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Review of the Literature

YOUTH WEIGHTLIFTING - A REVIEW ON THE RISKS, BENEFITS, AND LONG-TERM ATHLETE DEVELOPMENT ASSOCIATED WITH WEIGHTLIFTING AMONGST YOUTH ATHLETES.

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BLUF

Youth participation in weightlifting is mostly safe, has a multitude of benefits, both physiological and psychological, and has long term applications to athletic development.

ABSTRACT

Weightlifting has gained significant traction in recent years amongst children and adolescence both with its inclusion in strength and conditioning programs as well as overall participation in the sport. Although traditional resistance training programs are well documented in the scientific literature for both adults and youth, more advanced training concepts such as weightlifting have received much less exposure in the paediatric literature. This review attempts to compile data from the current scientific literature and focus on the extent of the potential risks, benefits, long term athletic development (LTAD), and its application for athletes and coaches to highlight new knowledge and bridge the gap of understanding within the area of youth weightlifting. A search of multiple databases was conducted using the Boolean operator's "youth" and "Weightlift*" retrieving 41 articles relevant to the topic of interest. The content of these studies indicated that youth weightlifting is mostly safe, effective and enjoyable if undertaken in the presence of qualified supervision and with a moderation in weights compared to elite adult programming. There is a need for limitations to be applied to junior weightlifters such as a restriction of weights less than 80% with no max lifts attempted until after 18 years old to avoid burning out and early retirement from the sport. There should also be a focus on fine motor skills and mastery of technique to increase one's chances of reaching their genetic potential in athletic performance later during adulthood. Although there are some inherent risks to youth weightlifting, the literature also indicates a multitude of benefits both physiological and psychological with a potential to reduce the risk of injury in other youth sports.

Key Words - Youth, children, adolescents, weightlifting, injury, long term athlete development (LTAD).

INTRODUCTION

Weightlifting is a strength/power sport and training methodology that involves the performance of the snatch and clean and jerk, as well as an assortment of modified variations of these lifts. The lifts are carried out in an explosive and highly technical manner and require a high degree of skill to move the bar from the floor to above the head in one or two movements (11, 18, 29, 31, 39). It is important not to confuse the terms weight lifting, resistance training, or powerlifting as it is its own unique subset of strength training (29, 31). Weightlifting has been around for an extensive period of time with the origins of its practice being traced back more than 4,000 years to the ancient tombs of Egypt dating approximately 2040 BC (39).

In 1983, the American Academy of Paediatrics originally proposed that weightlifting undertaken by children was an unnecessary risk, and that pre-pubertal children were unable to increase strength or muscle mass because they lacked the circulating androgen hormones. The paper concluded that weightlifting was unsafe, potentially injurious to the skeletal system, and should be avoided by preadolescents (34). A second study published shortly after by Sewall and Micheli (37) also reiterated these beliefs and proposed that any resistive training for pre-adolescents should be carried out with slow and controlled speeds and that competition in weightlifting should not be undertaken until after skeletal maturity is achieved (37). This positional standpoint, in conjunction with isolated reports of catastrophic injury associated with weight training, significantly impacted the medical community's perception of youth weightlifting for over two decades (33, 35, 41). It also created a significant challenge for experienced coaches and teachers who wanted to introduce young athletes to more advanced training techniques and the sport of weightlifting (18). It is still quite common to see age restrictions placed on children and adolescence (often 16-18yrs) in strength training facilities in countries like North America, Australia, Great Britain, and much of Europe today (35, 38). This seems rather obscure when considering some of the most successful Olympic weightlifting athletes in the history of the sport, such as Naim Suleymanglu (Turkish three time Olympic winner, seven time World champion with 46 world records), began their training as young as 8 years old with Niam setting his first world record at the age of 15 years old (38).

Participation in weightlifting and its inclusion in strength programs has since become increasingly popular in recent years (35). This is particularly evident among children and adolescence (19, 24), with an increase in youth participation of the sport and the use of weightlifting methods as part of resistance training for sports such as American Football, rugby,

football and basketball (20, 35). Resistance training programs that include weightlifting movements are now recommended as part of performance enhancing and injury reducing youth programs (16).

Along with its growing popularity, over the past 20 years, weightlifting has continued to come under increasing scrutiny from parents, teachers, coaches, and health care professionals, and has become more controversial than any other aspect of resistance training for young people (11, 18, 24, 38). It is important for parents and coaches to have a love and duty of care for their children and their safety should always be put first, however in today's society, there is a growing concern from these parties for what constitutes as appropriate training methodologies for youth. The lifts associated with weightlifting are uncommon in health clubs and are not often taught in adult fitness classes and as such, the public perception of the movements are most likely influenced by the media and TV in which individuals are lifting 2-3 times their bodyweight above their head in what seems like a dangerous and aggressive manner (18). Current literature however, highlights that the rate of injury among children and adolescents appears to be relatively low with 0.0017 injuries per 100 participation hours, especially when compared to other sports in which youth participate such as rugby and basketball which see approximately 0.8 at 0.03 injuries per 100 participation hours respectively (21). Most injuries that do occur such as the dropping of weights on hands and feet, are often due to preventable accidents that could be easily avoided with better supervision and coaching (33, 38). Other minor injuries such as muscle strains and overuse injuries could be avoided by appropriate programming and exercise progression. Not only are the risks associated with youth weightlifting minimal, but recent studies have also indicated a multitude of benefits as well as applications of weightlifting for long term athletic development in youth sports (5, 8, 12, 14, 16, 18-20, 24, 26, 29-32, 35, 38, 39, 41).

Although the risks, benefits, and applications of traditional resistance training programs are well documented in the scientific literature for both adults and youth, more advanced training concepts such as weightlifting have received much less exposure or research in the paediatric literature (5). Therefore, the purpose of this paper is to review the current scientific literature in relation to youth participation in weightlifting and, focus on the extent of the potential risks, benefits, long term athletic development (LTAD), and its application for athletes and coaches in an attempt to highlight new knowledge and bridge the gap of understanding within the area of youth weightlifting.

METHODS

A search of the literature was conducted through google scholar, WorldCat.org, ProQuest Central, SpringerLink, ScinceDirect, BioMed Central, PubMed, Scopus, and EBSCO, ASCA databases using the following search terms and Boolean operators:

"Youth" and "Weightlift*"

The following restrictions were then applied to the search:

- Papers written only in English
- No duplicates
- Peer reviewed

The search disclosed 176 articles which were then reduced to 41 papers after the review of abstracts in regards to restrictions and relevance. As there were many studies that presented data just on youth and "resistance training" and not specifically "Weightlifting", inclusion criteria comprised articles that contained 1) 'youths' aged 4-19 years old 2) youth 'Weightlifting' specifically 3) a detailed description of their methods. The final studies included in the review consisted of 14 original investigations and 25 review and positional papers.

