SCIENCE
TECHNOLOGY
PARK
NIS

19th to 21st October 2023

XXIV International Scientific Conference | FIS COMMUNICATIONS 2023 in Physical Education, sport and recreation

Book of Proceedings

Niš, 2023.

IMPLICATIONS OF AGE AND GENDER DISPARITIES IN STRENGTH TRAINING AMONG CHILDREN AND ADOLESCENTS

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UDC 796.012.11:316.47-053.6

ABSTRACT

When designing a strength training program, a physical fitness expert must take into account gender differences in muscle capabilities, the level of fitness, as well as the effects that these differences have on each individual. The aim of this study was to determine the implications of age and gender differences in strength training for children and adolescents. A review of studies was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). The following databases were used for literature search: Google Scholar, Medline, Science Direct, PubMed, Web of Science, and Research Gate. A total of 68 studies met the defined criteria for inclusion in the systematic review and further analysis. Numerous osteogenic benefits and essential factors of physical activity contribute to the growth and development of the skeletal system in boys and girls during this age period. Children who regularly engage in physical activities involving their body weight and participate in exercise programs that include strength training with external resistance experience an increase in bone density. Participation in such programs during the preadolescent period allows boys and girls to achieve strength gains and other abilities greater than the ordinary gains resulting from growth and maturation. Recent research has clearly shown that if the volume and intensity of exercise are appropriate for their age, boys and girls can increase muscle strength beyond the limits achievable through mere growth and maturation.

Keywords: exercise, strength, training, children, adolescents, individually or in combination.

INTRODUCTION

When designing a strength training program, a physical fitness expert must take into account gender differences in muscle capabilities, the level of fitness, as well as the effects that these differences have on each individual. Children do not grow at a uniform pace, and there are significant differences in physical development at each chronological age due to various factors. In a population of 14-year-old children, there can be a difference in height of up to 23 cm and a difference in body weight of 18 kg. Furthermore, an 11-year-old girl may be taller and physically more capable than a boy of the same age (Lloyd, Oliver, Faigenbaum, Mayer, & De Ste Croix, 2014). This is due to the onset of puberty, which varies between boys and girls (starting significantly earlier in girls), causing some of them to have a biological age that differs from their chronological age by several years. Since the level of maturation is related to the degree of overall physical preparedness, which includes the development of motor skills and muscle strength (Katzmarzyk, Malina, & Beunen, 1997), techniques used to assess the degree of maturation allow children to be assessed for motor abilities not solely based on chronological age. During the period of rapid growth and development, in males, muscle mass increases rapidly (from 25% at birth to 40% after maturation) due to increased testosterone hormone production (Malina, Bouchard, & Bar-Or, 2004), while in females during this period, due to increased estrogen production, the amount of body fat increases (which is stored in the pelvic, thigh, and breast areas), and the increase in muscle mass occurs continuously but at a

slower rate (Malina, Bouchard, & Bar-Or, 2004). In this pubertal period, which occurs around the age of 12 for girls and around the age of 14 for boys, changes in muscle imbalances and relative tightening of muscle-tendon units covering rapidly growing bones are often observed, which represents potential risk factors for injury during high physical stress (Micheli, 1991; Mayer, Ford, Divine, Wall, Kahanov, & Hewett, 2009; Van der Sluis, Elferink-Gemser, Coelho-e-Silva, Nijboer, Brink, & Visscher, 2014). Excessive stress and the vulnerability of developmental cartilage to trauma are primary concerns with children (Hewett, Myer, & Ford, 2005), as such injuries can cause permanent growth and development disturbances. To prevent such damage during this period, it is necessary to modify the training program and adapt it to these age characteristics. Therefore, it is essential to exercise correctly under the supervision of a physical fitness expert who will pay attention to proper movement technique and safety measures when performing weighted exercises (Kahrović, Murić, Radenković, 2019). The aim of this study was to determine the implications of age and gender differences in strength training for children and adolescents.

METHODS

A review of studies was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). The following databases were used for literature search: Google Scholar, Medline, Science Direct, PubMed, Web of Science, and Research Gate. The search was performed using the following keywords: exercise, strength, training, children, adolescents, individually or in combination. The search strategy was adapted for each database where possible to increase sensitivity. The selection of studies was performed using inclusion and exclusion criteria. The search and review of studies were conducted by four authors, and data quality assessment was performed by two authors.

