NASM
NATIONAL ACADEMY OF SPORTS MEDICINE

# YOUTH RESISTANCE TRAINING FOR LONG-TERM HEALTH: AN EVIDENCE-BASED REVIEW

www.nasm.org

# Table of Contents

# Contributors and Reviewers

Dr. Scott Cheatham, PhD, DPT, OCS, ATC, is a professor and associate chair in the Department of Kinesiology at California State University at Dominguez Hills in Carson, California. He is the owner of Sports Medicine Alliance, a concierge sports and orthopedic physical therapy company. Dr. Cheatham is a national presenter for various organizations and has authored over 150 peer-reviewed publications, textbook chapters, and home-study courses on the topics of sports medicine, orthopedics, and health and fitness. In addition to being a subject matter expert for NASM, Dr. Cheatham is an education and research consultant for various health and fitness organizations and the managing board member of the NASM Scientific Advisory Board. He received a doctor of physical therapy (DPT) and a doctor of philosophy (PhD) in physical therapy. He is a board-certified orthopedic physical therapist (OCS), certified athletic trainer (ATC), and certified ergonomic specialist. He also has certifications in NASM-CPT/CES/PES/CNC, NSCA-CSCS/CPT.

Dr. Brian Sutton, EdD, MS, MA, NASM-CPT, PES, CES, CSCS, is a 20-year veteran in the health and fitness industry, working as a personal trainer, author, content manager, and professor, and has overseen the development of several NASM programs, including Certified Personal Trainer, Certified Nutrition Coach, Certified Sports Nutrition Coach, Physique and Bodybuilding Coach, Weight Loss Speicalization, and many more. He earned an EdD in kinesiology from the University of North Carolina, Greensboro, an MA in sport and fitness management from the University of San Francisco, an MS in exercise science from PennWest University, and several certifications from NASM, ACSM, and NSCA. He served as an adjunct faculty member for PennWest University (2010–2018), teaching graduate-level courses in rehabilitation science, performance enhancement and injury prevention, and health and fitness.

Dr. Kellie C. Huxel Bliven, PhD, ATC, FNAP, is a professor and chair in the Department of Interdisciplinary Health Sciences at A.T. Still University in Mesa, Arizona. She teaches human anatomy courses to various health professions programs and previously taught in the online Kinesiology Program, where she developed the corrective exercise and orthopedic rehabilitation concentration. Dr. Huxel Bliven is the director of the Interdisciplinary Research Laboratory, and her research interests include understanding and improving shoulder function and health, systematic reviews and meta-analyses on injury risk factors, and diagnostic ultrasound and digital tools in anatomy and health sciences education. She is the editor-in-chief of the *Journal of Sport Rehabilitation* and a distinguished research fellow in the Athletic Training Academy of the National Academies of Practice. Dr. Huxel Bliven is a native of Cleveland Heights, Ohio. She received her

bachelor's degree in biology and physical education from Denison University in Granville, Ohio; master's degree in kinesiology from Indiana University in Bloomington, Indiana; and doctoral degree in kinesiology with an athletic training emphasis from Temple University in Philadelphia, Pennsylvania.

Dr. Adam Annaccone, EdD, LAT, ATC, CES, PES, is a clinical assistant professor at The University of Texas at Arlington in the Master of Science in Athletic Training Program. He directs the program's Standardized Patient Lab and is a Parliamentarian for the Faculty Senate. For over 20 years, he has worked in educational and clinical settings, serving as a licensed athletic trainer, a corrective exercise specialist, and a performance enhancement specialist. Additionally, he has extensive experience working as an independent contractor for several professional athletes, providing movement assessments, targeted neuromuscular manual therapy, and corrective/performance exercise programs. Dr. Annaccone spent three seasons with the NBA Phoenix Suns organization on their highly regarded sports medicine staff, serving as performance and recovery specialist/assistant athletic trainer. He is an active member of the athletic training profession, serving as the cochair of the Task Force for Sports Science, Health, and Data Analytics for the NATA. He received his doctoral degree from Indiana University of Pennsylvania, a master's degree from Clarion University, and a bachelor of science in athletic training from Duquesne University in Pittsburgh, Pennsylvania.

Mike Elliott, MS, ATC, PES, CES, is the senior director of High Performance at the Banner Sports Medicine High Performance Center. Mr. Elliott is responsible for assembling and overseeing the multidisciplinary high-performance team to optimize athlete performance enhancement, injury prevention, and return to play. He previously served as vice president of performance health care for the Utah Jazz. He led the NBA team's medical and sports science efforts, including overseeing athletic training, strength and conditioning programs, and sports nutrition and mental performance programs. Under his leadership, the Utah Jazz health and performance department was named corecipient of the 2019–2020 Joe O'Toole/David Craig Athletic Training Staff of the Year Awards by the National Basketball Athletic Trainers Association. Before working with the Utah Jazz, he spent 14 seasons (2003–2017) with the Phoenix Suns, serving on the athletic training staff as director of performance, head strength and conditioning coach, and assistant athletic trainer. Mr. Elliott was named NBA Strength and Conditioning Coach of the Year by the National Basketball Strength and Conditioning Association (NBSCA) for the 2013–2014 season. He earned his bachelor's in exercise science from Arizona State University and a master's in performance enhancement and injury prevention from PennWest University. He is a certified athletic trainer and is qualified as a performance enhancement specialist and corrective exercise specialist by the NASM. Mr. Elliott is a NASM Scientific Advisory Board member.

# Abstract

Resistance training is currently recognized as an important part of a youth physical activity program for long-term health. Youth inactivity has become a growing issue in many countries around the world. Inactivity has been linked to pediatric dynapenia (muscle weakness) and other chronic health conditions. Youth resistance training has become an important intervention to combat youth muscle weakness. This evidence-based review will explore important topics related to youth resistance training as they apply to the fitness and wellness professional. The role of the professional will be discussed along with suggested resistance exercise design and programming strategies for youth resistance training.

# Introduction

Youth inactivity is becoming prevalent in many countries and is a growing concern. There are several factors that contribute to physical inactivity, such as increased screen time on electronic devices, socialization through technology instead of in-person, and reduced focus on physical activity in schools (Faigenbaum et al., 2019). Further, the COVID-19 pandemic exacerbated the problem of using technology for entertainment and socialization through isolation and limiting the ability to engage in physical activity in public spaces (Abbas, Athar, & Jilani, 2023). Researchers estimate that globally, youths were 20% less physically active during the COVID-19 pandemic (Neville et al., 2022), and these low levels persist post-pandemic compared to pre-pandemic levels (Centers for Disease Control and Prevention [CDC], 2024; Salway et al., 2023). It is imperative that the health and fitness industry focus on youths, a high-risk population, to change behaviors and attitudes toward physical activity and change the trajectory of one's health and activity profile.

More recently, experts have been concerned about youth inactivity being a risk factor for pediatric dynapenia and other chronic health conditions (Faigenbaum et al., 2019; Milton et al., 2023; World Health Organization [WHO], 2010). Dynapenia is defined as a loss of muscle strength and power associated with aging that is unrelated to neurological or muscular disease (Clark & Manini, 2012). In pediatric populations, pediatric dynapenia refers to a loss of muscle strength and power with normal muscle mass as a result of inactivity and chronic medical conditions. Pediatric dynapenia is a growing concern among medical experts (Faigenbaum et al., 2019). Experts have suggested increasing physical activity with a focus on resistance training to combat the negative consequences of inactivity, including pediatric dynapenia, and to promote long-term health (Duncombe et al., 2022; Faigenbaum et al., 2019; Piercy et al., 2018). Resistance training may include an array of exercise movements that incorporate the individual's body weight and various weighted objects, such as but not limited to dumbbells, barbells, kettlebells, and medicine balls. Resistance training may be included in a youth-integrated training program, strength and conditioning program, physical education class, group fitness class, or an individual's fitness program.

The past 30 years have produced some compelling research evidence documenting that resistance training can be beneficial and safe for youths when properly taught and supervised by a qualified professional (Faigenbaum & Geisler, 2021; Lloyd et al., 2014). Despite the positive research, there has been controversy around parents' and coaches' understanding of the safety and efficacy of youth resistance training, which may create a barrier when trying to promote the importance of youth physical activity and resistance training (ten Hoor et al., 2015). It is important for fitness and wellness professionals to be aware of outdated and negative stigmas about resistance training held by some individuals and to educate them about current evidence and recommendations that support safe and supervised resistance training.

This evidence-based review will cover the latest research on youth resistance training for long-term health. The goal of this paper is to provide the fitness and wellness professional with the latest evidence on youth physical activity trends, consequences of inactivity, benefits of youth resistance training, safety of youth resistance training, public promotion and parent/coach views, and the role of the fitness and wellness professional.

