BRIEF REVIEW

Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review

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Abstract

Bedoya, AA, Miltenberger, MR, and Lopez, RM. Plyometric training effects on athletic performance in youth soccer athletes: A systematic review. *J Strength Cond Res* 29(8): 2351–2360, 2015—The purpose of this systematic review was to critically analyze the literature to determine the effectiveness of plyometric training on athletic performance in youth soccer athletes. A total of 7 studies were included in this review after meeting the following criteria: (a) used plyometric training programs to assess athletic performance, (b) subjects were soccer athletes aged preadolescent up to 17 years, and (c) were published from 2000 to January 2014. Study methods were assessed using the PEDro scale with scores ranging from 4 to 6. Results showed similarities and differences in methodologies and procedures among the included studies. Athletic performance consisting of kicking distance, speed, jumping ability, and agility significantly improved because of plyometric training interventions. The current evidence suggests that plyometric training should be completed 2 days per week for 8–10 weeks during soccer practice with a 72-hour rest period between plyometric training days. The initial number of foot contacts should be 50–60 per session and increase to no more than 80–120 foot contacts per session for this age group to prevent overuse injuries. A total of 3–4 plyometric training exercises should be performed 2–4 sets for 6–15 repetitions per training session. The evidence and the literature suggest that plyometric training for this age group should only be implemented using recommended safety guidelines such as those published by the Canadian Society for Exercise Physiology and the National Strength and Conditioning Association and under appropriate supervision by trained personnel.

Key Words children, adolescents, explosive training, jumping, speed, agility

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Introduction

Youth soccer is a growing sport. According to the High School Athletics Participation Survey conducted by The National Federation of State High School Association, a total of 782,514 male and female high school students participated in soccer for the school year 2012–2013 (1). Soccer is the fifth most popular sport among high school males and fourth most popular among high school females. A total of 7,713,577 males and females participated in high school athletics (1). According to the U.S. Youth Soccer, over 3,000,000 youth players between the ages of 5 and 19 years register for soccer teams every year. When the U.S. Youth Soccer began in 1974, just more than 100,000 youth players registered (19). This is a dramatic increase showing how the popularity of soccer quickly continues to grow.

Plyometric training is a very popular form of physical conditioning that involves performing body weight jumping-type exercises using the stretch-shortening cycle (SSC) muscle action (12,13). The purpose of plyometric training is to increase the power of subsequent movements using both natural elastic components of muscle and tendon and the stretch reflex (13). According to Markovic and Mikulic, the SSC enhances the ability of the neural and musculotendinous systems to produce maximal force in the shortest amount of time, prompting the use of plyometric training as a bridge between strength and speed (12). According to Markovic and Mikulic, plyometric training has frequently been used for improving human neuromuscular function and improving performance in both explosive and endurance athletic events (12). Various sports may benefit from plyometric training. Soccer is a sport in which the need for power is innate. The explosive movements of plyometric training are similar to the demands placed on athletes playing soccer.

It has been proposed in the past that plyometric training was detrimental to the youth population, increasing the risk for injury and stunted growth (2,6,9). However, plyometric training has been shown to be beneficial in youth athletes when age-appropriate training guidelines are followed, such as those recommended by the Canadian Society for Exercise

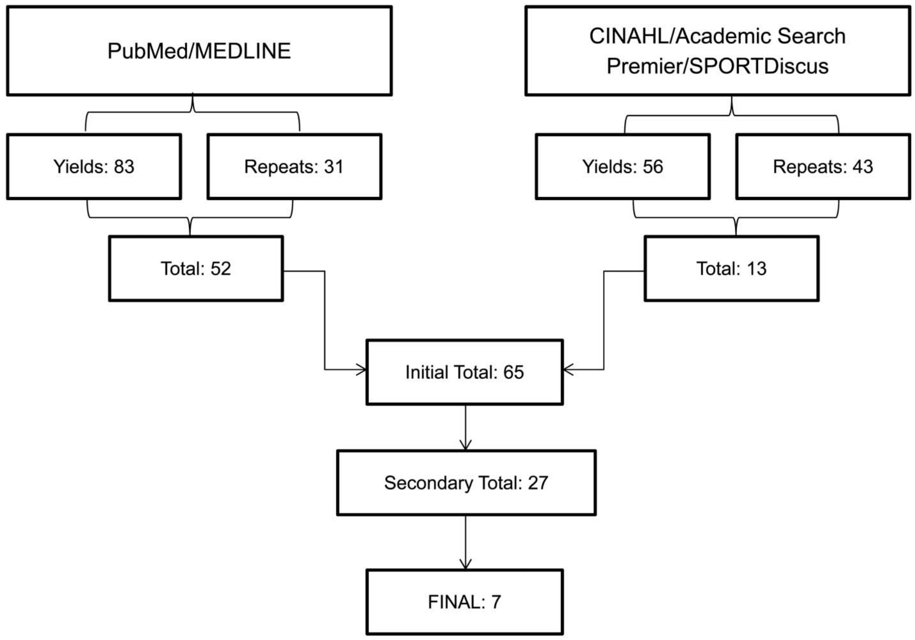

Figure 1. Selection process for the articles included in the systematic review.

