The Impact of Resistance Training on High School Athletes: A Synthesis of the Research Literature

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Abstract

This synthesis highlights the impact that resistance training has on adolescent high school athletes. More specifically, the review of literature examined the appropriate methodologies in programming for athletes and coaches, the physiological responses experienced by the athlete, and the sport-specific training outcomes experienced as a result. The synthesis used eleven peer-reviewed, scholarly articles that researched resistance training effects on adolescent athletes. Results demonstrated that most of adaptation that occurs because of program participation is primarily neuromuscular. Physiological adaptations in size will occur over a larger extent of time due to both training response and maturity. Intensity and complexity of desired movements should correlate to the athlete's experience and performance levels at the time of initial programming. Due to the wide variety of sports and activities that experienced sport-specific skill improvement from training administration, coaches and athletes looking to improve performance should explore possible means of program implementation.

Chapter 1 – Introduction

In the realm of athletics, coaches and athletes are constantly looking for “an edge” in the quest to display excellence in his or her craft. Many professionals believe that improving performance can be achieved through demonstrating more effective and efficient sport-specific skills and movements. For many athletes, these improvements can be achieved to some extend through participation in resistance training programs. There seems to be an increase in the number of young athletes that are engaging in resistance training programs in a scholastic program, community fitness facilities, or sport-related training centers. These athletes are using programs and facilities with the goal of improving their athletic performance and reducing their risk of injury throughout the athletic season (Faigenbaum & Myer, 2010).

Resistance Training as a whole can promote many positive physiological and psychological benefits when administered properly. Many times, young athletes who engage in resistance training will experience improvements in their self-esteem and confidence. During athletic contests, these improvements in self-efficacy can also translate to gaining the mental edge, which could mean the difference between performing at the athlete’s highest level or giving a sub-par performance (Benjamin & Glow, 2003). Once an athlete experiences maturity with movement patterns included in resistance training, setting new personal records in the gym can result in a continued increase in confidence. The constant aim to perform at a higher level in resistance training compared to the previous training session serves as competitive moments in the off-season, as athletes in the gym will often engage in self-competition to improve and increase their performance.

While the recent boom in the field of strength and conditioning possesses many positive contributions to athletics at various ages and levels, there still remains a large amount of pushback from coaches and other sport-related individuals who question strength training's efficacy and overall benefits (Mannie, 2014). Not every coach or athlete who engages in the administration or supervision of a resistance training program is deemed an "expert" in the field and poorly designed programs can do more harm than good for young athletes. Understanding proper physiological parameters and growth patterns will not only ensure a positive outcome in the productivity of the program, but will also help to promote a physically and emotionally safe environment for students who are looking to utilize these techniques in their quest for improved athletic performance. These parameters include selection of an appropriate total volume for the workouts, demonstrated proficiency in all complex movements before the load progresses, proper warm-up and cool-down protocols, and ensuring safety through examining facilities and equipment prior to engagement (Council, 2008). When proper administration and supervision of programs is effectively demonstrated, current literature suggests that the positive effects of adolescent engagement in resistance training far out-weigh the negative effects. The increase in the level of competition in athletics across all age groups confirms the notion that effort put forth in the weight room is now a mandatory component of any young athlete's journey towards achieving athletic superiority.

Statement of the Problem

For individual athletes and coaches, finding the competitive edge in their respective field can serve as the motivation for many of the decisions made and actions that are taken. Regarding the importance of resistance training on the hunt for the competitive edge, muscular power has been deemed the defining physical attribute of athletes that hold the status of "elite" in many team sports (Marius Meylan, Cronin, Hopkins, & Oliver. 2014). Weight training is also necessary for sport-specific injury prevention. Youth athletes engaging in resistance training possess greater muscle size when compared to untrained youth athletes. The high levels of stress placed upon the tendons of adolescent athletes suggests a need for exercises that promote the mechanical strength of the tendons, which will help meet the demands that are placed on the tendon by the muscle contractions throughout elite-level athletic competition (Mersmann, Charcharis, Bohn, Arampatzis. 2017). To better facilitate performance outcomes, it is necessary to educate professionals in the field regarding appropriate guidelines for training adolescent athletes. Coaches and prescribers need background knowledge on a variety of training methods to address the many different sport-specific demands placed on an athlete's body, as well as the physiological responses that occur as a result.

Purpose of the Synthesis

The purpose of this synthesis is to review the literature on the impact of resistance training on adolescent high school aged athletes. The goal is to identify the proper methodologies and caveats to address the sport-specific demands on an athlete, as well as develop sound reasoning to back the idea of high school athletes engaging in a structured resistance training program. The following research questions will serve as the central focus for this study:

1. What methods of training are best utilized for adolescent and young athletes?
2. Which sports are impacted most by resistance training?
3. What are the strengths/weaknesses/caveats (cautions) regarding resistance training for adolescent athletes?
4. What are the best practices (proper implementation /administration) for coaches regarding the use of resistance training for adolescent athletes?

Operational Definitions

The following terms will be defined for the purpose of this synthesis project:

1. Resistance Training - a specialized method of conditioning that involves the progressive use of a wide range of resistive loads, including body mass, and a variety of training modalities (e.g., machine-based training, free weight training, plyometric training, complex training, and functional training) designed to enhance muscular fitness and athletic performance (Behm et al., 2008).
2. Adolescent – period of life beginning with the onset of physiologically normal puberty, and ending when an adult identity and behavior are accepted. Roughly between the ages of 10 and 19 years (Canadian Paediatric Society, 2008).
3. Strength - the maximum force that can be developed in a muscle or group of muscles during a single maximal contraction (Kraemer & Fry, 1995)
4. Power – equivalent to energy output per unit of time, or rate of doing work (Sapega & Drillins, 1983).
5. Plyometric Training - a series of explosive bodyweight resistance exercises using the stretch-shortening cycle of the muscle fiber to enhance physical capacities, such as speed, strength, and power (Booth, 2016).
6. Hypertrophy - a condition involving enlargement of muscles. May be induced pathologically or non-pathologically, as in weight training (Jonas, 2005)

Assumptions

The assumptions used in the synthesis are as follows:

1. The literature review was exhaustive and comprehensive.
2. All participants in the studies completed tests and training programs to the best of their abilities.

3. Participants were an appropriate reflection of the population under study.
4. Results reported were reflective of the population under study.

Delimitations

The following delimitations were used for the synthesis:

1. All participants in this study were between the ages of 10 and 19 years.
2. All literature selected was peer-reviewed and published between years 2008 and 2018.
3. All subjects were members of a scholastic sport team or an outside athletic organization.

Limitations

The following limitations were existent throughout the course of the study:

1. Potentially limited existing data due to research on student athletes between the ages of 10 and 19 years.
2. Differences in knowledge and perceived importance of resistance training may exist due to past experiences, available coaches and resources.
3. The overall status of nutrition, rest, and other potential physical activity outlets that may be taking place throughout the course of the study.
4. Athlete's motivation level at the time of the completed training session.
5. Quality of equipment and facilities available for resistance training sessions.

Chapter 2 – Methods

The purpose of this chapter is to review the methods that were used to investigate the impact that resistance training has on adolescent or high school aged athletes. The articles that were selected for this study were discovered using the EBSCO Host online database from The College at Brockport Drake Memorial Library. Within the EBSCO Host database, the Academic Search Complete and SPORTDiscus search engines were selected. The criteria that was set for the selected articles were to be peer reviewed, full-text articles that were published between 2008 and the time of this synthesis. Eleven articles were selected using these databases to aid in supporting the study's purpose.

