



## **Resistance Training in Children and Young Adults: A Critical Review**

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**ABSTRACT:** Resistance training is a method used by many athletes to increase their levels of performance. The benefits of this method are known to be increased strength, power and endurance. Resistance training in children has been a topic that has been long debated and there are some widely accepted beliefs and principles that guide clinicians involved in the discipline of sport and exercise medicine. While weight training is a form of resistance training that has proven beneficial effects on health and wellbeing, powerlifting and heavy weight training should be avoided, as lifting maximal weights through various ranges of motion as fast as possible can lead to serious limb injuries. In order to determine the risks and benefits of resistance training in children and adolescents, it is important to review the literature to find a clear consensus. Further prospective research should be completed to determine the long-term sequelae of resistance training in children in comparison to the general population.

**KEY WORDS** Strength, Conditioning, Aerobic, Anaerobic, Musculoskeletal

### **INTRODUCTION**

Resistance training is a method used by many athletes to increase their levels of performance. The benefits of this method are known to be increased strength, power and endurance. Resistance training in children has been a topic that has been long debated and there are some widely accepted beliefs and principles. While weight training is a form of resistance training that is shown to have benefits, powerlifting and heavy weights should be avoided, as lifting maximal weights through various ranges of motion as fast as possible can lead to serious limb injuries. In order to determine the risks and benefits of resistance training in children and adolescents, it is important to review the literature. Further prospective research should be completed to determine the long-term sequelae of resistance training in children in comparison to the general population. [1]. This area warrants attention given the



interest of both clinicians (sports physicians and orthopaedic surgeons) and basic scientists to the obesity epidemic and the considerable health burden associated with physical inactivity.

## METHODS

A search of the literature revealed many potential studies for review. The Ovid Medline database was used for the search. The terms “resistance training” and “children” were entered with the search results limited to the last 20 years and English language. One hundred one studies were returned in the results section. Twenty studies were deemed suitable as their content included resistance training and addressed outcomes relating to the implementation of resistance training against children and adolescents. Additionally they were published in the last five years barring one as per the review requirements. These studies offered a comparison between resistance training and another modality in subjects and controls, or were themselves reviews of the literature of resistance training in the youth population.

## DISCUSSION

A review of current position and consensus statements as well as systematic reviews revealed many shared similar opinions. In 2014 the UK Strength and Conditioning council released an international consensus [2] regarding youth resistance training. This statement was formed following the critical analysis of previous reviews and new studies. The statement and data were in turn by leading organizations in the fields of sport medicine, exercise science and paediatrics. This paper supported many of the findings of studies discussed in the below reviews. Such findings included:

- Resistance training (not power-lifting) has many potential benefits for participants during all stages of life.
- Programs should be well structured with adequate supervision and should focus on developing proper techniques as well as increasing fitness and strength.
- Activities that incorporate resistance training can support and encourage participation in later life.
- Seniors should recognize the benefits of

training and that avoidance can lead to poor health outcomes in later life.

This study benefitted from being reviewed and endorsed by multiple internationally reputable organizations. It based its findings from over 200 studies and synthesized this data to form an extremely strong statement.

Another strong study suggested children and young adults have been shown to have improvements in strength (30-50%) and overall health when involved in a well-organised and supervised program [3]. This review evaluated articles and consensus statements over a 28-year period (1980-2008). Also included were recommendations, position statements and consensus guidelines from a number of reputable medical and sporting societies. It states that young athletes should have their goals and expectations discussed prior to commencing an exercise program. Athletes should start with no-load exercises and a sufficient warm up, and then aim to complete either large-muscle or multi-joint exercises early and finishing with small-muscle and single-joint ones. Additionally machine weights should be avoided due to large increments (5-10 pounds) and their design being potentially unsuitable for the young athlete. This is one of the few reviews to address power lifting in the paediatric setting. While many of the discussed

reviews suggest overall avoidance Dahab and McCambridge suggest a method to potentially allow the process to become safer despite displaying caution [3].

A 2013 multi-faceted review of resistance training in the youth population attempted to build on the initial review by Kraemer in 1989 [4]. This paper aimed to provide insight into previous and current literature and as well as provide future directions of paediatric exercise research [4]. The authors hypothesized that many risk factors and disease associated with a sedentary lifestyle stem from childhood and that measures should be started to increase activity early. Additionally low muscular strength during childhood itself was a risk factor for disease development and attempts must be made to identify this early. It suggested that children of today's generation are overall more sedentary than their counterparts of the past and that physical activities and regimes of the past may be worth reincorporating into newer children's' activities. From these statements it must be considered whether a certain amount of exercise or resistance training be mandatory in children's schooling. Additionally long term prospective studies may be useful in determining long-term sequelae.

