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Examination of the Effects of Plyometric Training on Physical Fitness Variables of Pubertal and Adolescent Children

Mehmet Akif SARI[1], Yaşar Tekin CAN[2], Mustafa KILIÇ[3],

[1] Dr., Directorate of National Education, Training Science, Elazığ, Turkey,

Orcid: 0000-0002-0482-6008

[2]Directorate of National Education, Deputy Director of Institution, Elazığ, Turkey,

Orcid: 0009-0006-6498-0476

[3]Directorate of National Education, Physical Education and Sports Teaching, Elazığ, Turkey,
Orcid: 0009-0005-8810-5118

Abstract

In this study, the effects of plyometric training (PT) on physical fitness variables were investigated in sedentary children in the pubertal and adolescent period who did not engage in any physical activity other than physical education and sports classes. The study included 30 male students between the ages of 12-14. The study group received a total of 80 minutes of plyometric training, including warm-up and cool-down periods, on a grass field, 2 days a week, 2 lesson hours per day (2 groups of 15 people and 40 minutes for each group) for 6 weeks. Full rest was given between movements. Two measurements were made after the familiarization study. After the warm-up at the beginning of the first training (pre-test) and 24 hours after the training in the 6th week (post-test). Statistical analyses were performed with SPSS For Windows version 24.0. The Shapiro-Wilk test was used to check whether the data had a normal distribution. Since the data showed a normal distribution, the paired sample t-test was used. The critical value for statistical significance was determined as $p<0.05$. When the research data were compared, significant differences were observed in the pre-test and post-test, vertical jump ($p=0.018$), agility t-test ($p=0.006$) and 30-meter sprint test ($p=0.000$). As a result; It was determined that plyometric training applied to sedentary students in the 12-14 age group was effective on the measured variables of physical fitness, and could also be applied as an effective and fun method for children who are new to sports during the preparation period for school sports.

Keywords: Physical Fitness, Plyometric Training, Vertical Jump, Neuromuscular Adaptation, School Sports.

Öz

Bu çalışmada, beden eğitimi ve spor dersi dışında herhangi bir fiziksel aktivitede bulunmayan pubertal ve adölesan dönemdeki hareketsiz çocuklarda pliometrik antrenmanın (PA) fiziksel uygunluk değişkenleri üzerine etkileri incelenmiştir. Araştırmaya 12-14 yaş aralığında 30 erkek öğrenci katılmıştır. Araştırma grubuna; 6 hafta boyunca çim sahada, haftada 2 gün, günde 2 ders saati (15'er kişilik 2 grup ve her grup için 40 dakika), ısınma ve soğuma süreleri dahil toplam 80 dakika Pliometrik antrenman uygulanmıştır. Hareketler arasında tam dinlenme verilmiştir. Familizasyon çalışması sonrası iki ölçüm yapılmıştır. İlk antrenmanın başlangıcında ısınmadan sonra (ön test) ve 6. hafta da antrenmandan 24 saat sonra (son test). İstatistiksel analizler SPSS For Windows 24.0 sürümü ile yapılmıştır. Verilerin normal dağılıma sahip olup olmadığı Shapiro-Wilk testi ile kontrol edilmiştir. Veriler normal dağılım gösterdiğinden eşleştirilmiş örneklem t-testi kullanılmıştır. İstatistiksel anlamlılık için kritik değer p<0,05 olarak belirlenmiştir. Araştırma verileri karşılaştırıldığında ön test ve son testte, dikey sıçramada (p=0,018), çeviklik t-testinde (p=0,006) ve 30 metre sprint testinde (p=0,000) anlamlı farklılıklar görülmüştür. Sonuç olarak; 12-14 yaş grubu sedanter öğrencilere uygulanan pliometrik antrenmanın, fiziksel uygunluğun ölçülen değişkenleri üzerinde etkili olduğu, aynı zamanda, okul sporlarına hazırlık döneminde spora yeni başlayan çocuklar için etkili ve eğlenceli bir yöntem olarak uygulanabileceği belirlenmiştir.

Anahtar Kelimeler: Fiziksel Uygunluk, Pliometrik Antrenman, Dikey Sıçrama, Nöromüsküler Adaptasyon, Okul Sporları.

