Youth Resistance Training

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Summary

The popularity and use of resistance training, including training for sport, appears to be increasing among children and early and late adolescents. The use of resistance training in developing athletes appears to be on the increase, despite well intended but poorly supported position statements, anecdotal reports and conjecture regarding potential injury. Indeed, current scientific data indicates that, properly supervised resistance training can enhance performance, reduce injury potential and enhance health aspects of children and early and late adolescents

Introduction and Background: Rationale for strength training among children and adolescents

Resistance training or strength training are general terms and are concerned with regular exercise used for enhancing strength and strength related characteristics such as, rate of force development, power and strength-endurance. Resistance training may involve body weight exercises, resistance producing devices such as stretch bands, or various machines, free weights (weight training) or more commonly a combination of these. Resistance training can be part of an overall program for health or for sport or it may stand-alone. From a sport perspective, resistance training also encompasses the competitive aspects of bodybuilding, powerlifting and weightlifting. As the popularity and number of participants engaging in some form of resistance training increases among all levels and ages of the population, it becomes increasingly important to understand the potential consequences of the training process, particularly when the consequences concern more vulnerable or fragile segments of the population. Therefore, our purpose is to offer the reader a broad and comprehensive review that addresses the potential consequences of the training process as it affects children and adolescents, particularly as it pertains to training for sports.

Controversial Issue: It is apparent to the authors that considerable controversy and lack of understanding currently surrounds children and resistance training, especially as it concerns training for sport. This controversy has also been previously noted.[13, 32, 68] Often the controversy has its roots in opinion, or a sort of consensus practice (sometimes called a "rich tradition" [97, 99]), rather than demonstrable data. The resulting controversy becomes apparent in two parts: First, does resistance training produce substantial alterations in structure, strength and power among children (up to approximately 10 yrs – Tanner stages I and II), early adolescents (approximately 10 – 13 yrs – Tanner stages II and IV) and adolescents (approximately 14 – 18 yrs – Tanner stage V); and second, does resistance training expose children and adolescents to potential injury?

- **Part 1:** Consider the following: Does resistance training produce substantial alterations in structure, strength and power among children and adolescents?

To begin to understand this issue a discussion of the "trigger hypothesis" is necessary. The triggering effect for improved performance (including strength development) - "results from the modulating effects of hormones that initiate puberty and influence functional development and subsequent organic adaptations" - prior to this "critical period" little or no effects from physical conditioning will occur.[48] The idea of a "trigger", indicates that little or no alteration in performance, physical composition or strength-based physiology is likely to occur until puberty or beyond. This misconception has often been misrepresented in popularised models that claim

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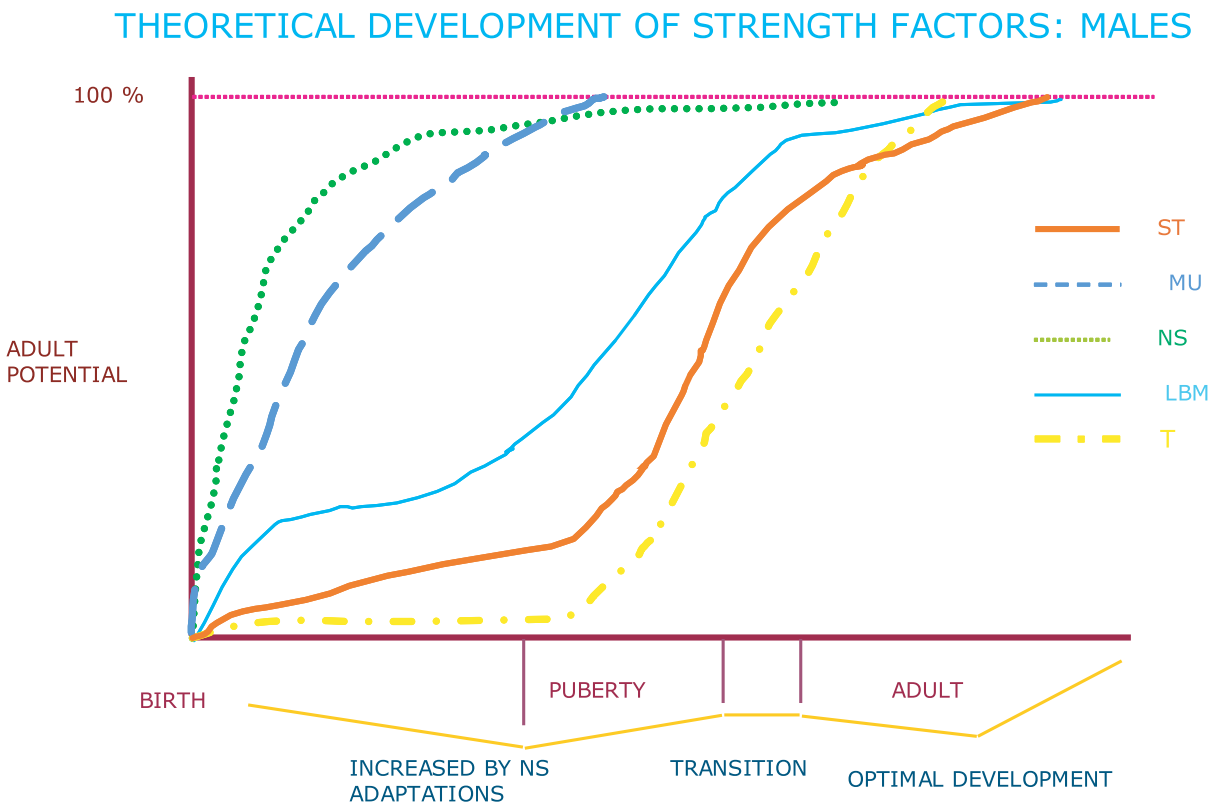

