Pediatric Exercise Science, 2017, 29, 14-18
https://doi.org/10.1123/pes.2016-0262

Human Kinetics
COMMENTARY

Resistance Exercise and Youth: Survival of the Strongest

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Research evidence continues to define the unique health- and performance-related benefits of resistance exercise for children and adolescents. While the effectiveness of resistance exercise in increasing muscle strength and motor skill performance has been demonstrated repeatedly, current scientific evidence indicates that the right "dose" of resistance exercise can enhance physical performance in young athletes and reduce the risk of developing cardiometabolic disease. The papers discussed in this commentary add to our understanding of the potential benefits of youth resistance exercise by defining dose-response relationships for key training variables, exploring sex-specific adaptations to this type of training, and examining the relationship between muscular strength early in life and cardiometabolic risk later in life. Noteworthy is the identification of unique, sex-specific thresholds for normalized strength to detect high risk cardiometabolic phenotypes in youth. New insights indicate that stronger boys and girls will be better prepared for sport and for life.

Citation

Lesinski, M., Prieske, O., Granacher, U. Effects and dose-response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis. *Br J Sports Med.* 2016; 50 (13):781–95.

Objectives: To quantify age, sex, sport and training type-specific effects of resistance training on physical performance, and to characterize dose-response relationships of resistance training parameters that could maximize gains in physical performance in youth athletes. *Design*: Systematic review and meta-analysis of intervention studies. ***Data Sources:*** Studies were identified by systematic literature search in the databases PubMed and Web of Science (1985–2015). Weighted mean standardized mean differences (SMDwm) were calculated using random-effects models. ***Eligibility Criteria for Selected Studies:*** Only studies with an active control group were included if these investigated the effects of resistance training in youth athletes (6–18 years) and tested at least one physical performance measure. ***Results***: 43 studies met the inclusion criteria. Our analyses revealed moderate effects of resistance training on muscle strength and vertical jump performance (SMDwm 0.8–1.09), and small effects on linear sprint, agility and sport-specific performance (SMDwm 0.58–0.75). Effects were moderated by sex and resistance training type. Independently computed dose-response relationships for resistance training parameters revealed that a training period of >23 weeks, 5 sets/exercise, 6–8 repetitions/set, a training intensity of 80–89% of 1 repetition maximum (RM), and 3–4 min rest between sets were most effective to improve muscle strength (SMDwm 2.09–3.40). ***Summary/Conclusions:*** Resistance training is an effective method to enhance muscle strength and jump performance in youth athletes, moderated by sex and resistance training type. Dose-response relationships for key training parameters indicate that youth coaches should primarily implement resistance training programs with fewer repetitions and higher intensities to improve physical performance measures of youth athletes.

Commentary

The importance of enhancing muscular fitness early in life is recognized as a critical competent of long-term athletic development programs (12). A growing number of youth are participating in fitness programs that include resistance exercise and the latest position statement on youth resistance training provides strong support for participation in well-designed resistance training programs that are supervised by qualified professionals (13). Furthermore, a consensus statement from the International Olympic committee states that young athletes who are not exposed to this type of conditioning early in life will inevitably need to address neuromuscular deficiencies later in life as part of sports training or injury rehabilitation (1). However, additional information is needed to better understand the dose-response relationships of resistance training on physical performance in youth to optimize training adaptations, enhance long-term outcomes, and reduce the risk of sports-related injuries.

Lesinski and colleagues present a systematic review and meta-analysis of the extant literature on the dose-response relationships of resistance training on physical performance in young athletes (11). The authors analyzed

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the effects of resistance training on proxies of physical performance in young athletes by considering potential moderator variables and characterized dose-response relationships of resistance training parameters by quantitatively analyzing intervention studies. While 576 studies were identified in their initial search, 43 studies met their inclusion criteria. It was concluded that resistance training is an effective method for enhancing muscle strength and jumping performance in young athletes, and the effect is moderated by sex and resistance training type. They reported that girls made greater resistance training–related performance gains than boys, and training programs with free weights were the most effective for increasing muscle strength.