The articles and studies selected for the critical mass were found using a variety of key words that were relative to the research topic and research questions. The keywords that were identified were: *Resistance training, strength training, weight training, resistance exercise, weightlifting, adolescents, teenager, young adults, teen, youth, athlete, athletics and sports.* The key words that were just stated were used in different combinations to serve as the generator for potential articles that met the research criteria. The combinations included: *1. Resistance training AND adolescent AND athlete, 2. Strength training AND adolescent AND athlete, 3. Weight training AND adolescents AND athletics, 4. Resistance training AND youth AND athletics, 5. Resistance training AND young adults AND sports,* and one final search that included *6. Resistance training OR strength training OR weight training OR resistance exercise AND adolescents OR teenager OR young adult OR teen OR youth.*

The first search only produced ten hits. Of those ten hits, four of the selected articles for the critical mass were acquired. The second search produced 40 hits, where an additional article was selected and added to the study. In the third search, eleven articles were produced and there were no new additions to the critical mass. The fourth search saw only five results, with no new additions to the critical mass once again. The fifth search produced 20 results, with no new additions to the mass. The final search produced 237 total hits. With a productive increase experienced, the hits were assessed and narrowed down to eleven articles that fully met the criteria for the study. It was important to read through the many articles and establish that the research fit the criteria for the research questions, including subject ages that stayed within the study's delimitations. Some of the articles featured subjects that did not fit the predetermined age requirements for the study. Many of the articles that surfaced from the search focused on how the effects of resistance training could be used to combat childhood obesity in sedentary adolescents. These articles were excluded, as the articles needed to be geared towards the effects that resistance training has on athletes. Many of the articles also included potential results that stemmed from proper dieting and supplementation practices. These nutritional concepts exceeded the scope of the study.

Of the eleven articles that were selected for the study, the total number of participants that were used for the overall critical mass was 324 participants. This included 223 males and 101 females within the eleven articles. Included in the critical mass were 8 quantitative studies, two narrative reviews of other research samples, and a meta-analysis.

Four of the selected articles were provided by *Pediatric Exercise Science* (Marius Meylan et al., 2014, Behringer, vom Heede, Matthews, & Mester, 2011, Behringer, Neuerburg, Matthews, & Mester, 2013, Legerlotz, Marzilger, Bohn, & Arampatzis, 2016). Two more of the articles were from the *Journal of Sport Science* (Sander, Keiner, Wirth, & Schmidtbleicher, 2013, Low, Harsley, Shaw, & Peart, 2015), with an additional article originating from the *Journal of Applied Sport Sciences* (Mohamed, Rahim, & Shaharudin, 2017). Three more articles were retrieved from the Athletic Trainers Association (Van de Velde, De Mey, Maenhout, Calders, & Cools, 2011), Sports Medicine (Cormie, McGuigan, & Newton, 2011), and the *Journal of Coaching Science* (Bishop, Smith, & Gee, 2016) respectively.

The proficiency level of the athletes selected for the critical mass ranged from novice level in middle school to elite youth athletes from affiliates outside of scholastic athletic programs. The sports that were represented in the selected studies were soccer, badminton, team handball, tennis, swimming, and Olympic weightlifting (snatch and clean and jerk exercises). Each of the athletes within the research critical mass engaged in some variety of resistance training protocol throughout the duration of their respective study.

Chapter 3 – Review of Literature

The purpose of this chapter is to review the literature that examines the impact of resistance training on adolescent athletes. Specifically, this chapter will go in-depth on the different phases of completing a training program for adolescents. This will include the preparation phase of the program, experiences during the execution of the program, and the benefits or outcomes that are experienced upon completion. The specific topics being discussed include: Appropriate Methodologies in Programming, Physiological Response, and Sport-Specific Training Outcomes.

Appropriate Methodologies in Programming

During the preparation phase of programming a resistance training (RT) regimen, there are specific characteristics to the training that should be considered by prescribers, coaches, and the athletes (if self-administered). These characteristics include proper goal orientation, the sport-specific demands on the athlete, and ensuring that the program always remains developmentally appropriate for the athlete.

A review constructed by Cormie, McGuigan, and Newton (2011) looked at previous findings that they collected regarding the body's ability to generate maximal power and research examples of training program development that focus on maximal power enhancement. The authors conducted a literature search using the search terms that included: 'maximal power', 'muscular power', 'power training', and 'ballistic training'. Upon retrieving articles from their search, the studies were reviewed for any potential factors that may attribute to maximal power adaptation through the utilization of training programs. Their research confirmed a major role of strength in terms of power production, suggesting that increasing strength will correlate to an increase in power in most novice lifters. Many adolescent athletes will claim the role of a novice lifter due to their inexperience with RT programs. The research also supports the idea that movement pattern specificity should be considered, meaning that the selection of exercises for a program can influence the degree of improved performance. For example, early stages of an athlete's career should consist of RT exclusively, while trained athletes may look to utilize ballistic training, plyometric training, and Olympic weight lifting as modalities for improvement. Load specificity is another important consideration for prescribers. Heavy loads in a program may improve performance in high power-producing sports, such as football, rugby, or wrestling. Light loads are recommended for sports that consist of high power needs against light external loads, such as sprinting, jumping, or striking skills. Prescribers should always consider the client. During the goal orientation process, the athlete's window of adaptation (level of potential to see significant increases in performance relative to status) should be identified when the parameters of the program are being placed. The research also supports the claim that a multi-faceted approach to programming should be integrated for the greatest long-term improvements, which stems from variation within the specificity of the program.

A meta-analysis constructed by Behringer, vom Heede, Matthews, and Mester (2011) was created to evaluate if RT is effective in motor performance skill improvement in children and adolescents and determine if there are any parameters of programs that may impact the client or the program. The article further facilitates the conception that there is a negative correlation between age and skills selected for improvement, meaning that younger participants in RT programs will experience the greatest improvement. These larger improvements in children are potentially due to the higher degree of neural adaptation, as neuromuscular characteristics play a large role in movement optimization.

The role of motor skills in sport suggests a positive transfer of resistance training effects to athletic performance for children and adolescents. The meta-analysis suggested a positive correlation between motor performance skills and mean intensity of applied training stimulus. This could imply that the minimal load to elicit a response should be at least 50% of the participant's one repetition maximum of a desired exercise or movement. With that said, program intensity should be considered when coaches or professionals are prescribing resistance training programs to children or adolescents.

A study conducted by Marius Meylan, Cronin, Hopkins, and Oliver (2014) sought to identify potential relationships between adjusting measures of strength and power in youth athletes and their increases in power production and maturation. A group of 74 males between the ages of 11 and 15 were tested on the ballistic concentric squat exercise by means of a supine squat machine. When tested, movement completion was conducted at five different randomized percentages of the subject's one repetition max. These percentages consisted of 80%, 100%, 120%, 140%, and 160%. The velocity, the mean force, and the power of the squat movements were all calculated. A caveat resulting from the research for future professionals is to caution any comparisons between athletes at different maturity stages, as differences in strength, power, and velocity may be the result of body mass adjustment that stems from the maturation process. These increases in mass that are accompanied by maturation equate to an increase in muscle cross-sectional area. Since muscle fiber quantity can positively correlate to strength, this mass increase will also positively correlate to force production. To ensure that prescriptions are remaining developmentally appropriate for the athletes, professionals should be conscious of the many qualitative factors that promote performance differences in young athletes at different maturity stages. These factors include motor unit recruitment rate, type II muscle fiber hypertrophy, and rate of testosterone production. When guiding adolescent athletes through training, moments of growth spurts during the maturation process may add difficulty to performance skills. Factors include differential timing in limb and torso development and a hindered ability in synchronized activation of motor units and muscular coordination. This concept is referred to as "adolescent awkwardness".