Figure 1: Theoretical alterations in male physiology with age: Increases in testosterone are strongly related to alterations in LBM and strength. The increase in T at puberty is believed to be the primary trigger for increased responsiveness to physical training (modified from 48).

ST = Maximum strength levels

MU-D – Motor Unit differentiation

MU – Motor Unit maturation

NS – Nervous system maturation

LBM – Alterations in Lean Body Mass due to maturation

T – Alterations in Testosterone due to maturation

"windows of opportunity" around puberty. An example of the potential trigger effects are shown in *Figure 1*. Some support for this hypothesis has been gathered from data dealing with the development of aerobic capabilities among pre-pubescent children and adolescents.[56,60] However, there are several reasons for modification of this hypothesis in terms of resistance training:[74]

1. The first reason is careful and systematic pobservation. For example: children in beginning gymnastics programs typically cannot perform simple tumbling or body weight supported exercises. Within a few weeks or months they can achieve reasonable proficiency. This can only occur with some improvement in strength, thus the gymnastic training serves as a form of resistance training.[75,80] Young female gymnasts have shown remarkable enhancements in fitness with continually increasing performance levels in probably the most mature and consistent talent identification program in the United States. The Talent Opportunity Program (TOPS) has been operating since 1993 and has annually demonstrated increased strength fitness among the participants.[35,77,78,82]

2. Evidence indicates that maturation aspects of the nervous systems occur earlier than the alterations in hormones or increases lean body mass (LBM) occurring with puberty. As the nervous system is directly associated with training induced alterations in force production capabilities (e.g. strength) then there is reason to believe that nervous system adaptations to resistance training could also affect positive performance alterations among children.

3. Furthermore, a degree of hypertrophy can occur without marked hormonal (e.g. testosterone) influence. This adaptation can be often be observed among women taking up resistance training. Thus, theoretically there is a reasonable expectation for some degree of hypertrophy among children. This is supported, at least indirectly, by age/training related differences noted in body composition measurements of highly trained female gymnasts.[9,62,79]

4. Additionally, a good deal of research has shown that children, as well as early and late adolescents, can increase strength, power, and endurance and make physical alterations as a result of resistance training.

Concerning this last (#4) point: Several studies and reviews of the literature[8,24,25,27-31,50] including two meta-analyses[26,61] have dealt with children of various ages and the effects of resistance training. These reviews indicate that:

• In boys (< 13 yrs) and girls (< 12 yrs) there clearly can be an increased level of strength and strength-endurance as a result of resistance training and there appears to be only a minor sex (male – female) effect on absolute or relative strength gains. In adolescents (up to 18 yrs) there can be increased strength, power and strength-endurance and the absolute gains do reflect sex differences.

• Although, with resistance training there can be a degree of hypertrophy that occurs in children, a greater degree of hypertrophy can be expected among early and late adolescents. This effect may be mediated by hormonal and other maturation effects that accompany growth. In this context, alterations in body composition, such as: loss of fat, decreased percent fat and increased lean body mass (LBM) can also occur as a result of resistance training and early and late adolescents generally respond more favourably.

• Isokinetic and isometric programs do not produce the same degree of strength gain (or hypertrophy) as other forms of resistance training such as variable resistance machines and free weights.

• The magnitude of effect (i.e. alterations in body composition, strength, power, hypertrophy etc.) is a function of sex (in older children), the training mode and method (e.g. training intensity, training volume) and the experimental design. The evidence to date indicates that the more effective programs lasted more than 8 weeks and involved multiple sets per exercises.

"Young female gymnasts have shown remarkable enhancements in fitness with continually increasing performance levels."

Among children, the primary mechanism underlying gains in maximum strength and related characteristics such as rate of force development and power, appears to be primarily neural,as there is less demonstrable hypertrophy. However, among early, and particularly late adolescents, the effects of strength training appear to be a result of both hypertrophic and neural mechanisms.[59,70, 101]

Psychosocial Aspects of Youth Resistance Training: Training, and particularly resistance training, can have substantial influence on various emotional and psychological aspects of people of all ages.[8,29] For adults, resistance training has been shown to improve measures of self image, self esteem, body cathexis and general outlook on life,[21,52,100] and these data agree with observations made for children and adolescents.[27,71] As with physiological alterations, it is likely that the methods of manipulating program variables (i.e. volume and intensity factors, exercise selection etc.), can have a profound impact on the adaptations derived from the training program. Also of importance is good record keeping (a type of monitoring); this process should be started at the beginning of any training program. The record keeping creates a history for the child or adolescent, so that progress can be charted. These records can provide strong evidence of positive progress and reinforce positive emotional and psychological factors for the trainee.

