticity of the musculoskeletal and neuromotor systems [36]. This is a unique period of opportunity to instil the correct movement patterns and the foundation for lifelong fitness habits. When resistance training is introduced in a well-organised manner. Molina-Garcia et al. (2020) elaborated that children can build a very strong base of muscular fitness that can help them build up to a healthy body, to reduce risk of obesity and to boost their confidence in physical activity [37]. Research from Cereda (2023) study supports the integration of RT into youth physical education/sport programmes with a focus on the potential

for early training interventions to positively affect not only physical outcomes [38]. Till et al. (2022) emphasised that practitioners can help children experience developmentally appropriate resistance training that fosters holistic development, while setting the stage for athletic success and lifelong physical activity participation [39].

Muscular Fitness Outcomes

Resistance training in preadolescents has been shown to produce significant increases in strength even if no marked increases in muscle mass are noted [13]. The study by Tumkur Anil Kumar et al. (2021) shown that these improvements are likely to be a function primarily of neuromuscular adaptations, including increased motor unit recruitment and coordination, rather than increases in muscle size [17]. Preadolescent children benefit from RT because it helps them develop greater control of their muscles, better movement efficiency, and helps them acquire strength very quickly when training is appropriately designed [40]. Iversen et al. (2021) studies have also illustrated strength gains anywhere from 13% to 30% during intervention periods of 8 to 12 weeks [41]. These gains are especially prominent when training is progressive, there is a variety of movement patterns, and training is supervised to ensure safety and proper form. Meta-analyses have also verified these reported results, showing medium to large effect sizes in strength gains during resistance training programmes with kids [42]. These gains not only help increase the athletic potential, they also help prevent injury, improve posture and increase the ability to function on a day-to-day basis.

In addition to strength, muscular endurance also is enhanced with RT in preadolescents. Sagiv and Sagiv (2020) study identified that Muscular endurance is the ability of muscles to continue contracting repeatedly or to hold a contraction for a period of time, vital to sports and physical activities [43]. However, Nugent et al. (2023) studies comparing high-repetition at a moderate load to low-repetition at a heavier load have determined the former to be especially effective in enhancing endurance in young participants [44]. For example, children trained with 13-15 repetitions per set gained more in endurance than those who trained with 6-8 repetitions [45]. These outcomes emphasise the importance of adjusting factors like repetition and load to customise training to specific goals. Although, Gäßler et al. (2018) mentioned that frequently assessed in youth as strength, muscular endurance is related to enhanced aerobic fitness, greater participation in physical activity and lower fatigue during extended efforts [46]. Endurance-based resistance programmes are particularly advantageous for preadolescents in team sports and physical education [47].

The positive effects of RT on the development of power and speed in preadolescents are also possible [48]. Moreover, Marta et al. (2022) discussed that combination of both resistance training and plyometric exercises like jumping drills and medicine ball throws improve explosive strength and speed to a significant extent [49]. These adaptations are the result of increased rate of force development and improved neuromuscular coordination that result from consistent training. Hughes et al. (2023)

study review of training interventions in youth populations have shown moderate-to-large improvements in power, and small-to-moderate improvements in sprint performance and agility [50]. While the Morris et al. (2022) evidence appears to be that traditional RT alone improves power to some extent, it would seem that including explosive movements in training regimes would be particularly effective [51]. Prepubescent athletes who participate in a structured and progressive program containing both resistance and plyometric elements are often shown to exhibit greater levels of performance.

Although changes in body composition in preadolescents are often limited because of hormonal factors, resistance training has been associated with improvements in lean muscle mass and reduction in percentage body fat [52]. A study by Marquez et al. (2023) outlined that resistance training also helps to improve posture, increase joint stability, enhance balance and more coordinated movement patterns-which are critical in athletic development as well as injury prevention [53]. Katsanis et al. (2021) highlighted that functional resistance training, such as suspension training or bodyweight circuits may be particularly effective in improving coordination and total-body strength [54]. These programmes are designed to emulate real life movement patterns and to develop several physical qualities at the same time. Although, Vandoni et al. (2024) study elaborated that children that engage in resistance training often show better movement quality, fewer musculoskeletal complaints, and better self-confidence in physical tasks [55]. When combined with aerobic exercise and healthy nutrition, resistance training is a core piece of lifelong physical fitness.