To identify relevant studies and exclude irrelevant titles during the electronic search, authors initially screened all titles. In the initial screening, 194 potentially eligible studies were identified. To decide whether to include studies in the systematic review and undergo a review by all authors, studies had to meet specific criteria. For studies to be included in the final analysis, they had to be written in English, test at least two groups of participants (1 experimental + 1 control), be original reports of scientific studies, and involve children and adolescents of both genders as participants. Exclusion criteria for studies from further analysis were studies written in languages other than English, inadequate participant samples, absence of a control group, results presented inadequately, or missing parameters necessary for further analysis. Descriptive methods were used for data analysis. All authors reviewed the selected studies systematically, and a final check was performed by two authors.

RESULTS

Through the electronic database search, a total of 194 relevant studies published in English were identified. After removing duplicates, the number of studies was reduced to 115. Out of these, 16 studies were excluded based on the review of titles and abstracts, 15 studies were excluded due to inadequate sample sizes, 11 studies were excluded due to inadequate outcome data, and 5 studies were excluded due to an inadequate number of participants. A total of 68 studies met the defined criteria for inclusion in the systematic review and further analysis. The overall sample size comprised 1,344 participants, including 624 females and 720 males. Among the 68 studies that met the inclusion criteria for the systematic review and further analysis, 63 studies included both male and female participants, three studies included only boys, and one included only girls. In children subjected to programmed strength training with external resistance for a duration of 8 to 12 weeks, improvements were observed in specific motor skills such as long jump, vertical jump, 30-meter sprint, and agility (Behringer, von Heede, Matthews, & Mester, 2011; Faigenbaum, Farrell, Fabiano, Radler, Naclerio, Ratamess, Kang, & Myer, 2011; Falk, & Mor, 1996; Weltman, Janney, Rians, Strand, Berg, Tippet, Wise, & Katch, 1986). Increasing muscle capabilities is considered the foundation for long-term physical development, as a certain level of force production is required to acquire specific movement skills (Faigenbaum, Lloyd, Myer, 2013; Lloyd, Cronin, Faigenbaum, 2016). To expedite skill development and prevent injuries, children are recommended to participate in specific muscle strengthening programs (Faigenbaum & Westcott, 2009). Participation in strength training programs for youth not only increases muscle strength and endurance but also affects various other health and fitness-related measures (Lloyd, Faigenbaum, Stone, Oliver, Jeffreys, Moody, 2014; Smith, Eather, Morgan, Plotnikoff, Faigenbaum, Lubans, 2014). This type of activity can alter certain anatomical and psychosocial parameters, reducing the risk of injuries for athletes and recreational

participants (Valovich-McLeod, Decoster, Loud, Micheli, Parker, Sandrey, & White, 2011), improving motor skills (Behringer, von Heede, Matthews, & Mester, 2011; Faigenbaum, & Schram, 2004;), increasing bone density (McKay, MacLean, Petit, MacKO´Brien, Jansen, Beck, & Khan, 2005; Morris, Naughton, Gibbs, Carlson, & Wark, 1997; Nichols, Sanborn, & Love, 2001), and thus enhancing athletic performance in competitions. Various strength training programs, in addition to improving muscle fitness and bone density, reduce cardiovascular risk factors (Faigenbaum, Lloyd, MacDonald, Myer, 2016; Lloyd, Faigenbaum, Stone, 2014; Smith, Eather, Morgan, Plotnikoff, Faigenbaum, Lubans, 2014). Children who do not engage in physical activities have poorer motor skills (Fransen, Deprez, Pion, 2014). The difference in coordination (one of the most crucial motor skills) is increasing between active, normal-weight children and physically inactive obese children (D´Hondt, Deforche, Gentier, 2013). There is a declining trend in children meeting recommended levels of physical activity (Tremblay, Gray, Akinroye, 2014). Low levels of physical activity result in obesity (Katzmarzyk, Barreira, Broyles, 2015), which hinders the development of high levels of muscle fitness. If motor skills are not improved and muscle strength is not increased in early childhood, children may become less physically active and more susceptible to certain diseases after maturation (Faigenbaum, Lloyd, Myer, 2013). There is no relevant scientific research indicating that programmed physical exercise in adequately nourished boys and girls delays or slows their growth or level of maturation (Malina, 1994; Falk, & Eliakim, 2003). Strength training for children is an effective and safe method of physical preparation (Behm, Faigenbaum, Falk, & Klentrou, 2008; Blimkie, 1993; Faigenbaum, 2000; Faigenbaum, Kramer, Blimkie, Jeffreys, Micheli, Nitka, & Rowland, 2009; Faigenbaum, Milliken, Moulton, & Westcott, 2005; Faigenbaum, & Myer, 2010; Falk, & Tenenbaum, 1996; Lloyd, & Oliver, 2012). Older studies did not show an increase in muscle strength levels among preadolescents who participated in strength training programs (Docherty, Wenger, Collis, & Quinney, 1987; Hetherington, 1976;). However, more recent research has clearly demonstrated that boys and girls can increase muscle strength beyond what can be achieved through growth and maturation alone, provided that the intensity and volume of training are appropriate (Faigenbaum, & Mediate, 2006; Faigenbaum, Milliken, La Rosa-Loud, Burak, Doherty, & Westcott, 2002; Faigenbaum, Zaichkowsky, Westcott, Micheli, & Fehlandt, 1993; Lillegard, Brown, Wilson, Henderson, & Lewis, 1997; Pfeiffer, & Francis, 1986; Ramsay, Blimkie, Smith, Garner, & MacDougall, 1990; Weltman, Janney, Rians, Strand, Berg, Tippet, Wise, & Katch, 1986).