Youth Sports and Resistance Training

A great deal of evidence indicates that stronger athletes (either relative or absolute) have distinct performance advantages in a wide variety of sports and sport related parameters.[6,12,17,18, 19,36,47,90,93,95,102] However, gaining strength, and resultant improved performance, depends upon many factors including, how volume and intensity factors are manipulated within the training program, the length of training, the degree of exercise specificity, lag time (time it takes to "transfer" strength gains to sport performance which can be several months) and the level

"Resistance training can improve strength and strength related variables among children and adolescents."

of athlete.[91,92] Considering the relationship between strength and other performance activities it is reasonable to believe that resistance training among youth would have a large potential to enhance their performance abilities. Therefore, of particular interest for this discussion is: Does resistance training effect alterations in physiology and sports performance among children, and early and late adolescents.

In addressing this question again, one must start with simple observation. It is apparent that in most sports stronger children and adolescents learn proper technique more rapidly and progress at a faster rate than do their weaker counterparts. This observation is especially apparent in strength-power sports such as gymnastics, throwing, rugby or American football. This conclusion is not based on cursory observation, but rather years of careful, detailed observation and monitoring of athletes as well as discussions with developmental coaches and sports scientists interested in this area (for example Bill Sands, Head of Biomechanics and Engineering, USOC and Kyle Pierce, Head USA weightlifting Development Center, Shreveport, LA.). Correlational studies also support these observations. For example: Carlock *et al*.[17] found strong correlations among vertical jump performance characteristics and power output, weightlifting movements (snatch and clean & jerk) and the 1 RM squat among junior weightlifters. Young *et al*.[103] found that "strength qualities" were strongly related to sprinting performance among junior track and field athletes. A longitudinal study lasting eight months leading up to the Sydney Olympic games showed that the Bosco Test (60 s explosive strength-endurance test) could predict 92% of the participants of the 2000 Olympic team and later predicted who would actually be on the floor competing and who would be named alternates.[81] Moreover, the average Olympic team athlete out performed their non-Olympic team aspirants on every physical ability test, most of which required high-levels of strength, explosive strength or strength endurance.[83] Although careful observation and correlational studies are a first step in the development of understanding "cause and effect", these observations and studies are not definitive. In order to more firmly establish cause and effects, longitudinal studies are necessary.

Longitudinal studies have also supported the observations and correlational studies. Although not all studies agree, several studies indicate that resistance training – even when using non-specific programs – can enhance performances in children and adolescents. For example: Motor performance has been shown to be markedly increased among children.[25,58,101] These studies included alterations in strength, flexibility, jumping and sprinting abilities. Using high school age (14 -18 yrs) American football players, Cahill and Griffith[14] found that resistance exercise increased maximum strength and related this to better sport performance and fewer knee injuries. Swimming times (100m) were not effected by short-term (6 weeks) non-specific isometric strength training,[1] among children and adolescents, but longer periods of dynamic strength training were shown to result in improvement.[10] Resistance training was shown to improve maximum strength of the knee flexors/extensors and improved time to peak force as well as landing mechanics among high-school female athletes. These results of resistance training may potentially improve jumping performance as well as reduce injury potential.[49] Twelve weeks of periodized resistance training among high school baseball players resulted in enhanced linear bat velocity, centre of percussion velocity, and hand velocity.[98]

Weightlifting training has been used to examine the potential effects of resistance exercise among youth in a number of studies. Among 11 and 12 yr old boys, weightlifting training produced marked increases in strength and speed-strength parameters as well as measures of cardio-respiratory fitness.[84] A series of studies carried out in the Soviet Union beginning in the 1950's and continuing through the 1980's examined the effects of weightlifting training on the physical development, physiology and performance of children and adolescents. The results of these studies have been discussed in detail by Dvorkin.[22] The data gleaned from these studies indicate that from 12 years to 22 years of age weightlifting training can produce positive alterations in body composition, cardiorespiratory variables such as resting heart rate, blood pressure and PWC(170), and increases in a variety of motor fitness parameters (e.g. jumping and sprinting) as well as weightlifting performance.

Although some of these studies were not tightly controlled, taking the observational, correlational and longitudinal data as a whole, there can be little doubt that resistance training can improve strength and strength related variables (e.g. rate of force development, power, strength-endurance, etc.) among children and adolescents. Furthermore, the data indicates that, with appropriate training, there is good reason to believe that sports performance can be positively enhanced.

- **Part 2:** Consider the following: Does resistance training expose children and adolescents to potential injury?