DISCUSSION

Injuries and Risks Associated with Youth Weightlifting

Original concerns of youth involvement in weightlifting were related to the potential damage to the epiphyseal growth plates of a developing child's bone structure (24). Although it is well known that the epiphyseal growth plate is much weaker than the surrounding connective tissue, there is no evidence within the literature to suggest that weightlifting, and more generally resistance training, causes injury to these structural components particularly when delivered by a qualified professional (24, 31).

The risks prevalent to weightlifting that have been documented in the literature include factors such as unsafe environment and equipment, overly fatigued training, poor technique, excessive load and volume of training, limited rest intervals and recovery, and lack of qualified supervision (12, 14, 24, 31, 38)(41, 42). Researchers have also previously highlighted the importance of not treating children like "miniature adults" owing to clear differences in physical growth and stature and their requirements for slightly altered training regimes (30, 42). Although there are some risks associated with youth participation in weightlifting, they can be greatly reduced with appropriate supervision and instruction from coaches, sensible program design progressions, and careful selection of training equipment (12, 31).

The literature suggests that there is some risk associated with resistance training for individuals of all ages including youth, although it is difficult to determine the extent to which these injuries occurred directly as a result of weightlifting specifically (13). In 1979, over half of the 35,512 "weightlifting" injuries requiring emergency room treatment in the United States involved 10-19 year olds, with the 1987 report showing 8,590 children 14 and under were taken to the emergency room for similar related injuries (13). It is important to note, however, that the National Electronic Injury Surveillance System (NEISS) which was used to report these cases did not distinguish between injuries associated with resistance training, powerlifting, and weightlifting and considered any form of lifting weight to be categorised into "weightlifting" (13). Furthermore, these injuries were said to be caused by weightlifting exercises and equipment from the patients, however it would be incorrect to conclude that the injuries were indeed caused by such activities and devices (13). These studies also failed to examine the conditions that may have predisposed the subjects to injury or the training history and program of the patients. A large majority of the injuries that occurred also took place at home in unsupervised training conditions (20). Even so, it is important to understand that there is some inherent risk associated with youth participation in weightlifting and therefore it is imperative to ensure that correct supervision and developmental programming with reduced loads for athletes under the age of 18 years old is given to reduce any risks. Technique rather than the amount of weight lifted should be the primary focus for junior athletes in their initial stages of development as youth weightlifters (39, 40).

The current literature suggests that children have a lower risk of resistance training injuries to skeletal, muscular and connective tissues when compared to adults (33) and that these injuries could have easily be prevented by increased supervision and stricter safety guidelines (32). Younger children tend to be subject to more accidental injuries such as fractures to the hands and feet from dropping weight plates during activities such as weightlifting. To reduce further non-accidental risk associated with children and adolescence in the weight room, focus should be placed on safe equipment and perfecting proper technique. If the individual is allowed to incorrectly perform a movement at lighter weights, then the risk of injury will be greatly increased if the athlete is allowed to perform the technique at heavier weights. Some methods that coaches and instructors can use to improve exercise technique include; giving continuous and immediate feedback verbally, as well as the use of visual feedback to help individuals become cognizant of exercise techniques carried out with visually identifiable poor biomechanics. Mirrors or video may be useful in these situations (33). Ultimately the literature (as seen in the summary of table 2.) indicates that there is very strong evidence to support the benefits of direct supervision to improve both the efficacy and safety of weightlifting in youth athletes.

Despite previous misconceptions about youth involvement in weightlifting, it is now recognised by global health authorities and leading strength and conditioning and sport science associations that youth participation in the sport of weightlifting and the practical application of weightlifting movements as part of a strength and conditioning programme can be safe, effective and enjoyable as long as qualified supervision and instruction are given and progression of the athlete is based on technical performance of each lift (14, 24, 29). These major medical communities include: American Academy of Family Physicians, American Academy of Orthopaedic Surgeons, American College of Sports Medicine, American Medical Society for Sports Medicine, American Orthopaedic Society for Sports Medicine, American Osteopathic Academy of Sports Medicine, The National Strength and Conditioning Association (NSCA), Australian Strength and Conditioning Association (ASCA), United Kingdom Strength and Conditioning Association (UKSCA), and the British Association of Sport and Exercise Science (BASES) (24, 31, 33). The NSCA positional statement on youth resistance training concludes that youth resistance training is beneficial for both health and physical performance and is effective in reducing the risk of injury if it carried out by suitably qualified professionals (12). The UKSCA positional statement on youth resistance training also reinforces the multitude of benefits associated with weightlifting and its subset of movements for youth (28). BASES published a report reiterating the same ideals, that resistance training is safe and effective if delivered by qualified professionals (3). The Canadian Society for Exercise Physiology was another organisation to release a positional paper in 2008 which deemed weightlifting to be a safe sport, and that with proper coaching and good planning there was no reason to keep children from participating (5). The same study found that the risk of musculoskeletal injury resulting from age-appropriate weightlifting does not appear to be any higher than other sports that youth athletes may regularly participate in (5). In this instance, age-appropriate weightlifting was in the context of both biological and training age of the athlete. Regardless of the skill of the individual, as a youth, the focus should be placed on learning the correct exercise technique and safe training procedures instead of the amount of resistance or weight lifted. An appropriately prescribed program should incorporate a suitable warmup and cooldown, emphasis on correct technique, gradual training progressions, and appropriate choice of exercise with a reduction in volume and load for ages 12-17 years old (1,5,40).

One of the most noteworthy documents within the paediatric literature is the 2014 International consensus statement on youth resistance training that supported the use of weightlifting in youth populations, indicating that it is safe and has a multitude of benefits when delivered by a qualified professional (29). These claims within this document are heavily substantiated as the positional statement was supported by 10 of the world leading authorities from the fields of sports and exercise science, strength and conditioning, and sports and exercise medicine. To date, there is no scientific evidence to suggest that weightlifting movements carried out with correct technique and sensible progression during practice or competition are riskier than any other sports and activities that young athletes may regularly participate in (see table 1) (11, 16, 17, 39). Thus, it becomes evident that with appropriate supervision and programming that considers an athletes training and biological age, weightlifting is considerably safer than previously believed.