1. INTRODUCTION

The fact that sports can be a part of life is a behavior that we will gain in childhood. It is insufficient to define sports as a contribution to the successive biological maturation processes for children who are constantly developing. In addition to physical development, it is also extremely important for the development of mental health, attitudes and behaviors. It has been proven by scientific studies that sports play a major role in children gaining joint awareness, ensuring neuromuscular integrity, and in short, in achieving physical fitness with multi-faceted development. It is known that movements that create stress in the skeleton and muscles of children in the growth age increase strength, agility and speed, increase the size and mineralization and density of the bone, strengthen the connection of tendons to the bone and ensure that they have a proper anatomical structure. In addition, a physically active lifestyle in pediatric years can help reduce the risk of developing some chronic diseases later in life, Rowland (2007)[1]. Sports activities and regular exercise activities that children participate in contribute to the healthy development of the physical structure; while preventing deterioration of posture in older ages. Childhood, where growth progresses rapidly, shows a continuous change with development and maturation in biological, psychological, mental and social aspects. Therefore, it is accepted that regular exercise activities and participation in sports activities in childhood are extremely important in order to be healthy, to achieve physical fitness and to preserve body integrity in later ages Strong (2005)[2]; Huang et al. (2009)[3].

In light of this information, children who are new to sports have difficulty in getting the desired efficiency from sports branches during the preparation period for school sports compared to children who have achieved physical fitness and have a sports background. Children who have not achieved physical fitness have a low level of performing sports-specific movements well and safely, which increases their likelihood of injury or disability. In addition, equipment and time are needed to reach the performance level required by school sports branches. Considering all the limitations, specialized, economical training methods such as plyometric training are needed. The aim of our study is to examine the effect of plyometric training on the physical fitness level of sedentary children and also to determine its usability during the preparation period for school sports.

Physical Fitness

Physical fitness can also be defined as the ability to perform daily activities well and successfully. Physical fitness includes cardiorespiratory endurance, muscular endurance, muscular strength, muscular power, speed, flexibility, agility, balance, reaction time and body composition (Özer 2006)[4]. In this respect, a person with good physical fitness is someone who can move for a long time without getting tired, Zorba and Saygın, (2007)[5]. The development of physical fitness in children means that biological growth and maturation occur at the best level, Dumlupınar, (2007)[6]. Increasing research clearly shows that physical activity and physical fitness are associated with health benefits in children, Poitras et al. (2016)[7] Therefore, understanding and developing strategies that will encourage physical activity and improve children's fitness levels is more important than ever. These strategies can be developed in the school environment or in different contexts, Popovic et al. (2021)[8]

There are three stages in long-term training that play a role in children's reaching and maintaining physical fitness: 1 Basic training period, 2 Developmental training period, 3 High-level training period. In the basic training period, the aim is to develop characteristics in a general and multi-faceted way (Dumlupınar, (2007)[6]; Assoc. Prof. Dr. Uğur DÜNDAR, (2017)[9]; Karabina and Pirselimoğlu, (2017)[10]

The physical fitness of children and adolescents is an important source for their future health, however, when the physical fitness findings are evaluated as a result of the research consisting of more than 860,000 children and adolescents, a general decreasing trend is seen, and the majority of studies on the subject report a decrease in physical fitness over time, Eberhardt et al. (2020)[11]

Strength

It is one of the most important elements of performance, it is defined as the ability to resist any resistance or to resist resistance for a certain period of time, Sayın, (2011)[12]. According to the physiological definition, the tension created by muscle contraction is the strength itself. It is known that people with high strength levels are good at performing motor skills. During strength development, there are some changes related to biological development in the adolescence period. The adolescence period, known as the entrance to puberty between childhood and adulthood, when physical, sexual differentiation and psychosocial change occur, is between the ages of 14-17 in boys and 13-17 in girls, Hasırcı et al. (2009)[13] Strength development slows down in the pre-adolescent puberty period and strength development accelerates again due to hormonal changes that occur in the adolescence period. It has been stated that the peak level of strength development in boys, who enter puberty 2 years later than girls, is between the ages of 13-15, Muratlı, (2007)[14]. However, it has been reported that strength training during the pubertal period, which covers the age range of 10-13, may be harmful, Gül, (2011)[15]. In another study, it has been reported that in children who are under load during training, the cartilage structure called the epiphyseal plate, which grows the bones in length, will be affected by training-related stress and growth and development will be negatively affected accordingly, thus increasing the risk of injury, Eniseler, (2009)[16].