**IMPORTANT INFORMATION**

**Describing "Youth"**

Fitness and wellness professionals should consider that many expert organizations, such as the World Health Organization (WHO), use the terms "child" or "adolescent" to define young individuals with corresponding age ranges (Arora et al., 2015; Sawyer et al., 2018). For this review, the term "*youth*" will be used for simplicity, which represents children (6 to 12 years of age) and adolescents (13 to 18 years of age) (Faigenbaum & Geisler, 2021). Thus, the "youth" classification includes a total age range of 6 to 18 years, which will be used throughout this document.

# Youth Physical Activity Trends

Physical activity guidelines from the United States and the WHO recommend that youths participate in weekly physical activity that includes aerobic and muscle-strengthening activities. The guidelines are as follows (Bull et al., 2020; Piercy et al., 2018):

- Youths should participate in 60 minutes or more of moderate to vigorous daily aerobic physical activity.
- At least 3 days per week or more, the 60 minutes of physical activity should include aerobic, muscle-strengthening, and bone-strengthening exercises.

Unfortunately, many youths fall short of these physical activity guidelines (Michael et al., 2023). For example, U.S. statistics (2019–2021) revealed that only 24% of youths participated in 60 minutes of moderate to vigorous activity each day, and 45% participated in muscle-strengthening exercise ≥3 days per week (Michael et al., 2023). Similar inactivity trends have been reported in other countries, such as Canada, Australia, Mexico, and Spain (Faigenbaum et al., 2019; Milton et al., 2023). Unfortunately, the growing trend of inactivity among youths can result in long-term health risks.

**GETTING TECHNICAL**

**Exercise Deficit Disorder**

Fitness and wellness professionals should consider that U.S. and WHO youth physical activity guidelines recommend a combination of moderate to vigorous aerobic and resistance exercise daily for 60 minutes or more. Experts have developed the term *Exercise Deficit Disorder* (EDD) to classify youths who fail to meet these minimum recommendations and may be at risk of adverse health conditions such as pediatric dynapenia (Faigenbaum et al., 2020).

More recently, youth resistance training has become an important topic among healthcare experts due to the growing trends in youth inactivity and muscle weakness (Faigenbaum & Geisler, 2021). This evidence-based review focuses on the benefits of youth resistance training with an understanding that youth physical activity programs should include an integrated exercise approach grounded in resistance exercise (Stricker et al., 2020).

# Consequences of Youth Inactivity

Inactive youths may be at higher risk for pediatric dynapenia and other health-related consequences. The U.S. Centers for Disease Control and Prevention (CDC) documents that inactivity can lead to overweight and obesity, hyperlipidemia, high blood pressure, insulin resistance, and glucose intolerance. These are all risk factors for cardiovascular disease (CDC, 2024; Cuenca-García et al., 2014). Inactivity from youth through adulthood can also increase the risk for type 2 diabetes, different types of cancer (breast, colon, endometrial, and lung), and low bone density (CDC, 2024) (**Figure 1**). Besides the aforementioned health conditions, a growing concern among healthcare experts is pediatric dynapenia or muscle weakness, which may have greater downstream negative consequences for young individuals. The fitness and wellness professional should consider that these consequences may be avoided if physical activity and healthy lifestyle habits are adopted at a young age (Cuenca-García et al., 2014).

## Pediatric Dynapenia

Pediatric dynapenia, or loss of muscle strength and power with normal muscle mass, has become a concern among researchers and healthcare experts (Faigenbaum & Geisler, 2021). The combined presence of muscle weakness and reduced fundamental motor skills early in life may predispose youths to negative changes in physical activity, body composition, and related comorbidities later in life (Faigenbaum & Geisler, 2021). **Figure 2** illustrates the downward cascade of adverse outcomes

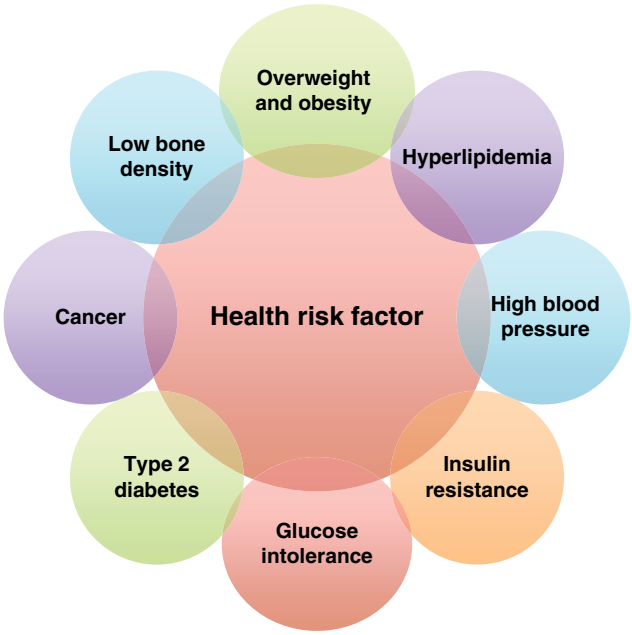


**Figure 1. Health Risk Factors Related to Inactivity**

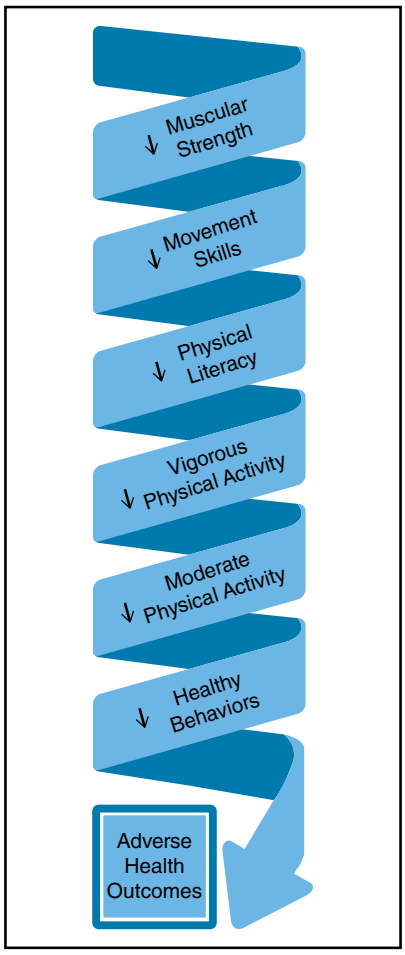


**Figure 2. Downward Cascade of Adverse Outcomes Related to Pediatric Dynapenia**

Adapted from Faigenbaum, A. D., & Geisler, S. (2021). The promise of youth resistance training. *B&G Bewegungstherapie und Gesundheitssport*, 37(02), 47–51. https://doi.org/10.1055/a-1378-3385

related to pediatric dynapenia. The interrelated factors may lead to physical inactivity and adverse health outcomes (Faigenbaum & Geisler, 2021). Experts postulate that pediatric dynapenia may be a major factor for the inactivity consequences noted in the prior section (Faigenbaum et al., 2019). The fitness and wellness professional can play a key role in promoting physical activity and healthy lifestyles among youth clients to potentially prevent or reduce adverse health outcomes (Faigenbaum et al., 2019).

**GETTING TECHNICAL**

**Dynapenia versus Sarcopenia**

The terms "dynapenia" and "sarcopenia" have been used by healthcare professionals and researchers to describe muscle weakness and muscle loss. ***Dynapenia*** is often defined as a loss of muscle strength and power with normal muscle mass (Jung et al., 2022). This has been traditionally applied to older adults. More recently, it has been called pediatric dynapenia in youth due to the growing trends of inactivity across many countries (Faigenbaum et al., 2019). ***Sarcopenia,*** or "age-related muscle loss," is a progressive condition of reduced muscle strength, reduced performance, and muscle loss, often occurring in older adults (Yuan & Larsson, 2023). For more information on sarcopenia, the professional is encouraged to read the *NASM Guide to Sarcopenia: An Evidence-Based Review.*

https://www.nasm.org/resources/downloads

# Public Promotion, Parental and Coaching Views of Youth Resistance Training

Over the past several years, different healthcare organizations and governing bodies have published position statements supporting resistance training as part of a comprehensive youth physical activity and long-term health program (**Figure 3**). These organizations are unified in their support of youth resistance training to help with long-term physical development, improve physical literacy, reduce injury risk, and enhance overall health and wellness (Bergeron et al., 2015; CDC, 2011; Faigenbaum et al., 2009; Lloyd et al., 2014; McCambridge & Stricker, 2008; Piercy et al., 2018; Stricker et al., 2020; Valovich McLeod et al., 2011; WHO, 2010). The fitness and wellness professional should consider that parents may not be aware of such position statements due to a lack of public education (Stricker et al., 2020).