This question of injury potential is the primary focus of the current controversy, especially as it concerns sport. In the authors experience, and that of others[32] it is not uncommon to encounter websites such as:

www. Kidshealth.org/parent/nutrition fit/fitness/strength training.html

www.findarticles.com/p/articles/mi qn4196/is 20060706/ai n16531916

www.goswim.tv/articles comments.php?id=1025 0 16 0 C

Many parents, teachers, gym and health club staff and physicians mistakenly believe resistance training, and in particular the sports of weightlifting and powerlifting are dangerous activities, particularly for children.[43] In this context it is quite common to find resistance training and weightlifting facilities highly restricted for children and many adolescents (often restricted up to age 16-18 yrs) in North America, Great Britain and much of Europe. Within the last 10 years the authors have had many discussions/presentations, with parents, coaches, teachers, physicians etc. concerning the efficacy and safety of resistance training and in particular weightlifting. These discussions have been both in formal settings,[64-67,77, 86,87] as well as informal settings. To better understand how this controversy has arisen a brief history of the medical/scientific efforts to address resistance training including resistance training for sport is necessary. In 1983, the American Academy of Pediatrics[3] produced a position statement that has had serious negative impact for more than two decades. Much of the reasoning behind this position stand was based on injuries to the epiphysis[39,42] and musculo-skeletal system maturity. The position paper concluded that resistance training should be used with

Swimming is recommended as part of the training at this age

"The initial emphasis for children should be on general physical development that is compatible with sports specific fitness and this emphasis should continue for at least two to three years."

extreme caution and that weightlifting has a high injury rate and should be avoided by preadolescents. Sewall and Micheli[85] concurred with the American Academy of Pediatrics, recommending that any resistive training for preadolescents should be controlled and with slow movement speed and that weightlifting competition should not take place until after skeletal maturity is achieved. In contrast, Micheli[54] stated later that there was little scientific evidence regarding injury potential of preadolescents involved in resistance training and that the potential for growth plate injury may actually be less in the prepubescent than in the pubescent, because the growth plate is actually much stronger and more resistant to sheer stress in younger children than in adolescents." Furthermore, several studies and reviews of the literature, have reported positive performance, physical and physiological adaptations in children and early and late adolescents, with no associated elevated injury potential.[8,13,29,30,71]

A second position paper by the American Academy of Pediatrics[4] recommended, "Unless good data becomes available that demonstrates safety, children and adolescents should avoid the practice of weight lifting, power lifting, and body building…" *(p. 802)*. This conclusion was again stated in a 3rd position stance[5] by the American Academy of Paediatrics in 2001 *(recommendation 2, p. 1472)*. First, we must assume that the authors are referring to organized sports, as the terms weightlifting, powerlifting and bodybuilding are spelled incorrectly if referring to these sports.[57] The correct spelling is important as these sports and competitive activities are often confused with recreational or non-competitive activities. Again these statements are made with little or no supporting data and, apparently, little understanding of the activities involved. No literature specifically examining these competitive sports was cited, although several studies and reviews[2,20,23,42,55] and opinion papers[32,68] were available in 2001. Surprisingly, there is little or no evidence provided in the APA statements[3,4,5] of contact with the international or national governing bodies (in particular USA Weightlifting) of these sports or their scientific committees in order to gain additional insights into the effects of resistance training and particularly the effects of these sports on children and adolescents. Indeed, considerable research and experiential data, concerning youth weightlifting, published or translated into English, has been available since at least the 1970's and 1980's.[2,22,38,46,55,68, 73,84] Most of these studies and reviews[2,20,22,23,32,38,42, 46,55,73,84] do not appear to support the APA proscription of these sports. Similar positions largely based on the same data as the APA seem to have been taken by other organizations. A position paper by the American College of Sports Medicine was in support of weight training, but not with maximal weights,[28] although the term "maximal weights" was not well defined. This statement, by implication, would constitute a position against resistance training as part of sports training or competitive weightlifting for children and adolescents up to approximately 16 years old (Tanner Stage V). An exhaustive literature review and position paper by the National Strength and Conditioning Association[29] supported children's resistive training if programs are appropriate and supervised by trained professionals. However, they failed to specifically address competitive sports including weightlifting and powerlifting, but do recommend against "inter-individual competition, effectively precluding involvement in the sport. BASES (British Association of Sport and Exercise Sciences)[8] have produced a document in which resistance training recommendations for various age/developmental levels (children, early and late adolescence) are made. Although, BASES (8) do make some very sound recommendations it is unclear as to their stance on using resistance training for sports and indeed appear to warn against sport training, including weightlifting and powerlifting for children and early adolescents.

However, an important question arises – *Is there objective evidence substantiating these ideas?*

Reviews and studies of injury type and injury rates associated with weight training (and weightlifting) indicate that rates of injury are not excessive and the incidence of injury is less than those associated with sports such as American football, basketball, gymnastics, football or rugby.[42,89] Although serious injury can occur they are uncommon.[42,51,72,89] Injuries that may occur, are generally the result of poor technique, excessive loading, fatigued training, poorly designed equipment, ready access to the equipment, or above all, lack of qualified supervision.[51,89]

These problems appear to be essentially the same as those encountered by adults.

