SYSTEMATIC REVIEW: THE EFFECT OF PLYOMETRIC EXERCISE PROGRAM ON CHILDREN'S DEVELOPMENT

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Abstract. Children with low motor competence have lower levels of physical fitness. Therefore, improving physical abilities in children with low motor competence can be an appropriate intervention, one of which is plyometric training. The aim was to examine the range and quality of literature, evaluate the efficacy and safety of plyometric training to improve motor performance in children. This study used a systematic literature review. Data sources were identified by searching the Elsevier database, PubMed, ScienceDirect, and Google Scholar. Search terms included "plyometric training," "children," "early childhood," "pediatric plyometric," "early childhood physical training," "low motor ability," "running training," and "jump training," in various combinations. Results: Five studies found positive results due to the subjects included in the inclusion group. Plyometric training at prepubertal age with a training period of 4-12 weeks, can improve children's physical and motor fitness. Plyometrics in children safely does not cause injury to children. Conclusion: Plyometric intervention during childhood improves physical and motor fitness without causing injury.

Keyword : Plyometric Training, Early Childhood, Physical training, Low motor ability.

INTRODUCTION

Physical activity engagement in daily life can minimize the risk of significant adverse physical health outcomes, such as cardiovascular disease, type two diabetes, obesity, osteoporosis, breast and colon cancer (Pedersen & Saltin, 2015).). During childhood and adolescence, adequate levels of daily physical activity increase the propensity to engage in physical activity into adulthood (Alvarez-Pitti et al., 2020). Increasing physical activity is a national health initiative for children of all abilities (22). Current Public health enterprise recommend 60 twinkles or further of moderate to vigorous physical exertion most days of the week for academy-aged children. Physical activity should be fun, developmentally appropriate, and should consist of a variety of activities. Children have the opportunity to start playing competitive sports at 7-8 years of age. However, before that, school-age children engage in playground games and recreational sports where they run, jump, skip, kick and throw.

Children with low motor competence have lower levels of physical fitness (Haga, 2009), lower levels of physical activity (Wrotniak et al., 2006), and participate in fewer recreational and play activities (Witzke & Snow, 2015). Wrotniak et al. suggest that running and jumping are fundamental skills for participating in active games and sports. Therefore, improving running and jumping ability in children with low motor competence could be an appropriate intervention to improve physical fitness, increase physical activity levels, and increase participation in recreational and play activities. However, there is little research on interventions that aim specifically to improve running and jumping ability in children with low motor competence or in young children.

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exercise can increase a child's speed of movement, increase power production and strengthen bones (Cesar & Malatesta, 2009). Plyometric training programs have been shown to be effective in adults and pubertal children to improve running speed and jumping ability (Markovic, 2007) and to increase strength (de Villarreal et al., 2010). Strength training can improve muscle performance and muscle group coordination, but to improve sports performance, children benefit more from practicing and perfecting the skills of the sport. Therefore, plyometric training may be an appropriate intervention to improve children's performance in sports. children's motor skills in running, jumping, skipping, hopping, kicking and throwing.

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Plyometric training produces dynamic movements and greater forces on muscles and bones. Historically, plyometric training was considered unsafe for youth, and a predetermined level of strength was a prerequisite for participation in plyometric programs. However, an update from the National Strength and Conditioning Association determined that this recommendation was not supported by current research or observations of daily play activities (Barbara Kitchenham, 2014). Currently, a number of studies have examined the effect of plyometric training in young children. Only 2 studies on prepubertal children were included in a meta-analysis of plyometric training (Markovic, 2007). Clearly, more research is needed to understand young children's response to plyometric training. It is also important to determine the safest and most effective methods for advancing the training load and to clarify the need for strength or motor skill prerequisites for participation in plyometric training.