Physiology (CSEP) and the National Strength and Conditioning Association (NSCA) (2,6). Some benefits of plyometric training are increased neuromuscular function (2,9,12), increased bone mineral density (20), improved cardiovascular risk profile, facilitated weight control, enhanced psychosocial well-being, and decreased risk for injury in sports (2,9,12).

As with any type of physical activity, there is risk for injury. However, with plyometric training, there is no more risk for injury than any other sport or recreational activity in which children and adolescents ordinarily participate. In fact, children and adolescents are performing plyometric exercises in their daily routines. Plyometric exercises typically include hops and jumps that use the SSC to create muscle power (6). When children play on playgrounds and they are jumping, skipping, and hopping, they are considered performing plyometric exercises (6). As long as proper supervision and training indications are followed, there is no reason why children and adolescents should not participate in plyometric training (2,6,9).

Existing research on the effects of plyometrics on soccer has been limited to the collegiate and elite adult levels (4,7). Recently, research has been performed combining plyometric training and youth soccer (3,5,13–18). Researchers have used plyometric training protocols within experimental groups and tested the subjects' athletic abilities. Many types of testing involve jumping, speed, and agility. However, to date, there is no source that combines the findings from these various studies.

The purpose of this systematic review was to critically analyze the literature to determine the effectiveness of plyometric training on athletic performance in youth soccer athletes.

Methods

Experimental Approach to the Problem

This systematic review answers the question, "Does plyometric training increase sport performance in youth soccer players?" Inclusion criteria consisted of studies that used plyometric training programs to assess athletic performance in youth soccer players. Studies that used subjects aged

Table 1. PEDro scale scores of critically reviewed articles.

Articles	PEDro scores
Buchheit et al. (3)	4
Diallo et al. (5)	6
Meylan and Malatesta (13)	5
Michailidis et al. (14)	5
Rubley et al. (16)	5
Siegler et al. (17)	5
Thomas et al. (18)	5

preadolescence up to 17 years were considered. All articles published up to January 2014 were considered to be included in the systematic review.

One independent reviewer (A.A.B.) performed a computerized search for research articles published in English with no start date to January 2014 in the following databases: MEDLINE/PubMed, Academic Search Premier, SPORTDiscus, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The key words and phrases searched were "plyometric training soccer," "plyometric soccer performance," "youth soccer plyometrics," and "youth plyometrics." Research articles were immediately excluded if any of the following words/phrases were found in the title of the article: "ACL," "injury prevention," "adult," or "collegiate."

Determining Quality of Studies. To determine the quality of the evidence, the authors reviewed the considered articles and provided PEDro (Physiotherapy Evidence Database) scores for each article. Only studies with PEDro scores of 4 or higher were considered for the systematic review. According to Maher et al. (10) the PEDro scale is an 11-item scale designed for rating methodological quality of randomized control trials. Each satisfied item (except for item 1) contributes 1 point to the total PEDro score (0–10 points) (10).

Statistical Analyses. Once the authors completed the PEDro scoring, a kappa statistic was determined. Statistical Package for the Social Sciences (SPSS, Armonk, NY) 22.0 for Mac was used to calculate kappa statistics. According to Viera and Garrett (21), "precision, as it pertains to agreement between

Table 2. Summary of reviewed articles.*

Study	Subject ages and sex	Plyometric training protocol	Performance tests	Results
Buchheit et al. (3)	20 males, 14.5 ± 0.5 y	1 d·wk^{-1} for 10 wk	10- and 30-m sprints, RSA, CMJ, hop test	All performances significantly improved except 10-m sprints in both groups
Diallo et al. (5)	20 males, 12.3 y	3 d·wk^{-1} for 10 wk	Sprint cycling, SJ, CMJ, DJ, MB5, RRJ15, 20-, 30-, 40-m sprints	All performances significantly improved for training group
Meylan and Malatesta (13)	25 males, 13 ± 0.6 y	2 d·wk^{-1} for 8 wk	SJ, CMJ, contact test, MB5, 10-m sprint, agility test	All performances significantly improved except SJ and MB5 in training group
Michailidis et al. (14)	45 males, 10.6 ± 0.5 y	2 d·wk^{-1} for 12 wk	30-m sprint with splits, SLJ, MB5, CMJ, DJ, 10RM squat, sprint cycling, kicking test, agility test	All performances significantly improved except sprint cycling for training group
Rubley et al. (16)	16 females, 13.4 ± 0.5 y	1 d·wk^{-1} for 14 wk	Kicking test, VJ	All performances significantly improved for training group
Siegler et al. (17)	34 females, 16.27 ± 1.38 y	3 d·wk^{-1} for 10 wk	LIST, CMJ, 20-m sprint, sprint cycling	All performances significantly improved except VJ and sprint cycling for training group
Thomas et al. (18)	12 males, 17.3 ± 0.4 y	2 d·wk^{-1} for 6 wk	CMJ, 20-m sprint with splits, 505 agility test	All performances improved except 20-m sprint with splits for both groups

*RSA = repeated sprint ability; CMJ = counter movement jump; DJ = depth jump; MB5 = multiple 5 bounds test; RRJ15 = 15-s repeated rebound jump test; SJ = squat jump; SLJ = static long jump; VJ = vertical jump; LIST = Loughborough Intermittent Shuttle Test; RM = repetition maximum.