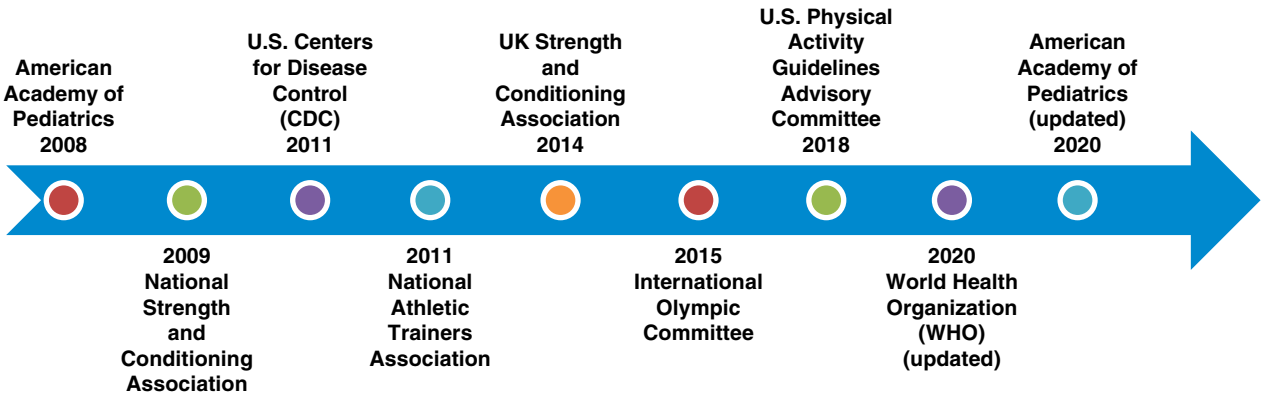


**Figure 3. Timeline of Professional Organizations Supporting Youth Resistance Training**

## FOOD FOR THOUGHT

### Physical Literacy

Many countries use the physical literacy model as a foundation for community physical activity programming for young individuals (Cornish et al., 2020). **Physical literacy** among young individuals describes a holistic foundation for physical activity engagement based on developing fundamental movement skills. Researchers define physical literacy as the following: "physical literacy is defined as the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life" (Cornish et al., 2020). Higher physical literacy has a strong association with youth physical activity. Researchers have documented that youths with healthy body mass index (BMI), waist circumference, and body weight were more likely to have higher physical literacy scores than individuals with higher BMI, waist circumference, and body weight (Cornish et al., 2020). Physical activity focusing on resistance training is a good way for youths to increase physical literacy (Faigenbaum, 2018; Zwolski et al., 2017).

# Parent Perceptions Regarding Youth Resistance Training

Despite the overwhelming support from healthcare experts and available evidence, parents may still be misinformed about the safety and efficacy of youth resistance training. A 2015 study (n = 314) of Dutch parents documented that 96% surveyed supported their child (12 to 15 years old) participating in aerobic exercise (ten Hoor et al., 2015). However, 30% of parents surveyed would not allow their child to participate in resistance training. They believed resistance training was detrimental to their child's health, causing injuries and impairing physical development (ten Hoor et al., 2015). A 2022 qualitative study of parents (n = 31) documented that parents of youth club soccer players generally supported strength and conditioning programs for their kids (Duncan et al., 2022). The surveyed parents understood the overall benefits (e.g., improved strength, injury risk mitigation) if taught and supervised by a qualified professional. However, some parents still expressed safety concerns regarding the potential negative effects of resistance training on growth (e.g., resistance training impairs growth).

Currently, there are few published studies on parental perceptions of youth resistance training, which still leaves many questions. The available evidence does support the expert opinion that some parents may have a negative view of resistance training due to different misconceptions (Faigenbaum et al., 2022). When working with youths and parents, the professional should clarify any misconceptions about youth resistance training and stress the importance of muscle strength and power for long-term health.

## Misconceptions: Youth Resistance Training

As discussed in the prior section, some parents may have a negative perception of youth resistance training due to the lack of public education and misconceptions. Despite the large amount of support, there is still a lack of public education and knowledge about the safety and efficacy of this type of exercise. Due to these issues, there are common misconceptions that parents and possibly coaches may have about resistance training (ten Hoor et al., 2015). A 2020 position statement by the American Academy of Pediatrics (AAP) provides a summary of common myths and what the research evidence documents regarding these concerns (Faigenbaum et al., 2022; Stricker et al., 2020) (**Table 1**).

| Misconceptions | Research Evidence |
|---|---|
| **A child is unable to increase strength before puberty.** | Prepubertal children can gain strength by an increase in neurological recruitment of muscle fibers, and gains in strength can be made with low injury rates if resistance training programs are well supervised with an emphasis on proper technique. |
| **Young boys and girls may get "muscle bound" if they resistance train.** | Prepubertal strength gains occur by neurological mechanisms, and pubertal gains may augment muscle growth by actual muscle hypertrophy enhanced by pubertal hormones. |
| **Resistance training may decrease aerobic performance in youth.** | Improvements in aerobic performance have been shown with combined aerobic and resistance training programs, and combined aerobic and resistance programs do not appear to impair strength gains in children. |
| **Resistance training may stunt growth.** | Well-designed resistance training programs have not been shown to have a negative effect on apophyseal (growth plate) health, linear growth, and cardiovascular health in youth. |
| **Children are stronger now than ever before.** | There is a need to target strength deficits and build strength reserves due to declining measures of muscular fitness in modern-day youth. |
| **1RM testing is unsafe for youth.** | *1RM testing may be a safe method for assessing muscular strength in youth, provided that qualified supervision is present and appropriate testing guidelines are followed. |

*1RM = one repetition maximum.
Adapted from the American Academy of Pediatrics (Stricker et al., 2020).

**Table 1. Common Misconceptions and Evidence Regarding Youth Resistance Training**

# Sport Coach Perceptions Regarding Youth Resistance Training

Youth coaches (e.g., sports coaches, physical educators) may play a role in guiding youths with resistance training as part of their organized sport, physical education class, or fitness program. Youth coaches may have a better perception regarding the importance of youth resistance training than parents. Survey studies have documented that youth sports coaches believe youth resistance training is safe and can improve athletic development and long-term health. However, researchers have expressed concerns regarding the lack of youth resistance training knowledge and programming guidelines for coaches (Evans & Thomas, 2012; Shaw et al., 2023). There is still a need for further investigations to develop evidence-based guidelines. This topic is understudied, with only a few published studies resulting in many unanswered questions. Further investigations are needed to develop universal guidelines for youth coaches.

**GETTING TECHNICAL**

The fitness and wellness professional should consider the nomenclature regarding resistance training and weightlifting. *Resistance training* is a general term that describes an exercise requiring the muscle to contract against resistance. Types of resistance include but are not limited to dumbbells, barbells, kettlebells, medicine balls, resistance bands, selectorized machines, and other weighted objects (e.g., sandbags) (Pierce et al., 2022). *Weightlifting* is considered a competitive sport that includes two primary movements: snatch and clean and jerk. Weightlifters primarily use barbells, dumbbells, and different types of lifting racks (Pierce et al., 2022). Youth exercise programming for both forms of exercise has similar principles but should be done with caution. Weightlifting requires more advanced coaching by a qualified professional on technique, exercises and their derivatives, and safety (Pierce et al., 2022).

# Benefits of Youth Resistance Training

While physical inactivity is associated with many adverse health outcomes, health promotion and programming should focus on educating and motivating youths about why and how physical activity, specifically resistance training, should become a healthy habit. The major health benefits of youth resistance training include but are not limited to improved muscle strength and power, physical literacy, cardiometabolic function, body composition, and mental health. **Table 2** provides an expanded list of documented health benefits from youth resistance training (Barahona-Fuentes et al., 2021; Donnelly et al., 2016; Faigenbaum et al., 2019; García-Hermoso et al., 2023; Jansson et al., 2022; Marinelli et al.,

2024; Ribeiro et al., 2022; Robinson et al., 2023; Sánchez Pastor et al., 2023; Zwolski et al., 2017). Muscle strength and power are prerequisites for youths to perform fundamental movements and are essential components of health and fitness. Some youths may be unable to make such observable gains due to possible strength barriers (Faigenbaum & Geisler, 2021; Faigenbaum et al., 2019). Adequate muscle fitness allows youths to perform different physical activities successfully and develop their physical literacy (Zwolski et al., 2017).

| Benefits of Youth Resistance Exercise | |
|---|---|
| Increased muscular fitness | Increased physical literacy |
| Increased movement skills | Increased physical activity |
| Increased fat-free mass | Increased strength reserves |
| Increased cognitive function and academic outcomes | Increased hormonal adaptations |
| Reduced depression and anxiety | Reduced kinesiophobia (fear of movement) |
| Reduced adiposity | Reduced injury risk |
| Reduced cardiometabolic risks | Reduced risk of chronic disease |
| Reduced risk of all-cause mortality | Reduced insulin resistance |