Physiological Response

A narrative review was completed by Legerlotz, Marzilger, Bohn, and Arampatzis (2016) to further understand the mechanisms affected by resistance training during youth. This included injury risk of involved tissues, as well as the morphological and structure changes that occur from RT program participation. The current literature reviewed suggests that RT programs have the capability of providing gains in strength that are largely a result of neural adaptation. While these results are prevalent, they are usually not the sole product of neural change, as muscular parameters will also adapt throughout the process of the program thanks to both training response and maturation. The literature supports that while the increase in muscle force and growth can lead to higher strains in tendinous tissue, effectively administering training programs can reduce the risk of injury by preventing potential imbalances with muscles and tendons. These tendons possess morphological and material properties that have the ability to positively respond to training stimuli. The review also supports the concept that effective training can additionally reduce injury risk by enhancing skeletal health, as adaptation of bone density occurs due to the stress applied from resistance training where structural damage does not occur. The review cautions readers that usually the parameters of training programs are not set for a long enough time to properly assess complete physiological adaptation.

A 2-year study was conducted by Sander, Keiner, Wirth, and Schmidtbleicher (2013) that sought to examine the influence of strength training that utilizes periodization principles on power performance. A total of 134 elite youth soccer players from two professional-affiliated training centers in Germany were gathered for the study and broken up to three subdivisions based on age (13, 15, 17). The subjects completed a resistance training program in conjunction with their current soccer training programs. Those athletes were tested on the 30 meter sprint and their one repetition max of the back squat and front squat exercise. The results for significance were compared to a control group that did not participate in resistance training. The following exercises were selected for the training program administered in the study: front squat, back squat, bench press, deadlift, neck presses, and trunk exercises. Of the mixed age groups within the study (13, 15, 17), the youngest participants were able to demonstrate the greatest increases in power development from the program. This further proves the window of adaptation principle. The length of the experiment helped to support the ideas that the improvements exhibited were very minimally impacted by neuromuscular adaptation that occurs early onset in most training programs. Since the youngest group was able to demonstrated the largest increase in body mass from pre-test to post-test, there also displayed the greatest increases in muscle cross-sectional area, thus possessing more muscle fibers to engage for strength and power activities The results of the study support that these exercises are beneficial towards improvements in strength and sprinting performance. Authors of the experiment caution that the length of the study could also support the idea that improvements in strength and sprinting movements could stem from development in the maturity of the movement pattern needed to complete the exercises. This is another effect derived from the maturation process.

To further evaluate potential physiological responses, a study conducted by Low, Harsley, Shaw, and Peart (2015) looked to assess whether prior heavy resistance exercise would improve repeated sprint performance in trained youth soccer players. Sixteen adolescent male soccer players within the study completed anaerobic sprint testing with the addition of maximal effort resistance training to their current athletic program, specifically adding the back-squat exercise. The subjects were divided into testing groups that utilize resistance training and did not utilize training. The resistance training group worked up to 91 percent of their one repetition maximum in training, looking to reap the benefits of a phenomena known as post-activation potentiation (PAP). PAP is defined as an instance where the recent history of muscle contraction against a near-maximal resistance can directly affect a person's subsequent rate of force development (RFD) or the ability to quickly generate force. The results of the study showed the results of the resistance training group were positive, though the difference in comparison scores were small. Since the differences in compared sprint performances occurred larger during the earlier repetitions of the study, the results suggest that the effects from PAP may have weathered. The predetermined 8-minute rest period between the resistance training session and the sprint testing may be too long to fully explore the potential benefits of PAP. Overall, the use of maximal effort resistance training with the squat exercise does seem to promote improvements in sprinting performance using post-activation potentiation.

Sport-Specific Training Outcomes

Behringer, Neuerburg, Matthews, and Mester (2013) conducted a study that looked to assess how the use of a traditional resistance training program and a plyometric training program compare in terms of positively affecting tennis serve velocity in adolescent tennis players. 36 male adolescent tennis players were randomly placed into three different focus groups. These groups included a general resistance training group, a plyometric training group, and a control group. The two programs included were implemented twice per week to supplement their current tennis training. The resistance training program included the following exercises: deadlift, abdominal flexions, back extensions, lateral flexions, leg press, chest press, and lat pulldowns. The plyometric training exercises included: rope skipping, lateral barrier leaps, countermovement jumps, split squats, and medicine ball chest and overhead passes. Pre-tests and post-tests consisted of the 10 repetition maxes of the exercises included in the resistance training program, as well as the precision and velocity of their tennis serve. The post-test was conducted upon completion of the 8-week intervention. The results of the study showed a significant positive correlation between serving velocity and participation in the plyometric program, while the resistance training group still experienced overall improvement in serving performance. These findings could be supported by the claim that "light loads are recommended for sports that consist of high power against light external loads" (Cormie et al., 2011), which fits the concept of a racquet sport serve against a light ball. A potential caution with the findings of this study could be that "technical maturity is needed to effectively transfer strength gains from an unspecific resistance training program to a sport-specific movement" (p. 381), which remains a reoccurring caveat when researching performance transferability with the adolescent population. Nonetheless, the results from the study conclude that the implementation of either a resistance training or plyometric training program twice per week will assist in improving tennis serve velocity.

Van Den Tillaar, Waade, and Roass (2015) also conducted a study that sought to compare resistance-based squat training with plyometric training effects on performance in team handball players. Participants that consisted of 26 male and female handball palyers were randomly assigned to a RT group and a plyometric group, where each participant completed two training sessions per week for a six-week time period. At the post-test, both training programs demonstrated improvements in sprint performance, agility, and aerobic fitness. No significant improvements in vertical jump, lower body strength, and throwing velocity were exhibited, nor were any significant differences found in the compared results of the resistance training group and the plyometric group. It was concluded that traditional resistance training and plyometric training approaches are appropriate programs to implement into the overall training programs of male and female team handball players with the goal of improving physical performance.

A study conducted by Van de Velde, De May, Maenhout, Calders, and Cools (2011) examined both muscular strength and endurance training programs and their potential effects on scapular-muscle performance in swimmers. The swimmers were randomly placed into either endurance or strength focus groups where both completed a series of scapular-based movement tests on an isokinetic dynamometer. Throughout their prescribed training programs, load and volume were tailored to fit the goals of the study. The results of the study went on to show no significant differences in the measured variables from either training program. While strength and endurance were not affected, scapular muscle symmetry showed a positive correlation to the training. The authors believe that due to the nature of the sport of swimming, “achieving bilateral symmetry may be valuable for injury prevention in swimmers” (p. 166), thus incorporating resistance training programs with goals oriented to either muscular strength or muscular endurance can have positive effects on swimming performance through injury prevention improvements.

Middleton, Bishop, Smith, and Gee (2016) conducted research that investigated a potential relationship between participation in sport-specific performance training through resistance and plyometric-mixed methods and badminton functional performance. One athlete completed a pre-test, an 8-week post-test, and a 16-week withdrawal test consisting of countermovement jumps, medicine ball throws, 10-meter sprints, and badminton-specific agility. During the post-test, the athlete demonstrated significant positive improvements in the countermovement jump and the medicine ball throw. Negative changes were experienced in the 10-meter sprint, which the authors believe may have stemmed from the 1.2 kilogram increase in body mass the athlete experienced as a result from the physiological adaptation of muscular hypertrophy from program participation. After the 16-week withdrawal test, scores still demonstrated a positive change when compared to the initial pre-test scores. The results of the study suggests that a mixed-methods approach to training prescription with both traditional resistance training and plyometric training can positively benefit elite badminton players by improving functional performance.