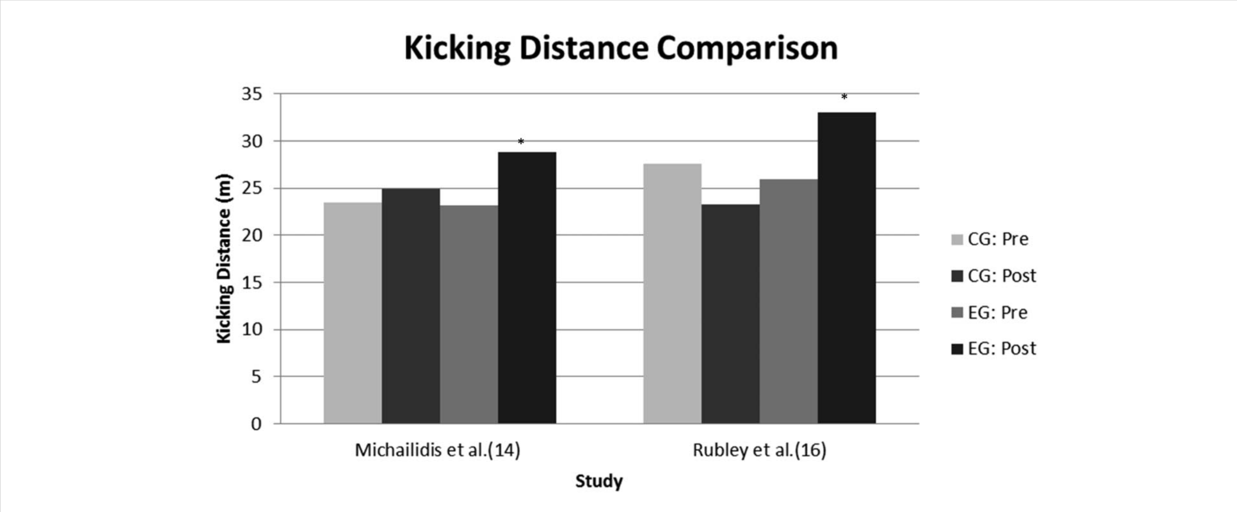

Figure 2. Kicking distance comparison. *Significant results ($p \leq 0.05$). CG = control group; EG = experimental group.

observers (interobserver agreement), is often reported in a kappa statistic." The kappa statistic was used to show the authors' agreement in the PEDro scores to help the authors determine eligibility of the articles in the systematic review. The authors compared the kappa statistic with the Interpretation of Kappa scale by Viera and Garrett (21). The goal was to have "almost perfect agreement" at 0.81–0.99 to "perfect agreement" at 1.00.

Results

The initial search yielded 139 articles with 74 repeats to give an initial total of 65 articles. The next step was to exclude any articles that did not meet the requirements previously listed such as misguided key words in the titles. This provided a secondary total of 27 articles. On further assessment, 20 of the studies were excluded because they did not meet the requirements such as different patient populations and different sports or training protocols, leaving 7 eligible studies. A summary of the article selection process can be found in Figure 1.

The authors reviewed the articles separately and compared PEDro scores. The initial kappa statistic for interobserver agreement was 0.638 on a 0.00–1.00 scale. The initial kappa statistic fell in the moderate agreement category on the Interpretation of Kappa scale by Viera and Garrett (21). Because the goal was much higher, the authors compared