The American Academy of Paediatrics also provided a policy statement regarding strength training. The benefits of resistance training are addressed in both a general and paediatric population [5]. Benefits when incorporated into a weight-control program of obese children include increased metabolic rate with low impact. Additionally it may improve bone mineralization and density. This statement also addresses the potential risks and at-risk groups for resistance training amongst the young population. It maintains a position shared by many papers that power lifting and bodybuilding should be avoided until participants reach physical and skeletal maturity [5]. Groups such as children with hypertension, seizure disorders, heart or skeletal growth conditions, as well as cancer

and chemotherapy using children should be withheld due to systemic manifestations of their conditions [5].

Another group reviewed the literature to determine the effects of resistance on multiple physical and psychological aspects of overweight children [6]. Forty studies were deemed to be satisfactory. The studies that were identified were either Randomized or Non-randomized Control trials) (RCT/NRCT) as well as Uncontrolled trials (UCT). The results gathered demonstrated that resistance training created moderate to large effects on strength in overweight and obese children but only small to moderate changes in body composition. It also highlighted a lack of literature reviewing the psychosocial impact of resistance training [6]. Strengths of this study included a significant number of participants (1505) over multiple continents and ethnicities; and analysis of three different kinds of studies with multiple subgroup analyses. However it did include multiple studies with different interventions, poor definition of a control group, and many of the studies used different forms of data analyses as well as outcome measurement. Despite this it is still a powerful study.

A guideline was created in 2012 to advise Australian government policy on the relationship between physical activity (including resistance training) and the paediatric and young adult population (5-17 years of age) [7]. This review searched multiple medical databases in order to provide evidence-based advice to create recommendations and encourage physicality. The search included any experimental or longitudinal study that provided a valid and reliable objective or subjective measure of physical activity. Results were compared using eleven indicators that were ranked against each other with the final tally including 127 studies. The results and subsequent recommendations were also compared to guidelines worldwide (E.g. USA, UK and Canada) and previous Australian recommendations. The new recommendations

suggested that children/young people should undertake 60 minutes of moderate-vigorous activity each day, strength training should be done at least three times per week, and that more exercise is associated with further benefits [7].

The final meta-analysis reviewed literature regarding the effects of bone health and growth in girls subjected to weight/resistance based training. This was performed due to the growing attention and evidence regarding the osteogenic potential for the paediatric population. Additionally it addressed the female sex due to the increase prevalence of osteoporosis in elderly women. Following a literature review on multiple medical databases 17 suitable studies were identified. The review found the impact of weight-bearing activities to have small but significant effect size on areal Bone Mineral Density (effect size 0.19) and Bone Mineral Content at the lumbar spine as well as increased Bone Mineral Content at the femoral neck. However it advised that further investigations are needed to quantify and understand the dose-response relationship of weight training and also explore the role of puberty in skeletal development [8].

Much of the Australian literature gives reference to a statement and brief review of the literature by an Australian Institute of Sport Strength and Conditioning Coach from 2003 [9]. It provided a recommendation for pre-adolescent athletes that weight training should concentrate on skills and techniques, as well as big muscle groups should be targeted using free and body weight with relatively light loads [9]. Finally, exercise programs should gradually be introduced so the participant becomes accustomed to it. While from a reputable source this is still an expert opinion piece (level 4 evidence) potentially decreasing the strength of its conclusions. It is also in need of a contemporary update having been published over one decade ago.

Following this the subsequent articles found were randomized or unrandomised studies or

retrospective and prospective reviews. Many of the studies focused on regular school-aged children [9]. They reviewed the efficacy of exercise in a hospital vs. home setting where 110 children into either hospital or home based, and a control group. Following six-month regimes the study found comparable decreases in BMI-Z score, and Percentage Body Fat (%BF) (4%, 0.16 vs. 4.4%, 0.23) in both the home and hospital exercised group. The home-based group also showed a 4.4cm decrease in waist circumference [10]. This study demonstrated that it is possible to have measurable benefits in a home-based exercise group. However many variables remain unexplored such as patient.

Further school-based studies have also demonstrated that in the school setting classes led by specialist PE teachers have shown greater increases in motor and health-related abilities in comparison to generalist teachers. These specialist classes included age-tailored PE groups that incorporated strength training [11]. Several studies have attempted to identify differences between the sexes in these school-aged children.