The lifts carried out in weightlifting involve much more complex neural activation patterns than regular resistance training exercises, however, the injury rate and risk associated with weightlifting is reportedly lower than any other forms of resistance training sports in general (11, 12, 16, 18, 29, 31, 38). It is important to note however, that these statistics are often in relation to injuries that occur during competition and there are other injuries that may not be accounted for within the data that take into consideration injuries that do not require time away from training such as muscle strains and other overuse injuries. It has also been established in retrospective analysis that weightlifting is safer than many other competitive sports and activities in which youth athletes participate (see table 1) (11, 12, 19, 31). One study by Hamill (21) illustrated that weightlifting amongst school age pupils (11-18 years old) was markedly safer than many other sports in which these youngsters regularly participated. It also concluded that there appears to be no rational case for anxiety concerning the performance of weightlifting movements and their variants in children and adolescents. The study indicated that the overall injury rate per 100 participant hours in rugby was 0.8000, 0.1400 for soccer/rugby, 0.0035 for resistance training, and 0.0017 for weightlifting (21). These findings may be partially explained by the fact that weightlifting is a closed skill sport that is typically carried out in the supervision of qualified coaches and a gradual progression of training loads which are dictated by technique and skill demonstrated by the athlete (12). A study by Pierce *et al* (35) further supports the safety of youth weightlifting in which a sample of 70 boys and girls aged 7-16 years old was examined and found that over a year long period of weightlifting competition and training sessions, that any injury sustained from weightlifting sessions resulted in no loss of training days (35). The athletes within the study also reported no increased reports of injuries while lifting consistently heavier loads, further highlighting the potential gains and relatively low risks associated with youth weightlifting provided appropriate training guidelines are followed and competent coaching is available (35). Another study by Byrd (6) supported these findings as it monitored youth weightlifters (aged 12-15) and their performance over time and found significant improvements in overall loads lifted in the snatch, clean and jerk, and combined lifts. The investigation also emphasized over the course of all the athletes training sessions and a total of 534 competitive lifts, that there were no reported injuries that required either medical attention or for the individual to miss training (6). A similar paper by Chaouachi (8) examined the use of weightlifting within conventional youth resistance training and found that it was not only appropriate, but also very beneficial (8). Another study conducted by Faigenbaum *et al* (15) also reported significant gains in muscular strength without any incidence of injury when weightlifting movements were incorporated into youth training programs. A recent study by Faigenbaum and Polakowski (18) had similar findings and reiterated once again that the snatch and clean and jerk are safe additions that should be included in a resistance training program for children with a multitude of benefits.

Although many of these papers do support the safety of weightlifting for youth athletes there is still some minor risk involved that needs to be addressed. The literature indicates that lower back pain is the number one musculoskeletal problem in north American adults, and that the greatest concern for children and adolescence who resistance train is the risk of an overuse soft tissue injury, particularly in the lower back (5). However, the literature identifies this issue for resistance training in general, and not in regard to weightlifting specifically. It would therefore be wrong to speculate and more accurate to mention that it could be a possibility. Although there is some minor inherent risk when it comes to weightlifting, it becomes evident (as seen in the summary of table 2), that the scrutiny surrounding youth weightlifting may in fact be unwarranted and encouraged by the uninformed, with the literature clearly indicating the effectiveness of its practice by young athletes if carried out under the supervision of qualified coaches to correctly programme and monitor exercise progression and technique.

Table 1 - Multi-sport comparative injury rates. (21)

Sport	Injuries per 100 participation hours
Schoolchild Soccer	6.2
UK Rugby	1.92
South African Rugby	0.7
UK Basketball	1.03
USA Basketball	0.03
USA Athletics	0.57
UK Athletics	0.26
UK Cross-Country	0.37
USA Cross-Country	0
Fives	0.21
P.E.	0.18
Squash	0.1
USA Football	0.1
Badminton	0.05
USA gymnastics	0.044
UK Tennis	0.07
USA Powerlifting	0.0027
USA Tennis	0.001
Rackets	0.03
USA Volleyball	0.0013
Weight training	0.0035 (85,733hrs)
Weightlifting	0.0017 (168,551 hrs)

There were very few articles published within the last 10 years that were found within the literature to highlight any negative effects on paediatric involvement in weightlifting. One of these was a study by Vertonghen and Jikkemien (40) investigating the social-psychological implications of power sports and martial arts which found that participation of youth in power sports such as weightlifting can lead to an increase in antisocial behaviour. The results of the study suggested that participation in these power sports leads to an increase in antisocial involvement outside of the sports situation. The authors hypothesise that these negative effects arise from both the practice of power sports itself, as well as consistent exposure to a “macho” culture which is prevalent within the sporting clubs. However, some of researchers have made comments on the methodology of the paper indicating that there are doubts about the validity of the self-composed questionnaire and an absence of specifying which type of guidance was used within the selected power sports of the study. Another two studies were conducted by Wilson (41, 42) suggesting that high volume and high intensity lifting by youth athletes and their use of elite adult programming causes a premature peak in athletic performance and ultimately an early retirement from the sport. In an attempt to reduce these statistics, the paper proposes a reduction in loads lifted by youth weightlifters (less than 80% and no max lifts attempted) until approximately 18 years of age to ensure peaking of athletic potential in the mid-twenties. The adoption of an elite adult program by youth lifters should also be avoided, with more focus being placed on technique and skill mastery up until the age of 17-18 years old.

Although injuries do occur less in weightlifting than other sports, injury risk has been associated with maturity level. The literature indicated that two thirds of injuries sustained by youth patients (8-13yrs) were to the hand and foot and most often due to “dropping” and “pinching” in the injury descriptions with an increased percentage of fractures in the same cohort relative to other groups (33). It is therefore important to take into account training age, technical competency and maturational status when training younger athletes in strength and conditioning programs that involve technical movements such as weightlifting (29). In some countries, children as young as 8 are taught weightlifting and advanced multi-joint lifts (13, 16). The preponderance of literature indicates that there are no valid reasons to suggest that children cannot effectively begin learning weightlifting skills during this period if they are taught correctly and in accordance with their biological and psychological maturity (20). The use of PVC piping or wooden dowels can be adopted to teach technical components of the lifts at this stage. The risks associated with weightlifting can also be limited if the individuals

are educated and forced to abide by appropriate weight room etiquette, equipment safety, reduction of horseplay and proper handling of heavy objects in the weight room (33).

