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OPINION EDITORIAL
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Youth Resistance Training: The Past, the Present, and the Future

EXERCISE IS MEDICINE

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Abstract

Based on anecdotal and preliminary evidence, the perception of youth resistance training (RT) was critical in the past. Accordingly, this opinion editorial aims to summarize information on youth RT by taking past and present research findings into account to deduce future research avenues.
In the 1970s, two often reported misconceptions with youth RT were premature epiphyseal closure due to repetitive loading and ineffectiveness of RT in pre-pubertals because of a lack of circulating testosterone. Today, it is well-established that youth RT has manifold health (e.g., body composition, injury prevention) and fitness (muscle strength and power, endurance, speed) benefits. Physiological adaptations responsible for RT-induced strength gains comprise primarily neural factors in the pre-pubertal child and neural as well as morphological factors in adolescents.
The number of scientific studies and thus the evidence on positive RT effects has grown exponentially over the past years. An important future task of pediatric strength and conditioning specialists will be the translation and dissemination of research findings into sports practice (schools, sport clubs). Schools could be a suitable setting for the widespread implementation of youth RT. Efforts should be undertaken to equip schools and public gyms with RT material and to include RT contents into school curricula.

Zusammenfassung

Anekdotische und präliminäre Evidenz haben dazu geführt, dass Krafttraining (KT) mit Heranwachsenden in der Vergangenheit kritisch eingeordnet wurde. Das Ziel dieses «Opinion Editorials» ist es daher, die fachwissenschaftliche Literatur zum Thema KT mit Heranwachsenden zusammen-
zufassen und dabei die ersten Studien aus den 1950ern sowie aktuelle Forschungsarbeiten zu berücksichtigen, um Ableitungen für zukünftige Herausforderungen im Kontext der kindlichen Bewegungsförderung zu treffen.
In den 1970er-Jahren herrschten insbesondere zwei Fehlinterpretationen zum Thema KT mit Kindern und Jugendlichen vor. Erstens, das regelmässige Heben von Lasten führt zu einem frühzeitigen Verschluss der Epiphysenfugen und zweitens, KT im präpuberalen Alter ist ineffektiv aufgrund eines Mangels an zirkulierenden androgenen Hormonen. Heute ist sehr gut belegt, dass KT vielfältige Anpassungsprozesse in Bezug auf die Gesundheit (Körperzusammensetzung, Verletzungsprävention) und die körperliche Fitness (Kraft, Schnelligkeit) von Kindern auslöst. Im präpuberalen Alter sind v.a. neuronale Anpassungsprozesse für die Kraftzuwächse verantwortlich, im puberalen und postpuberalen Alter sind es neuronale sowie morphologische Anpassungen.
Die Anzahl der fachwissenschaftlichen Publikationen zum KT mit Heranwachsenden erfuhr ein exponentielles Wachstum während der letzten Jahre. Vor diesem Hintergrund ist es in Zukunft viel weniger ein Erkenntnisproblem als vielmehr ein Umsetzungsproblem, mit dem sich Wissenschaftler und Sportpraktiker konfrontiert sehen. Schulen sind besonders geeignet, um KT mit Heranwachsenden umzusetzen, da dort Kinder unabhängig von ihrem

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sozioökonomischen Status erreicht werden können. Schule und Vereine sollten mit einfachen und kostengünstigen Krafttrainingsmitteln ausgestattet werden. Die Integration von Krafttrainingsinhalten in die Schulcurricula ist erforderlich.

Schlüsselwörter: Plyometrisches Training, Widerstandstraining, Kinder, Jugendliche, Pädiatrie

Introduction

There is probably no other topic in pediatric exercise science and physiology than youth resistance training (RT) that has been so controversially discussed. Opinions from researchers, medical doctors, coaches, and physical education teachers ranged from denial due to preliminary or even anecdotal evidence on adverse health-events to endorsement based on more recent research findings on the manifold health and fitness benefits of youth RT. Of note, RT involves the progressive use of a wide range of resistive loads, movement velocities, and training modalities including isometric and isoinertial resistance exercises using body mass, weight machines, free weights, elastic bands, medicine balls, and plyometrics. Given the wide variety of RT methods, exercise programs can be specifically designed according to the needs of the individual (e.g., age, sex, expertise). Therefore, it is timely to describe and summarize information on youth RT by taking past and present research findings into account to deduce future research avenues.