To further assess the relationship between training methods and sport-specific improvements, a study conducted by Mohamed, Rahim, and Shaharudin (2017) evaluated the effects that isokinetic and isotonic training had on strength, power, and muscular balance of the rotator cuff to benefit Olympic weightlifters. For testing, the weightlifters performed internal and external shoulder rotation exercises at different degrees of shoulder abduction on an isokinetic dynamometer. For the training programs, the lifters were split into an isokinetic group and an isotonic group. They trained three times per week for the eight weeks that make up the preparatory phase of their training cycle. The results of the study showed no significant differences between the training methods upon completion of the program. Some improvements were observed in peak torque and time of completed movement within the isokinetic training sessions. Due to the fact that the participants were advanced-level athletes, even the small changes viewed within the study could be significant for potential use of the methods in the future. The movements that make up the parameters of Olympic weightlifting are the snatch and the clean and jerk exercises. These exercises are widely utilized by strength coaches and athletic coaches around the world due to the strength and power needed to complete these multi-joint movements. With their high usage rate, identifying potential outcomes of training methods that can be used to improve power, torque and equilibrium in the rotator cuff muscles could assist in improvement of specific-movement performance, which in turn could help improve athletic performance.

Chapter 4 – Discussion

The purpose of this chapter is to synthesize the results from the articles described in chapter 3 and answer the research questions established in chapter 1. This synthesis project examined eleven articles in order to develop a better understanding of the effects that resistance training can have on adolescents and young athletes. Interventions stemming from the review of literature were categorized into three themes: appropriate methodologies for programming, physiological responses, and sport-specific training outcomes. This section of the synthesis will use these findings and relate them to the four selected research questions.

Questions 1: What methods of training are best utilized for adolescent and young athletes?

The results from the studies suggest that the early stages of an adolescent athlete's training career should be immersed with general resistance training principals and exercises. As the young athlete begins to mature and become more conditioned in both their training and their athletic performance, more complex training methods can be incorporated into their training. These methods may include ballistic training, plyometric training, and Olympic weightlifting exercises that included the snatch, the clean, and the jerk (Cormie et al., 2011).

Many of the studies **(**Behringer et al., 2013, Van Den Tillaar et al., 2015, Middleton et al., 2016**)** examined the potential for a greater positive effect on athletic performance stemming from plyometric training compared to general resistance training. The results suggest that both methods of training were able to provide positive performance outcomes on the athlete's ability to generate power. Positive outcomes were also demonstrated in sprinting performance, agility, and power in lower body exercises, such as the squat or the clean. Results also suggest that professionals prescribing training programs for adolescent athletes should consider a mixed method approach that includes both plyometric and general resistance training exercises in their program (Behringer et al., 2013, Van Den Tillaar et al., 2015, & Middleton et al., 2016).

Due to the unpredictability of athletics collectively, achieving bilateral symmetry throughout the body should be a primary goal for a young athlete training with the goal of achieving an elite status. In many sports or activities, the use of the upper body in a unilateral fashion may provide instances of muscular imbalance in the athlete’s body. This could serve as a breaking point in the athlete’s ability to demonstrate proficiency. Results from studies **(**Van de Velde et al., 2011, Mohamed et al., 2017**)** that examined scapular muscle exercises and the effects on athletes suggest that there was an increase in the athlete’s demonstration of muscular symmetry, even though overall power increases in the upper body were insignificant. Preventing muscular imbalance is a crucial component to injury prevention in an athlete, as well as a necessary component in development of performance in sports that utilize a high volume of action or stabilization at the shoulder joint. These sports may include swimming or Olympic weight lifting (Van de Velde et al., 2011 & Mohamed et al., 2017).

The athlete’s ability to sprint can also be a determinant in their level of proficiency in their respective sport. Research results from Sandler show a positive correlation between the athlete’s sprinting performance and their lower body strength. Compound lower body exercises, such as the back squat, the front squat, the deadlift, and the clean, all can have a positive impact on sprinting performance and their one repetition maximum strength. If technical maturity has been demonstrated by the young athlete during training, these compound exercises should serve as the staple of a resistance training program (Sander et al., 2013).

The phenomena of post-activation potentiation demonstrated positive results in an athletes ability to generate power. With these results noted, the concept of maximal effort exercises with 90 percent of an athletes single repetition max being paired with a maximal exertion exercise against a low external load shortly after should be considered when prescribing programs with a goal of overall power development (Low et al., 2015).

Question 2: Which sports are impacted most by resistance training?

Almost all forms of athletic contests and physical performance can be impacted through contextual training parameters that are set within an athlete's sport-specific program. For high power output sports with physical contact against an opponent (football, rugby, wrestling, etc.), resistance training with heavy loads can facilitate neuromuscular adaptation to prepare the athlete's body to endure the stresses that are place upon it during these specific sporting contests. For sports with high power output against low external loads (sprinting, jumping, striking with implements), light loads can be used in a more dynamic fashion within the athlete's training. This principal further supports the need for plyometric training outlets in a specific athlete's program (Cormie et al., 2011).

Resistance training can serve as an effective method for improving motor skills during childhood and adolescents. These skills consist of running, jumping, and throwing; implying that athletes competing in the sports that encompass the aforementioned skills could see performance improvements resulting from resistance training (Behringer et al., 2011). Sprint performances exhibited a positive correlation to multiple training parameters, including plyometric training and compound resistance training movements and exercises in the lower body. With linear sprinting actions widely existing in the realm of sports (football, basketball, soccer, track & field, etc.), these skills support the concept of resistance training in the lives of many adolescent athletes seeking improvement and proficiency. The stresses that are placed on the athlete during a contest may foster potential imbalances throughout the body from compromising during action at the cost of completing a task, drill, or challenge. Sports that require muscular symmetry and physiological synchronization (swimming, Olympic weight lifting, gymnastics) can be improved through a resistance training program that includes a strong blend of both bilateral and unilateral exercises for the upper and lower limbs (Van de Velde et al., 2011 & Mohamed et al., 2017).

Question 3: What are the strengths/weaknesses/caveats (cautions) regarding resistance training for adolescent athletes?

Many of the studies deem that muscular strength and power is a strong determinate in a young athlete's ability to display excellence in a particular sport or activity. Since resistance training can provide athletes with the means to improve strength and power through both neural and physiological adaptation, this serves as a powerful argument for the concept that adolescent athletes should engage in some method of resistance training (Legerlotz et al., 2016).

On the other hand, the increases experienced in the athlete's ability to generate power could pose potential strains to the tissues composed in the tendons throughout a young athlete's maturing body. Both the morphological and material properties of those tendons have the ability to positively respond to resistance training stimuli. Adaptation to skeletal muscle can also occur as a result from the stress applied on the body from resistance training without any structural damage occurring. This supports the notion that effectively administering and monitoring an athlete's training program can reduce risk of injury through improvements to skeletal health and preventing imbalances that may occur between the muscles and tendons acting at different joints in the body (Legerlotz et al., 2016).

When looking to administer a training program for adolescent and youth athletes, there are some existing cautions in the literature that should be considered before potential prescribers move forward. Throughout the adolescent stage of an athlete's life, growth spurts in the body will occur. These growth spurts may add to the complexity of skill development and performance due to differential timing in the growth of the limbs and the torso. There may also be a decreased ability to activate motor units in a synchronized fashion and demonstrate muscular coordination. These concepts as a sum are referred to as "adolescent awkwardness". Athletes and professionals should exercise caution in the load or degree of difficulty in a movement in the program if this maturation stage exists (Marius Meylan et al., 2014). An athlete's current levels of performance should also be assessed and considered when the parameters of their program are being set. This caveat exists dialectically, as integrated loads of an insufficient resistance may not foster any physiological adaptation, while a load that is superior to the athlete's maximal capabilities can possess the potential for injury risk and overtraining symptoms (Cormie et al., 2011). Coaches and prescribers should also be aware that an adolescent athlete's level of experience with strength training may affect their window of adaptation. Athletes with minimal experience may experience a greater degree of improvement within a predetermined intervention period of the training when compared to a young athlete who has previously engaged in some form of resistance training. This is supported by the concept that greater improvements in more inexperienced athletes are facilitated by a higher degree of neural adaptation, as neural characteristics play a large role in movement optimization (Behringer et al., 2011). When examining the degree to which the results an athlete experiences in their resistance training program carries over to their sport-specific performances, another caution should be considered when assessment is taking place. When working with adolescent athletes, technical maturity is usually not obtained by the athlete within their sport or field. If an insignificant correlation occurs between an athlete's resistance training and sport performance, the athlete and coach may want to consider that technical maturity may be needed to apply positive improvements in general strength training movements to a sport-specific movement concept (Behringer et al., 2013).