Several retrospective case reports published in the 1970s and 1980s reported injuries to the growth plate in prepuberty (Gumbs et al. (1982)[17]) and in adolescence (Benton, (1983)[18]). However, most of these injuries occurred due to improper lifting techniques, maximum lifting, or lack of qualified adult supervision, Faigenbaum et al. (2009)[19]

In this respect, unlike traditional strength-building exercises, it is recommended that athletes perform strength training with body weights in the early adolescence period without using extra loads. Based on these explanations, the healthiest period to begin strength training is the postpubertal adolescence period, Gürsoy et al. (2007)[20]

It has been reported that strength training contributes to the increase in bone mineral density, improvement in body composition, general increase in athletic performance in children, and is beneficial in eliminating the risk of injury, Faigenbaum et al. (2009)19 In addition, it is known

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to provide benefits in protecting general performance, general flexibility and motor skills, Kızılet et al. (2010)[21]

Agility

Agility is the ability to move the body between two points and change direction as easily, quickly, fluently and in a controlled manner as possible with the participation of balance, speed, strength and neuro-muscle coordination, Turner, (2011)[22]. In other words, it is stated that the reactions of the whole body, such as speed and direction changes, in response to a stimulus, Sheppard and Young, (2006)[23]. When looking at recent studies in the literature, for agility, physical characteristics such as speed, direction changes, sudden stops, re-acceleration and strength, as well as cognitive factors such as visual and intuitive perception and quick decision-making are quite important, Armstrong and Greig, (2018)[24]

Speed

It is the speed or pace of receiving information, processing this information and being able to act appropriately for the situation at the highest speed, or the speed or pace of behavior, Muratlı et al. (2005)[25] It is also one of the basic motoric characteristics such as agility and strength, and it is hereditary and can only be brought to an efficient level with coordinated and conscious work, Bompa, (1998)[26]. As can be understood from the definitions, it is based on the cognitive process, it is the ability to perform a movement at full speed as a result of the central nervous system and muscular system working together under the guidance of the athlete's will.

Plyometric Training (PT)

In order to ensure the physical fitness of the individual and to reach the highest efficiency in different sports branches, it is necessary to develop complementary elements such as agility, strength and speed at a high level. For this purpose, there are specialized training types applied with different strategies and techniques in training science. One of these is (PT) Plyometric training, Johnson et al. (2011)[27]

PT is basically a series of special movements that include jumps and leaps. It has been a preferred training branch for many years both in professional athletes and in children who do a certain sport in adolescence due to its economy, applicability to the lower and upper extremities of the body, adjustability of intensity and variety of movements.

Conceptually, PT is characterized by the operation of the stretching-shortening cycle (Stretch-Shortening Cycle, (SSC)) that develops during the transition from a rapid eccentric muscle contraction (deceleration) to a rapid concentric muscle contraction (acceleration), Bedoya et al. (2015)[28] SSC tasks exploit the elastic properties of connective tissue and muscle fibres by enabling the muscle to accumulate elastic energy during the acceleration/negative phase and then release it during the acceleration/positive phase to increase muscle force and power output, Michailidis et al. (2013)[29] This regime of SSC muscle contractions is a typical part of muscle activity in a number of specific sports activities, including acceleration, change of direction, vertical and horizontal jumps, Cormie et al. (2011)[30] Plyometrics, also known as jump training or "plyos", involve exercises based on the production of maximal muscular force in the shortest possible time in order to increase speed and power, Markovic et al. (2007)[31] This training discipline first appeared in Russian sports literature in 1966 in the work of V. M. Zaciorski, Radcliffe and Farentinos, (2009)[32].