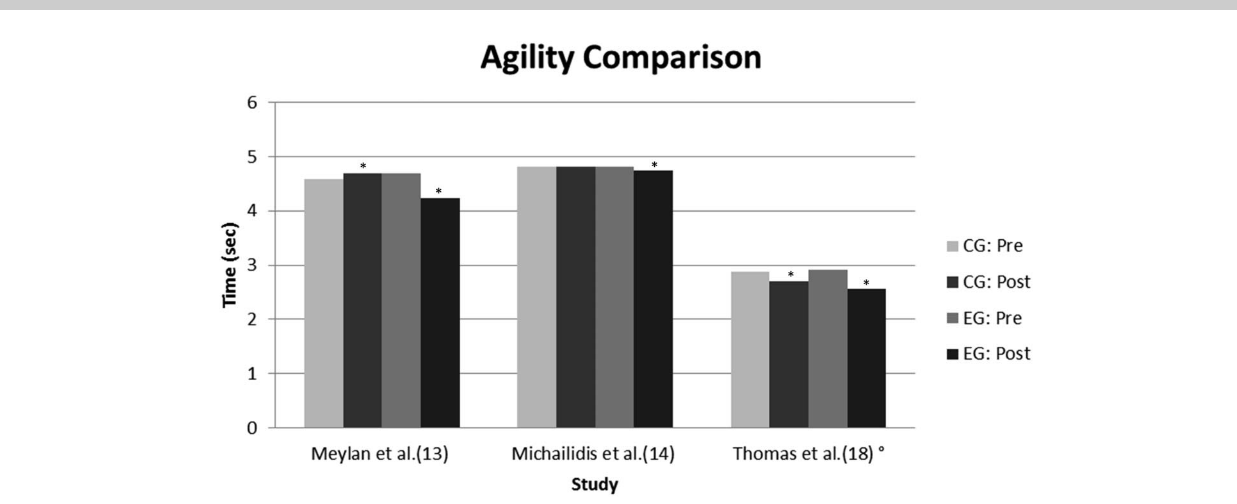

Figure 3. Agility comparison. *Significant results ($p \leq 0.05$); °2 EG and no CG (Thomas et al. (18) used depth jump and countermovement jump); CG = control group; EG = experimental group.

notes and revisited the PEDro scores. The second interobserver agreement kappa statistic was 1.00. This kappa statistic shows that the authors reached perfect agreement on the PEDro scores of the selected articles. A list of PEDro scores can be found in Table 1. The range of PEDro scores for the 7 articles is 4–6, with the mean score of 5.

Overall results for the 7 studies in this review are presented in Table 2. The studies by Rubley et al. and Siegler et al. were the only to use female subjects (16,17). The remainder of the 7 studies used male subjects (3,5,13,14,18). None of the studies used both males and females. Ages between all the studies ranged from 10 to 17 years. Both Diallo et al. (5) and Michailidis et al. (14) used subjects in the prepubertal phase of maturation. Buchheit et al. (3) Meylan and Malatesta (13), and Rubley et al. (16) used subjects in the pubertal phases of maturation. And finally, the subjects in the studies by Siegler et al. (17) and Thomas et al. (18) were in the postpubertal stage of maturation.

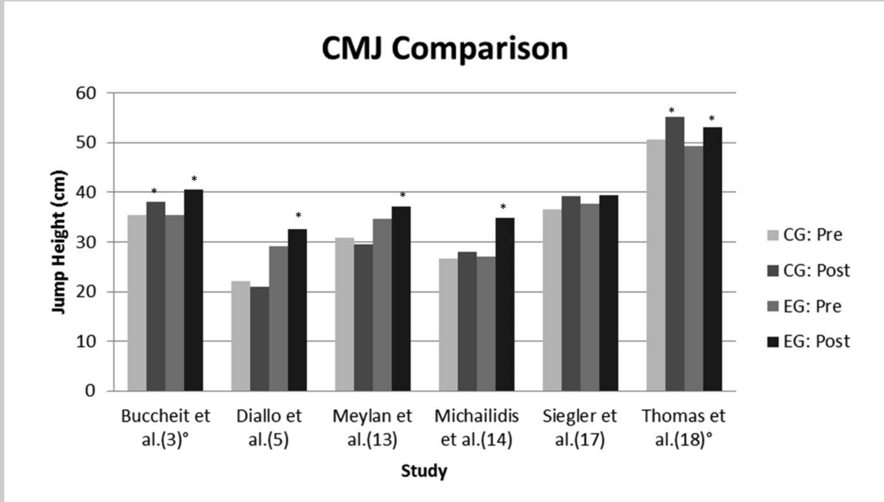

Figure 4. Countermovement jump comparison. *Significant results ($p \leq 0.05$); °2 EG and no CG (Buchheit et al. (3) used sprint group and explosive group; Thomas et al. (18) used depth jump and countermovement jump); CG = control group; EG = experimental group.

The plyometric training protocols used in the studies ranged from 6 to 12 weeks and 1–3 days per week. Buchheit et al. (3) Diallo et al. (5), and Siegler et al. (17) used a plyometric training program for the duration of 10 weeks. The studies that used plyometrics in less than 10 weeks were by Meylan and Malatesta (13) at 8 weeks and by Thomas et al. (18) at 6 weeks. Michailidis et al. (14) and Rubley et al. (16) used plyometric training over 10 weeks at 12 and 14 weeks, respectively. All studies followed specific guidelines for appropriate rest to plyometric training periods for the proper age groups. All of the studies used a training group and a control group except Buchheit et al. and Thomas et al. (5,13,14,16,17). They both used 2 training groups and no control group (3,18).