Psychological and Social Benefits of Resistance Training

Resistance training per se is traditionally linked to its role in physical development, but has more recently been acknowledged as having important psychological and social values, particularly in preadolescents [56]. As this age group is going through important stages in emotional and social growth, the integration of structured physical activity such as resistance training into their routine can be an important tool to use to enhance overall well-being [57]. Research has shown that participating in regular strength-based exercise can lead to increased self-esteem, self-confidence and body image in youth. A study conducted by Collins et al. (2019) focused on the idea that resistance training plays a role in a more positive self-perception especially in children who may not be competent otherwise in traditional sports environment [42]. Unlike team sports that may have a strong focus on competition and athletic ability, Ramalingam et al. (2019) mentioned that resistance training can be a more individualised, progressive framework where children can feel success on their own level of time [58]. This autonomy and ability to monitor personal improvement can result in improved feelings of competence and self-worth.

In addition, Dale et al. (2019) study helping build self-esteem, resistance training has been associated with decreases in symptoms of anxiety and depression in young populations [59]. Exercise-induced release of endorphins,

neurochemical changes and enhanced sleep patterns are all thought to play a role in such outcomes. A meta-analysis by Biddle et al. (2019) reported consistent evidence that physical activity, including resistance training, has a positive effect on mood and psychological health for children and adolescents [60]. Notably, Ogundele et al. (2018) identified that RT might be especially beneficial for children who have difficulty with social anxiety or behavioural disorders because it offers a sense of structure that focuses on routine and personal goals rather than social performance [61]. Moreover, Tabibnia and Radecki (2018) illustrated that discipline, and commitment that is required in resistance training, it may help in the development of emotional regulation and resilience [62]. These psychological benefits are critical during the preadolescent years, because they help establish the basis for healthy coping mechanisms and stress management into adolescence and adulthood.

The social aspect of resistance training should not be ignored also. Bruner et al. (2021) study offered in group settings such as school programmes, community centres or sports clubs, resistance training helps create a sense of belonging and social connectedness [63]. Participants frequently participate in cooperative learning experiences, peer spotting and goal setting activities, all of which encourage communication skills and teamwork. According to a review by Andersen et al. (2019) participation in organised sports and structured physical activity (including resistance training) is related to better social functioning, lower levels of isolation and better peer relationships [64]. For preadolescents, who developmentally are beginning to value peer acceptance and friendships more, these social benefits have special value [65]. Additionally, Fisher et al. (2023) identified that structured resistance training programmes tend to involve adult supervision and mentorship, which also promote social development by way of positive role modelling and supportive relationships with coaches or instructors [66].

Resistance training can also have a positive effect on behavioural and academic performance due to its psychological/social influence. Andermo et al. (2020) study highlighted that nature of resistance training encourages goal setting and time management, as well as following rules that can carry over to one's behaviour in the classroom and subsequent academic performance [67]. A study by Mao et al. (2024) showed that physical activity interventions such as resistance training were linked with improvement of executive function and cognitive control in preadolescents [68]. Furthermore, when children are successful and encouraged in one area (physical training), they become confident to tackle challenges in other areas of life. Fragala et al. (2019) discussed that resistance training, therefore, becomes a physical activity not just, but through which larger psychosocial growth can occur [69]. When combined with appropriate, inclusive programming as well as positive reinforcement, resistance training can provide a life-changing experience for children at an important stage of development. Gupta et al. (2023) mentioned that psychological and social benefits of resistance training in preadolescents are profound and well-supported by

current research as a highly recommended component of youth fitness and health promotion programmes [70].

Physical Literacy and Long-Term Development

Physical literacy describes the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for being physically active for life [71]. Among the many strategies that help its development, resistance training (RT) has been shown to be especially effective, thanks to its structured, goal-oriented and entertaining nature. Although, Weiss (2020) evidence from various youth fitness studies verifies that RT has the potential to support not only change in motor skills and physical capacity, but also to bring about greater motivation and confidence in movement [72]. Dudka et al. (2022) elaborated that muscular strength helping to create an all-round picture as the children become better equipped and more enthusiastic to participate in a range of physical activities [73]. As a result, resistance training fits very well with the underpinnings of physical literacy, particularly during the important years of motor learning and development in preadolescents.