The Past

One of the first RT studies with youth was published in 1949 in the Journal of Bone and Joint Surgery [1]. Gallagher and Delorme [1] designed a progressive lower limbs RT program to treat boys aged 13-19 years with knee injuries (e.g., patella dislocation).
Despite many methodological shortcomings of this study (e.g., heterogenous sample), findings were promising and showed substantial lower limbs strength and power increases.
Subsequent studies in the 1950s and 60s indicated positive effects on motor coordination and muscle strength in high-school boys aged 14-18 years [2]. In the 1970s, two preliminary studies together with anecdotal evidence from weightlifting resulted in a negative perception of youth RT. While Vrijens [3] could not find significant lower and upper limbs strength gains after an eight-week progressive RT program in pre-pubescent boys, Ryan and Salciccioli [4]) showed fractures of the distal radial epiphysis in five adolescent weightlifters aged 14-17. Based on these preliminary findings, it was concluded that due to a lack of pre-pubertal circulating testosterone, exercise-induced strength gains are not possible and that the repetitive lifting of high loads may damage the epiphysis and stunt growth. Further anecdotal evidence came from the visual inspection of weightlifters' body statures. Youth and adult weightlifters are often characterized by short limbs which was interpreted as a sign of premature epiphyseal closure due to the repetitive lifting of loads. Today, we know well that short-limbs are more of a talent selection criteria in weightlifting than a consequence of the repetitive lifting of loads.
Taken together, the preliminary and anecdotal evidence prompted the American Academy of

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Pediatrics in 1983 to red-flag youth weightlifting *(Figure 1)* [5]. Only four years later, a study was published that emphasized the safety of a 14-week supervised RT with no adverse effects on bone, muscle, or epiphyses in pre-pubertal boys [6]. In 2001, Sadres and colleagues [7] examined the effects of a two-year RT program with two weekly sessions in pre-pubertal boys and observed no significant difference between the intervention and the control group in the annual growth rate.

Figure 1: Past, present and future of youth resistance training.

The Present

Ever since the millennium, an exponential growth in number of scientific publications on youth RT can be noticed in the electronic database PubMed. This solid foundation of evidence has resulted in the inclusion of strengthening exercises three days a week into the youth physical activity recommendations of the World-Health-Organization (WHO) [8]. In 2014, Lloyd and colleagues [9] published an international consensus position statement on youth RT that was endorsed by several scientific societies such as the American Academy of Pediatrics and the National Strength and Conditioning Association *(Figure 1)*. The extensive body of literature on youth RT included original research, narrative and systematic reviews, meta-analyses, and even umbrella reviews. Overall, these studies showed the positive effects of RT on motor skill acquisition, performance enhancement, injury prevention, body composition, and psychosocial well-being in athletic and non-athletic youth. For instance, Lesinski et al. [10] reported in their umbrella review including 14 meta- analyses that RT is particularly effective in improving measures of muscle strength, power, linear, and change-of-direction speed, and sport-specific performance in healthy youth. The respective effect size magnitudes decreased

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along the line of the above mentioned physical qualities with large magnitudes for measures of strength and power and moderate-to-small magnitudes for speed and sport-specific performance.
Besides physical fitness improvements, Collins and colleagues [11] observed small but positive RT-related effects on body composition including body fat and skinfolds.
Moderator analyses showed similar RT effects in boys and girls on muscle strength, irrespective of the maturation status [12]. Pre-pubertal children appear to particularly benefit from plyometric jump training in terms of speed improvements [13]. Moreover, relative strength gains according to body mass appear to be higher in pre-pubertals compared with pubertals and post-pubertals. When combining RT interventions with other exercise modalities, it seems that a mesocycle of balance training prior to RT facilitates the exercise-induced effects of the subsequent RT program [14]. Particularly for youth athletes, it is worthwhile to consider that RT at moderate movement velocities is incorporated prior to power training to establish an adequate foundation of muscle strength for subsequent power training activities [15]. When it comes to injury prevention, neuromuscular training proved to be an effective multimodal exercise modality including specific strength and conditioning activities such as dynamic stability, balance, core focused strength, plyometric, speed, and agility exercises that has the potential to reduce lower limbs injuries by approximately 40% after 10-12 weeks of training with 2-3 weekly sessions [16]. In general, evidence on physiological adaptations following youth RT are scarce and more research is needed in the future. The available literature indicates that primarily neural adaptations are responsible for the observed strength gains in pre- pubertals [17]. Due to an increase in circulating testosterone levels with puberty, adequate RT stimuli can induce muscle hypertrophy as in adults. With reference to the muscle memory theory, puberty and post-puberty may represent a window of opportunity for youth to practice RT because adaptations in the muscle cells (myonuclei) may have long-lasting retraining effects later in life [18].