Weightlifting: A case in point

Although most medical/scientific groups dealing with children and adolescents are now aware of the potential benefits of resistance training, the controversial aspects are exacerbated when dealing with training for, particularly weightlifting.[68] It is arguable that weightlifting has come under more scrutiny and has been in the past more controversial than any other aspect of resistance training for young people. For example: the sport of weightlifting (and generally the use of ballistic movements such as weightlifting movements and plyometric exercises) have been criticized by individuals in opinion articles as producing excessive injury rates in both young and older athletes,[11] Although, injuries in weightlifting and related activities can occur, the incidence of injury appears to be relatively low and severe injury is uncommon.[42,44] Indeed, it can be argued that weightlifting training and related activities may in fact reduce injury potential for some activities and sports.[44,89]

This controversy exists even though information is available indicating that, under proper supervision, these activities are no more and are usually less injurious to children or adolescents than are other sports.[32] Dvorkin[22] indicated that weightlifting training resulted in positive improvements in body composition, cardio-respiratory characteristics and general well-being. Furthermore, there was no indication that weightlifting training "stunted" growth among children and adolescents. These studies, reported by Dvorkin are particularly compelling as in many cases large groups of adolescents were tracked continuously from age 13 to age 19 years and compared to control groups of non-exercising peers or similar age groups involved in track and field.

In addition, the weightlifting injury rate appears to be even lower than other forms of resistance training.[42] More recently, Pierce, Byrd, and Stone[68] reported no days of training lost from injuries incurred in weightlifting over a period of a year's competition and training by 70 female and male children ranging in age from 7 to 16 years (mean age: 15 girls = 12.3 ± 2.6, 55 boys = 11.6 ± 2.0 yrs). The young lifters were allowed to perform maximal and near-maximal lifts in competition as long as correct technique was maintained. Both the males and females increased strength as measured by weightlifting performance. A more detailed study[13] of 3 females (13.7 ± 1.2 y) and 8 males (12.5 ± 1.6 y) across a year's competition (534 competition lifts) produced similar results. Both boys and girls showed marked weightlifting performance improvement and no injuries requiring medical attention or loss of training time.[13] The conclusion drawn from these observations was that weightlifting is safer than is generally believed, especially if training and competition are appropriate for the age group and are well supervised. The authors of these papers[13,68] emphasized that these results must be viewed in light of the scientific approach to training and competition with these children. Only under these conditions do the authors' suggest that resistive training or weightlifting is appropriate for children, a factor that should be true for all sports. Inappropriate training programs and competition format for any sport may increase the potential for injury.

According to Balyi and Hamilton[7] consideration of developmental factors are absolutely essential when training children/adolescents. They propose that eight to twelve years of training is necessary for a talented athlete to reach elite levels. To some extent this progression can be noted in American football and basketball with three years participation in middle school, four years in high school, and generally four to five years in college before playing professional sports. Unfortunately, well-meaning but overzealous coaches and parents often try to hurry this process in weightlifting (and many other sports).

Dr. Tamás Aján, President of the International Weightlifting Federation and Member of the International Olympic Committee, and Lazar Baroga state in their book Weightlifting: Fitness for all Sports[2] – "initial stage of training" for weightlifting should take place between the ages of 11 to 16. Starting at the ages of 11 to 12, they suggest however, the aim of training should focus on general physical preparation and that specialized training should not comprise more than 40% of the total training plan. This plan includes a variety of dynamic exercises and exercises to assist in the development of movement habits and characteristics necessary for sport development. Participation in activities associated with track and field and basic gymnastics along with sporting games such as basketball, volleyball, and

"Training can be a positive force in a young person's life."

swimming are recommended as part of the training at this age, along with exercises with use of free weight exercise aimed at general strengthening. These authors also suggest that the aims and objectives in the second year of training (ages 12-13) should be on general physical development (50%) and stress "correct habits of execution" when learning the technique of the competition exercises. Specialized training should be added gradually in subsequent years, keeping in mind that for the greatest results over the long-term, each phase of training should be built on the previous phase.

In Bulgaria the starting age for weightlifting training decreased an average of 2 years from 1983 to 1993. In this small country that has been highly successful in weightlifting, the recommended age to begin training is ten years old.[20] The training plan for these young athletes was well integrated with their physical development and each phase of training was built on the previous phase. Importantly, a considerable amount of time was spent on general physical development in earlier years with specialized training added gradually in successive years. It must be remembered that many, and likely, most of the athletes participating in many Eastern European weightlifting programs were selected, based primarily on genetic potential, through a comprehensive talent identification search.[20]

The initial emphasis for children starting at these recommended ages should be on general physical development that is compatible with sports specific fitness and this emphasis should continue for at least two to three years.[2,53] For example: weightlifting developmental fitness for children would include considerable training dealing with basic body strengthening (e.g. weight-training, gymnastics, tumbling), strength-endurance factors and enhancing cardio-respiratory ability, mobility and range of motion. However, it should be noted that emphasis on cardiovascular endurance that includes typical aerobic exercise (e.g. long distance running, swimming, cycling, etc.) should be limited or avoided. This limitation is necessary because, typical aerobic exercise has been shown to compromise adaptation to strength and high power training.

The use of these concepts for training children and adolescents for weightlifting should be considered for training in other sports as well.