There were multiple performance tests used to determine how plyometric training affects athletic performance in all the studies. The studies by Diallo et al. (5) and Rubley et al. (16) were the only to report that all performances were significantly improved within the training group compared with the control group. The studies by Michailidis et al. (14) and Rubley et al. (16) were the only that used sport-specific testing through kicking tests, whereas Siegler et al. (17) used a modified Loughborough Intermittent Shuttle Test (LIST) to test the performance of the soccer team as a whole. Michailidis et al. found that kicking distance increased significantly ($p \leq 0.05$) compared with no change in the control group (14). Rubley et al. (16) found a significant improvement in kicking distance ($p < 0.001$) in the training group compared with a decrease in kicking distance in the control group. A comparison of kicking distances can be found in Figure 2. Siegler et al. recorded that the training

Table 3. Summary of CSEP and NSCA recommended guidelines.*

The CSEP and NSCA are in agreement with recommendations for resistance training in children and adolescents. The following is a summary of the general guidelines (2,6):

- Qualified professionals should provide instruction and supervision
- Ensure a safe environment
- Begin each session with a 5–10 min dynamic warm-up
- Start resistance training 2 or 3 nonconsecutive days per week
- Begin with 8–12 exercises that strengthen the upper body, lower body, midsection
- Initially perform 1 or 2 sets of 8–15 repetitions with a light to moderate load (about 60% 1RM) to learn proper form and technique
- Focus on learning correct exercise technique
- Gradually progress to more advanced movements
- Cool down with less-intensive activities and static stretching

*CSEP = Canadian Society for Exercise Physiology; NSCA = National Strength and Conditioning Association.

TABLE 4. Plyometric training program example based on current authors' recommendations.

Weeks	Exercises	Sets/ Repetitions	Comments
1–2	Forward/backward hops	−2 × 8	Can increase sets and repetitions as needed 1 exercise at a time
	Lateral hops	−2 × 8	
	Power skips	−3 × 8	
3–4	Forward hops over 6-inch cone	−2 × 8	Easily introduce cone- and stress-controlled quality over quantity
	Lateral hops	−3 × 12	
	Single leg hops (both legs)	−2 × 10	
5–6	On and off box jumps (12-inch)	−2 × 10	Box height is a suggestion, may need different heights for different athletes
	Lateral hops over 10-inch hurdles	−3 × 6	
	Power skips	−4 × 8	
	Toe taps on soccer ball	−2 × 12	
7–8	On and off box jumps (12 and 18 inch)	−2 × 12	Progressions should be individualized based on quality and quantity of performance
	Box drop jumps for height	−3 × 10	
	Single leg hops over agility cone (both legs)	−2 × 8	
	High knees over 10-inch hurdles	−4 × 10	

group increased performance significantly in the abridged LIST ($p = 0.02$), whereas the control group showed a non-significant increase in performance (17).

Many of the studies used sprint tests to determine if sport performance increased. Buchheit et al. (3) noted a trend toward a significant interaction for repeated sprint ability ($p = 0.09$) in the sprint training group but not in the 10- and 30-m sprints compared with the explosive training group. Diallo et al. (5) reported a significant increase in the training group for 20-, 30-, and 40-m sprints ($p < 0.01$) compared with the control group. A significant increase was found by Meylan and Malatesta (13) in the 10-m sprint test ($p = 0.004$) for the training group compared with the control group. The control group had a modest increase in sprint performance, whereas the training group had a significant increase in sprint performance ($p \leq 0.05$), according to Michailidis et al. (14). Results in the study by Siegler et al. showed that the training group increased performance significantly in the 20-m sprint ($p = 0.0003$) compared with the control group ($p = 0.15$) (17). The study by Thomas et al. (18) was the only to find no improvement in sprint testing (20-m sprint) in both the training and control groups.

The multiple 5-bound test (MB5) was used by 3 of the 7 articles. Diallo et al. (5) reported a significant increase ($p < 0.01$) in MB5 improvement in the training group compared with no change in the control group. Meylan and Malatesta (13) found that the training intervention had no effect on either the control group or training group. A significant increase ($p \leq 0.05$) in performance was seen in the training group compared with the control group according to Michailidis et al. (14).

Agility tests and sprint cycling tests were used in 3 studies each to test sport performance. Meylan and Malatesta (13) reported a significant increase in the training group in the agility test ($p < 0.001$) compared with a significant increase in the control group ($p = 0.03$). Michailidis et al. (14) found that the training group significantly increased in agility performance ($p \leq 0.05$), whereas the control group did not change. Thomas et al. observed a significant increase in agility performance in both training groups ($p \leq 0.05$) (18). Comparisons of agility tests can be found in Figure 3. Sprint cycling performance significantly increased ($p < 0.01$) in the training group compared with the control group according to Diallo et al. (5). There was no significant increase in sprint cycling in the training group compared with the control in the studies by Michailidis et al. and the Siegler et al. (14,17).