The Future

Youth physical inactivity has reached the level of a pandemic with consequences ranging from impaired physical fitness to increased obesity and diabetes rates. In 2016, only 19% of youth aged 11-17 years followed WHO recommendations of 60 minutes daily physical activity [19]. The COVID-19 pandemic even reinforced these sedentary trends. Secular declines in physical activity and fitness further highlight this downward spiral. In other words, the living conditions of today's youth have tremendously changed over the past decades, which afford a concerted call for action including researchers, sport practitioners, and political decision makers. Adequate countermeasures are needed that have the potential to slow, stop, or even reverse these negative trends. RT could be an adequate candidate because of its broad spectrum of effects on motor skill learning, performance, injury prevention, and psychosocial well-being. The current problem with youth RT is no longer the lack of evidence or missing reports and guidelines. The future challenge for researchers will much rather be the translation and dissemination of the available research findings into sports and even clinical practice (physical education, sports clubs, long-term athlete development, hospitals). For

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instance, schools and public gyms should be equipped with cost-efficient RT materials such as Swiss balls, dumbbells, resistance bands etc. In addition, RT contents should make it into the school curricula starting at the primary school level and progressing to secondary schools (Figure 1). The advantage of RT contents implemented in school curricula is that every child can be reached irrespective of the family's socioeconomic status.

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References

1. Gallagher JR, DeLorme TL. The use of the technique of progressive-resistance exercise in adolescence. J Bone Joint Surg Am. 1949 Oct;31A(4):847-58.
2. Calvin S. Effects of Progressive Resistive Exercises on the Motor Coordination of Boys. Res Quarterly Am Assoc Heal Phys Educ Recreat. 1959;30(4):387-98.
3. Vrijens J. Muscle Strength Development in the Pre- and Post-Pubescent Age. Hebbelinck M, Borms J, editors. Vol. 11, Pediatric Work Physiology. S.Karger AG; 1978. p. 0.
4. Ryan JR, Salciccioli GG. Fractures of the distal radial epiphysis in adolescent weight lifters. Am J Sports Med. 1976;4(1):26-7.
5. Weight Training and Weight Lifting: Information for the Pediatrician. Phys Sportsmed. 1983 Mar;11(3):157-61.
6. Rians CB, Weltman A, Cahill BR, Janney CA, Tippett SR, Katch FI. Strength training for prepubescent males: is it safe? Am J Sports Med. 1987;15(5):483-9.
7. Sadres E, Eliakim A, Constantini N, Lidor R, Falk B. The Effect of Long-Term Resistance Training on Anthropometric Measures, Muscle Strength, and Self Concept in Pre-Pubertal Boys. Pediatr Exerc Sci. 2001;13(4):357-72.
8. Physical activity [Internet]. [cited 2023 Jun 2]. Available from: https://www.who.int/news-room/fact-sheets/detail/physical-activity.
9. Lloyd RS, Faigenbaum AD, Stone MH, Oliver JL, Jeffreys I, Moody JA, et al. Position statement on youth resistance training: the 2014 International Consensus. Br J Sports Med. 2014 Apr;48(7):498-505.
10. Lesinski M, Herz M, Schmelcher A, Granacher U. Effects of Resistance Training on Physical Fitness in Healthy Children and Adolescents: An Umbrella Review. Sports Med. 2020 Nov;50(11):1901-28.
11. Collins H, Fawkner S, Booth JN, Duncan A. The effect of resistance training interventions on weight status in youth: a meta-analysis. Sport Med – open. 2018 Aug;4(1):41.
12. Peitz M, Behringer M, Granacher U. A systematic review on the effects of resistance and plyometric training on physical fitness in youth- What do comparative studies tell us? PLoS One.

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https://doi.org/10.34045/SEMS/2023/23

2018;13(10):e0205525.
13. Ramirez-Campillo R, Sortwell A, Moran J, Afonso J, Clemente FM, Lloyd RS, et al. Plyometric-Jump Training Effects on Physical Fitness and Sport-Specific Performance According to Maturity: A Systematic Review with Meta-analysis. Sport Med – Open. 2023;9(1):23.
14. Granacher U, Behm DG. Relevance and Effectiveness of Combined Resistance and Balance Training to Improve Balance and Muscular Fitness in Healthy Youth and Youth Athletes: A Scoping Review. Sports Med. 2023 Feb;53(2):349-70.
15. Behm DG, Young JD, Whitten JHD, Reid JC, Quigley PJ, Low J, et al. Effectiveness of Traditional Strength vs. Power Training on Muscle Strength, Power and Speed with Youth: A Systematic Review and Meta-Analysis. Front Physiol. 2017;8:423.
16. Steib S, Rahlf AL, Pfeifer K, Zech A. Dose-Response Relationship of Neuromuscular Training for Injury Prevention in Youth Athletes: A Meta-Analysis. Front Physiol. 2017;8:920.
17. Granacher U, Goesele A, Roggo K, Wischer T, Fischer S, Zuerny C, et al. Effects and mechanisms of strength training in children. Int J Sports Med. 2011 May;32(5):357-64.
18. Gundersen K, Bruusgaard JC, Egner IM, Eftestøl E, Bengtsen M. Muscle memory: virtues of your youth? J Physiol. 2018 Sep;596(18):4289-90.
19. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1,6 million participants. Lancet Child Adolesc Heal. 2020 Jan 1;4(1):23-35.

ADOLESCENTS CHILDREN PEDIATRIC PLYOMETRIC TRAINING STRENGTH TRAINING