Guidelines for Training/Coaching Children and Adolescents

When training adolescents and particularly children there are several questions that must be addressed before beginning the training process:

1. Is the child psychologically and physcially ready to participate?

From a psychological perspective it is important that children and adolescents be encouraged to participate in physical activity that challenges and provides satisfaction and enjoyment. For children especially, the tasks must be rewarding and "fun". The encouragement provided by coaches/instructors should promote self-improvement and satisfaction along with good performances. At the same time care should be taken in helping the children (and adolescents) deal with poor performances or not always reaching goals. This means that the coach/instructor must help the young person develop realistic expectations and realize that it often takes a considerable amount of time to learn new skills or change physiology/psychology (e.g. get fit). Pressure by coaches and instructors to exceed previous goals must be weighed against the potential negative effects on some young people who may be vulnerable psychologically. Often there is a fine line between "pressure" and encouragement", usually painted with the brush of fun.

Level of emotional and intellectual maturity is important to recognise in children (and adolescents) before starting a training program. If the child is unable to understand what is being asked of them in terms of training, or they cannot handle the rigors and

discipline of the training program emotionally, then the coach must recognise this aspect. Correction of this type of problem may entail redirecting the young person into other types of less demanding activities.

There is evidence that appropriate physical training can promote psychological well-being and character development.[15,25] Coaches/instructors can consider linking aspects of training to other facets of life and that these difficult parts of life can be overcome with similar diligence. Thus, it can be argued that training, including training for sport, can be a positive force in the young person's life. Sport training has long been recognized as a primary tool for the inculcation of important societal values and "life in microcosm" such that participants are offered opportunities to practice many of our most highly prized character traits.

From a physical standpoint, not all children are ready to perform similar resistance training tasks. For children, Tanner staging, by medical personnel, could be performed – however, realistically this process is time consuming, personally invasive and expensive. So, again it falls upon the shoulders of the coach/instructor to make a decision concerning the appropriateness of resistance training and the type of program that would be most useful. Conceptually, the coach/instructor must be able to appropriately distinguish between chronological age and physiological age (Tanner stage) as well as recognise differences in emotional and psychological maturity.

2. Does the resistance training equipment fit the child?

While the quality of instruction offered by the coach/instructor is likely the major factor in whether children and adolescents achieve "success" as a result of resistance training, the equipment also can have considerable impact. All equipment should be in working order. The equipment should be regularly inspected. Most machines are made for adults and are not easily adjusted for smaller bodies. Although, some companies make child friendly equipment, the use of free weights should be considered as the major mode of training for a number of reasons including: First, there is evidence that free weights (barbells, dumbbells, associated racks and benches) can produce superior results, especially in terms of transfer of training effect.[91] Free weights allow the use of multi-joint exercises (such as squats and pulling movements) that are quite similar to multi-joint activities of many sports and even daily living. These large muscle mass, multi-joint exercises are metabolically more taxing and can potentially affect body composition alterations better than smaller muscle mass exercises. Second, free weights fit any body size and to enhance this aspect, smaller barbells (length and diameter) are available. As a result of the equipment fitting the child, the performance of a number of exercises not normally available on machines is possible. This type of adaptability of free weights allows a large variety of exercises to be performed periodically and this aspect may help to reduce training monotony and keep the child/adolescent interested and looking forward to future training sessions.

3. Does the child and the supervisor understand proper lifting technique for every exercise in the program?

Appropriate technique is important for several reasons including:

• Poor technique will limit physiological adaptations and gains in performance, thus progress will stagnate

• In a sports context, poor technique can severely limit the "transferability" of the exercise. So, the potential for enhanced gains in sports performance activities is reduced.

• Poor technique increases the potential for injury

For these reasons development of good technique is a necessity. It is also paramount that proper technique be taught initially in any training program. This means that the coach/instructor needs to understand technique and know how to teach it properly. This early concentration on technique is especially important for large muscle mass multi-joint exercises. Technique, poor or otherwise, developed initially and used for long periods (i.e. several years) may be difficult if not impossible to change later. Thus the establishment of good technique from the start of a training program is paramount to safety, success and enjoyment. In this context lack of sufficient strength will limit technique acquisition.

4. Does the child and the supervisor understand safety standards, correct spotting techniques and when they should be used?

Although uncommon compared to most sports, weight training can produce injuries, including severe injuries. Most of the injuries produced in training

"Weight training exercises that have a large skill-based component, would appear to facilitate enhanced development across a wide spectrum of performances."

appear to occur as a result of poor technique or lack of adherence to simple safety procedures including reasonable supervision.[8,29,51,71] The potential for injury can be reduced by implementing some "common sense" safety guidelines. These guidelines include:

- Education for all participants as to good safety procedures
- In case of injury, appropriate emergency assistance procedures should be in place and every supervisor and participant should be aware of these procedures
- Make sure the training area is kept clean, neat and that no obstacles are present
- Make sure that all participants warm-up before each training session
- Allow participants to have ready access to fluids during and after training
- Make sure that participants understand proper breathing techniques and that these techniques may reduce injury
- Although most strength training exercises do not require spotting, some do - particularly squats and bench press exercises. Make sure that proper spotting techniques are always used. In weightlifting movements, the athlete should be taught, how to avoid injury during a missed lift (i.e. how to miss correctly)
- Make sure that each session is properly supervised.