Therefore it becomes evident that although it was previously understood that youth participation in weightlifting was an unnecessary risk, current research indicates that this common misconception is not only false, but that the sport of weightlifting and the practical application of weightlifting movements as part of a strength and conditioning programme can be safe, effective and enjoyable if qualified supervision and instruction are given and appropriate programming is applied.

Table 2 - Summary of articles indicating the injury risk, benefits, and long-term athletic development of youth weightlifting.

Author	Type of Study (Original/ Review)	Position on Injury Risk	Position on Benefits of Youth Weightlifting	Position on LTAD	Youth Weightlifting is Good/Bad
Barker, A., Lloyd, R.S., Buchheit, M., Williams, C., & Oliver, J. (3)	Review	Resistance training is safe and effective if delivered by qualified professionals	Multiple benefits: enhancing speed/strength/power, transference of resistance training gains to other skills such as sprinting/jumping/throwing.	N/A	Good
Bayli, I. & Hamilton, A. (4)	Review	N/A	N/A	The consideration of developmental factors is important. 8-12 years of training is necessary to reach elite levels with progression seen 3 years in middle school, 4 in high school, and 5 in college before moving into professional sports.	Good
Behm, D.G., Faigenbaum, A.D., Falk, B., & Klentrou, P. (5)	Review	Safe with relatively low risk if qualified coaches and safety measures are put into practice	Enhance neuromuscular organisation	N/A	Good
Byrd, R., Pierce, K., Rielly, L., & Brady, J. (6)	Original Study	11 subjects over a minimum of 22months showed no injuries reported over a total of 534 competitive lifts and no time missed from training due to injury	N/A	N/A	Good
Cahill, B.R. & Griffith, E.H. (7)	Original Study	N/A	Addition to pre-season training saw a reduction in knee injuries and those that required surgery over 4 competitive seasons among adolescent football players	N/A	Good
Chaouachi, A., Hammami, R., Kaabi, S., Chamari, K., Drinkwater, E.J., & Behm, D.G. (8)	Original Study	Safe for youth if conducted with appropriate and qualified supervision	Appropriate and beneficial for youth. Weightlifting was far superior to traditional resistance training in developing physical qualities of young athletes such as counter movement jump height, horizontal jump height, and 5/20m sprint times.	Children should start early to learn the complex neural activation patterns from a young age to increase likelihood of strength or power gains	Good

Dvorkin, L. (9)	Original Study	No indication that the participation in weightlifting training caused 'stunted' growth of any kind	Positive improvements in body composition, cardio-respiratory characteristics and general wellbeing in 13-19 year olds.	N/A	Good
Ebada, K.a.-R. (10)	Original Study	N/A	A children's resistance training program incorporating weightlifting resulted in an average 4.9% increase in 9 strength tests (e.g. snatch, clean, and squats)	N/A	Good
Faigenbaum, A. & Mcfarland, J. (11)	Review	Safe If conducted with qualified supervision	N/A	3 phases of education, progression, and function.	Good
Faigenbaum, A.D., Kraemer, W.J., Blimkie, C.J., Jeffreys, I., Micheli, L.J., Nitka, M., & Rowland, T.W. (12)	Review	Safe with minimal risk of injury under qualified supervision and age appropriate training guidelines. Injuries that did occur in high school for resistance training were mostly due to aggressive progression of training loads or improper technique.	Gains in muscular strength	Childhood is the ideal time to begin learning these complex neural activation patterns. Age appropriate training progressions are essential.	Good
Faigenbaum, A.D., Kraemer, W.J., Cahill, B., Chandler, J., Dziados, J., Elfrink, L.D., Forman, E., Gaudiose, M., Micheli, L., & Nitka, M. (13)	Review	Most injuries occur due to accidents therefore its safe if proper supervision and coaching is provided	N/A	Competition should focus on proper technique and focus on self-improvement rather than other children their own age. Proper technique should be stressed before increased loads are applied	Good
Faigenbaum, A.D., Lloyd, R.S., & Myer, G.D. (14)	Review	Weightlifting progressions for youth have proven to be safe and effective	Beneficial for bone formation and growth during childhood	N/A	Good
Faigenbaum, A.D., Mcfarland, J.E., Keiper, F.B., Tevlin, W., Ratamess, N.A., Kang, J., & Hoffman, J.R. (15)	Original Study	No incidence of injury	Significant gains in muscular strength are found without any incidence of injury when weightlifting movements were incorporated into youth training programs	N/A	Good
Faigenbaum, A.D. & Myer, G.D. (16)	Review	No report of injury with low risk	Significant gains in strength	N/A	Good
Faigenbaum, A.D., Myer, G.D., Naclerio, F., & Casas, A.A. (17)	Review	Weightlifting for youth is much safer than most other sports they participate in. Some reports indicate risk to growth cartilage but only under lack of appropriate supervision. Injuries occurred unsupervised e.g. 13yo bilateral fracture of the	N/A	Every child is unique and progresses at their own rate therefore progressions should be applied accordingly	Good

		distal radial epiphyses lifting 30kg overhead in a makeshift gym at home, and 16yo fractured left distal radius when benching 48kg without supervision.			
Faigenbaum, A.D. & Polakowski, C. (18)	Review	Safe if given correct coaching and supervision. Less risk of injury compared to other sports	Higher likelihood of reaching their athletic potential in later years if they participate in weightlifting from a young age.	Children are not miniature adults and emotional maturity should be considered when introducing progressions.	Good
Fry, A.C. & Schilling, B.K. (19)	Review	Safe with reduced risk of injury if appropriate supervision is given	N/A	Starting early is beneficial for young athletes. The individual must have the desire and capacity of training	Good
Haff, G.G. (20)	Review	Injury rates are far less than other sports in which young athletes participate	Increased strength and power gains from inclusion of weightlifting	N/A	Good
Hamill, B. (21)	Review	Markedly safer than many other sports in which youth regularly participate. The overall injury rate per 100 participant hours in weightlifting was 0.0017 compared to 0.07 for UK tennis, and 0.57 for USA athletics	N/A	N/A	Good
Hedrick, A. & Wada, H. (22)	Review	Low risk of injury	Potential to reduce risk of injury in other sports	N/A	Good
Hejna, W.F., Rosenberg, A., Buturusis, D.J., & Krieger, A. (23)	Original Study	N/A	The risk of injury in sport can be decreased, as well as a reduction in time to return to play post injury	N/A	Good
Kite, R.J., Lloyd, R., & Hamill, B. (24)	Review	Safe with little risk of injury under qualified supervision and appropriate progression	Numerous physiological and psychological benefits: reducing risk of injury, increasing muscular strength and power, improving body composition and motor control, and increased bone mineral density, improved cognitive brain function, health and behaviour outcomes, and beneficial social effects.	Emphasis on skills mastery and technique before progressing into increased intensities and volumes	Good
Lavallee, M.E. & Balam, T. (25)	Review	Injury rates are low with severe injury being uncommon. Most common method of acute injury is by an athlete dropping weight onto themselves. Muscle strains account for 46-60% of all acute injuries in strength training. Common sites of injury are knees, elbows and lower back stress.	N/A	N/A	Good but can assume some risk