PT helps improve athletic ability, ballistic skills, kinesthetic awareness, rhythm, and coordination in general, Chapman et al. (2007)[33] It is an effective physical conditioning tool that enhances the stretch-shortening cycle and promotes improvements in skill-related measures of athletic performance as well as health and injury resistance, Vera-Assaoka et al. (2020)[34] PT

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has many benefits for improving overall performance in athletes. It increases explosive strength, muscular power, speed and quickness, agility, neuromuscular coordination, vertical jump performance, leg strength, increases joint awareness, and enhances athletes' skill performance in football and other sports. Roopchand-Martin and Lue-Chin, (2010)[35] It is well-established in the scientific literature as a safe and effective training regimen for improving numerous high-intensity actions such as sprinting, jumping, and changes of direction in youth football players, Negra et al. (2020)[36]

In addition, PT also improves various athletic performance elements such as jumping, running and agility in prepubertal children, Kotzamanidis C. (2006)[37]

This training form is a preferred method especially when aiming to improve vertical jump ability and leg muscle strength. While improving leg muscle strength in general and vertical jump performance in particular, they are also critical elements for successful athletic performance as well as the smooth performance of daily life activities and professional tasks and jobs, Markovic et al. (2007)[31] It has become a frequently preferred system in improving the physical capacity of healthy individuals and athletes, and intensive scientific studies have been conducted in the last thirty years.

Sports activities (e.g. football, handball, basketball, athletics) require explosive power, Markovic et al. (2007)[31], because players perform many explosive movements such as kicking, tackling, jumping, turning, running and changing speed and direction during the match, Chaouachi et al. (2009)[38]. As is known, explosive strength is defined as the ability of an individual's neuro-muscular system to exert effort in the shortest time and is one of the fundamental aspects of good athletic performance, Verhošanski, (1979)[39]. Explosive muscle movements such as sprinting, jumping and change of direction speed (CODS) together with aerobic power have been shown to affect game performance in young football players, Ramírez-Campillo et al. (2015)[40] For these reasons, explosive strength is considered an important factor in competitive events, Wang et al. (2023)[41] Plyometric exercises generally involve stopping, starting and changing direction explosively, Slimani et al. (2016)[42]

Various training strategies such as heavy resistance training, explosive-type resistance training, and plyometric training can be used to increase explosive strength and dynamic athletic performance, WILSON et al. (1993)[43] Plyometric training is advantageous in every aspect for school sports. Compared to traditional resistance training, the ballistic nature of PT prevents deceleration towards the end of a given movement and provides increased performance, Suchomel et al. (2018)[44] The main reason for the improvement in jumping ability following PT is the increase in central nervous system adaptation, muscle strength, and explosiveness. Specifically, neural adaptation is characterized by changes in muscle activation strategy that include increased activation of agonist muscles and decreased activation of antagonist muscles or improvements in muscle excitability due to lengthening and shortening, Bedoya et al. (2015)[28]

In this context, the inclusion of integrative neuromuscular programming as part of physical education and sports participation may provide a mechanism for the development of dynamic preventive actions and the increase of physical activity levels and sports skills in children and adolescents, Myer et al. (2016)[45] Since it has been stated that in children, training-induced strength gains are related to neuromuscular mechanisms rather than hypertrophic factors, Malina, (2006)[46]

There are different forms of PT, used according to the purpose of the program and all consist of natural movements, de Villarreal et al. (2009)[47], and include minimal, non-strength movements similar to those encountered in children's play activities, Michailidis et al. (2013)[29], and can be economical and not demanding compared to other resistance training methods, since it involves exercises that require little or no equipment, usually using body mass as resistance, Chu and Myer, (2013)[48]. In addition, it can be performed in a relatively small physical space; This may be advantageous in certain situations where athletes may have to train in environments such as home (pandemic restrictions), Gentil et al. (2020)[49]. It may also be considered more enjoyable than other training methods, especially among children and adolescents, Barrio et al. (2023)[50]

The application of PT to improve strength in pubertal and adolescent athletes was initially seen as undesirable. Because adolescents are in the period when growth and development are at their most intense, which makes them more susceptible to excessive fatigue and sports injuries, Clemente et al. (2020)[51] While PT was thought to be unsafe, especially in childhood, in recent years this concern has given way to the view that it can be effectively used to improve the condition of children, respecting the principle of specificity, using good techniques and taking safety precautions, Ramirez-Campillo et al. (2018)[52]

However, compared to adults, adolescents have a higher nerve load, which makes it difficult to effectively regulate the SSC process, Viru et al. (1999)[53]