**Table 2. Benefits of Youth Resistance Exercise**

# Reducing Injury Risk

When developing resistance exercise programs for clients, the goal is always to achieve the benefits while at the same time being mindful to reduce injury risk. Researchers have documented that youth athletes who incorporate resistance training into their training have decreased injury rates due to increased bone density and strength, muscle–tendon strength, and coordination (Myers et al., 2017). Resistance training can have similar benefits for inactive youths in building injury resistance and physical literacy (Stricker et al., 2020; Zwolski et al., 2017). Integrated exercise that includes a combination of exercises such as resistance, core, balance, plyometrics, and speed, agility, and quickness (SAQ) has been shown to reduce youth injury rates and address common risk factors (**Table 3**) (Fort-Vanmeerhaeghe et al., 2016; Hanlon et al., 2020). Intrinsic risk factors for injury are considered internal or personal to the individual and may include physical variables (Mandorino et al., 2023). Some intrinsic risk factors, such as muscle strength deficits or lack of flexibility, are modifiable and can be addressed with corrective interventions, such as muscle-strengthening exercises and stretching. Extrinsic factors are external to an individual that may cause harm (Mandorino et al., 2023). Some extrinsic factors, such as shoe type, are modifiable and can be corrected.

| Intrinsic Risk Factors | Extrinsic Risk Factors |
|---|---|
| Age and biological sex | *Level of competition or skill |
| Prior injury | *Shoe type |
| Body size | *Use of taping or bracing equipment |
| Anatomical alignment issues | Playing surface |
| Foot morphology | |
| *Muscle strength deficits | |
| *Lack of flexibility | |
| *Poor balance and coordination | |
| *Poor endurance | |
| *Psychological/social factors | |
| **Risk factors that may be modifiable.* | |

**Table 3. Youth Injury Risk Factors**

# Muscle Development (Strength and Hypertrophy)

Youth resistance training helps with muscle development by taking advantage of the synergistic effects of physiological adaptations from the exercise and the natural maturation of the young individual (Myers et al., 2017) (**Figure 4**). This results in improved muscle development, such as strength. Youths experience a heightened proliferation of central nervous system maturation (Myers et al., 2017). Youth muscle strength gains from resistance training may be attributed to changes in the nervous system versus muscle hypertrophy (Myers et al., 2017). More specifically, increased agonist motor unit activation will lead to greater motor output as measured by the rate of force development (Myers et al., 2017). Fitness and wellness professionals should consider that youth resistance training takes advantage of a maturing nervous system, which can produce positive results in muscle development (Myer et al., 2013). However, it is important that professionals design safe resistance training programs based on the youth's physiological profile and physical literacy. The upcoming section will provide resistance training programming recommendations for the fitness and wellness professional.

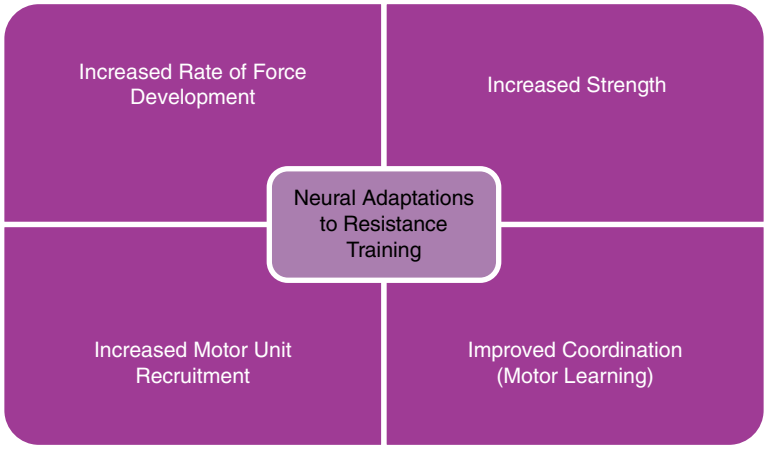


**Figure 4. Neural Adaptation to Resistance Training**

# Safety of Youth Resistance Training

The past 30+ years of research have produced some compelling evidence that resistance training can be beneficial and safe for youths when properly taught, programmed, and supervised by a qualified professional (Faigenbaum & Geisler, 2021; Lloyd et al., 2014; Myers et al., 2017; Stricker et al., 2020). One major concern regarding youth resistance training is the risk of epiphyseal plate (e.g., growth plate) injuries, especially when unsupervised or using inappropriate dosing. While possible, the occurrence of epiphyseal plate injuries is low. This concern emerged from studies and case reports in the 1970s and 1980s, which documented a growing trend of injuries (Faigenbaum et al., 2009). Over the years, experts have investigated these data further. It was determined that these injuries were related to improper lifting form and poor youth exercise programming during that period (Faigenbaum et al., 2009). It is important to note that explosive contractions of the muscle–tendon attachment at apophyseal areas (a growth plate where a muscle or tendon attaches) during physical activity (e.g., sports, active play, resistance exercise) may increase the risk of an avulsion fracture (Stricker et al., 2020). These types of bone injuries can be reduced with a safe training environment that includes proper instruction, programming, and supervision by a qualified professional (Stricker et al., 2020). Current expert opinion supports the idea that resistance training prior to epiphyseal plate closure is not harmful if programmed correctly (Milone et al., 2013; Myers et al., 2017).

Despite the presence of safety measures during youth resistance exercise, injuries can occur. The most common resistance training–related injuries occur in the lower back and trunk (Myers et al., 2017). Overall, these injuries are quite rare, and the risks can be further reduced with proper training and supervision. One study documented that resistance training–related injury rates occurred around 0.035 per 100 training hours (Hamill, 1994; Myers et al., 2017). Researchers have also documented a few

injuries with high-intensity lifting (e.g., 1RM [repetition maximum] training) with more complicated movements (e.g., bench press, back squat, and deadlift) (Faigenbaum et al., 2003; Myers et al., 2017). A study on youth powerlifters documented an injury rate of 0.29 per 100 training hours (Brown & Kimball, 1983). The fitness and wellness professional should consider that the majority of reported injuries appear to be soft-tissue-related (e.g., muscle strain, joint sprain, bruising) and non-life-threatening (Brown & Kimball, 1983; Hamill, 1994). Unfortunately, the majority of youth resistance training research has vaguely reported the specific types of injuries, which leaves a gap in understanding and classifying different injuries and potential causes (see "Getting Technical" box) (Mack et al., 2023).

Another concern among healthcare experts is the risk of overtraining by youths who participate in organized sports and cross-training with resistance exercise. In short, overtraining refers to a group of symptoms (e.g., reduced performance, fatigue, sleep disturbances, mood changes, increased resting heart rate, muscle soreness, and overuse injuries) resulting from excessive exercise with insufficient recovery to facilitate physiological adaptation (Brenner et al., 2024). Youth weekly practice, competition, and training loads need to be structured to allow adequate rest and recovery to avoid overtraining. A well-designed annual periodization program (e.g., preseason, in-season, and off-season) can help balance the training volumes and intensities (Stricker et al., 2020). Youth periodization for resistance training will be discussed in the upcoming sections.

## GETTING TECHNICAL

### Adverse Injury Reporting in Youth Resistance Training Research

Fitness and wellness professionals should consider the lack of adverse injury reporting from youth resistance training by researchers. A 2023 systematic review evaluated the body of evidence of adverse incidents in youth exercise research studies (Mack et al., 2023). The researchers found that most resistance training studies did not report adverse events, and when reported, the injuries were not defined well. Interestingly, the few studies that did report adverse events linked the injuries to training and testing (Mack et al., 2023). Professionals should consider that this systematic review only documented the reporting of injuries in the research. They did not formulate any opinion(s) on the efficacy and overall safety. The authors encouraged researchers to be transparent and accurately report injuries when they occurred (Mack et al., 2023). These findings supported the universal expert opinion that resistance training can be safe if taught, programmed, and supervised by a qualified professional. The fitness and wellness professional should consider that resistance training is safe for youths and may be part of a fitness, performance, or corrective exercise program (Piercy et al., 2018; Ruas et al., 2024; Zwolski et al., 2017).

# The Fitness and Wellness Professional

The fitness and wellness professional can play a major role in safely coaching youth clients participating in a resistance training program. Coaching youth clients using the research evidence and scientific principles may help them improve their muscle strength and long-term health. This section will discuss specific topics and best practices for youth resistance training as it applies to fitness and wellness professionals.

## Resistance Training Programming

The AAP provides recommendations on youth resistance training that are intended to be helpful to fitness and wellness professionals who develop and implement programs. First and foremost, they emphasize the importance of utilizing qualified professionals (e.g., licensed healthcare professionals and certified fitness and wellness professionals) who can safely teach, develop exercise programs, and supervise youths during their resistance training program (Stricker et al., 2020). A primary goal of the NASM is to provide education and equip professionals with the knowledge and skills to perform such tasks in a safe training environment. Professionals need to consider several factors when designing a youth resistance training program. They will be discussed next.