Chapter 4: What are the best practices (proper implementation /administration) for coaches regarding the use of resistance training for adolescent athletes?

Similar to the cautions in the aforementioned segment of the synthesis, the first step for a coach when administering a resistance training program to adolescent athletes should be some form of analysis or screening regarding the athlete's ability to proficiently demonstrate movement concepts and strength-related skills. Coaches must include movement patterns, loads, and exercise velocities that all relate to the sport-specific demands an athlete endures in competition. Multiple techniques must be integrated into the program for an athlete to experience the greatest long-term improvement, simply meaning that variation within the specificity of the program is needed (Cormie et al., 2011).

The intensity of the program should be considered by coaches when prescribing resistance training to adolescents. Research has shown that in order for a positive correlation to exist between the athlete's motor performance skills and the mean intensity of the workout, the stimulus should exist at about 50% of an athlete's one repetition maximum if they wish to elicit the desired effects of the program (Behringer et al., 2011). Thus, determining the maximal ability of a coach's athletes within the core movements included in the program is essential to facilitate the greatest response.

Coaches should also abandon any comparisons between teammates when training adolescent athletes. Adolescents within a group may exist at different stages of maturity and their differences in strength, power, and velocity may simply be a product of their adjustment to differences in body mass. Adolescent athletes further along in the maturity stages will experience increases in body mass and muscle cross-sectional area. Both of these factors will correlate to a larger degree of force production (Marius Meylan et al., 2014).

Coaches should look to tailor their intervention length to the schedule provided by the sport that the athlete participates in. A variety of interventions, such as an off-season program, a pre-season program, and an in-season program will necessitate adaptions in multiple training parameters. When a coach is dealing with withdrawal effects due to program abandonment associated with when changes occur in sport seasons, their programming should reflect an overall improvement in the focused movement concepts, regardless of the time off. The training and competition an athlete endures during peak intensity of a competitive sport season may serve as specific conditioning that allows an athlete to demonstrate continued growth. Coaches should understand this concept, as an overload in stimuli from training and athletics collectively may result in regression of performance stemming from fatigue. When programming is implemented appropriately, withdrawal performances will still reflect overall improvement when compared to the athlete’s infancy stage in the program (Middleton et al., 2016).

Chapter 5 – Conclusion and Recommendations for Future Research

The purpose of this chapter is to present conclusions from the research on the effects that resistance training program participation can have on adolescent athletes. This chapter will also look to provide recommendations to future researchers regarding the topic of resistance training with adolescents based on observed gaps in the literature.

Conclusion

To summarize, based on the literature that was reviewed, the physiological adaptations that an adolescent will experience through participation in a resistance training program will primarily be neuromuscular. The neural adaption that young athletes experience will be mostly responsible for the improvements in movement efficiency and developments in strength and power early in the program. As participation time in the program lengthens, athletes may experience increases in body mass due to growth that stems from a combination of the maturation process and muscular hypertrophy.

When prescribing resistance training to an adolescent athlete, it is crucial to use the athlete's baseline of strength and experience to select proper methodologies, exercises, progressions, volume, and load. Early in an athlete's career, resistance training should remain the exclusive focus of an organized, high quality program.

Intensity of the movements should also be considered and compared to the demands that the athlete's sport will put on them during a contest. Coaches should be aware of potential complications that may occur as a result of maturation in adolescents, such as "adolescent awkwardness".

Each of the focused sports included in the reviewed literature possessed potential for performance improvements that resulted from training. While the methods varied from traditional resistance training, plyometric training, ballistic training, or isokinetic training, the results showed that each approach had the ability to help improve sport-specific performances when utilized in an appropriate manner that correlated to potential needs within the parameters of the athlete's sport.

Recommendations for Future Research

Research regarding potential adaptation in youth and adolescents resulting from training is sparse. For future research regarding an adolescent athlete's participation in a resistance training program, professionals should note that the parameters of many training programs are usually not set to a long enough intervention period to properly assess for physiological adaption. A potential adjustment to future research could be to change the delimitations of articles within the study to include a specific time frame for the intervention period that is utilized in the study. This may provide further evidence of potential adaptations, without limiting the results to primarily neural adaptation.

Another recommendation is to include a skill proficiency level in the sample of the study. When athletes reach the status of "elite", it may be possible for them to reach the tail end of their window of adaption (Middleton et al., 2016). This may result in the effects from their training program to begin to taper off due to the achievement of physiological or technical maturity. To fully uncover the potential for improvement in adolescent athletes that engage in resistance training, setting parameters that eliminate potential candidates from the subject pool based on level of experience or skill proficiency may provide a more accurate representation of the potential adaptations that result from the program.

Final recommendations for future research including selecting a larger sample size for the study, a wider spectrum of sports or activities included in the population, additional methods of resistance training and their demonstrated responses (maximal effort training, dynamic effort training, conjugate training, etc.), the impact of resistance training participation on the degree of contribution to team success (or lack of) in team sports, and examining follow-up results of interventions or programs as subjects progress to the end of their time in the adolescent stage throughout their maturation. With the lack of comparable values between male and female representation in the subject group of the studies, a need for balance between genders may also be of importance.

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Appendix A

Article Grid

Author	Source	Purpose	Methods & Procedures	Analysis	Findings	Discussion/ Commonalities/Differences
Prue Cormie, Michael R. McGuigan, and Robert U. Newton	Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing Maximal Neuromuscular Power: Part 2 - Training Considerations for Improving Maximal Power Production. Sports Medicine, 41(2), 125-146.	The purpose of the review was to explore the practical application of findings of the ability to generate maximal muscular power by reviewing scientific literature relevant to the development of training programs that most effectively enhance maximal power production.	Part 1 highlighted influential factors to muscular power and considerations for training programs designed for advancements in muscular power. -Search for scientific literature was conducted. -Search terms included: 'maximal power', 'muscular power', 'power training', 'ballistic training', 'plyometric training', and 'weightlifting training'. -Studies were reviewed for potential factors that may influence maximal power	-Databases utilized for scientific literature search included: U.S. National Library of Medicine, MEDLINE, and SportDiscus search engines.	-Maximal power is considerably influenced by maximal strength, thus improvement in strength is necessary goal in program. -Movement patterns, loads, and velocities relative to sport-specific demand should be considered. -To enhance power in dynamic, multi-joint movements relative to sport: Ballistic, Plyometric, and weightlifting exercises can serve as primary	-Role of strength in power production: increase strength = increase power in novice subjects. Well-trained athletes need multi-faceted approach to training with targets on specific needs. -Movement pattern specificity: selected exercises for program can influence degree of performance improvement. Early Stage = resistance training; Trained athletes = ballistic, plyometric, weightlifting exercises. -Load specificity: heavy loads may improve performance in high power output sports (football, rugby, wrestling). Light loads are recommended for

			through utilization of training programs.		exercises. -Magnitude of potential for training-induced improvement in athletes can allow for greatest window of adaptation in muscular power output. -Multiple techniques must be integrated for greatest long-term improvement (variation within specificity needed).	high power output against low external loads (sprinting, jumping, striking). -Velocity specificity: for authentic training improvements, use loads that allow for similar velocity output to experienced velocities in specific sport. -Window of adaptation: consider an athlete's current levels of performance when setting parameters for training program. Integration of power training modalities: "there is a need for the integration of power training modalities (periodization) if long-term improvements in maximal power are to be optimized."
Michael Behringer, Andreas vom Heede, Maria Matthews, and Joachim Mester	Behringer, M., vom Heede, A., Matthews, M., & Mester, J. (2011). Effects of Strength Training on	The primary The purpose of the meta-analysis was (a) to evaluate whether	-Computerized search was conducted utilizing the following databased: Medline, PubMed, SportDiscus, ERIC,	-Results quantifies into a standard metric known as Effect Size (ES). Metric introduced by Glass in 1976. -Impact of variables	-Data supported that resistance training is an effective method for improving the selected motor skills	-The role of motor skills in sport suggests a positive transfer of resistance training affects to athletic performance in adolescents. -The higher gains found