It is recommended that elementary school-aged students include at least 60 minutes of moderate to vigorous intensity physical activity per day and participate in muscle and bone strengthening activities (McCarthy et al., 2021). Additionally, in the Active Healthy Kids Australia report, schools are encouraged to engage students in activities designed to improve motor performance skills proficiency and develop muscular fitness components such as power and strength (Sortwell et al., 2021). Despite the benefits and recommendations, physical inactivity is a concern for government health authorities as only 26% of five- to twelve-year-olds in Australia achieved Australia's physical activity guidelines in 2018 (Alvarez-Pitti et al., 2020). Considering that declines in physical activity levels begin at an early age, researchers have postulated that increasing children's motor performance skill proficiency levels could be critical to mitigating these declines (Barnett et al., 2016).

The aim of this systematic review was to examine the range and quality of the current research literature, to evaluate the efficacy and safety of plyometric training for improving motor performance in young children, and to determine whether this type of training can be used to improve the motor skills of children with low motor competence.

RESEARCH METHOD

This study uses a systematic literature review which is a literature review method that identifies, assesses, and interprets all findings on a research topic, to answer research questions that have been previously set (Barbara Kitchenham, 2014).). In this systematic literature review research using the Preferred Reporting Items for Systematic Reviews and Meta-analyses method or commonly called PRISMA. Systematic review is a method with the aim of helping to find the best results that can be obtained from systematic literature searches and then reading all literature sources that have been obtained and analyzing all literature data and making a conclusion from the results of literature data analysis in answering problems efficiently, relevant and clear. The stages of systematic literature review according to (Barbara Kitchenham, 2014) include, (1) Planning, (2) Data Collection, (3) Analysis and (4) Synthesis.

The literature review was conducted by searching for published studies in various databases such as Elsevier, PubMed, ScienceDirect, and Google Scholar using the keywords "plyometric training", "children", "early childhood", "pediatric plyometric", "early childhood physical training", "low motor skills", "running training", and "jump training," in various combinations. Studies selected had to meet the

inclusion criteria of performing plyometric training in early childhood and measuring physical and motor ability parameters. The search was conducted up to aPRIL 2023.
Primary research articles were selected if they (a) described the results of plyometric exercise interventions; (b) included measures of strength, balance, running speed, jumping ability or agility, motor skills; (c) included prepubertal children progressed 5- 14 times; and(d) used randomized control trials orquasi-experimental designs. Articles that met the 4 inclusion criteria were selected for final review. Reference lists of primary articles were searched for additional studies.
Data synthesis A total of 300 studies were retrieved after searches conducted using search terms were filtered by reading summaries. After excluding duplicate studies and applying the inclusion criteria, a total of 40 studies were selected, which were read in full and analyzed. Of these, the literature search found 9 articles and only 5 articles met the source inclusion criteria. The methodological quality of the 5 articles was assessed by Scimago Journal & Country Rank (SJR). The 5 journals were analyzed based on the suitability of the topic, research methods used, samples, interventions, instruments/parameters, and results of each article.

RESULT AND ANALYSIS

1.1 Quality assessment

Based on the results of the assessment of the reviewed studies, a limited amount of research was conducted in this topic area and caution is advised when interpreting the results. These 5 studies represent the researchers' initial attempts to evaluate the efficacy of plyometric exercise training in prepubertal children. Despite their moderate to high quality ratings, useful information can be obtained to determine the current state of knowledge regarding plyometric training and to identify recommendations for future research (Table 1).

Table 1. Scimago ranking results for determining journal quality

Author's	Ranking
(Sortwell et al., 2021)	Q3
(Arabatzi, 2018)	Q2
(Marzouki et al., 2022)	Q1
(Bogdanis et al., 2019)	Q1
(Almeida et al., 2020)	Q1

1.2 Effects of Plyometric Training

The purpose of this review was to first determine the effectiveness of plyometric training to improve motor performance, then to determine the optimal training dose, and finally to determine the safety of plyometric training for children. The following paragraphs describe our findings (Table 2). Five studies stated that plyometric training had a significant effect on children's motor performance and others, expressed with $P<0.05$.