### Training Age and Resistance Training Skill Competency

Training age and resistance training skill competency (RTSC) are two contemporary concepts that can be used in youth resistance exercise programming (Faigenbaum et al., 2016). Training age refers to the cumulative amount of time spent in formalized training, and RTSC incorporates the quantity of weight lifted, quality of lifted movement, and emotional maturity of the young individual (Faigenbaum et al., 2016; Smith et al., 2018; Stricker et al., 2020). As the youth's RTSC advances, the professional can progressively introduce advanced movements and higher loads requiring greater technical ability (Lloyd et al., 2014). Training age and RTSC can both be used to determine the youth's exercise experience to safely design their resistance exercise program (Stricker et al., 2020). For example, a 15-year-old female who began a supervised resistance exercise program at age 10 would have a training age of 5 with a good level of RTSC. She may be able to start with intermediate-level resistance (60% to 80% of 1RM) and perform more advanced movements (e.g., barbell squats). Consequently, a 14-year-old male who has just begun training will have a training age of 0 and a lower level of RTSC. He may have to begin with low-level resistance (≤60% 1RM) and develop proper technique before progressing with his exercise movements and training loads. The fitness and wellness professional can also interview the youth and parents and conduct scientifically valid fitness assessments to gather information related to the client's RTSC.

**COACHING TIP**

**When Is It Safe to Begin Youth Resistance Training?**

Determining the readiness of a youth to begin resistance training is multifactorial. Factors such as, but not limited to, chronological age, health status, activity level, exercise experience, physical maturity, emotional maturity, RTSC, physical literacy, and training age must be considered when assessing the readiness for resistance training (Myer et al., 2013; Zwolski et al., 2017). In general, experts propose the ages of *5* to *8* may be an appropriate chronological range to introduce resistance training because this is the time when youths begin organized sports (Faigenbaum et al., 2016, 2019, 2022; Myer et al., 2013).

## Resistance Training Movement Prerequisites

Another strategy the professional should consider is teaching youths with low RTSC (e.g., poor technical skills) the fundamental movements prior to more advanced resistance training movements. This will help the young individual build their catalog of essential prerequisite motor skills that are essential for advanced movements (Faigenbaum et al., 2016). Fundamental movements may include but are not limited to squat, hip-hinge, lunge, vertical press, horizontal push, horizontal pull, carry, rotation, and anti-rotation. Fundamental movements can be incorporated into youth resistance training programming at all training levels. The fitness and wellness professional is encouraged to review scholarly and reputable sources that teach fundamental movement patterns.

## Youth Resistance Training Program Design

The recommended youth resistance training programming can be described in three phases: beginning, intermediate, and advanced (Lloyd et al., 2014; Stricker et al., 2020). For *beginning* programs, the youth can start with a low resistance training intensity (≤60% 1RM) as proper technique is developed. As the individual's RTSC improves, the weight can be systematically increased in 5% to 10% increments with reduced repetitions. For *intermediate* programs, the youth can progress to a moderate resistance training intensity (≤80% 1RM) with an increase in sets and repetitions. For *advanced* programs, a higher exercise training intensity (≥80% 1RM) can be used with an increase in sets and repetitions (**Table 4**) (Lloyd et al., 2014; Stricker et al., 2020). The professional should consider that youths must demonstrate adequate RTSC and proficiency with the fundamental movements within each phase to participate safely and that advanced training should be introduced in periodic phases to avoid overtraining (Lloyd et al., 2014; Stricker et al., 2020).

| | Beginning | Intermediate | Advanced |
|---|---|---|---|
| **Frequency** | 2–3 sessions/week | 2–3 sessions/week | 2–3 sessions/week |
| **Intensity** | ≤60% 1RM | 60%–80% 1RM | ≥80% 1RM |
| ***RPE (CR10) scale** | 1–4 | 4–7 | 7–9 |
| **Sets** | 1–2 | 2–4 | 4–6 |
| **Reps** | 8–12 | 6–12 | 1–6 |
| **Rest** | 60 seconds | Up to 3 minutes | 3–5 minutes |
| **Tempo** | Slow/moderate | Moderate/fast | Fast |
| **Body region** | Upper/lower body and core | Upper/lower body and core | Upper/lower body and core |
| *RPE = rate of perceived exertion. | | | |

**Table 4. Youth Resistance Exercise Programming**

## Youth Resistance Training Variables

The fitness and wellness professional should use recommended exercise science concepts to progress and regress the youth with their resistance training program. The following is a list of common training variables to consider when designing a youth resistance training program (Faigenbaum & Geisler, 2021; Sutton, 2022):

- Multi-joint movements should occur before simple single-joint movements
- Resistance exercise should be performed in all planes of movement
- Exercises should be varied on a weekly basis to keep the stimulus effective
- Training load can be progressed from light to heavy
- Training volume, sets, and reps can be progressed based on program goals
- Utilize a proprioceptive-rich training environment to maximize neuromuscular effects
- The training environment can progress from known to unknown or anticipated to unanticipated

**IMPORTANT INFORMATION**

**Youth Fitness Assessment: Best Practices**

When designing a youth resistance exercise program, the professional should initially conduct a comprehensive fitness assessment to thoroughly understand the client's goals, parental goals/expectations, health risks, and the youth's physiological profile.

Information in the physiological profile may include but is not limited to blood pressure, resting heart rate, muscle performance, movement efficiency, aerobic capacity, muscle flexibility, joint mobility, and performance on relevant field or clinical tests. Other factors include but are not limited to youth training age, RTSC, physical and emotional readiness and maturity, sports coach input, nutritional behaviors, recovery strategies, and time availability.

Best practices for the fitness and wellness professional recommend creating a collaborative environment with the youth client, their parent(s), and any other relevant stakeholders. The youth client is a minor, so the professional must obtain consent from the youth and parent(s) prior to any assessments and training (Sutton, 2022).

## Youth Resistance Training Periodization

Initial youth resistance training should be programmed using linear periodization to allow for safe neuromuscular adaptation (Stricker et al., 2020). One advantage to linear periodization is the gradual increase in training load over predetermined periods or phases. This provides time for adaptation and may help prevent overtraining and potential injuries (Lorenz & Morrison, 2015). The other advantages are that each phase is predictable for both the professional and youth and often focuses on specific training goals that should be accomplished before progressing to the next level (Lorenz & Morrison, 2015). The main disadvantages to linear periodization are the youth's tolerance to different exercise loads and volumes, which may fluctuate throughout the program, and the maintenance of specific training characteristics (e.g., muscle strength) as they transition to different phases (Lorenz & Morrison, 2015). The youth's tolerance and availability to resistance train may also be influenced by their school, family, and social commitments.

For advanced resistance training programs, an undulating or nonlinear periodization model may be ideal because it changes exercise intensity, volume, and exercise selection daily or weekly. One advantage is the ability to modify the youth's program based on their recovery from a prior workout session. Another advantage is the ability to program different training parameters, such as strength and power, simultaneously in the same week (Lorenz & Morrison, 2015). Other advantages include weekly load fluctuations that may lead to better neuromuscular adaptations, and weekly programming changes may help avoid the detraining effects that occur with linear periodization (Lorenz & Morrison,

2015; Sutton, 2022). Disadvantages may include the inability to fully develop a specific performance characteristic (e.g., muscle strength) due to the weekly programming changes and the focus on several training parameters at one time (Lorenz & Morrison, 2015).

## Resistance Training Program Duration for Strength Gains

Physical activity guidelines from the U.S. and the WHO recommended that youths partake in a minimum training frequency of 3 days per week of resistance exercise (Bull et al., 2020; Piercy et al., 2018). However, to achieve reasonable strength gains, youths must exercise a minimum of 8 weeks at a frequency of 2 to 3 sessions per week (Lloyd et al., 2014; Stricker et al., 2020). Researchers have documented that progressive resistance training lasting >23 weeks is most effective at achieving maximum strength gains (Lesinski et al., 2016). The fitness and wellness professional should consider both minimum and optimal durations to achieve desirable muscle strength and power gains, depending on their client's goals, needs, abilities, and availability. The professionals must integrate target durations into their client's programming and educate the youth and their parents about realistic expectations.

## Integrated Training Programs

Integrated training for youth is also recommended to help with their complete neuromuscular development, improved health, and reduction of potential risk factors. Integrated training includes a combination of resistance, core, balance, plyometrics, SAQ, flexibility, mobility, and aerobic exercise (Fort-Vanmeerhaeghe et al., 2016; Stricker et al., 2020). The U.S. Physical Activity Guidelines recommend a type of integrated training for youths that includes resistance and aerobic exercise (Piercy et al., 2018). An integrated training program grounded in resistance training is recommended by experts to combat the loss of muscle strength and power (Faigenbaum et al., 2019; Lloyd et al., 2014; Stricker et al., 2020). This can be accomplished by focusing on resistance training and programming various other exercises within the integrated training framework. Using the NASM Optimum Performance Training® (OPT™) model is a beneficial strategy for these individuals because this model emphasizes integrated training protocols. However, it is important to keep resistance training as the primary exercise because it is the first-line intervention for preventing pediatric dynapenia (Faigenbaum et al., 2019). Professionals should also consider that the integrated training framework fits well into common periodization training models, such as linear and undulating (Sutton, 2022). Overall, integrated training grounded in resistance exercise provides a multidimensional approach to preventing pediatric dynapenia while simultaneously enhancing health and performance.