	Motor Performance Skills in Children and Adolescents: A Meta-Analysis. Pediatric Exercise Science, 23(2), 186-206.	resistance training can be an effective method for improving different types of motor performance skills in children and adolescents and (b) to identify subject- and program-related parameters which might have an impact on the effectiveness of the training intervention.	Web of Science, Evidence Based Medicine Reviews Multifile. -Inclusion criteria for article selection: Peer-reviewed, English language, German studies, Studies from the Gray literature. -Inclusion criteria for research: 1.) must include traditional resistance and plyometric training intervention, 2.) effects of RT and PT on motor performance skill reported in mean with standard deviation for treatment group and control group in a pre/posttest, and 3.) participants were 18 years old or younger. -Skills were grouped into running, jumping,	assessed by subgroup meta-analyses and z-tests. -Variable relationships determined by meta-regressions and Pearson correlation tests. -Production of all graphics performed using Statistica version 7.1.	(running, jumping, and throwing) during childhood and adolescence. -Negative correlation existed between age and improvement in the selected skills; younger participants experienced the greatest improvement. -Analysis of program design parameters showed a positive relationship between the average program intensity and the improvement demonstrated in the motor skills.	in children compared to adolescents potentially due to higher degree of neural adaptation; neural characteristics play a large role in movement optimization. -The level of experience a participant has with strength training may affect their window of adaptation, affecting their results in terms of the length of intervention (ceiling effect). -Positive correlation in motor performance skills and mean intensity of applied training stimulus could suggest that the "minimal threshold to elicit desired affects would be about 50% of a participant's 1 repetition max." -Program intensity should be considered when coaches or professionals are prescribing resistance training programs to children or adolescents.

			and thowing.			
Michael Behringer, Sebastian Neuerburg, Maria Matthews, and Joachim Mester	Behringer, M., Neuerburg, S., Matthews, M., & Mester, J. (2013). Effects of Two Different Resistance-Training Programs on Mean Tennis-Serve Velocity in Adolescents. Pediatric Exercise Science, 25(3), 370-384.	The purpose of the study was to assess two different resistance training programs and determine potential transferability to both precision consistency and velocity of serve in junior tennis players.	-Participants: 36 male adolescent tennis players (mean age = 15.03 years old, +/- 1.64) -Included members of local tennis clubs in Erkrath, Germany. -Excluded if: cardiovascular disease, metabolic disorders, or recent musculoskeletal injuries. -Needed approved consent from Parent and informed consent from participants. -No significant differences in height, weight, body-mass index, or tennis-related skills. -Randomly placed into three different focus groups: Resistance Training group (RG), Plyometric group	-2-way Analysis of Variance (ANOVA) was used to test effects of training on tested items. - 1-way ANOVA was used to identify additional information on group significance pertaining to interaction time. Significance level selected was 0.05. -Data for power analyses and reliability was calculated in IBM SPSS	-Service Performance: When comparing mean service velocity with all groups, PG improvements were significantly greater than changes that occurred for CG. RG increased insignificantly, with a 1.18% change from pre to post test. All three groups experienced insignificant changes in service precision. -10RM: Both RG and PG experienced significant increases in 10RM value. CG experienced an insignificant	-Due to the main finding that 8-week PG programs positively correlate to an increase in service velocity, tennis coaches should take sport-specific plyometric training into a strong consideration when planning the focus of their strength and conditioning programs for junior tennis players. -Regarding the insignificant results in mean service velocity from the RG: “it could be speculated that technical maturity is needed to effectively transfer strength gains from an unspecific resistance-training program to a sport specific movement.” (p.381). -The lack of RG improvement could be due to movement specificity or selected movement velocities pertaining to exercise selection within the

			(PG), and Control group (CG). -Training: 2 times per week selected from either Tuesday/Wednesday and Saturday/Sunday. Tennis training sessions still held two times per week. All conducted in same Erkrath training center. 8 total week program. -RG program: Deadlift, Abdominal Flexions, Back Extensions, Lateral Flexions, Leg Press, Chest Press, Lat Pulldowns. Repetitions range: 10-15 throughout program. Intensity range: 65-85% of calculated 1RM. -PG program: Rope Skipping, Lateral Barrier Leaps, Box Hopping, Counter Movement Jump		change. -Correlation: Participants with a greater increase in 10RM after intervention also demonstrated a greater increase in service velocity.	program. -Within the study, sport-related tennis training remaining constant for all participants could mean external factors played a role in the differences in service performance (nutrition, sleep, hydration, etc.) - "The significant positive correlation between changes in 10RM testing and changes in mean service velocity further demonstrates that muscle strength alone is a relevant moderator of service performance." (p.382)

			(w/ or w/o Box), Split-Squats, Med Ball Chest Pass, OH Pass. -Pre and post testing on 10 repetition maxes for groups was conducted. -Service velocity and service precision testing (20 repetitions) was also tested before and after the training cycle.			
Kirsten Legerlotz, Robert Marzilger, Sebastian Bohm, and Adamantios Arampatzis	Legerlotz, K., Marzilger, R., Bohm, S., & Arampatzis, A. (2016). Physiological Adaptations following Resistance Training in Youth Athletes--A Narrative Review. Pediatric Exercise Science, 28(4), 501-520.	The aim of the study is to understand the mechanisms for the effects of resistance training on functional parameters. Within the study, to assess the injury risk of the involved tissues, it is	-A search for literature was conducted, as well as manual screening on reference list for eligible literature. -Search syntax consisted of terms relative to training induced adaptation, biological structure (neural, muscular, skeletal, tendinous), and the youth/adolescent population.	The literature search was utilized on two electronic bibliographical databases: Web of Science, and MEDLINE.	-Current literature suggests resistance training programs can provide potential for gains in strength, largely a result from neural adaptation. -Performance changes not solely a result from neural changes, as	-Available literature on adaptation in youth resulting from training is sparse. -Evidence existing in studies suggests training-induced adaptation in youth mainly results from neural change. -Muscular performance changes are also aided by morphological changes from the muscle and tendons. -Nutrition and maturation remain variables that promote difficulty in

		necessary to examine the underlying morphological and structural changes of the respective tissues.	Caveats regarding research topic: muscle tissue biopsy needed for large scale investigation, expensive equipment needed for thorough data, dedication from participants/parent could alter data.		muscular parameters adapt with maturation and training as well. - "Increasing muscle force accompanying both growth and strength training will lead to higher strains in the tendinous tissue, making it more prone to injury, unless either tendon morphology or material properties are changed accordingly." -Morphological and material properties of tendons have ability to positively respond to training stimuli. -Adaptation to skeletal density occurs because	assessing levels of adaptation purely resulting from training. -Effectively administering and monitoring training programs can reduce risk of injury by enhancing skeletal health and preventing imbalances with muscles and tendons. -Caution: parameters of training program not usually set long enough to properly assess for physiological adaptation.