Table 2: Benefits of Plyometric Training for Children. Five studies reported statistically significant effects

Source authors	Objective	Design	Population/ sample	Outcome Size	Results
(Sortwell et al., 2021)	Testing the effect of a plyometric-based program on elementary school students' motor performance, upper and lower body muscle power, and reaction strength index	Eksperimental	N=61, aged 7-8 years	Motor performance	Significant improvements in motor performance skill proficiency, upper and lower body muscle strength in the plyometric group vs the comparison group ($P\leq 0.05$)
(Arabatzi,	Investigating the	Eksperim	N=34 aged	Measurement of	Postural sway decreased

2018)	impact of trampoline plyometrics on postural control, and jump height in prepubertal children	ent	9,30±0,55 years	postural sway and maximum height in turning movements and jump falls.	significantly (P<0.05).
(Marzouki et al., 2022)	Plyometric training (PT) for children's fitness	Eksperim ent	N=120 aged 10.00±1.15 years	Squat jump, standing long jump, 20m sprint, 5-10-5 shuttle, dynamic balance and aerobic speed	PT twice a week induced an improvement in physical fitness, which may have transferred health status during childhood. In addition, surface type and gender did not affect the training-induced changes in physical fitness.
(Bogdanis et al., 2019)	To examine the effect of 8 weeks of plyometric training on jumping, sprinting, and change of direction (COD) performance.	Eksperim ent	N=50 Aged 7-9 Years	Melompat, lari cepat, dan perubahan arah (COD)	Additional plyometric training improved sprint performance, COD more than regular calisthenics training, and jumping performance.
(Almeida et al., 2020)	To examine the effect of plyometric training (12 weeks, twice/week, 20 min/day) on physical fitness (PF) and gross motor coordination (GMC) in schoolchildren aged 7 to 9 years.	Eksperim ent	N=116 Aged 7-9 years	PF (grip strength, standing long jump (SLJ), crouching, sit and reach, square test, running speed, and 1 mile run test), GMC, Korper-coordinations-test fur Kinder (KTK), and body mass index (BMI) were evaluated.	12 weeks PT improves gross motor coordination components and health-related physical fitness in children

The evidence for recommending exercise doses is summarized in Table 3. Five studies showed statistically significant results and were used to assess the consistency of exercise dose. The categories evaluated were frequency, duration and exercise method. Miller et al., 2006 in (Sortwell et al., 2021), stated that the plyometric-based program intervention is divided into three phases (periods), with the first and second phases being three weeks long and the final phase being two weeks long. The plyometric framework requires eight weeks of planned changes in acute training variables such as; exercise choice, number of reps per set, to maximize exercise adaptation. The study of Andrew et al, (2022) showed that an eight-week plyometric training program into the first 10-15 minutes of a physical education lesson out of a total teaching of 50 minutes. In each session, the plyometric group performed eight different plyometric activities. For the plyometric exercises involving the use of a ball, students were instructed with a light rubber ball weighing 200 grams before performing them with a ball weighing 1 kilogram. The medicine ball activities in weeks seven and eight used a two-kilogram medicine ball. The sports teaching program demonstrated the efficacy of embedding a plyometric-based training intervention in the warm-up phase for eight weeks resulted in significant changes in motor performance skills, upper and lower body muscle strength in students aged seven to eight years. This is in line with (Bogdanis et al., 2019) 2019 that an additional 8-week plyometric training program is effective in improving sprint and COD performance. DJ, SJ, and SLJ were equally improved in both groups, suggesting that the plyometric training did not lead to additional improvements of the jump types.