Lavallee, M.E. & Mansfield, L.A. (26)	Review	N/A	Decreased risk of injury in other sports	Difference in starting age between eastern Europe and the west may be an indication of success. LTAD models should focus on maturation and periods of trainability rather than chronological age	Good
Lehnhard, R.A., Lehnhard, H.R., Young, R., & Butterfield, S.A. (27)	Original Study	N/A	Significant reductions in injury in male soccer team from 15.15 to 7.99 per 1,000 exposures	N/A	Good
Lloyd, R., Faigenbaum, A., Myer, G., Stone, M., Oliver, J., Jeffreys, I., & Pierce, K. (28)	Review	Safe and low risk of injury with appropriate coaching and supervision	Vast array of benefits such as bone formation and growth, and strength and power gains.	N/A	Good
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. (29)	Review	Safe, effective and enjoyable when qualified supervision and instruction are available.	Positive alterations in body composition, cardiorespiratory variables, various motor fitness parameters (e.g. jumping and sprinting) and overall weightlifting performance.	Progressions based on master of technique and maturation status	Good
Lloyd, R.S. & Oliver, J.L. (30)	Review	N/A	N/A	LTAD model is a strategic approach that focuses on maturation status of the athlete. Begin with functional movements and muscular strength before progressing to higher intensities and workloads	Good
Lloyd, R.S., Oliver, J.L., Meyers, R.W., Moody, J.A., & Stone, M.H. (31)	Review	Weightlifting and resistance training in general is safe and effective practice for young athletes	Its use is effective as an injury prevention mechanism strengthening the movement kinematics inherent to landing, cutting, and accelerating in other sports.	Training children based on biological status rather than chronological and maximising windows of opportunity to reach a greater physiological ceiling potential	Good
Myer, G.D., Faigenbaum, A.D., Ford, K.R., Best, T.M., Bergeron, M.F., & Hewett, T.E. (32)	Review	Reduced risk of injury with supervision and strict safety guidelines	N/A	Weightlifting can be beneficial in its application for LTAD	Good
Myer, G.D., Quatman, C.E., Khoury, J., Wall, E.J., & Hewett, T.E. (33)	Original Study	Most injuries occur due to accident and lack of qualified supervision. Sprain and strains increased in occurrence with age (mainly in 19-22yo category). Children have lower risk of joint sprains and muscle strains. But weightlifting is	Can result in beneficial adaptation to bone, ligaments and tendons. Also reduction in injury rates in sport and reduction in time to	N/A	Good

		safe if undertaken with qualified coaching	return to play after injury		
Pediatrics, A. (34)	Original Study	An unnecessary risk. Weightlifting has a high injury rate and should be avoided by preadolescents. Half of the reported 35,000 annual injuries occur in children 10-19yo. Due to dropped weights and poor supervision.	Pre-pubertal children are unable to increase strength or muscle mass because they lack the circulating androgen hormones.	N/A	Bad
Pierce, K., Brewer, C., Ramsey, M., Byrd, R., Sands, W.A., Stone, M.E., & Stone, M.H. (35)	Review	Safer than generally believed, especially under qualified supervision	Increasing vertical jump performance, increases in strength and speed strength parameters, improvements in body composition, resting heart rate, blood pressure as well as cardiorespiratory fitness. Decreases the risk of injury in sports in which young athletes participate.	Start early with children in weightlifting and progression to increased loading should only occur after demonstration of mastery of technique.	Good
Servedio, F.J. (36)	Original Study	Danger comes from lack of supervision and/or care taken to employ proper safety measures.	Significant increases in strength, speed-strength parameters, and measures of cardiorespiratory fitness in 11-12 year old boys. Reduced risk of injury due to increased strength gains.	Weightlifting from a younger age allows for development of skills and practice to be able to compete at an older age.	Good, however injuries can occur at times
Sewall, L. & Micheli, L.J. (37)	Original Study	N/A	Prepubescent children can make significant gains in muscle strength in response to progressive resistive training.	N/A	Good
Stone, M.E. & Mizuguchi, S. (38)	Review	Safe, effective and has little risk of injury. Injuries are usually a result of accidents that could be avoided with correct supervision and focus of the individual	Positive alterations in body composition, cardiorespiratory variables (resting heart rate, blood pressure and physical work capacity), and increase a multitude of motor fitness parameters such as jumping and sprinting. Also can result in a reduction of sports related injuries.	Begin with general physical preparation (development of biomotor abilities), progress to more complex loaded movements with maturity and demonstration of mastery of technique	Good
Stone, M.H., Pierce, K.C., Sands, W.A., & Stone, M.E. (39)	Review	Safe activity with very low injury rate compared to other sports	N/A	Begin with general physical development and move onto increased intensities and volumes only when the athlete can demonstrate adequate skill and technique.	Good

Vertonghen, J. & Theeboom, M. (40)	Original Study	N/A	Weightlifting can lead to an increase in antisocial behaviour in youth	N/A	Bad
Wilson, G.J. (2014) (41)	Original Study	Some risk involved. Athletes peaking too early and retiring from competition.	Developing musculature and neuromuscular connection to cope with competition weights at a later stage in development.	Young athletes are pushed too hard too soon peaking too early. Suggests heavy weights should not be lifted until after 18yo and competition should focus on technique such as repetitions based format with athletes lifting only up to bodyweight in load. Physiological peak should occur in mid 20's	Bad
Wilson, G.J. (2017) (42)	Original Study	Athletes peak too soon and burnout and retire from competition. Athletes are unable to maintain optimal performance. Injuries towards the end of the career due to overuse generally in the knees and lower back	N/A	Youth weightlifters should focus on lower training volumes and intensities with 4-6 weekly training sessions. 1 technical session per day max 5 days a week. Don't train young athletes with the same methods as adult elite athletes. No loads greater than 80% only once good technique is achieved. No maximum lifts attempted during this phase. Physiological peak for athletes should be achieved in their early to mid-twenties and consider the long term views to resist the temptation of creating a teenage superstar by using adult elite programs.	Bad
Yahia, A.R., Arfa, Y., Salah, F.Z.B., & Dziri, C. (43)	Original Study	N/A	Promotes bone development in a longitudinal direction	N/A	Good