DISCUSSION

There are numerous osteogenic benefits and essential factors of physical activity in the growth and development of the skeletal system in boys and girls during this age period, especially activities involving their own body weight or external resistance (Vicente-Rodriguez, 2006). During the growth and development of children, there is an increase in muscle mass, leading to an increase in muscle strength. The growth curves of muscle strength during preadolescence and adolescence in boys and girls are similar. During this period of rapid growth and development, muscles or muscle groups first increase in muscle mass and then in the ability to generate a significant force (Buenen, & Malina, 1988). This is supported by the results of a meta-analysis indicating that adolescents, compared to children, achieved a 50% greater increase in muscle strength (Behringer, von Heede, Yue, & Mester, 2010). The greatest increase in strength in girls also occurs at the end of the rapid growth and development phase, although girls exhibit larger individual differences in the relationship between strength and height and strength and body mass compared to boys (Malina, Bouchard, & Bar-Or, 2004). Regardless of the fact that muscle strength levels are nearly identical in boys and girls during preadolescence, hormonal differences that manifest during puberty are responsible for the rapid increase in muscle strength in boys and the plateauing of muscle strength in girls (Lloyd, Faigenbaum, Stone, Oliver, Jeffreys, Moody, 2014; Malina, Bouchard, & Bar-Or, 2004). Another crucial factor in the expression of muscle strength in children is the development of the central nervous system. Skillful and coordinated movements and quick reactions cannot be successfully executed without the presence or complete mineralization of motor neurons (nerve fibers). Children should not be expected to achieve the same level of skill as adults in response to training stimuli or to react in the same way because motor neuron mineralization is incomplete until sexual maturity (Kraemer, Fry, Frykman, Conroy, & Hoffman, 1989). A carefully designed strength training program during early childhood, characterized by rapid changes in the central nervous system, can have long-lasting positive effects (Myer, Faigenbaum, Edwards, Clark, Best, Sallis, 2015). Physiological functions are closely linked to biological age relative to chronological age. Children who mature earlier have greater muscle mass, absolute strength, and a more muscular appearance, whereas children who mature later tend to be leaner and taller (Malina, Bouchard, & Bar-Or, 2004). Although in the past, many