Arabatzi (2018) & Marzouki et al., (2022) stated that: A 4-week plyometric intervention protocol on a mini trampoline improved postural balance and vertical jump performance in prepubertal children. our results suggest that the current plyometric exercise protocol performed on a trampoline alters swaying posture during normal calm stance in prepubertal children. however, the results of this study are in

accordance with previous studies that reported improved balance ability after balance training on dura discs, or mini trampolines, in adults and children.
Another study based on (Almeida et al., 2020), research, explained that 12 weeks of plyometric training consisted of a twice-weekly exercise protocol on non-consecutive days (Tuesdays and Thursdays) for twelve weeks under monitored and controlled conditions. The protocol included low-intensity jumps followed by lateral jumps, squat jumps, left and right single-leg vertical jumps, and increasing levels of jump difficulty. The daily training session was divided into three parts: warm-up (jogging at a self-selected comfortable pace followed by stretching for 3 minutes), training, and cooling down. The plyometric training group showed improvements after 12 weeks in the static state of muscle strength, abdominal and lower limb strength tests, and agility and speed tests ($p<0.05$). Effect sizes in the plyometric training group were small to moderate in most tests, except for the standing long jump, sideways jump, and overall CEC score, which displayed large effect sizes.

Table 3. Plyometric Exercise Dosage

Construct	Article	Results	Conclusion
Duration	(Sortwell et al., 2021)	Effect of 8 wk Program	Current evidence suggests that a training effect can be achieved with a 4 week program. Two studies show that a training effect can be achieved with the 8 week program. One study showed that the effect of training can be achieved in 12 weeks.
	(Arabatzi, 2018)	Effect of 4 wk Program	
	(Marzouki et al., 2022)	Effect of 4 wk Program	
	(Bogdanis et al., 2019)	Effect of 8 wk Program	
	(Almeida et al., 2020)	Effect of 12 wk Program	
Frequency	(Sortwell et al., 2021)	1 times a wk / 50 minuts, (8 sessions)	3 studies stated that 8-12 exercise sessions produce an effect, 2 studies stated 16-24 sessions produce an effect.
	(Arabatzi, 2018)	3 times a wk (12 sessions)	
	(Marzouki et al., 2022)	2 times a wk / 60 minutes, (8 sessions)	
	(Bogdanis et al., 2019)	2 times a wk / 27 minutes (16 sessions)	
	(Almeida et al., 2020)	2 times a wk (24 sessions)	
Training method	(Sortwell et al., 2021)	Dribbling, catching, throwing, kicking the ball	Modified sports, group exercises, games
	(Arabatzi, 2018)	2 foot jump on a mini trampoline	Low intensity plyometric exercises
	(Marzouki et al., 2022)	Low-intensity aerobic activity and dynamic stretching of the lower leg muscles	Low intensity plyometric exercises
	(Bogdanis et al., 2019)	Plyometric components for the lower limbs (e.g. handsprings, round-offs, vaulting)	Two rounds of six exercises in circuit form
	(Almeida et al., 2020)	low intensity jumps followed by lateral jumps, squat jumps, left and right. single-leg vertical jump, and increased jump difficulty	plyometric speed and agility training

1.3 Safety

Sortwell et al., (2021), suggested that qualified PE teachers implement plyometric warm-ups and PE teaching programs. Student data was recorded during each lesson and no students suffered injury or pain during the plyometric warm-up. Plyometric activities consisted of dribbling, catching, throwing, kicking

the ball. This is in accordance with the study of (Bogdanis et al., 2019) stated that it should be noted during the intervention period, no injuries were observed, None of the participants had done systematic plyometric training in the past. All participants were injury-free six months before the study began and no gymnasts were injured during the study. Another study (Almeida et al., 2020), conducted a study with subjects encouraged to perform all plyometric exercises explosively and there was no damage or injury during the plyometric exercise program.