The Potential Benefits of Weightlifting

Weightlifting in children and adolescence has seen a growing interest in recent years in an attempt to improve health, enhance sports performance, and for young athletes to develop good feelings about themselves (18). The benefits of weightlifting for youth athletes are vast and can positively influence both physiological and psychological qualities of an individual (24). When considering the observational, correlation and longitudinal data as a whole it becomes evident that the incorporation of weightlifting in a strength and conditioning regime, as well as participation in the sport, can be effective at reducing risk of injury, increasing strength and strength related variables (e.g. rate of force development, power, strength endurance etc.), improving body composition, refining motor control, and increasing bone mineral density (8, 14, 20, 24, 38). Potential psychological benefits also include potential long term health benefits, improved cognitive brain function, improved health and behaviour outcomes, and beneficial social and psychological effects (24).

It was previously speculated that the risk vs reward for resistance training modalities such as weightlifting in children was not warranted and that weightlifting would not result in any adaptations because of the lack of circulating androgens in these young athletes (33), however, the current literature states otherwise. Rather than thinking about the risk associated with "exposing" young athletes to weightlifting, coaches should be considering the risk of "not exposing" these athletes to such a regime that could better prepare them for competitive sporting situations (31). Current literature suggests that the incorporation of weightlifting exercises into a youth athletes training regime can produce positive outcomes in body composition, cardiorespiratory variables (e.g. heart rate), blood pressure, PWC(170), various motor fitness parameters (including jumping and sprinting) and overall weightlifting performance (29, 35). Studies indicate that there is a significant window for grains in strength and power with little risk of injury when qualified instruction and a stepwise progression of a weightlifting training program is incorporated (12, 31).

Weightlifting should not only be viewed from a performance enhancement perspective but also from an injury prevention standpoint (31). There is growing evidence that resistance training such as weightlifting may reduce injury potential for

some activities and sports with the literature suggesting that appropriately designed programs can help to reduce acute and overuse injuries by 15-50% (26, 33, 35). With 3.5 million sports related injuries in youth athletes requiring a medical visit each year in the United States, and with 1.3 million cases per year in Europe for children under the age of 15, there is a significant impact on the health sector and the communities involved (29). The literature suggests that beneficial adaptations can occur as a result of participating in activities such as weightlifting including adaptations to bones, ligaments, and tendons, which is further supported by epidemiology based reports (14, 33). Weightlifting is proposed to create adaptations to the connective tissues and skeletal system which can increase tolerance of the impact and ground reaction forces that young athletes are likely to experience in the sporting environment (31). Although there is a lack of published research investigating the effectiveness of weightlifting on actual sports performance in children and adolescent athletes, weightlifting and its derivative lifts, replicates the kinetic and kinematic patterns present in lower limb locomotion where force application into the ground via triple extension of the ankle, knee, and hip is critical (31). With beneficial adaptations to strength and power resulting from the inclusion of weightlifting into a strength and conditioning program, the potential to transfer these adaptations to sporting movements such as sprinting, accelerating, decelerating, changing direction, and jumping would seem very likely (9, 31, 35). By strengthening these movement kinematics, weightlifting may also provide an effective injury prevention strategy during these actions (3). A study by Lehnhard *et* al (27) indicated that with the addition of a strength training program to a male soccer team, the athletes reported significant reductions in injury. Cahill and Griffith (7) also reported a reduction in knee injuries and those that required surgery over 4 competitive season among adolescent football players after the addition of weight training into their pre-season conditioning. Hejna *et al* (23) also found that not only can the risk of injury in sport be decreased, but also the time to return to play post injury with the inclusion of resistance training in a young athletes (13-19yrs) training regime. Therefore, it becomes evident that weightlifting and its inclusion in strength and conditioning programs for youth athletes is not only safe, as previously outlined, but also useful to reduce injuries during competitive play.

Youth Weightlifting has a multitude of benefits that are not only restricted to reduction of injuries in sports. One particular review by Pierce *et al* (35) outlined an array of benefits from weightlifting assisting in improvements athletic performance as well as its ability to potentially reduce the risk of injury in youth athletes. Another study by Hedrick and Wada (22) also reiterated these claims with findings from Stone *et al* (39) in their overview of weightlifting doing the same. An investigation conducted by Chaouachi *et al* (8) reported that weightlifting was far superior to traditional resistance training in developing physical qualities of young athletes, and was highly recommended to be included in a strength training program alongside traditional resistance training and plyometrics. The investigation highlighted that weightlifting was more than 80% likely to provide substantially better improvements for countermovement jump, horizontal jump, and 5 and 20m sprint times than plyometric training. The British Weightlifting positional statement also endorses the use of weightlifting to increase strength, speed and power in youth athletes, as well as improving fundamental movement skills and refining posture (24). Servedeo (36) also found when studying 11-12 year old boys, that weightlifting produced significant increases in strength, speed-strength parameters, and measures of cardiorespiratory fitness. A study conducted by Ebada (10) initiated a children's resistance training program that incorporated weightlifting components and found that the weightlifting training program resulted in an average 4.9% increase in 9 strength tests (e.g. snatch, clean, and squats). The Canadian positional statement paper also found that the inclusion of weightlifting in youth strength and athletic development programs could potentially enhance neuromuscular organization (5). An older study by Dvorkin (9) examined subjects between 13-19yrs and discovered that weightlifting training produced positive improvements in body composition, cardio-respiratory characteristics and general wellbeing (9). The paper also showed that there was no indication that the participation in weightlifting training caused 'stunted' growth of any kind (9). Therefore, the multitude of benefits becomes evident when weightlifting is included in youth training programmes to enhance physical qualities and performance of a young athlete.

Weightlifting can also be beneficial on bone formation in youth athletes. The 2014 International Consensus on youth resistance training, the Canadian Society for Exercise Physiology, the NSCA, and the UKSCA all highlight in their positional statements that when appropriately prescribed and coached weightlifting programs are implemented, the mechanical stress from the training may actually be beneficial for bone formation and growth (5, 12, 28, 29). Another study conducted by Yahia *et al* (41) found that practice of weightlifting by young people under the age of 13 has an effect on joint modelling and therefore the thickening and the density of bones, thus highlighting that weightlifting practice promotes bone development in the longitudinal direction in young athletes. Faigenbaum *et al* (12) also found that adolescent weightlifters have a bone mineral density and bone mineral content that is well above values of age matched controls suggesting weightlifting can impart some benefit on bone development in youth athletes.