					of stress applied because of resistance training; structural damage does not occur.	
Cesar Marius Meylan, John Cronin, Will G. Hopkins, and Jonathan Oliver	Marius Meylan, C., Cronin, J., Hopkins, W. G., & Oliver, J. (2014). Adjustment of Measures of Strength and Power in Youth Male Athletes Differing in Body Mass and Maturation. Pediatric Exercise Science, 26(1), 41-48.	The purpose of the study was to identify the relationship between adjusted measures of strength and power in youth athletes and increases in power and maturation.	-74 males between the ages of 11 and 15 years old. -All were nominated by their respective Physical Education teacher. -Written consent obtained by participants/parent. -Height, Weight, BMI, maturity status through Peak height velocity all determined. Grouped by maturity status. -Testing: Ballistic concentric squats on a supine squat machine. -Tested completion of movement at 5 different randomized percentages of	-The 1 repetition maximums for each participation where estimated with the load-velocity relationship upon examination of initial performance. -Data from text and figures in research were presented as means +/- the determined standard deviation. -Values for assessing the magnitude of the effects where set at .2 (small), .6 (moderate), 1.2 (large), and 2.0 (very large).	-Future professionals should caution any comparisons between athletes at different maturity stages if differences in strength, power, and velocity are simply a product of body mass adjustment. -Power development was the product of increases in strength that stemmed from maturity, as well as increases in velocity capability. -Difficulty existed to demonstrate	-Large increases in strength and power could be attributed to increases in body mass and muscle cross-sectional area because of the maturation process; both of which correlate to force production. -Performance differences in young athletes of different maturity stages can stem from many qualitative factors that include motor unit recruitment rate, type II muscle fiber hypertrophy, and rate of testosterone production. -Again, the positive relationship is still demonstrated between strength and power, where one variable cannot be proficient without proficiency in the

			1RM (80, 100, 120, 140, and 160 percent). -Velocity (vertical displacement by the time of the squat), mean force (total weight moved by acceleration of movement), and power were calculated.		maximal force at higher velocities when athletes were near peak height velocity. -Increasing power without negatively affecting the force-velocity relationship should result from training fast velocity movements when near maximal peak height velocity.	other. -Moments of growth spurts in the maturation process add complexity to adolescent performance with differential timing in limb and torso growth, as well as a hindered ability in synchronized activation of motor units and muscular coordination. This is referred to as "adolescent awkwardness".
Andre Sander, Michael Keiner, Klaus Wirth, and Dietmar Schmidtbleiche r	Sander, A., Keiner, M., Wirth, K., & Schmidtbleicher, D. (2013). Influence of a 2-year strength training programme on power performance in elite youth soccer players. European Journal Of Sport	The purpose of the study was to examine the influence of periodization -based strength training for power performance after 2 years.	-134 elite youth soccer players were selected from 2 professional-affiliated training centers in Germany. -Broken up into 3 subdivisions where the age ranges for each were 17, 15, and 13 respectively. -Each group of participants had a strength training	-SPSS 19.0 software used to analyze data. -Percent change data and Cohen's effect sizes used to identify effect magnitude between the treatments. -Cohen's correlation analysis used to assess relationship between both sprint performance and 1	- All three divisions of participants experienced significant increases in strength and sprinting performance with the addition of strength training to their soccer program. -The group of participants at	-Due to the length of the experiment, improvements experienced in strength of the participants is believed to be impacted very minimally from neuromuscular adaptation that occurs early in strength training program engagement. -Largely significant improvements in strength from youngest group is related to their largest

	Science, 13(5), 445-451.		group with soccer training (STG) and a group that just did soccer training (CG). -For STG, resistance training occurred twice per week on non-consecutive days. Exercises: Front and back squat, bench press, deadlift, neck presses, and truck exercises. Mixed methods were utilized for load and volume throughout training. -Test included height, body mass, 30-meter sprint, and 1 rep max on both the back squat and front squat. -2-year study with a 1-year intervention period.	rep max of back and front squat with body weight of participant.	age 13 experienced the largest improvement in performance of both tests, believed to be aided the post by the maturation process over the long period of time within the experiment. -The study demonstrates that the use of compound weightlifting movements (examples from training program) are appropriate for training youth athletes and beneficial for programming towards increases in sprinting performance.	demonstrated increase in body weight and mass throughout the testing periods. This allowed for greatest increases in muscle cross-sectional area, thus more muscle fibers to engage for strength activities. -Length of the experiment could also relate the improvements in 1 rep max and sprinting performance to the development of movement pattern maturity in both the front and back squat and sprinting from 2 years' worth of practiced repetitions.
Annemie Van de Velde,	Van de Velde, A., De Mey, K.,	The purpose of the study	-18 adolescent swimmers (11	-Biodex was used to measure peak	-There were no significant	-Due to the nature of the sport of swimming,

Kristof De Mey, Annelies Maenhout, Patrick Calders, and Ann M. Cools	Maenhout, A., Calders, P., & Cools, A. M. (2011). Scapular-Muscle Performance: Two Training Programs in Adolescent Swimmers. Journal Of Athletic Training (National Athletic Trainers' Association, 46(2), 160-167.	is to evaluate isokinetic scapular-muscle performance in a population of adolescent swimmers and to compare the results of training programs designed for strength or muscle endurance.	female, 7 male) from the same club where they completed 4 to 6 sessions per week. (mean age – 14.7 years old +/- 1.3) -Exclusions: cervical or thoracic condition, pervious shoulder surgery, shoulder pain that hinders swim training. -Testing- scapular protraction/retraction muscular strength and endurance using an isokinetic dynamometer. -Participants randomly divided into two different groups: a muscular strength focus and a muscular endurance focus. -Training: 3 times per week for 12 total weeks. Load and volume tailored for goals (strength = 3x10, endurance	force and protraction/retraction ratios. -Shapiro-Wilcoxon test was utilized to control data distribution. -A general linear model 3-way ANOVA was used for the statistical analysis in the research.	differences in the measured variables resulting from the utilization of training programs geared to improve muscular strength and muscular endurance. Both helped to improve strength in swimmers. -Both groups saw an increase in peak force of protraction from the training program. For retraction, participants saw an increase in force to the non-dominant side. -Neither of the training groups experienced a positive adaptation to muscular endurance from	"achieving bilateral symmetry may be very valuable for injury prevention in swimmers". -Proposal- "stroke rates in swimming could be the basis for a strength program". Perhaps the lack of improvement from the training programs could be altered with volume adjustments to replicate sport-specificity more efficiently. -The negative result in muscular endurance from the training could be due to fatigue stemming from the combined load of shoulder strength training programs and swim training sessions.

			= 3x20). -Exercises: Horizontal flexion of the humerus (dynamic hugs & elbow push-ups), External rotations, and scapular retractions.		the training. -Trapezius muscle strength demonstrated improved symmetry because of the training.	
Roland Van Den Tillaar, Lars Waade, and Truls Roass	VAN DEN TILLAAR, R., WAADE, L., & ROAAS, T. (2015). COMPARISON OF THE EFFECTS OF 6 WEEKS OF SQUAT TRAINING WITH A PLYOMETRIC TRAINING PROGRAMME UPON DIFFERENT PHYSICAL PERFORMANC E TESTS IN ADOLESCENT TEAM HANDBALL PLAYERS. Acta	The aim of the study was to compare the effects of six weeks of squat training with those of plyometric training upon different types of physical performance in adolescent male and female team handball players.	-Participants; 26 male and female handball players from 2 different teams (mean age = 13.8 +/- .5). -Testing administered from February – April. -Testing: 10-minute general warm-up, random-ordered selection from the following tests: 1.) explosive lower body strength through countermovement jumps, 2.) maximum effort sprints of 30 meters, 3.) multi-directional agility tests, 4.) throwing	-One-way ANOVA was utilized for the participants' measurements during the initial test. -2 x 2 ANOVA was used for comparative effects from the two groups. -Statistical analysis performed using SPSS version 19.0	-As a result of the two training programs, the participants experienced improvements in sprint performance, agility, and aerobic fitness. -No changes were experienced to jumping height, lower limb strength, and peak throwing velocity. -No significant differences were observed between the training effects of the	-The research was conducted through the duration of the season, thus neural and muscular fatigue from use in the season could affect the improvement (or lack of) to some of the variables in the study. -The lack of changes experienced in jumping and throwing could be attributed to the volume of similar movement patterns the athletes practice and demonstrate throughout the course of the season. -Both plyometric training and squat training can be effectively utilized in a training program to improve sprinting, agility, and aerobic capacity in