experts (doctors, coaches, and sports scientists) as well as parents were concerned that strength training in children could disrupt normal bone development and stunt growth, it is now widely agreed that strength training for children is an effective and safe method of physical preparation (Behm et al., 2008; Blimkie, 1993; Faigenbaum, 2000; Faigenbaum et al., 2009; Faigenbaum, et al., 2005; Faigenbaum, & Myer, 2010; Falk, & Tenenbaum, 1996; Lloyd, & Oliver, 2012). Children should be involved in strength training programs tailored to their individual goals and at a level and intensity that aligns with their age. Additionally, strength training should be adapted to their maturity (biological age) and their level of fitness. Most leading medical and sports organizations worldwide support children's participation in various strength training programs, provided that these programs are adequately designed, age-appropriate, and supervised by experts (British Association of Exercise and Sport Sciences, 2004; American Academy of Pediatrics, 2008). It is essential to emphasize that strength training programs designed for adults should not be applied to youth because the intensity and volume of training are too demanding, and the recovery time between training episodes is too short to allow for proper adaptation. Care must be taken because children are physically immature and not just smaller versions of adults, and overestimating their current capabilities, regardless of how large and strong they may be, will increase the risk of injury and lead to long-term health issues. Strength exercises that are tailored to age and fitness level, in addition to increasing muscle strength, also improve bone density and strength (Society of Health and Physical Educators, 2014). Since muscle strength naturally increases from childhood through the teenage years to full maturity, progress achieved through short-term, low-intensity, and low-volume strength training cannot be distinguished from progress attributed to normal growth and maturation. Older studies did not show an increase in muscle strength levels among preadolescents who participated in strength training programs (Docherty et al., 1987; Hetherington, 1976). While an insufficient amount of evidence can be attributed to methodological shortcomings, such as inadequate training volume or intensity and the short duration of the study, as a form of evidence that strength training is not an effective training method for children, the results of these studies are still often cited. Recent research has clearly demonstrated that boys and girls can increase muscle strength beyond what can be achieved through mere growth and maturation if the intensity and volume of training are adequate (Faigenbaum, & Mediate, 2006; Faigenbaum et al., 2002; Faigenbaum et al., 1993; Lillegard et al., 1997; Pfeiffer, & Francis, 1986; Ramsay et al., 1990; Weltman et al., 1986). In contrast to adults, assessing the degree of strength change in children, due to the simultaneous growth and development process, is very complex. Nevertheless, scientific study data suggest that the strength gains resulting from training interventions during the detraining period are unstable and decline to the level of the control group (Faigenbaum, Westcott, Micheli, Outerbridge, Long, La Rosa-Loud, & Zaichkowsky, 1996; Ingle, Sleap, & Tolfrey, 2006; Tsolakis, Vagenas, & Dessypris, 2004). Changes in muscle hypertrophy significantly contribute to the increase in muscle strength resulting from exercise in adolescents and adults. For preadolescents, it is uncertain whether muscle hypertrophy is primarily responsible for the increase in muscle strength due to training (Ozmun, Mikesky, & Surburg, 1994; Ramsay, Blimikie, Smith, Garner, & MacDougall, 1990). It is not possible to conclude whether muscle hypertrophy occurs in preadolescents as a result of strength training without presenting objective scientific facts. Studies with more precise measurement techniques, longer duration, and a larger scope are necessary to detect potential muscle hypertrophy resulting from youth training. Furthermore, as years pass, the angle of muscle fiber pennation increases (Ormsbee, Pdaro, Ilich, Purcell, Siervo, Folsom, & Panton, 2014), but it is unclear whether strength training can change muscle in this way without a significant increase in overall muscle mass. During the period of intense growth and development, strength gains induced by training are associated with muscle hypertrophy due to hormonal influences. In adolescent girls, other growth factors (growth hormone and insulin-like growth factor) are responsible for muscle development, although lower testosterone levels compared to adolescents limit the size of muscle hypertrophy resulting from training (Kraemer, 1988). Studies have shown that in children who regularly engage in physical activity involving body weight resistance and participate in a strength training program with external resistance, bone density increases (McKay et al., 2005; Morris et al., 1997; Nichols et al., 2001). In addition, authors believe that regular participation in strength training programs in the pre-competitive period increases injury resilience in young athletes (Emery, 2005; Hewett, Myer, & Ford, 2005). Achieving the maximum level of adaptation can be aided by well-planned recovery strategies, such as adequate cooling at the end of training, a carefully prepared meal after a training episode, and quality sleep. Instead of passively raising the legs and placing them in a vertical position in a supine position, young athletes' bodies respond better and recover faster through a combination of active recovery and cold water therapy (Kinugasa, & Kilding, 2009). Adequately prescribed and well-programmed strength training for young athletes is relatively safe compared to activities in other sports disciplines (Hamill, 1994). The belief that strength training is