If young athletes are given the opportunity to participate in weightlifting in their early years of development, studies have indicated that they are more likely to reach their genetic potential in musculoskeletal strength and power during adulthood (18). Research suggests that the dominance of Eastern European and Asian countries in sports such as weightlifting may be partially due to an earlier start to training (19). Some studies even suggest that by participating in preparatory conditioning from a young age in sports such as weightlifting, it may reduce overuse injuries seen later in their athletic career (26). It therefore becomes evident that there are a multitude of benefits to participating in weightlifting from a young age if training load and volume are taken into account and adjusted according to training and biological age of the athlete.

Long Term Athlete Development in Youth Weightlifting and its Practical Application to Coaches and Athletes

The risk vs reward of weightlifting for young athletes is very much in favour of the reward with its ability to not only reduce the risk of injury, but also its benefits in regards to the long term athletic development (LTAD) of an individual (26). Due to the complexity of the neural activation patterns involved in weightlifting, childhood is seen as the ideal time to develop the coordination, skill and technique to perform these lifts correctly. This will ultimately better prepare the athlete for performance at a later stage in their development (12). It is essential for coaches to be aware of the considerable amount of time it takes to master these lifts and the appropriate progressions from basic exercises such as the front squat, to skill transfer exercises such as the overhead squat, and finally the competition lifts such as the snatch and clean and jerk (8, 11, 18). As youth athletes are all unique, coaches should be able to show proficiency in the ability to prescribe weightlifting programs for youth with different needs, goals, and abilities (17, 29). The NSCA guidelines advise that an instructor-to-child ratio of 1 to 10 is acceptable, although additional supervision may be needed during the initial phases of the program or if an individual requires more attention (13).

The LTAD model was constructed for the development of youth athletes and is accepted by a range of sporting organisations globally (31). The model takes into consideration the maturational status of an individual and offers a more strategic approach to athletic development (30). It considers a 5 step process including the fundamental (6-10 years), training to train (10 to 13-14 years), training to compete (13-18 years), training to win (17-18 years and above) (1, 2). The premise behind the model is for strength and conditioning coaches to expose young athletes to specific training stimulus at various stages of development where they are more likely to be susceptible to accelerated adaptation (30). The model also states that failure to use these windows will result in the limitation of future athletic potential (4). Although there have been different interpretations and adaptations of the model, it ultimately creates a structured and logical approach to youth athletic development and allows individuals to be trained based on their biological status rather than chronological age. This has not only been predicted to be a safer approach, but also more effective at exposing the individual to the correct training stimulus during windows of opportunity to reach a greater physiological ceiling potential (31).

Wilson (41, 42) outlines some possible progressions for the long-term development of youth athletes to maximise their athletic potential and prolong their career in the sport of weightlifting. The paper argues that high volume, high intensity weights too early in an athlete's career can cause the athlete to peak too early and to burn out ultimately retiring from the sport. The papers suggest that heavy weights above 80% should not be lifted until after 18 years old so that the athlete is able to peak performance around the mid-twenties. Ultimately the goal of a LTAD model should be to maintain an individual's optimal performance for the longest period, whilst minimising the occurrence of injury. The literature suggests that technique and skills should be the focus for junior weightlifters (17 years and under) to develop the coordination and neuromuscular connections to cope with competitive weights at a later stage in their development (training to win phase)(8, 12, 13, 24, 30, 35, 38). An appropriate progression of training stimulus for youth around 12-16 years old should therefore be;

- Lower training volumes and intensities with 4-6 sessions per week (with no greater than 50% on technical training).
- One technical session per day, maximum 5 days per week.
- No loads greater than 80% only once good technique is achieved with no maximum lifts attempted during this phase.
- Physiological peak for athletes should be around the mid-twenties and coaches should resist the temptation to create a teenage superstar through the adoption of adult elite programs.

A study by Lloyd, and Rhodri (31) proposes a similar long term athletic development profile for youth weightlifters but breaks the process into 3 stages: prepubertal training with a focus on fundamentals and learning to train (associated with age-related neural developments), pubertal training with a focus on training to train, and a post pubertal training with a focus on training to compete and training to win which is said to result of altered sex hormone concentrations ultimately creating larger muscle mass and force producing capabilities (31). Faigenbaum (11) outlines a slightly different approach to the development with the first stage focusing on education of the athlete including how to miss a lift and how to technically perform a lift with a dowel. The second stage in this article involves the progression of the athlete to increased intensities and volumes, with the final stage focusing on function with altered sets, reps and rest periods to individualise the program. The study highlights that these lifts may be learnt as early as 8 years old, but resistance is not added until adequate neuromuscular control can be demonstrated. Another study conducted by Bayli and Hamilton (4) outlines the importance of the consideration of developmental factors when training youth. They outline that 8-12 years of training is necessary to reach elite levels with progression seen 3 years in middle school, 4 in high school, and 5 in college before moving into professional sports. This is reinforced by Wilson (41, 42) who argues that these athletes should not be reaching peak performance until their mid-20's and that coaches and parents should resist the temptation to produce teenage superstars through the application of intense elite adult programs. Regardless of the number of stages of progression, the literature follows the same generalised principles that when training youth weightlifters, the initial focus should be on technical mastery before progressing to higher loads and volumes at a much later stage in their athletic development.

Irrespective of the age of the athlete, the addition of weightlifting into a youngsters training program should only be considered if the child is eager to learn, has the emotional maturity to follow directions and adhere to safety

considerations, and qualified coaching is available (18). Young athletes considering taking up the practice of weightlifting should also be aware of the potential for injury and understand that they can get hurt if they don't play close attention to coaching instructions (18). It is also important to note that current literature indicates emphasis on cardiovascular endurance such as aerobic exercise should be limited or avoided while training youth weightlifting as it may compromise the ability to gain strength and particularly explosiveness in the athlete (38).