A 2013 study evaluated strength and spontaneous physical activity in 102 schoolchildren (aged 10-14 years) over 19 weeks randomized into either a physical education or guided strength class [12]. The results in this study showed that while both the female and male participants experienced increased upper and lower limb strength only the males demonstrated higher levels of spontaneous physical activity and energy expenditure. While no definite reason was attributed to this sex difference a hypothesis that girls' earlier pubertal development may contribute to these decreases rates of spontaneous activity [12]. A smaller study also aimed to investigate Integrative Neuromuscular Training (INT) and PE classes against control group of only PE over an eight-week period. The study found that PE including INT could result in improvements in specific health and

skill-related fitness components in children however the most sensitive finding was the increase in young girls undergoing the INT and PE class. The reasons behind and long-term sequelae are uncertain and further studies looking into the sex-specific outcomes in school age children were recommended as well as larger cohort studies with a large distribution of age groups [13].

Studies have also looked at specific components of fitness. One group reviewed the effects of an eight-week training program of resistance training alone or combined resistance and endurance training against a control group in 125 prepubescent children [14]. Both experimental groups showed significant increases in almost all strength testing physical where only experimental group with endurance training showed a significant increase in  $VO_{2max}$  test results [14]. A 2013 study took 164 students and evaluated their core endurance using 5 difference trunk and core muscular endurance tests. The participants undertook a six-week course of moderate-to-high intensity, equipment-free, dynamic core conditioning warm up routine once a week for the course duration. Evaluation of the data revealed significant improvements in all 5 outcomes/exercises. Additionally greater improvements were found in the older participants, which had been attributed to several theories including trainability [15]. A study in 2014 also demonstrated that in comparison to men, boys had increased neuromuscular fatigue resistance and decreased recovery times in comparison to adults [16]. This study only provided a single assessment and may have benefited from repeated measurements over time to see if this results remains the same with training.

There have also been several studies that have reviewed resistance training in elite young athlete. An RCT evaluated the efficacy of plyometric training in nine elite pre-pubertal elite female gymnasts over a 20-month period. This period encompassed two training periods

separated by a competition and transitional period. Plyometric performance was measured using drop jumps (DJs) from 20, 40, 60, 80, and 100 cm height. Other variables measured were flight time (FT), contact time (CT), flight-contact ratio (FC), and estimated mechanical power (Bosco Expression (BE)). This study found increases of all variables except for contact time at DJ height of 80 and 100cm suggesting a combined strength and plyometric-based program is effective in elite level gymnasts [17]. A similar study reviewed 24 elite pre-pubertal academy soccer players following a 26-week High Intensity Interval Training (HIIT) and resistance-training program. The participants were randomized into an experimental and a control group (the control completed regular soccer training). Significant improvements were found in the experimental groups with improvements in all tests barring the 15-meter sprint time. These results included; 6.72% increase in jump height; 49.57% vs. 19.67% increase in Yo-Yo intermittent Endurance test and a 7.26% increase in Sit and Reach flexibility testing. This study supported previous studies in suggesting that significant improvements in strength and fitness can be gained in children when enrolled in structured resistance and HIIT training [18].

The last studies to be reviewed include several studies that look at rather unique aspects of resistance training in the paediatric population. An RCT performed reviewed resistance training in peri-menarchal females in comparison to regular PE classes. The outcome in this study was skeletal growth. All participants (44 girls) all of whom were six months post-menarche did not differ in bone growth over a seven-month resistance-training period. However subgroup analysis revealed that for Tanner 2 or 3 level girls at baseline, resistance-based training produced differential gains at the hip and spine in comparison to the control group [19]. Physical activity has also been found to beneficial in children with Type 1 Diabetes. Following a study of 27 diabetic

children in comparison to 32 healthy children comparable increases in bone mineral density were found in both groups' lumbar spine measurements over nine months [20]. Another study performed over a four-year period also supported this notion with it prospectively finding that in children who undertook more moderate intensity physical activity, a measurable increase in bone mineral density and size were noted with no change in fracture risk [21]; this is in keeping with previous and more recent literature which supports the view of "resistance training as medicine" in children and young adults and the inherent plasticity of skeletal muscle to dynamic loading conditions [22-24].

#### CONCLUSION

The topic of resistance training in the paediatric population has yielded a significant amount of research and discussion. Throughout the years the overwhelming consensus is that resistance training provides positive benefits for many different groups of children in regards to overall health, strength and fitness. However, certain exercises such as powerlifting should be avoided and certain paediatric groups should seek medical clearance from a sports physician or orthopaedic surgeon before commencing an exercise program. Further prospective research should be completed to determine the long-term sequelae of resistance training in children in comparison to the general population.

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