These findings add to our understanding of the efficacy of resistance training on young athletes by considering potential moderator variables including age, sex, sport and type of resistance training. In addition, dose-response relationships for key training variables revealed that a training period of more than 23 weeks, 5 sets per exercise, 6–8 repetitions per set, a training intensity of 80–89% of 1 repetition maximum, and 3–4 min rest between sets were most effective. These findings expand previous recommendations and highlight the potential value of systematically progressing the intensity and volume of youth resistance training programs to improve physical performance measures. While low intensity/low volume training is appropriate for beginners with no or limited resistance training experience, this approach seems to be suboptimal for maximizing the physical preparedness of young athletes. Moreover, these findings underscore the importance of strength and conditioning for young females who appear to be particularly responsive to progressive resistance exercise. Yet regardless of age, sex or training experience, youth need to be exposed to the right dose of resistance exercise with qualified supervision, technique-driven progression and developmentally appropriate instruction.

Notwithstanding the observable influence of resistance exercise on physical performance in young athletes, the importance of these findings for less athletic participants should not be overlooked. Secular trends indicate that modern day youth are not as strong as their predecessors and recent findings underscore a potential synergistic adaptation between muscular strength and motor skill performance in children and adolescents (4). Since muscular strength is considered a building block for long term athletic development (12), the importance of enhancing muscular strength early in life should be considered foundational for all boys and girls. Without prerequisite levels of muscular strength, it is unlikely that youth will be willing and able to engage in the recommended amount of daily physical activity with energy, vigor and enthusiasm. Moreover, weak children appear to be at greater risk for fracture with exposure to exercise (3).

Lesinski and colleagues' review has raised awareness about the dose-response relationships of resistance exercise on physical performance and shed needed light on sex-related differences in training-induced performance adaptations. While they found no significant differences in effect sizes for any proxy measure of physical performance between prepubertal and pubertal athletes, most of the reviewed studies did not report biological maturity status of the participants. Thus additional research is needed to examine the effects of maturity status on resistance training-induced adaptations in youth, and to elucidate the sex-specific effects of resistance training since their findings were based on five studies only investigating young female athletes. Future studies should also consider the individual responses to different types of resistance exercise (e.g., plyometrics and weightlifting) because it is unlikely that one combination of resistance training program variables will optimize physical performance in all youth (18). Lastly, we need to better inform clinicians and practitioners about the safety and efficacy of supervised and properly progressed youth resistance exercise programs because deeply held misperceptions associated with this type of training still persist.

Citation

Fraser, B, Huynh, Q., Schmidt, M., Dwyer, T., Venn, A., Magnussen, C., Childhood muscular fitness phenotypes and adult metabolic syndrome. *Med Sci Sports Exerc*. 2016; 48 (9):1715–1722.

Purpose: The objective of this study is to determine whether childhood muscular fitness phenotypes (strength, endurance, and power) are independently associated with adult metabolic syndrome (MetS). ***Methods***: We conducted a longitudinal study including 737 participants who had muscular fitness measures in 1985 when age 9, 12, or 15 yr and attended follow-up in young adulthood 20 yr later when measures of MetS were collected. Childhood measures of muscular fitness included strength (right and left grip, leg, and shoulder extension and flexion), endurance (number of push-ups in 30 s), and power (distance of a standing long jump). A muscular fitness score was created using all individual muscular fitness phenotypes. In adulthood, waist circumference, blood pressure, HDL cholesterol, triglycerides, and glucose were measured. Adult outcomes were MetS defined using the harmonized definition and a continuous MetS risk score. ***Results***: Participants with childhood muscular strength, muscular power, and combined muscular fitness score in the highest third had significantly lower relative risk (RR) for MetS and a lower continuous MetS score in adulthood independent of cardiorespiratory fitness than those in the lowest third (strength: RR = 0.21 (0.09, 0.49) b = -0.46 (-0.59, -0.34) power: RR = 0.26 (0.12, 0.60), b = -0.36 (-0.49, -0.23) fitness score: RR = 0.20 (0.09, 0.47), b = -0.45 (-0.58, -0.33)). However,