Every study used at least 1 jumping test to determine the effects of plyometric training on athletic performance. According to Buchheit et al. (3) a significant interaction was observed for the countermovement jump (CMJ) ($p = 0.05$) in the explosive training group compared with the sprint training group. Diallo et al. (5) reported that the CMJ ($p < 0.01$) and squat jump (SJ) ($p \leq 0.05$) improved significantly in the training group compared with the control group. Meylan and Malatesta (13) saw a significant improvement was made in the CMJ ($p = 0.004$) in the training group compared with the control group. The training group significantly improved in all of the following tests: SJ ($p \leq 0.05$), CMJ ($p \leq 0.05$), and depth jump (DJ) ($p \leq 0.05$) compared with the control group according to Michailidis et al. (14). Rubley et al. (16) found that the training group significantly improved in vertical jump (VJ) ($p < 0.001$) compared with the control group. Finally, Thomas et al. (18) reported that both training groups showed significant improvement in the CMJ ($p \leq 0.05$). Figure 4 is a comparison of the 6 studies that tested the effects of plyometric training on CMJ. Tables 3 and 4 contain a summary of current guidelines and an example of a plyometrics training program based on the studies exampined.

Discussion

The purpose of this systematic review was to critically analyze the literature to determine the effectiveness of plyometric training on athletic performance in youth soccer athletes. The main findings from this review are: (a) plyometric training is appropriate for youth when following an adequate and properly supervised program, (b) youth soccer athletes' performance significantly improved during sport-specific testing after plyometric training, and (c) plyometric training is beneficial for this population in relatively low quantities of volume and frequency.

As stated previously, various sports may benefit from plyometric training. The purpose of plyometric training is to increase the power of subsequent movements using both natural elastic components of muscle and tendon and the stretch reflex (15). According to Potach and Chu, athletic success depends on proper function of all active muscles and the speed at which these muscles produce force. This force-speed relationship is known as power (15). According to Markovic and Mikulic (12), the SSC enhances the ability of the neural and musculotendinous systems to produce maximal force in the shortest amount of time, prompting the use of plyometric training as a bridge between strength and speed. The more power the athletes can produce, the better athletic performance they will have. In soccer, the athletes use a combination of running, jumping, and changing directions. The more power they have, the better they can perform those tasks, which lead to better soccer performance. In theory, by having the athletes perform plyometric training during practices, they will increase power performance for game situations.

All the studies used a control group and a plyometric training group except the studies by Buchheit et al. (3) and Thomas et al. (18). Buchheit et al. (3) used a sprint training group and an explosive training group. Thomas et al. used 2 plyometric training groups, one performed CMJ exercises and the other DJ exercises (17). In all of the studies, the training protocols were performed after warm-ups and during practice. For the studies with control groups and plyometric training groups, the control groups performed regular soccer drills or endurance training whereas the plyometric training groups performed the training protocols. It was convenient for all researchers to use time when the subjects were all together at regular soccer practices. For Buchheit et al. (3) and Thomas et al. (18) both training groups performed the training protocols at the same time in place of practicing soccer. Both Meylan and Malatesta (13) and Michailidis et al. (14) reported that the plyometric training lasted 20–25 minutes, whereas Siegler et al. (17) reported plyometric training lasted 10–15 minutes. None of the other studies reported how long the training interventions lasted. Because all of the researchers followed specific plyometric training guidelines, all the subjects had adequate rest periods between sessions.

Three studies reported the number of foot contacts used during the training sessions. Diallo et al. (5) reported that the training group had 200 jumps per session for the first 5 weeks and progressed to 300 jumps per session in the second 5 weeks. Michailidis et al. (14) used 60 jumps per session and progressed to 120 jumps per session over the course of two 6-week macrocycles. Finally, Thomas et al. (18) reported 80–120 foot contacts over the course of 6 weeks. Based on recommendations in the current literature, Michailidis et al. (14) and Thomas et al. (18) complied with the number of contacts whereas Diallo et al. (5) was well above the recommended numbers. Johnson et al. report that current evidence for youth suggests that a twice-a-week program for 8–10 weeks should begin at 50–60 jumps a session and increasing repetitions weekly by 12–18 repetitions to a maximum of 90–190 repetitions (8).

The number of exercises and the amounts of sets and repetitions were comparable across all the studies. Buchheit et al. (3) had the sprint training group perform 2–3 sets of 5–6 sprints and the explosive training group perform 4–6 sets of 4–6 exercises. Meylan and Malatesta (13) reported 4 plyometric training exercises for 2–4 sets and 6–12 repetitions (reps) per session. Michailidis et al. (14) was very similar to Meylan and Malatesta at 4 exercises and 2–4 sets for 5–10 reps per session. Rubley et al. (16) used 3–4 exercises with 1–4 sets and 5–20 reps depending on the difficulty of the exercises. Siegler et al. (17) only reported that exercises were performed for 3–5 sets. Both Diallo et al. (5) and Thomas et al. (18) did not report number of exercises, sets, or reps. The amount of sets and reps used across the studies are comparable with the number of foot contacts recommended as stated previously. All of the studies also used a gradual progression to not overload the subjects, which would increase the risk for injury. According to the NSCA, there is the potential for injury or illness to occur from plyometric training if the intensity, volume, or frequency exceeds the ability of the participants (6). The only study that reported an injury during the research process was by Buchheit et al. (3). Buchheit et al. stated that 1 participant sustained an injury during a soccer game and no injuries presented as a result of the plyometric training (3).