dangerous for children is not in line with the recorded risk and the needs of children, as injuries mostly occurred when instructions, training loads, and supervision levels were inadequate (Faigenbaum, & Myer, 2010), and in situations where safety guidelines for fitness professionals were not followed. In strength training studies for children and adolescents in which participants followed specific guidelines, no serious injuries were reported (Faigenbaum, & Myer, 2010). Furthermore, it has been demonstrated that testing one-repetition maximum (1RM) in young individuals is safe, provided that testing rules and guidelines, such as immediate supervision by fitness professionals, individual load increases, and adequate warm-up time, are followed (Hetzler, DeRenne, Buxton, Ho, Chai, & Seichi, 1997; Kravitz, Akalan, Nowicki, & Kinzey, 2003). To participate in this type of physical activity, such as strength training, since there is no minimum age threshold, children should be emotionally mature enough. In this case, they will meet the demands and solve the tasks set before them (Lloyd, Faigenbaum, Stone, Oliver, Jeffreys, Moody, 2014; Myer, Lloyd, Brent, & Faigenbaum, 2013). The goal of a strength training program for young people should include teaching gym etiquette, promoting a desire for physical activity, educating children about their bodies, and fostering enjoyment and fun. It is very likely that children who engage in sports and enjoy physical activities in their later years will continue to be active (Castro, Crim, Young, Joseph, & Evans, 1995). Fitness professionals should emphasize proper exercise, demonstrate exercise techniques well, and possess the necessary communication skills to relate to children at their level of understanding (Faigenbaum, Lloyd, Sheehan, & Myer, 2013; Lloyd, Faigenbaum, Stone, Oliver, Jeffreys, Moody, 2014). Poor exercise technique can result in excessive strain on musculoskeletal tissues and injury. Therefore, if it is not possible to perform an exercise with proper technique, it is necessary to reduce the level of external resistance and focus on developing the correct technique (Byrd, Pierce, Rielly, & Brady, 2003; Faigenbaum, & Polakowski, 1999)

CONCLUSION

There is no relevant scientific research indicating that programmed physical activity in well-nourished boys and girls delays or hinders their growth or the degree of maturation. Numerous osteogenic benefits and essential factors of physical activity contribute to the growth and development of the skeletal system in boys and girls during this age period. Children who regularly engage in physical activities involving their body weight and participate in exercise programs that include strength training with external resistance experience an increase in bone density. Participation in such programs during the preadolescent period allows boys and girls to achieve strength gains and other abilities greater than the ordinary gains resulting from growth and maturation. Recent research has clearly shown that if the volume and intensity of exercise are appropriate for their age, boys and girls can increase muscle strength beyond the limits achievable through mere growth and maturation. In addition to improving muscle fitness and increasing bone density, strength training programs reduce cardiovascular risk factors. It should be emphasized that programmed strength training designed for adults should not be applied to young individuals because the volume and intensity of such training are too demanding, and the recovery time between workouts is too short to allow for adequate adaptation. Care should be taken because children are physically immature to the extent that slightly reduced adult training cannot be applied to them. Fitness professionals should focus on proper exercise, demonstrate exercise techniques well, and possess the necessary communication skills to relate to children at a level they can understand. Poor exercise technique can lead to excessive strain on musculoskeletal tissues and injury. Therefore, if it is not possible to perform an exercise with proper technique, it is necessary to reduce the level of external resistance and focus on developing the correct technique. The goal of strength training programs for young individuals should also include teaching gym etiquette, promoting a desire for physical activity, educating children about their bodies, and fostering enjoyment and fun.

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CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

796/799(082)

SCIENTIFIC Conference "FIS Communications 2023" in physical education, sport and recreation (24 ; 2023 ; Niš)

Book of Proceedings / XXIV Scientific Conference "FIS Communications 2023" in physical education, sport and recreation, (Niš, Serbia, october 19-21, 2023) ; [editor in chief Nenad Stojiljković]. - Niš : Universtity, Faculty of sport and physical education, 2023 (Niš : Medivest). - 408 str. : ilustr. ; 29 cm

Tiraž 200. - Str. 7: Foreword / Nenad Stojiljković. - Bibliografija uz svaki rad.

ISBN 978-86-81474-28-0

a) Спорт -- Зборници b) Физичка култура -- Зборници

COBISS.SR-ID 131064841