adjustment for childhood waist circumference reduced the effect sizes for both adult outcomes by 17–60%. ***Conclusion***: Phenotypes of childhood muscular fitness can be used to predict adult MetS independent of cardiorespiratory fitness. Although a large proportion of the effect of childhood muscular fitness on adult MetS is potentially being mediated by child waist circumference, these data suggest that promotion of muscular fitness among children might provide additional protection against developing adult MetS.

Commentary

Metabolic syndrome (MetS) is a clustering of cardiometabolic risk factors that is now affecting children and adolescents. This public health concern is fueled by the growing prevalence of physical inactivity among school-age youth (21). While higher levels of cardiorespiratory fitness are associated with healthier cardiometabolic profiles, researchers are starting to explore the importance of muscular fitness in regards to health promotion and disease prevention in children and adolescents (2,8). Muscular fitness is a global term that includes the phenotypes of muscular strength, muscular power, and local muscular endurance.

While previous research has examined the relationship between muscular strength in adolescents and cardiovascular risk in young adulthood (9), Fraser and colleagues provide longitudinal evidence of the association between muscular fitness in childhood and MetS in adulthood, independent of cardiorespiratory fitness (7). Using 20 year follow-up data from 737 participants (376 female) age 9–15 years, they found that youth with muscular strength, muscular power and combined muscular fitness score in the highest third had significantly lower relative risk for MetS and a lower continuous MetS score in adulthood independent of cardiorespiratory fitness than those in the lowest third. While adjustment for childhood waist circumference reduced the effect sizes for both adult outcomes, these findings indicate that phenotypes of childhood muscular fitness can be used to predict adult MetS independent of cardiorespiratory fitness.

These findings expose the cardiometabolic benefits of muscular fitness early in life, although childhood waist circumference mediated part of this effect. Previous cross sectional data from this research group found that during childhood muscular fitness phenotypes were inversely and independently related with waist circumference and body mass index (14). It seems that the cardiometabolic benefits of muscular fitness during this developmental period may be related to its effects on muscle metabolism (e.g., enhanced lipid oxidation and glucose transport), muscle structure (e.g., skeletal muscle growth and hypertrophy), and energy expenditure (20). Improvement in muscular fitness during the growing years make outdoor games and sport activities easier to perform and more enjoyable. As physically active youth gain confidence and competence in their physical prowess, they will be more likely to engage regularly in moderate to vigorous bouts of physical activity that offer cardiometabolic health benefits.

Since many chronic diseases that appear in adulthood begin in childhood when lifestyle habits such as physical activity are established, these important findings support the need for youth to participate regularly in a variety of physical activities including those that enhance muscular fitness. Current trends in physical activity among youth are a public health concern (21), and epidemiological findings demonstrate an increasing waist circumference in adolescents despite reported pediatric weight stabilization (6). These changing patterns in physical activity and abdominal obesity pose serious health concerns that might not be detected by body mass index alone. Since childhood muscular fitness can be used to predict adult cardiometabolic outcomes independently of childhood cardiorespiratory fitness, school and community based interventions are needed to enhance muscular fitness and alter physical activity trajectories. While all youth can benefit from daily physical activity, contemporary finds indicate that those who are the weakest have the most to gain.

Citation

Peterson, M., Zhang, P·, Saltarelli, W., Visich, P., Gordon, P., Low muscle strength thresholds for the detection of cardiometabolic risk in adolescents. *Am J Prev Med*. 2016; 50 (5):593–599.