Multiple athletic performance testing protocols were used throughout the included studies. A kicking for distance test was used by Michailidis et al. and Rubley et al. (14,16). Both studies showed significant increases in kicking distance after a plyometric training program used by the training groups. Because the subjects in the study by Michailidis et al. were 10-year-old boys and in the study by Rubley et al. were 13-year-old girls, it is suggested that plyometric training increases kicking distance in prepubertal and pubertal youth soccer athletes. Rubley et al. state that the results propose the implementation of this type of low-level plyometrics into practice once a week for benefits in lower-body power and kicking distance in adolescent soccer players (16).

To confirm this assumption, more research should be conducted looking at comparisons between plyometric training and kicking distance.

Siegler et al. (17) used an abridged LIST test to determine the effects of plyometric training on soccer-specific power performance. The regular LIST has been validated to be an accurate predictor of soccer performance in elite soccer players (17). Siegler et al. modified this test to apply to nonelite athletes. The modified LIST consists of 2 parts, Part A and Part B. Part A starts with a 5-minute warm-up and ends with 2 rounds of 15-minute game stimulation period and 2-minute rest. Part B is an exhaustive state that is timed until failure. The test consists of a combination of walking, sprinting, jogging, running, and rest. Siegler et al. (17) reported that the plyometric training group improved significantly in the abridged LIST over the control group ($p = 0.02$). This is the first time a modified LIST was used with youth subjects.

The impressive results warrant future researchers to follow the guidelines set by Siegler et al. (17) to validate this testing procedure. The subjects' soccer coach also noted an increase in wins, goals scored, and a decrease in goals allowed compared with the previous season. Siegler et al. (17) suggest that the training protocol is the main difference between groups and is the cause of the significant increase in performance in the experimental group. The main reason why plyometric training would cause such a significant increase in performance in this age group is youth athletes are still developing physically. Many adolescents are uncoordinated when participating in sport. Plyometric training in this age group will result in neural adaptations in the muscles making the athletes more efficient during quick movements. The improved coordination allows the youth athletes to be proficient in the speed, jumping, and agility needed to perform soccer skills.

All of the included studies saw significant improvements in performance during jumping tests. Multiple jumping tests were used, but the CMJ was the only jump test used in 6 of the 7 studies. Rubley et al. (16) used a 1-step approach VJ test instead of a CMJ test. According to Markovic (11), plyometric training produced somewhat greater (although not significantly) positive effects in the slow SSC jumps (particularly the CMJ) than in the concentric-only jumps (i.e., SJ), or even fast SSC jumps (i.e., DJ). In soccer, for instance, when heading the ball, the soccer athletes will use the slow SSC jumps. The keeper will also use these types of jumps while waiting for an athlete to shoot at the goal. Improvements in all jumps would be beneficial depending on the instance, but the majority of the jumping in soccer is due to slow SSC. Improvements in the CMJ can potentially translate into improvements on the field during a soccer game.

The researchers from the included studies suggest that plyometric training is appropriate for the studied age groups (3,5,13,14,16–18). The results from these studies suggest that soccer practice alone is not going to improve the explosiveness of the athletes' soccer performance. It is suggested that implementing this type of specialized training into soccer practice can increase power-related components needed to win matches (13,18). According to Diallo et al. (5) a detraining period of 8 weeks after the implementation of plyometric training did not cause a decrease in performance. This suggests that plyometric training is beneficial for the youth soccer population. Almost all sport seasons have a preseason training period to get prepared for the upcoming season. Most soccer seasons begin with preseason practices in preparation for the competitive season. The detraining finding by Diallo et al. (5) means that if plyometric training were incorporated into soccer preseason training and then stopped for 8 weeks when the regular season came, the youth soccer athletes would still maintain the same effects the plyometric training had during the preseason. The athletes would perform better throughout the season. This would be very beneficial to youth soccer teams.