	Kinesiologiae Universitatis Tartuensis, 2175-88.		performances (with approach and non-approach), and 5.) leg strength squats of either 20, 30, or 40 kilograms. End with aerobic fitness test: Yo-Yo Intermittent Recovery Test level 1. -Participants engaged in a pre-test, a retest (after one week), and a post-test. -After retest, players were matched based on throwing performance and then randomly assigned to either a plyometric training group or a squat training group. -Training occurred 2 times per week for 6 total weeks along with handball training.		plyometric program compared to the squat program.	team handball athletes.
Geoff Middleton,	Middleton, G., Bishop, D. C.,	The aim of the study was	-1 Athlete (18 years old).	-Standard error of measurements were	-The athlete demonstrated a	-The decreases in sprinting performance

Daniel C. Bishop, Chris Smith, and Thomas I. Gee,	Smith, C., & Gee, T. I. (2016). Effectiveness of a low-frequency sports-specific resistance and plyometric training programme: the case of an elite junior Badminton player. International Journal Of Coaching Science, 10(2), 24-33.	to identify improvement in Badminton-specific functional performance of an elite under-19 player because of a low-frequency sports-specific resistance and plyometric training program.	-Nationally ranked in U19 Doubles play in Badminton -Resistance and Plyometric training added to the subject's current badminton training cycle. -Program constructed to improve speed, range of movement, and quality of movement. -Data was collected at pre-test, post-test at 8 weeks, and a withdrawal test at 16 weeks. -Testing included: countermovement jumps, medicine ball throws, 10-meter sprint, badminton-specific agility test.	calculated to account for potential human error. -Contact jump mats from SMARTJUMP were utilized for countermovement jump measurements. -Electronic timing gates from SMARTSPEED were used to measure times from the 10-meter sprint test.	significant increase in countermovement jump performance and medicine ball throw performance after the 8-week intervention. -The athlete demonstrated a negative change in 10-meter sprint performance at the 8-week intervention test. -When the 16-week withdrawal test demonstrated inferior scores when compared to the 8-week intervention, they were still improved scores when compared to the baseline scores in the pre-test. -Sprinting and	may have stemmed from the 1.2-kilogram increase in body mass the athlete experienced because of the muscular hypertrophy response to an 8-week resistance training program. -Similarly, the significant increases in power-based movements (CMJ and medicine ball throws) are theorized to be the result of neuromuscular adaptation to the resistance and plyometric training. -The movement-based tests (10-meter sprint and agility test) saw improvements between testing periods "due to specific conditioning effects the athlete received because of training and competition during the competitive season." -Note to future researchers and prescribers: when athletes reach the status of 'elite', it is possible for them to

					agility performance also demonstrated improvements from the 8-week intervention to the 6-week withdrawal period.	reach a "ceiling effect" where the effects of their training program begin to tapper off due to a decrease in size of their window of physiological adaptation.
Daniel Low, Paul Harsley, Matthew Shaw, and Daniel Peart	Low, D., Harsley, P., Shaw, M., & Peart, D. (2015). The effect of heavy resistance exercise on repeated sprint performance in youth athletes. Journal Of Sports Sciences, 33(10), 1028-1034.	The purpose of the study was to assess whether prior heavy resistance exercise would improve the repeated sprint performance of 16 trained youth soccer players	-16 adolescent male soccer players were selected (Mean age – 17.1 +/- .65 years old). -Criteria: Needed a minimum of 6 months experience performing back squat exercises. -Subjects completed anaerobic sprint testing on two separate occasions. -Testing: 10-minute warm-up consisting of a dynamic stretching routine, 6 repetitions of 35-meter sprints split up by a 10 second rest period in	-IBM SPSS Statistics 21 software was utilized for all statistical analysis in this study. -Electronic single beam training gates (Brower Timing) were used for sprint timing	-The first two of the six total sprints conducted in the test were faster for the heavy resistance training group compared to the group that did not resistance training. The final four reps were not significantly different. -Total time to complete the test was faster for the resistance training group compared to the non-resistance	-Only showing improvements in the first two sprinting repetitions from the heavy resistance training group suggests that PAP effects have weathered. 8-minute rest period between resistance training and sprint test may be too long to reap benefits of PAP. -Due to only 2 repetitions of sprints showing differences in times, muscle fiber type and muscle coordination may be contributing factors with back squat and sprint performance.

			between. -Subjects randomly divided to two groups: anaerobic sprint testing with and without heavy resistance training prior to performance. -Heavy resistance training group completed back squats at 91% of their 1RM for 3 repetitions and rested 8 minutes prior to the start of their sprint session (squat 1RM calculated 7 days prior to sprint testing). -Test is looking for results of post activation potentiation.		training group.	
Iqbal Wan Mohamed, Mohamad Faiz Abdul Rahim, and Shazlin Shaharudin	Mohamed, I. W., Rahim, M. A., & Shaharudin, S. (2017). Effects of isokinetic versus isotonic training on	The purpose of this study was to evaluate the effects of isokinetic versus	-19 total participants (mean age = 14.74 +/- 1.37 years old). -Criteria: At least 2 years of competitive	-Isokinetic dynamometer measurements constructed by Multi-Joint System 3 Pro from Biodex Medical System.	-No significant differences in power and strength when comparing rotator cuff muscles of	-Since the participants where advanced-level athletes, even a small change resulting from the training group could be viewed as significant with the potential of future

	strength, power and muscular balance of rotator cuff muscles among advanced level of adolescent weightlifters. International Journal Of Applied Sports Sciences, 29(2), 143-154.	isotonic training on strength, power and muscular balance of the rotator cuff.	weightlifting experience (Snatch/ Clean n' Jerk). -Exclusions: any musculoskeletal injury or rehabilitation within the past two years. -Testing: pre and post-test of internal and external rotation of the shoulder (rotator cuff function) at different degrees of shoulder abduction on an isokinetic dynamometer. -Two different training groups: isokinetic training and isotonic training. -Training: 3 times per week for 8 weeks during the preparatory phase of the lifters' training cycle.	-Power and torque statistics were measured with Statistical Package for the Social Science (SPSS) version 22. -Two-way ANOVA used for statistical analysis for comparative factors between the two training groups.	weightlifters training with either isokinetic or isotonic training parameters. -Peak torque and time showed small improvements in the isokinetic training sessions.	implementation. -Internal and external rotation strength are needed for overhead balance strength, which is essential for success in weightlifting at the completion of the snatch and the jerk movement. Exercises that may further promote adaptation of the rotator cuff muscles may be beneficial for this athlete. -Like many unilateral sports, achieving synchronized strength in both limbs will have a positive relationship in improvement of many bilateral exercises. This is true with regards to rotator cuff utilization in all weightlifting exercises. -"Weightlifting is a sport that demands dynamic strength and power which involves a multi joint movement and whole

						body lifts." Due to the peak interest in these movements by many coaches and prescribers, noting the potential outcomes of training methods to improve power, torque and balance strength of the rotator cuff to improve weightlifting performance could be pivotal.