In Europe, weightlifting training often begins as early as 3-4 years of age. In the West and countries such as the United States, this occurs much later in middle school. This is partly due to the previous misconception that strength training in youth can pose a significant risk to a young athlete's health (26). Due to the complex neural activation patterns involved in weightlifting, it is essential to place a large emphasis on the safe use of equipment to avoid accidental injury. It is also crucial to focus on the acquisition of proper lifting techniques through gross and fine motor skills, rather than the loads lifted (38). This is especially true in the early stages of a program. Individuals should always start by performing the lifts with a wooden dowel or long PVC piping instead of a weightlifting bar (11, 17, 31). This stage should focus on the concomitant development of fundamental movement competency and other physical attributes such as balance, co-ordination, basic muscle strength, and posture (24, 38). Regardless of an individual's age or gender, a young athlete must be able to demonstrate technical proficiency of fundamental weightlifting skills, even if entering the program at a later chronological age, before attempting more complex or loaded movements. There should be an emphasis on skill mastery and technique development before considering increasing loads and volume (24). It is critical in the initial stages of development to focus more on individuals embracing self-improvement and feeling good about their performances and ability to perform a multi-joint lift, rather than competing against each other (13). Once a youth develops the skill, technique, and confidence to perform these lifts correctly, the individual may wish to increase intensity and volume of their training at a progression that allows the development of muscular strength and power (11, 33). This progression can be added gradually to focus more on specialized training (30). It is important to note that any competitions that young athletes may be involved in under the age of 13 years old, should be judged on the basis of technical execution to emphasise developing technical competency as a primary focus before considering any form of load (24, 38). Events such as the youth Olympic games require athletes as young as 14 to be lifting over double their body weight which seems to pose unnecessary risk and be counterproductive for their long-term development (41). Other sports in the youth Olympic games such as athletics and swimming recognise these limitations and reduce the intensity of their events for the junior athletes. It would be a sensible consideration for the IWF to do the same and reduce the maximum loading of the young teenage lifters. A repetition-based competition with a reduced load, similar to the athlete's body weight, would be a potential option for future events. This would allow the athletes to gain experience in a competition setting whilst maintaining focus on technique and possibly prolonging their athletic career (41, 42).

In terms of the practical application of weightlifting for coaches and athletes, the literature suggests that light moderate training intensities (less than 75% of 1 repetition maximum) are the most appropriate for young weightlifters (18). When constructing a training program, 1h of training performed 2-3 days a week is adequate. Each training session should include a warm up, several sets of basic exercises, skill transfer exercises, or competitive lift (depending on the training age of the athlete), and conclude with abdominal, medicine ball, or sprinting exercises (18). Young athletes should perform the competition lifts such as the snatch and clean and jerk in sets of 3-5 repetitions, with strength lifts such as the squat in sets of 5-10 repetitions.

Therefore, it becomes evident that due to the complexity of neural activation patterns involved in weightlifting, coaches should focus on teaching the lifts and technique from an early age with light loads. An athlete should only progress to heavier intensities and volumes once mastery of technique is achieved. This should take place in the later stages of their long-term athletic development to ensure a greater chance of athletic success and a prolonged career within the sport.

Further Research

There is an increasing interest and involvement in the participation of youth in weightlifting, yet there is still a significant gap in the literature in regard to its application. Traditional resistance training programs have been well documented in the scientific literature for both adults and youth, however more advanced training concepts such as weightlifting have received much less exposure and research in the paediatric literature. It becomes evident within this review that in recent years there has been a change in opinion to recognise that youth weightlifting can be safe if carried out under the supervision of qualified professionals, however there are still areas that need to be further investigated. The LTAD model is still in its infancy with many interpretations of its application to youth weightlifting. Although there is a general consensus that technique and skills mastery should be engaged from a young age followed by progressions into higher volumes and intensities, the progressions are rather ambiguous and thus future studies may benefit from focusing on a more sequential based approach with each stage of the LTAD including; fundamentals, learn to train, train to train, train to compete, and train to win. There are some suggestions for coaches and athletes within the literature for the practical application and programming of weightlifting for children and adolescence, however more research is needed. Therefore, future research may also profit from examining the specifics of weightlifting programming including intensities, volumes, set/repetition ranges, as well as movement patterns to create greater improvements to the athletic potential of the youth.

Further research should be conducted into the LTAD of weightlifting athletes from the Youth Olympic Games to elite senior competition to determine why the dropout rate is so high and the possibility of junior athletes peaking their athletic potential at too young an age through the application of elite adult programs and training loads being too high.

Another possible avenue for future research is the health of retired weightlifting athletes and an examination of the percentage of problems to their lower back and knees. The current literature highlights a possible risk of these areas in weightlifters due to the high training loads (particularly in the later stages of their careers (42)) and it would be beneficial to understand the extent to which these problems extend once the athletes have retired from the sport.

There should also be a push to educate the public and professionals within the industry of the current literature findings and the change in direction to understand that youth weightlifting can be a safe and effective method of training if the progressions are applied appropriately and qualified supervision is given. This would, with any luck, result in the adoption of weightlifting by schools and youth sporting clubs worldwide ultimately increasing the athletic potential of the youngsters, reducing their risk of injury within the sports they play, and provide a better quality of life for youths overall.

CONCLUSIONS AND PRACTICAL APPLICATIONS

- Despite a history of scrutiny over the safety of youth participation in weightlifting and its incorporation into resistance training regimes, the literature clearly indicates that it can be safe, effective and enjoyable if it is supervised, and correct programme progression is implemented by qualified professionals. Most injuries that occur are due to preventable accidents with most other sports in which youth participate being much more injury prone.
- There is no evidence within the literature to indicate that weightlifting in youth population's stunts growth or causes damage to the epiphyseal growth plates.
- Weightlifting has been shown to have a multitude of benefits to young athletes including; positive outcomes in strength and power gains, bone formation and body composition, cardiorespiratory variables, blood pressure, PWC (170), motor fitness parameters such as jumping and sprinting, overall weightlifting performance, as well as potential psychological benefits.
- With such a high injury rate in sports worldwide, the inclusion of weightlifting in youth training programmes should be a staple to not only enhance athletic performance but also from an injury prevention standpoint.
- With the knowledge of its safety and benefits, individuals should be encouraged to participate in weightlifting from a young age, knowing that it could also greatly increase their chances of reaching their genetic potential in musculoskeletal strength and power during adulthood.
- Every young athlete is unique, and it is important for their coach to consider training age, technical competency, and maturation status when training these athletes in the sport of weightlifting.
- Training of youth should be presented in a progressive manner with the initial emphasis being placed on fundamental movement ability, advancing into technical mastery of the competition lifts in time. Load and volume should not be applied to the movements until complete technical competency can be displayed with emphasis of competition being placed on technical execution and self-improvement.
- With the benefit of future generations in mind, weightlifting should be considered as a principle training method in schools and youth sporting clubs worldwide to increase the athletic potential of children and adolescents, as well as provide a better quality of life for youths overall.

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