## Youth Education

Educating youths and parents on the importance of resistance training, efficacy and safety, support by healthcare experts, and addressing misconceptions may help with engagement and adherence to a resistance training program. Fitness and wellness professionals are uniquely qualified to coach

and educate youth clients and parents. Proper education may help youths and parents understand key concepts that will translate into greater exercise compliance, self-efficacy, and an appreciation for physical activity focusing on resistance exercise.

## Youth Exercise: Underserved Communities and the Pediatric Inactivity Triad

The recommended physical activity standards for youth provide good exercise standards but do not offer solutions for underserved populations (e.g., racial/ethnic minorities, rural communities, those with low socioeconomic status, and individuals with physical disabilities) across the world (Mendoza-Vasconez et al., 2016). Youths in underserved communities may not have access to quality education, fitness facilities, or resources to pay for expert coaching. This can result in a lack of accessibility to accurate information and opportunities for youths to participate in structured physical activity programs grounded in resistance training (Craike et al., 2018). When working with individuals living in underserved communities, the fitness and wellness professional must consider the youth client's access to accurate information, health care, exercise facilities, sports participation, and resources.

Another emerging model is the *Pediatric Inactivity Triad* (PIT). This model describes the integrated effects of pediatric inactivity (i.e., EDD), pediatric dynapenia, and physical illiteracy (**Figure 5**). These conditions are all unique and can occur alone, but together may create greater health issues for youths later in life (Faigenbaum et al., 2020). Experts consider the PIT as an emerging problem that may be influenced by socioeconomic factors. More specifically, the PIT may be affected by potential negative influences from inactive schools (e.g., lack of physical education and sports programs), communities, and home life (Faigenbaum et al., 2020). As noted earlier, these behaviors may be found in underserved communities due to a lack of access to accurate information, resources, and expert coaching. It is important to note that there are other adaptations to this PIT model for different populations, such as individuals with chronic health issues (Wilkinson et al., 2022). This version of the PIT model attempts to

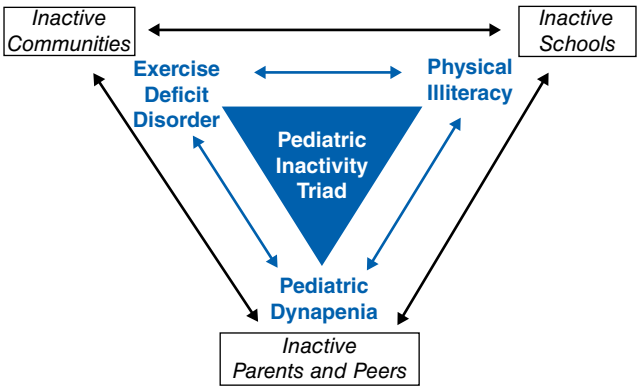


**Figure 5. The Pediatric Inactivity Triad Model**

Adapted from Faigenbaum, A. D., MacDonald, J. P., Carvalho, C., & Rebullido, T. R. (2020). The pediatric inactivity triad: A triple jeopardy for modern day youth. *ACSM's Health & Fitness Journal, 24*(4), 10–17. https://doi.org/10.1249/fit.0000000000000584

address inactivity using an approach based on socioeconomic factors and influences from schools, the community, and parents (Faigenbaum et al., 2020).

Fitness and wellness professionals should consider the potential barriers to underserved populations and different socioeconomic influences. Providing the client and their parent(s) with expert coaching and accurate information regarding physical activity guidelines, healthy lifestyle behaviors, exercise adherence strategies, exercise progression, and alternatives for resistance training and integrated training may help them find ways to stay physically active (Bantham et al., 2021; Sutton, 2022).

# Conclusion

Youth inactivity has become a global concern due to the potential long-term health consequences such as pediatric dynapenia. Experts have suggested increasing physical activity with a focus on resistance training to combat pediatric dynapenia and other potential health issues. The research on youth resistance training is growing with a greater understanding of the efficacy and safety of this form of exercise. Different healthcare organizations and governing bodies have published position statements supporting resistance training. Unfortunately, there are still misconceptions among parents and other adults regarding the safety and efficacy of this type of exercise. These individuals may restrict youths from participating in resistance training due to the fear of injury. Fitness and wellness professionals are uniquely qualified to coach and educate youths and their parent(s) about the importance of resistance training within an integrated training framework. The topics covered in this evidence-based review provide the professional with the latest information on this topic. The fitness and wellness professional is encouraged to study these topics further to develop a more comprehensive understanding.

# Key Takeaways

- **Youth Inactivity:** Experts have been concerned about the lack of physical activity among younger individuals in many countries. Youth inactivity is a risk factor for dynapenia and other health-related conditions.
- **Pediatric Dynapenia:** Defined as a loss of muscle strength and power with normal muscle mass in young individuals. This condition is linked to chronic medical conditions such as but not limited to metabolic dysfunction, cardiovascular risks, and major causes of premature death.
- **U.S. Physical Activity Guidelines:** National recommendations for weekly aerobic and resistance exercise in young individuals. Children and adolescents should participate in 60 minutes or more of moderate to vigorous daily aerobic physical activity and include muscle- and bone-strengthening exercises.
- **Benefits of Youth Resistance Training:** The major health benefits of youth resistance training include but are not limited to improved muscle performance, physical literacy, cardiometabolic function, body composition, injury resistance, and mental health.
- **Physical Literacy:** Defined as the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life.
- **Safety of Youth Resistance Training:** The past 30+ years of research have produced compelling evidence that resistance training can be beneficial and safe for youths when properly taught, programmed, and supervised by a qualified professional.
- **Public Promotion of Resistance Training:** To date, nine different healthcare organizations and governing bodies have published positioning statements supporting youth resistance training.
- **Parent Perceptions:** Despite the overwhelming support by healthcare experts and available evidence, some parents or other adults may still be misinformed about the safety and efficacy of youth resistance exercise.
- **Youth Sports Coaches:** Coaches may have a better perspective than parents on the importance of youth resistance training and seem to support this form of exercise. More education is needed to properly educate coaches on resistance training program design and coaching practices.
- **Youth Resistance Training Programming:** The AAP recommends that youth resistance training be administered by a qualified professional who can safely teach, develop exercise programs, and supervise youths.
- **Youth Resistance Training Periodization:** Initial youth resistance exercise should be programmed using linear periodization to allow for safe neuromuscular adaptation. For advanced resistance training, the undulating or nonlinear periodization model may be ideal because it changes exercise intensity, volume, and exercise selection on a daily or weekly basis.
- **Resistance Training Program Duration for Strength Gains:** To achieve reasonable strength gains, youths must exercise a minimum of 8 weeks for a frequency of 2 to 3 sessions per week. Researchers have documented that resistance training lasting >23 weeks is most effective at achieving maximum strength gains. The fitness and wellness professional should consider both minimum and optimal durations to achieve desirable

muscle strength and power gains, depending on their client's goals, needs, abilities, and availability.

- **Integrated Exercise:** Integrated exercise programming for youth is also recommended to help with their complete neuromuscular development. Experts recommend an integrated exercise program grounded in resistance training for youths.
- **Youth Exercise: Underserved Communities and PIT:** Youths in underserved communities may not have access to quality education, facilities, or resources. This can result in a lack of accessibility to accurate information and opportunities to participate in a physical activity program grounded in resistance training. The PIT describes a model for addressing inactivity and socioeconomic barriers.

# References


Abbas, S. A., Athar, S., & Jilani, N. Z. (2023). The impact of the COVID-19 pandemic on the physical and mental health of school-aged children. *HCA Healthcare Journal of Medicine*, *4*(3), 223–228. https://doi.org/10.36518/2689-0216.1547

Arora, S. K., Shah, D., Chaturvedi, S., & Gupta, P. (2015). Defining and measuring vulnerability in young people. *Indian Journal of Community Medicine*, *40*(3), 193–197. https://doi.org/10.4103/0970-0218.158868

Bantham, A., Taverno Ross, S. E., Sebastião, E., & Hall, G. (2021). Overcoming barriers to physical activity in underserved populations. *Progress in Cardiovascular Diseases*, *64*, 64–71. https://doi.org/https://doi.org/10.1016/j.pcad.2020.11.002

Barahona-Fuentes, G., Huerta Ojeda, Á., & Chirosa-Ríos, L. (2021). Effects of training with different modes of strength intervention on psychosocial disorders in adolescents: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *18*(18), 9477. https://doi.org/10.3390/ijerph18189477

Bergeron, M. F., Mountjoy, M., Armstrong, N., Chia, M., Côté, J., Emery, C. A., Faigenbaum, A., Hall, G., Jr., Kriemler, S., Léglise, M., Malina, R. M., Pensgaard, A. M., Sanchez, A., Soligard, T., Sundgot-Borgen, J., van Mechelen, W., Weissensteiner, J. R., & Engebretsen, L. (2015). International Olympic Committee consensus statement on youth athletic development. *British Journal of Sports Medicine*, *49*(13), 843–851. https://doi.org/10.1136/bjsports-2015-094962

Brenner, J. S., Watson, A., & Council on Sports Medicine & Fitness. (2024). Overuse injuries, overtraining, and burnout in young athletes. *Pediatrics*, 153(2), e2023065129. https://doi.org/10.1542/peds.2023-065129

Brown, E. W., & Kimball, R. G. (1983). Medical history associated with adolescent powerlifting. *Pediatrics*, 72(5), 636–644.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J. P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., . . . Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Centers for Disease Control and Prevention. (2011). School health guidelines to promote healthy eating and physical activity. *MMWR Recommendations and Reports*, *60*(RR-5), 1–76.