The role of resistance training in long-term athletic development (LTAD) is beginning to be recognised in sport science and youth fitness models. Pichardo et al. (2018) emphasised that LTAD frameworks place an importance on structured and age appropriate training that encourages progressive physical improvement through developmental stages [74]. For preadolescents who are in a sensitive period of motor skills acquisition, RT helps develop movement proficiency, stability, and muscular control that provide a base for more complex physical tasks that are met with in adolescence and adulthood [75]. Although, Perry et al. (2023) studies indicated that youths who practise resistance training at an early age are more likely to participate in physical activity in later life, and minimise the risks posed by the sedentary lifestyle, including cardiovascular diseases, and musculoskeletal problems [76]. Moreover, Martín-Rodríguez et al. (2024) mentioned advantages of these early interventions to physical fitness itself, but to emotional fortitude and psychological wellbeing - qualities important to sustained athletic participation and healthy lifestyles [77].

Another huge benefit of resistance training in youth is the high correlation between resistance training and injury prevention and physical safety during play or competitive sports. Research over the past two decades has repeatedly shown that children taking part in supervised resistance training programmes have fewer sports related injuries [14]. These programmes strengthen neuromuscular coordination, joint stability and posture control, all of which help to decrease the occurrence and severity of both acute and overuse injuries [78]. In addition, Logan et al. (2019) mentioned that strength training helps kids to be more conscious of their movement patterns and physical limitations, leading to more safe participation in recreational and competitive environments [79]. By raising both competence and confidence in movement, children are not only safeguarded from injury, they are more likely to go into physical activity with enthusiasm instead of fear or hesitancy [80]. This empowerment plays a direct role in their physical literacy by strengthening a

sense of control and mastery over their physical environment.

In addition to the physical and safety benefits, resistance training has been shown to promote longer term engagement with a physical activity by building movement skills that are transferrable and sustainable [81]. According to Prisniakova et al. (2023) study, programmes that emphasise correct technique, regular progression and setting goals help young participants internalize the importance of effort, discipline and self-improvement [82]. This approach develops "training literacy" as children acquire the skills and knowledge they need to continue their fitness practises independently as they get older. Moreover, Rodriguez-Ayllon et al. (2019) study address psychological and social aspects of physical activity, including self-esteem, peer interaction and body image, which are particularly important in shaping behaviour in preadolescents [56]. These psychosocial aspects further contribute towards the child's overall physical literacy, leaving a better-rounded basis for development in the long term [83]. As a part of school curricula, sports programmes, or community programmes, resistance training should be an integral part of youth development strategies, and not only for the aspiring athlete but for all children who want to live healthy and active lives.

Recommendations

Based on current knowledge of physiological adaptability and safety factors of preadolescent resistance training, several key recommendations arise for future studies in this area. Researchers should focus on creating age-appropriate and individualised training protocols that consider children's different levels of development, and ensure that the intensity and volume are made age-appropriate. It is equally important to emphasise the role of qualified supervision and proper techniques instruction as these factors significantly influence safety and training outcomes. Studies should also include longitudinal designs to examine the long-term effect of resistance training on muscular fitness, growth and general health through adolescence. Additionally, combining neuromuscular and psychological evaluations may provide a more comprehensive perspective of the impact of resistance training on strength, motor skill development, and motivation toward physical activity. The impact of various training activities such as bodyweight, resistance bands, and machine-based programmes should be investigated in future research to identify the most effective and practical training approaches in multiple settings, including schools and community programmes. These recommendations inform evidence-based practices that improve the preadolescents' physical development and lifelong health with safe and effective resistance training interventions.

Conclusion

In conclusion, resistance training in preadolescence provides a multifaceted spectrum of benefits that go far beyond physical strength and include critical psychological, social, and developmental areas. The evidence supports these findings that preadolescents can adapt to resistance training through neural mechanisms

for improved strength, endurance, and power and movement efficiency. Moreover, the psychological benefits, like increased self-esteem, decreased anxiety, improved emotional regulation, and enhanced social connectedness, make resistance training a great tool in youth development. It also helps with behavioural and academic results in a positive way by promoting discipline, goal-setting and routine. These findings support the inclusion of resistance training for youth in schools, sports programmes and health initiatives, and they debunk myths about the dangers of youth resistance training. Resistance training can help shape more confident, strong and well-rounded individuals from an early age by encouraging lifelong physical literacy and good habits.

Disclosures and statements

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