Introduction: There is an association between strength and health among adolescents, yet, what remains to be determined is sex-specific cut points for low strength in the detection of risk in this population. The purpose of this study was to determine thresholds of low grip strength in a large cohort (N = 1,326) of adolescents. ***Methods***: All data were collected between 2005 and 2008, and analyzed in 2014–2015. A cardiometabolic risk score (MetScore) was computed from the following components: percent body fat, fasting glucose, blood pressure, plasma triglyceride levels, and high-density lipoprotein cholesterol. A high-risk cardiometabolic phenotype was characterized as ³ 75th percentile of the MetScore. Conditional inference tree analyses were used to identify sex-specific, low normalized strength (grip strength/body mass) thresholds and risk categories. ***Results***: Lower strength was independently associated with increased odds of the high-risk cardiometabolic phenotype, such that for every 5% decrement of normalized strength, there were 1.48 and 1.45 increased odds ($p < .001$) for boys and girls, even after adjusting for cardiorespiratory fitness and physical activity. Conditional tree analysis revealed a high-risk threshold for boys (≤ 0.33) and girls (≤ 0.28), as well as an intermediate threshold (boys, >0.33 and ≤ 0.45; girls, > 0.28 and ≤ 0.36). ***Conclusions***: These sex-specific thresholds of low strength can be incorporated into a clinical setting for identifying adolescents that would benefit from lifestyle interventions to improve muscular fitness and reduce cardiometabolic risk.

Commentary

In older adult populations, the association between muscle weakness and fragility is well-established and, therefore, resistance exercise is often prescribed to prevent and manage sarcopenia and dynapenia (10). In an attempt to identify adults who may be at risk for these conditions and who may benefit from resistance exercise, researchers have identified cut-points or thresholds for low muscle strength in older adults (15). Yet due to the growing prevalence of cardiometabolic disease in youth, it is vital to expand clinical screening to younger populations. Very recently, the term pediatric dynapenia was used to describe a condition in youth characterized by low levels of muscle strength and power and consequent functional limitations not caused by neurologic or muscular disease (5).

Peterson and colleagues determined sex-specific cut points for low grip strength for the detection of cardiometabolic risk in youth (17). A large cohort of 1326 sixth grade students (696 female, age 10–12 years) were included in their analysis as part of the Cardiovascular Health Intervention Program. Handgrip strength, which has been found to be highly correlated with muscle strength in children and adolescents, was assessed using a hydraulic handgrip dynamometer. A cardiometabolic risk score (MetScore) was computed from percent body fat, fasting glucose, blood pressure, plasma triglycerides, and high density lipoprotein cholesterol. A high-risk cardiometabolic phenotype was defined as ³ 75th percentile of the MetScore. They found that lower levels of muscle strength were independently associated with increased odds of the high risk cardiometabolic phenotype. Importantly, they identified unique, sex-specific thresholds for normalized strength to detect high risk cardiometabolic phenotypes.

The significance of identifying weak youth early in life before they establish unhealthy habits and become resistant to exercise interventions later in life should not be marginalized. In a study of over 1 million adolescents, low muscle strength was a risk factor for major causes of death in young adulthood, and the effect sizes were equivalent to those of other risk factors including body mass index (16). In the pediatric clinic, the handgrip test could be used as a starting point for assessing muscular strength, evaluating physical activity habits and, when appropriate, making referrals to pediatric exercise specialists who can manage and treat muscle weakness with developmentally appropriate interventions that target strength deficits.

Recently, the American Heart Association recognized cardiorespiratory fitness as a clinical vital sign in adults (19). The underlying premise of this scientific statement was that cardiorespiratory fitness should be measured in clinical practice if it can enhance patient management. Yet there is a critical need to identify inactive patients early in life to prevent the inevitable cascade of adverse health consequences. Muscular fitness is the driving force of youth physical activity, and therefore should be recognized as a clinical vital sign in children and adolescents. The early identification of a young patient's departure from the critical strength level should preclude the clinician from deeming this patient as "healthy" and should encourage early intervention so that muscular fitness–and consequently physical activity status–can be improved.

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