Centers for Disease Control and Prevention. (2024). *CDC healthy schools: Physical activity facts*. Retrieved July 6, 2024 from https://www.cdc.gov/healthyschools/physicalactivity/facts.htm#:~:text=Increase%20the%20risk%20of%20factors,insulin%20resistance%20and%20glucose%20intolerance.&text=Increase%20the%20risk%20for%20developing%20type%202%20diabetes.

Clark, B. C., & Manini, T. M. (2012). What is dynapenia? *Nutrition*, *28*(5), 495–503. https://doi.org/10.1016/j.nut.2011.12.002

Cornish, K., Fox, G., Fyfe, T., Koopmans, E., Pousette, A., & Pelletier, C. A. (2020). Understanding physical literacy in the context of health: A rapid scoping review. *BMC Public Health*, *20*(1), 1569. https://doi.org/10.1186/s12889-020-09583-8

Craike, M., Wiesner, G., Hilland, T. A., & Bengoechea, E. G. (2018). Interventions to improve physical activity among socioeconomically disadvantaged groups: An umbrella review. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1), 43. https://doi.org/10.1186/s12966-018-0676-2

Cuenca-García, M., Ortega, F. B., Ruiz, J. R., González-Gross, M., Labayen, I., Jago, R., Martínez-Gómez, D., Dallongeville, J., Bel-Serrat, S., Marcos, A., Manios, Y., Breidenassel, C., Widhalm, K., Gottrand, F., Ferrari, M., Kafatos, A., Molnár, D., Moreno, L. A., De Henauw, S., . . . Sjöström, M. (2014). Combined influence of healthy diet and active lifestyle on cardiovascular disease risk factors in adolescents. *Scandinavian Journal of Medicine & Science in Sports*, *24*(3), 553–562. https://doi.org/10.1111/sms.12022

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K., & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Medicine & Science in Sports & Exercise*, *48*(6), 1197–1222. https://doi.org/10.1249/mss.0000000000000901

Duncan, M. J., Martins, R. M. G., & Eyre, E. L. J. (2022). "Sharpening your mind, strengthening your body" parental perceptions on the use of strength and conditioning in children and youth. *Children*, *9*(10), 1557. https://www.mdpi.com/2227-9067/9/10/1557

Duncombe, S. L., Barker, A. R., Bond, B., Earle, R., Varley-Campbell, J., Vlachopoulos, D., Walker, J. L., Weston, K. L., & Stylianou, M. (2022). School-based high-intensity interval training programs in children and adolescents: A systematic review and meta-analysis. *PLoS One*, *17*(5), e0266427. https://doi.org/10.1371/journal.pone.0266427

Evans, K., & Thomas, P. (2012). Perceptions and practices of Australian golf coaches towards physical fitness for golf. *Journal of Science and Medicine in Sport*, *15*, S130. https://doi.org/10.1016/j.jsams.2012.11.313

Faigenbaum, A. D. (2018). Youth resistance training: The good, the bad, and the ugly—The year that was 2017. *Pediatric Exercise Science*, *30*(1), 19-24. https://doi.org/10.1123/pes.2017-0290

Faigenbaum, A. D., & Geisler, S. (2021). The promise of youth resistance training. *B&G Bewegungstherapie und Gesundheitssport*, *37*(02), 47–51. https://doi.org/10.1055/a-1378-3385

Faigenbaum, A. D., Kraemer, W. J., Blimkie, C. J., Jeffreys, I., Micheli, L. J., Nitka, M., & Rowland, T. W. (2009). Youth resistance training: Updated position statement paper from the national strength and conditioning association. *Journal of Strength and Conditioning Research*, *23*(5 Suppl), S60–S79. https://doi.org/10.1519/JSC.0b013e31819df407

Faigenbaum, A. D., Lloyd, R. S., MacDonald, J., & Myer, G. D. (2016). Citius, Altius, Fortius: Beneficial effects of resistance training for young athletes: Narrative review. *British Journal of Sports Medicine*, *50*(1), 3–7. https://doi.org/10.1136/bjsports-2015-094621

Faigenbaum, A. D., MacDonald, J. P., Carvalho, C., & Rebullido, T. R. (2020). The pediatric inactivity triad: A triple jeopardy for modern day youth. *ACSM's Health & Fitness Journal*, *24*(4), 10–17. https://doi.org/10.1249/fit.0000000000000584

Faigenbaum, A. D., Milliken, L. A., & Westcott, W. L. (2003). Maximal strength testing in healthy children. *Journal of Strength and Conditioning Research*, 17(1), 162–166. https://doi.org/10.1519/1533-4287(2003)017<0162:mstihc>2.0.co;2

Faigenbaum, A. D., Rebullido, T. R., Peña, J., & Chulvi-Medrano, I. (2019). Resistance exercise for the prevention and treatment of pediatric dynapenia. *Journal of Science in Sport and Exercise*, *1*(3), 208–216. https://doi.org/10.1007/s42978-019-00038-0

Faigenbaum, A. D., Stracciolini, A., MacDonald, J. P., & Rial Rebullido, T. (2022). Mythology of youth resistance training. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsports-2022-105804

Fort-Vanmeerhaeghe, A., Romero-Rodriguez, D., Lloyd, R. S., Kushner, A., & Myer, G. D. (2016). Integrative neuromuscular training in youth athletes. Part II: Strategies to prevent injuries and improve performance. *Strength & Conditioning Journal*, *38*(4), 9–27. https://doi.org/10.1519/ssc.0000000000000234

García-Hermoso, A., López-Gil, J. F., Izquierdo, M., Ramírez-Vélez, R., & Ezzatvar, Y. (2023). Exercise and insulin resistance markers in children and adolescents with excess weight: A systematic review and network meta-analysis. *JAMA Pediatrics*, *177*(12), 1276–1284. https://doi.org/10.1001/jamapediatrics.2023.4038

Hamill, B. P. (1994). Relative safety of weightlifting and weight training. *Journal of Strength and Conditioning Research*, *8*(1), 53–57.

Hanlon, C., Krzak, J. J., Prodoehl, J., & Hall, K. D. (2020). Effect of injury prevention programs on lower extremity performance in youth athletes: A systematic review. *Sports Health*, *12*(1), 12–22. https://doi.org/10.1177/1941738119861117

Jansson, D., Lindberg, A. S., Lundberg, E., Domellöf, M., & Theos, A. (2022). Effects of resistance and endurance training alone or combined on hormonal adaptations and cytokines in healthy children and adolescents: A systematic review and meta-analysis. *Sports Medicine Open*, *8*(1), 81. https://doi.org/10.1186/s40798-022-00471-6

Jung, H., Tanaka, S., & Tanaka, R. (2022). Body composition characteristics of community-dwelling older adults with dynapenia. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.827114

Lesinski, M., Prieske, O., & Granacher, U. (2016). Effects and dose–response relationships of resistance training on physical performance in youth athletes: A systematic review and meta-analysis. *British Journal of Sports Medicine*, *50*(13), 781–795.

Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Oliver, J. L., Jeffreys, I., Moody, J. A., Brewer, C., Pierce, K. C., McCambridge, T. M., Howard, R., Herrington, L., Hainline, B., Micheli, L. J., Jaques, R., Kraemer, W. J., McBride, M. G., Best, T. M., Chu, D. A., Alvar, B. A., & Myer, G. D. (2014). Position statement on youth resistance training: The 2014 International Consensus. *British Journal of Sports Medicine*, *48*(7), 498–505. https://doi.org/10.1136/bjsports-2013-092952

Lorenz, D., & Morrison, S. (2015). Current concepts in periodization of strength and conditioning for the sports physical therapist. *International Journal of Sports Physical Therapy*, *10*(6), 734–747.