5. What resistance training program should the child follow?

Many strength training programs have been suggested for use by children[8,29] and are centred around higher repetitions (10 -15 rep/set). However, this type of training for any age should be initiated only after good technique has been established. In our opinion technique is best established with one-on-one supervision and by performing repetitions one at a time with feedback from the coach/instructor after each repetition. If proper technique is not being used –corrections should be made before going on to the next repetition. This one repetition at a time approach is especially important in learning the technique of complex multi-joint movements such as jumping, snatches or cleans. Only after good technique is established for each exercise should multiple repetitions be allowed per set. Otherwise, the multiple repetition approach simply promotes poor technique development.

After learning proper technique the type of program used depends on the age and goals of the child. In dealing with young children (8-10 yrs) early training should use higher repetitions per set, use a training session frequency of 2 - 3 days/wk and include a variety of upper and lower body exercises. While not always appropriate in a sport context, allowing the children/adolescents to take part in planning the program (e.g. pick out some exercises) may improve motivation and adherence to the program. Initially training may use one set per exercise, however training should rapidly progress towards a periodized training program and the use multiple sets.[29,63] The periodization process includes heavy and light days, "unload" weeks and active rest periods which can enhance recovery. When using strength training in a sport context, this aspect of training must be properly integrated into the overall training process otherwise optimum gains and performance improvements may stagnate and the potential for injury and overtraining will increase.[69,89]

6. Does the supervisor understand the potential results?

It is obvious from the many studies of various types of training programs that not all programs produce the same adaptations.[69,91] Essentially adherence to the training program directs the psychological, physiological and performance adaptations (or lack of adaptations). Considering this concept of "direction", perhaps the most important element in the entire training process is the coach/instructors knowledge of potential outcome. The coach/instructor is responsible for creating and implementing the training program. If the coach/instructor does not have sufficient knowledge of the potential training process outcomes, then training can become a relatively random process with an infinite number of possible qualitative outcomes.

A scientific background is necessary to properly construct a training program. In this respect, becoming a good coach/instructor is much like becoming a good medical doctor. A good physician will strive to obtain a science background so that they can better practice the art of medicine – likewise a good coach will obtain a good scientific background to better practice the art of coaching. A scientific background provides a basis to direct training in a more purposeful manner toward specific goals. Indeed, the scientific background enables the coach to make choices about training (and competition) that they might not realize would be possible otherwise. Part of

this background should also entail understanding the differences between training children, adolescent and adults.

7. Are there differences for training girls?

Currently, there is little doubt as to the popularity of all forms of resistance training among women and girls. Although, resistance training, particularly for sport, was once considered as "for men only" this is clearly no longer the case. Women and girls have broken with tradition and cultural morays, and now whole heartedly engage in various strength training activities, including bodybuilding and the strength/power sports powerlifting and weightlifting.

As previously stated, boys (< 13 yrs) and girls (< 12 yrs) can expect increased levels of maximum strength, power and strength-endurance as a result of resistance training, with only minor sex effects on absolute or relative measures of strength and associated variables. However, in adolescents (up to 18 yrs) the gains in maximum strength and related characteristics can be greater than in children and the absolute gains do reflect sex differences.

Adaptations to resistance training in adolescents and young women (and by assumption female children), are largely similar to men. However, genetic and hormonal differences appear to create enough variance to warrant alterations in the training of adolescent women in order to concentrate on specific mechano-physiological differences. For example: Androgens, in particular testosterone, influence a variety of non-sex characteristic linked male-female physiological differences such as lean body mass, maximum strength, peak rate of force development and power output.[41,88] Indeed, higher testosterone concentrations not only appear to be related to strength and explosive strength performances between men and women, but also may explain intra-sex differences.[16] Furthermore, differences in resting testosterone concentrations may also affect differences in the rate of adaptation, thus women or girls with higher concentrations may progress at a faster rate.[41,88]

Young women have less relative body mass in their upper body compared to young men. This difference is also reflected in lower absolute and relative strength measures for women compared to men.[92,96] This upper body difference may necessitate additional upper body exercise during certain phases of training or for specific activities in which the upper body is primarily engaged (such as throwing). An important performance and injury consideration is that the upper body is the link between many lower body activities and the performance outcome, for example squats. A weak upper body may limit squatting ability as the necessary support for holding the bar along the shoulder girdle is reduced.

Maximum strength refers to the greatest force that can be generated under a given set of circumstances and explosive strength deals with rate of force development.[91] Rate of force development (explosive strength) and power output among women are lower than men[34,96] and this difference may be partially accounted for by androgen differences.[16] However, many sports depend upon not only maximum strength but explosiveness (high rates of force development) and high power outputs. In order to succeed and produce reasonable performances in these "explosive strength sports" it would be desirable to enhance maximum rates of force development and peak power outputs. Thus, young women, who become involved in explosive activities, may want to concentrate their training not only on gaining maximum strength but also on power-oriented explosive movements. For example: while maximum strength is certainly a major factor in the success of weightlifters,[93] "explosiveness" is also a key[94]; therefore much of the training for weightlifting is explosive in nature. Although young women's peak power output during the snatch and clean & jerk are about 65% of men's, women have lifted more than twice their body mass in the clean & jerk. Indeed, a double body weight clean and jerk was achieved by two 16 yr old girls at the Junior World Weightlifting Championships in 2005. Similar arguments can be made for other sports requiring both high levels of maximum strength and explosive strength.