With respect to the safety of the exercises performed in this study using mini trampolines, research has shown that trampoline exercise involves a low risk of limb injury. In addition, research has supported the recommendation for the safe use of trampolines in the school environment as a tool to minimize the risk of injury. As already mentioned, trampoline exercise allows for exercise with reduced musculoskeletal load. However, to reduce the likelihood of injury, this protocol was implemented under the continuous supervision of the principal investigator and by applying all relevant safety regulations. While interventions performed on different surfaces were modified to avoid injuries and to improve postural stability. In addition, the performance of sports on appropriate surfaces such as mini-trampolines can reduce neuromuscular constraints that can lead to injury (Arabatzi, 2018).

Despite previous concerns regarding the risk of injury that strength training can pose in children, researchers agree that youth plyometric training (PT) approaches can provide a safe and effective strategy for conditioning and therefore should be included in youth fitness, health promotion, and injury prevention. Each exercise lasts approximately 5-10 seconds, and at least 90 seconds of rest is allowed after each set. Whenever an exercise is not performed correctly, it is stopped and repeated. During the training period, no damage or injury occurs (Marzouki et al., 2022). Plyomteric exercises can be one of the various developmentally appropriate activities included in training programs for young children. However, coaches should exercise caution when performing plyometric training interventions for young children as research to determine safety and efficacy is still in its infancy.

1.4 Plyometric Applications

The plyometric training programs used in the studies reviewed for this manuscript can be used to design exercise programs. The results of this review indicate that during middle childhood (ages five to seven years), the development of motor performance skills is critical and a sensitive period for rapid adaptation (Sortwell et al., 2021). Relevant programs to achieve this motor performance skill development can be implemented during physical education. The physical education curriculum has been identified as an ideal setting to assist children in developing (Arabatzi, 2018).

Training effects can be achieved with a twice-weekly program for 4-12 weeks on non-consecutive days. The training focus should be specific to the desired outcome, for example, if vertical jump height is the desired outcome, vertical strength should be emphasized in the plyometric training program. Training effects can also be achieved with a low intensity, 1-day-a-week program for 12 weeks. A PE education curriculum supplemented with explosive strength training such as plyometrics can engage students in a way that develops their movement performance skills and muscular fitness while still being sufficiently oriented towards improving motor skills. Plyometric training may be a safe and valid physical education pedagogical strategy to aid the development of motor performance skills.

The following plyometric training program based on the five studies can be applied in physical education. Training load should be increased weekly by performing increasing reps of each set each week. It is recommended that performing a low intensity plyometric program once a week results in smaller improvements in running and jumping ability. The first phase is low intensity, higher volume to safely introduce students to plyometric activities, followed by a second and third phase of progressively increasing intensity while reducing repetitions. Before the exercises are performed warm-up lasts for 10 to 15 minutes and followed by a set lesson the training session should be of 10-25 minutes duration and sufficient cool down. The plyometric station consists of upper and lower body exercises that have been preliminarily used with children. Children should wear appropriate footwear, exercise in an appropriate environment, and exercise on an absorbent surface (grass or mat). In plyometric exercises there is recovery with 20 seconds rest per session and 30 seconds between sets. Exercises should emphasize correct technique and adapt the exercises to the child's ability.

CONCLUSION

Although appropriate amounts of volume, intensity, and duration are required for low motoric interventions to be effectively improved. Collectively our findings suggest that plyometric training may be a safe and valid physical education pedagogical strategy to aid the development of motor performance skills. Therefore, PE curricula supplemented with explosive strength training such as plyometrics can engage students in ways that develop their movement performance skills and muscular fitness while still being sufficiently oriented towards improving motor skills.
Skill development exercises in a game-like environment can be part of the physical education curriculum, our findings suggest that physical education combined with plyometric training can improve motor performance skill proficiency, higher jumping, linear running speed, agility, balance, substantial improvements in sprint performance and COD and improved endurance performance than non-plyometric training among untrained schoolchildren and muscle strength in young primary school students. Plyometric training on a trampoline can be applied alone or combined with other task-specific exercises to safely improve postural balance and vertical jump performance, in prepubertal children.

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