Mack, D. E., Anzovino, D., Sanderson, M., Dotan, R., & Falk, B. (2023). Reporting of adverse events in

muscle strengthening interventions in youth: A systematic review. *Pediatric Exercise Science*, *35*(3), 127–143. https://doi.org/10.1123/pes.2021-0145

Mandorino, M., Figueiredo, A. J., Gjaka, M., & Tessitore, A. (2023). Injury incidence and risk factors in youth soccer players: A systematic literature review. Part II: Intrinsic and extrinsic risk factors. *Biology of Sport*, *40*(1), 27–49. https://doi.org/10.5114/biolsport.2023.109962

Marinelli, R., Parker, A. G., Levinger, I., Bourke, M., Patten, R., & Woessner, M. N. (2024). Resistance training and combined resistance and aerobic training as a treatment of depression and anxiety symptoms in young people: A systematic review and meta-analysis. *Early Intervention in Psychiatry*. https://doi.org/10.1111/eip.13528

McCambridge, T. M., & Stricker, P. R. (2008). Strength training by children and adolescents. *Pediatrics*, *121*(4), 835–840. https://doi.org/10.1542/peds.2007-3790

Mendoza-Vasconez, A. S., Linke, S., Muñoz, M., Pekmezi, D., Ainsworth, C., Cano, M., Williams, V., Marcus, B. H., & Larsen, B. A. (2016). Promoting physical activity among underserved populations. *Current Sports Medicine Reports*, *15*(4), 290–297. https://doi.org/10.1249/jsr.0000000000000276

Michael, S. L., Jones, S. E., Merlo, C. L., Sliwa, S. A., Lee, S. M., Cornett, K., Brener, N. D., Chen, T. J., Ashley, C. L., & Park, S. (2023). Dietary and physical activity behaviors in 2021 and changes from 2019 to 2021 among high school students—Youth Risk Behavior Survey, United States, 2021. *MMWR Supplements*, *72*(1), 75–83. https://doi.org/10.15585/mmwr.su7201a9

Milone, M. T., Bernstein, J., Freedman, K. B., & Tjoumakaris, F. (2013). There is no need to avoid resistance training (weight lifting) until physeal closure. *The Physician and Sports Medicine*, *41*(4), 101–105. https://doi.org/10.3810/psm.2013.11.2041

Milton, K., Gomersall, S. R., & Schipperijn, J. (2023). Let's get moving: The Global Status Report on Physical Activity 2022 calls for urgent action. *Journal of Sport and Health Science*, *12*(1), 5–6. https://doi.org/10.1016/j.jshs.2022.12.006

Myer, G. D., Lloyd, R. S., Brent, J. L., & Faigenbaum, A. D. (2013). How young is "too young" to start training? *ACSMs Health & Fitness Journal*, *17*(5), 14–23. https://doi.org/10.1249/FIT.0b013e3182a06c59

Myers, A. M., Beam, N. W., & Fakhoury, J. D. (2017). Resistance training for children and adolescents. *Translational Pediatrics*, *6*(3), 137–143. https://doi.org/10.21037/tp.2017.04.01

Neville, R. D., Lakes, K. D., Hopkins, W. G., Tarantino, G., Draper, C. E., Beck, R., & Madigan, S. (2022). Global changes in child and adolescent physical activity during the COVID-19 pandemic: A systematic review and meta-analysis. *JAMA Pediatrics*, *176*(9), 886–894. https://doi.org/10.1001/jamapediatrics.2022.2313

Pierce, K. C., Hornsby, W. G., & Stone, M. H. (2022). Weightlifting for children and adolescents: A narrative review. *Sports Health*, *14*(1), 45–56. https://doi.org/10.1177/19417381211056094

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., & Olson, R. D. (2018). The physical activity guidelines for Americans. *Journal of the American Medical Association*, *320*(19), 2020–2028. https://doi.org/10.1001/jama.2018.14854

Ribeiro, B., Forte, P., Vinhas, R., Marinho, D. A., Faíl, L. B., Pereira, A., Vieira, F., & Neiva, H. P. (2022). The benefits of resistance training in obese adolescents: A systematic review and meta-analysis. *Sports Medicine Open*, *8*(1), 109. https://doi.org/10.1186/s40798-022-00501-3

Robinson, K., Riley, N., Owen, K., Drew, R., Mavilidi, M. F., Hillman, C. H., Faigenbaum, A. D., García-Hermoso, A., & Lubans, D. R. (2023). Effects of resistance training on academic outcomes in school-aged youth: A systematic review and meta-analysis. *Sports Medicine*, *53*(11), 2095–2109. https://doi.org/10.1007/s40279-023-01881-6

Ruas, C., Ratel, S., Nosaka, K., Castellano, G., & Pinto, R. (2024). Resistance training effects on pubertal children with a risk of developing pediatric dynapenia. *European Journal of Applied Physiology, 124*, 2123–2137. https://doi.org/10.1007/s00421-024-05436-z

Salway, R., de Vocht, F., Emm-Collison, L., Sansum, K., House, D., Walker, R., Breheny, K., Williams, J. G., Hollingworth, W., & Jago, R. (2023). Comparison of children's physical activity profiles before and after COVID-19 lockdowns: A latent profile analysis. *PLoS One*, *18*(11), e0289344. https://doi.org/10.1371/journal.pone.0289344

Sánchez Pastor, A., García-Sánchez, C., Marquina Nieto, M., & de la Rubia, A. (2023). Influence of strength training variables on neuromuscular and morphological adaptations in prepubertal children: A systematic review. *International Journal of Environmental Research and Public Health*, *20*(6). https://doi.org/10.3390/ijerph20064833

Sawyer, S. M., Azzopardi, P. S., Wickremarathne, D., & Patton, G. C. (2018). The age of adolescence. The

*Lancet: Child and Adolescent Health*, *2*(3), 223–228. https://doi.org/10.1016/s2352-4642(18)30022-1

Shaw, J., Gould, Z. I., Oliver, J. L., & Lloyd, R. S. (2023). Perceptions and approaches of golf coaches towards strength and conditioning activities for youth golfers. *International Journal of Sports Science & Coaching*, *18*(5), 1629–1638. https://doi.org/10.1177/17479541221132371

Smith, J. J., DeMarco, M., Kennedy, S. G., Kelson, M., Barnett, L. M., Faigenbaum, A. D., & Lubans, D. R. (2018). Prevalence and correlates of resistance training skill competence in adolescents. *Journal of Sports Sciences*, *36*(11), 1241–1249.

Stricker, P. R., Faigenbaum, A. D., McCambridge, T. M., Council on Sports Medicine and Fitness, LaBella, C. R., Brooks, M. A., Canty, G., Diamond, A. B., Hennrikus, W., Logan, K., Moffatt, K., Nemeth, B. A., Pengel, K. B., & Peterson, A. R. (2020). Resistance training for children and adolescents. *Pediatrics*, *145*(6), e20201011. https://doi.org/10.1542/peds.2020-1011

Sutton, B. G. (Ed.). (2022). *NASM essentials of personal fitness training* (7th ed.). Jones & Bartlett Learning.

ten Hoor, G. A., Sleddens, E. F., Kremers, S. P., Schols, A. M., Kok, G., & Plasqui, G. (2015). Aerobic and strength exercises for youngsters aged 12 to 15: What do parents think? *BMC Public Health*, *15*, 994. https://doi.org/10.1186/s12889-015-2328-7

Valovich McLeod, T. C., Decoster, L. C., Loud, K. J., Micheli, L. J., Parker, J. T., Sandrey, M. A., & White, C. (2011). National Athletic Trainers' Association position statement: Prevention of pediatric overuse injuries. *Journal of Athletic Training*, *46*(2), 206–220. https://doi.org/10.4085/1062-6050-46.2.206

World Health Organization. (2010). WHO guidelines approved by the Guidelines Review Committee. In *Global Recommendations on Physical Activity for Health*. Copyright © World Health Organization 2010.

Wilkinson, T. J., O'Mahoney, L. L., Highton, P., Viana, J. L., Ribeiro, H. S., Lightfoot, C. J., Curtis, F., & Khunti, K. (2022). Physical activity and the 'pediatric inactivity triad' in children living with chronic kidney disease: A narrative review. *Therapeutic Advances in Chronic Disease*, *13*, 20406223221109971. https://doi.org/10.1177/20406223221109971

Yuan, S., & Larsson, S. C. (2023). Epidemiology of sarcopenia: Prevalence, risk factors, and consequences. *Metabolism–Clinical and Experimental*, *144*, 155533. https://doi.org/10.1016/j.metabol.2023.155533

Zwolski, C., Quatman-Yates, C., & Paterno, M. V. (2017). Resistance training in youth: Laying the foundation for injury prevention and physical literacy. *Sports Health*, *9*(5), 436–443. https://doi.org/10.1177/1941738117704153

# THANKS FOR READING!

NASM™
NATIONAL ACADEMY OF SPORTS MEDICINE

www.nasm.org