There are also sex-related differences in force absorption, active joint stabilization and biomechanics that are associated with a relatively greater potential for injury. This is especially apparent in anterior cruciate ligament injuries. Strength training as well as specific neuromuscular training (altering landing patterns after jumping) have been show to reduce these sex-related differences in injury potential among young women.[45,53]

As with boys, the differences in adaptation to training also depend upon a number of psycho-physiological factors such as chronological versus physiological age, physical and mental maturity and environmental/cultural conditions such as current involvement with sport, prior participation in activities that develop coordination, agility, balance and flexibility. Generally, the training programs for girls and young women should follow the same process as those for boys and young men. However, in some instances, particularly in terms of training for sport, specific differences should be incorporated; these include more emphasis on upper body strength, on explosiveness and on factors associated with jumping and landing.

Summary and Recommendations

The popularity and use of resistance training, particularly weight training, appears to be increasing among children, early and late adolescents. Furthermore, youth participation in the sport of weightlifting and the use of weightlifting methods as part of training for sports such as American football, rugby, football and basketball appear to be increasing as well. This popularity is evident by the proliferation of both lay and scientific articles, specialized magazines and publications dedicated to various forms of resistance training and simple observation of gymnasiums, and sports training halls. The use of resistance training appears to be on the increase despite the poorly supported position statements, anecdotal reports and conjecture regarding potential injury.

There is little doubt that among children and adolescents resistance training can produce marked increases in strength and power, as well as physiological parameters associated with both health and performance. However, the rise in the number of children and adolescents (8-18 years) using some form of resistance training is not without controversy. Although, there are still individuals who insist that training with free weights and particularly the sport of

weightlifting should be avoided until a person is fully developed, there is little objective evidence supporting such a position.

As with any physical activity or sport, resistance training should be carried out with reasonable safety measures in place. In normal supervised environments the potential for injury is remarkably low. It is clear that the potential for injury is an issue that requires ongoing scientific study. The need to clarify anecdotal reports and conjecture regarding injury is essential. There is no doubt that resistance training can be appropriate for children who are supervised in training and competition by well-qualified professionals. Well qualified implies an understanding of the sport sciences, especially those related to growth and maturation, with the ability and drive to apply this knowledge. Finally, in support of resistance training for children and adolescents involved in sport, motivation would be minimal without some form of competition in which the role of the resistance training is clearly defined.

To some extent, the lack of data is the issue; the alarmist negative response by well-meaning physicians, educators and coaches has done an immeasurable disservice to resistance training and the use of resistance training in sport. Indeed the sport of weightlifting is often condemned by the uninformed as being particularly injurious. However, objective data indicates that resistance training, including the integration of resistance training into sports training and including the sport of weightlifting is actually considerably safer than is generally believed. This is especially true if training and competition are appropriate for the age group and properly supervised.[13,68]

Based on available evidence and review of literature, the following should be expected for youth resistance training:

• Resistance training can increase the strength of children, early and late adolescents. Increases in strength and related characteristics (e.g. power) during childhood are primarily related to adaptations of the nervous system with hormonal and hypertrophy adaptations becoming increasing important with growth and maturation. Training may also produce beneficial psychosocial alterations such as improved self efficacy, body cathexis and feeling of well being.

• Weight training exercises that have a large skill-based component, would appear to facilitate enhanced development across a wide spectrum of performances. Due to the complex motor control/force characteristics required of complex movements[34,91] the use of large muscle mass, multi-joint exercises likely facilitates both muscle development and superior neural activation patterns.

• While injuries can occur, resistance training including the sports of weightlifting and powerlifting do not result in excessive injury rates, particularly if the activities are well supervised by knowledgeable trainers and coaches.

- It should be noted that several questionable practices that can accompany sport training may inhibit adaptation to resistance training protocols and may reduce strength (and related) performance. Of special note is: unsafe weight-loss techniques, particularly through means of dehydration should not be permitted. This would include but not be limited to use of sauna, body wraps, and reducing the intake of fluids.

• Educators and Coaches of youth (up to and including 18 years of age) should be required to demonstrate, through testing, knowledge of safety and proficiency in the sports sciences including the disciplines of physiology, biomechanics, psychology, human development and motor learning, particularly as they relate to resistance training.

• Coaches who fail to follow these recommendations should be censured, suspended, or banned.

We would hope that international and national sports governing bodies will institute long-term programs that focus not only upon the elite athlete but also the development of potential advanced and elite athletes. A first step should be the recognition of the importance of strength and conditioning in the overall developmental process.

There is a need for national sports bodies to develop an evidence-based framework for athlete development that addresses the need for strength & conditioning programmes for children and youths that can be implemented through an integrated player pathway. This programme should reflect best practice in providing a comprehensive education for athletes, coaches and parents in developing an individuals physical capacity. This program should also aim to develop a high level of movement literacy in younger ages, develop sports specific skills, including the development of gymnastic and weight-training exercise techniques, between the ages of 9-12, and train and deploy high quality strength coaches and weightlifting coaches to further develop technique and strength in children across a range of sports after 12 years of age.

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