Misconceptions about the potential danger of incorporating plyometrics with youth athletes may result in fewer teams using plyometrics with youth soccer. Lloyd et al. (9) suggested that the limited number of controlled studies that have used plyometric training in children is largely because of the possible misconceptions surrounding safety and ethical issues. Faigenbaum et al. (6) reported that resistance training was not recommended for children in the past because it was presumed that there was a high risk for injury. According to the National Electronic Surveillance System (NEISS) of the U.S. Consumer Product Safety Commission, many injuries were results of various types of resistance training. The NEISS data collected from emergency departments showed that these injuries were caused by inappropriate training techniques, excessive loading, poorly designed equipment, ready access to the equipment, or lack of qualified adult supervision (6). Faigenbaum et al. (6) states that it is misleading to generalize these findings to properly designed and supervised youth resistance training programs. In recent years, an increase in the number of controlled studies looking at the effect of plyometric training in youth sports has been shown to be beneficial for the youth population, further supported by consensus and position statements when following age-appropriate training guidelines (2,6,9).

The CSEP and the NSCA both report health benefits for children and adolescents from resistance training (2,6). A summary of the recommended guidelines can be found in Table 3. It has been shown that bone mineral density is increased after a plyometric training program in adolescent girls (20). Witzke and Snow assessed the effects of a 9-month plyometric training program in postpubertal girls between the ages of 13 and 15 years. They found that the plyometric training increased trochanteric bone mineral density compared with the control group (20). Plyometric training has also been shown to improve neuromuscular function. According to Markovic and Mikulic (12), neural control plays a key role in force potentiation during the SSC-type exercises. Lloyd et al. (9) report neural factors that may impact plyometric ability including motor unit recruitment, neural coordination, preactivation before ground contact, and stretch reflex responses immediately after ground contact. It is reasonable to assume that changes in muscle function and performance due to plyometric training have a neural origin (12). In children who participate in resistance training, neurological adaptations are inferred from strength gains that are not accompanied by muscle hypertrophy (2). There is minimal evidence of an increase in muscle size because of resistance training with this population (2).

The findings of this systematic review demonstrate the benefits of incorporating a plyometric training program in youth soccer. Implementing a plyometric program with this population should include proper planning and implementation. Plyometric training can be broken up into beginner, intermediate, and advanced phases. Once an individual is performing a phase of plyometric training with proper form and is not being challenged anymore, the individual can progress to the next phase. Each phase is categorized by number of contacts per session. The beginner phase is 80–100 contacts, the intermediate phase is 100–120 contacts, and the advanced phase is 120–140 contacts (15). Lloyd et al. (9) reported a plyometric progression model for children and adolescents. This model consists of 6 stages based on age and sex ranging from 6 to 19+ years. Each stage is geared toward specific goals of the youth athletes. It also takes into account learning techniques and appropriate progressions to minimize risk for injury and increase athletic performance (9). It is important that these recommendations be followed to ensure proper training and reduced risk for injury.

Practical Applications

The information presented in this systematic review is intended for use by coaches, strength and conditioning coaches, physical education teachers, athletic trainers, and anyone involved in youth soccer athletics. After reviewing the current literature on plyometric training and youth soccer athletes, we believe that plyometric training is a safe and effective way to improve soccer performance in the youth athletic population from the ages of 10 to 17 years for both males and females. Athletic performance consisting of kicking distance, speed, jumping ability, and agility significantly improved because of plyometric training interventions. Coaches or anyone implementing plyometric training should use extreme caution when selecting the workout protocols and should follow the guidelines from valid sources (2,6). The youth athletes' safety must come first.

The following are our recommendations based on the critically evaluated literature (2,3,5,6,8,9,13–18) in this review:

- The instructors of plyometric training should be trained and have a thorough understanding of plyometrics. They should focus on teaching youth athletes proper techniques to ensure minimal risk for injury and optimal benefits.
- Plyometric training should be performed on a grass or turf field where soccer practices occur to reduce risk for injury.
- Plyometric training should be completed 2 days per week for 8–10 weeks with a 72-hour rest period between plyometric training days. The total time for plyometric training should last between 10 and 25 minutes depending on number of athletes and level of plyometric training. The best time to perform plyometric training is at the beginning of practice, after warm-ups. Regular soccer practice can resume after the training session. The entire practice combined with plyometric training should last 90 minutes including warm-up and cool-down.
- The initial number of foot contacts should be 50–60 per session and increase to no more than 80–120 foot contacts per session for this age group to prevent overuse injuries. Progressions should only be made when the athletes no longer find the current amount of foot contacts challenging while performing proper techniques. Another form of progression is increasing jumping height. These 2 progressions should not occur at the same time.
- Three to four plyometric training exercises should be performed 2–4 sets for 6–15 reps per training session. Plyometric training exercises should consist of body weight exercises only, no use of additional weights.
- It is important to note that plyometric training should be individualized to each athlete with regard to sets/reps and progressions. This should be based on how challenged the athlete is feeling with the exercises and the quality and quantity of the technique. If the quality of movements is deteriorating, the athlete should not continue the exercise. The athlete should stop for the day to prevent injury.
- Finally, the exercises should be altered or changed regularly to keep the interest of the youth athlete. This will keep the athlete intrigued and wanting to perform proper techniques.

An example of an appropriate plyometric training program can be found in Table 4.

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