With the increase in training frequency, motor neurons connect more frequently to the appropriate muscle fibers, making the synthesis and release of neurotransmitters more efficient. This leads to a clearer transmission of nerve impulses to the muscles and thus activation of more muscle fibers, Chen et al. (2023)[54] The principle of progressive load training with training frequency aims to promote ongoing adaptations and mainly involves gradually increasing training loads over time by changing training volume and intensity, Ramírez-Campillo et al. (2015)[40] In this respect, it would be useful to prepare the PT content with the progressive load principle. Due to the nature of PT, pressure is created on joints, tendons and vertebrae during jumps. In order to minimize risks, training should be done on suitable surfaces that can absorb pressure, while it can be done on grass fields, non-deformed carpet pitches, wrestling mats or tatami floors, hard surfaces such as asphalt, paving stones or concrete should not be preferred for PT, Clutch et al. (1983)[55] It has been stated that PT done in water and on sand surfaces causes less muscle damage compared to a hard surface, Arazi et al. (2016)[56] It has been reported that the optimal jumping and leaping height for PT should not be higher than 95 cm. In many studies, the appropriate height is seen to be 50 cm, Muratlı et al. (2005)[25] The minimum PT duration should be at least 6 weeks for significant benefits and performance increase in young athletes, Fischetti and Greco, (2017)[57].

In a systematic review of the effects of PT on agility in male soccer players, the greatest improvement in agility was seen after two and six weeks of PT, with six and eight weeks being the most effective PT programs. Improvement in PT was more robust with a series of exercises focused on gradually increasing intensity, including jumps and lower extremity activation. Based on the analysis of the included studies, it is recommended that the minimum duration for improvement in agility and other motor skills is six weeks, with the usual weekly load being given in two to three training sessions. Ilma Čaprić et al. (2022)[58] In addition to this information, programs with a short PT frequency of two sessions per week have been proven to be effective in groups of individuals with various fitness levels and sports experience, Milič et al. (2008)[59]. For example, a two-week training program of three sessions per week including high-intensity plyometric exercises (180 to 250 jumps per session) may be recommended as a short-term strategy that will optimize the likelihood of experienced athletes achieving significant improvements in explosive strength and sprinting, Slimani et al. (2016)[42]

1.1. Theoretical Framework

To date, most studies have focused on physically active individuals participating in a specific sport. As can be seen, the effects of plyometric training on physical fitness in sedentary children have been limited. The aim is to investigate the effects of plyometric training on physical fitness in middle school students during puberty and adolescence and to offer relevant recommendations

2. METHOD

30 male students participated in the study with the approval of their parents. A state secondary school 7th grade students were informed about the PT model and their interest and attention were attracted to participate. A PT program was applied for 6 weeks, 2 days during the week and 2 lesson hours per day (2 groups of 15 people and 40 minutes each) including warm-up and cool-down periods, totaling 80 minutes per week. A familirization study was conducted before the measurements to ensure that the students were familiar with the tests. Before starting the first training, vertical jump, agility t-test and 30-meter sprint measurements were made for pre-test purposes and the specified measurements were made again for post-test purposes the day after the training at the end of the 6th week. An experimental method with a pre-test and post-test design without a control group was used in the study.

Ethics Committee Approval

This study was conducted in accordance with the ethics committee after receiving the approval of the Fırat University Social and Human Sciences Research Ethics Committee (Session Date 01.03.2024, Session Number: 2024/05), with the permission of the Elazığ Provincial Directorate of National Education. Scientific Research Permit Evaluation Commission Strategy Development Branch R&D Unit (Meeting Date 29.03.2024, Meeting Number: E-79137285-44-99902049)

Data Collection

Height and Body Weight Measurement

Students' weights were determined with a Tanita brand scale with a sensitivity of 20 grams, while wearing only shorts and bare feet. Their heights were determined with a Holtain Ltd. brand sliding caliper height meter while the subjects were standing upright.

BMI: Calculated by dividing the subjects' weights by the square of their heights.

BMI = weight/height (m2).

Vertical Jump

To determine the children's vertical jumping abilities, a TKK 5406 Jumpmeter (Jumping Measurement Device) with a measurement range of 5 cm to 99 cm, a minimum measurement increment of 0.1 cm, and a sensitivity of ±2.0 kgf was used. The rope connected to the indicator on the measurement device was tied to the waist and adjusted. They were told to jump upwards with both feet by bending their knees 90° and to maintain their balance when they fell to the contact point on the ground and not to step in any direction. 2 trials were performed with a 1-minute interval and the best score was recorded. Ross and Marfell-Jones, (1991)[60].

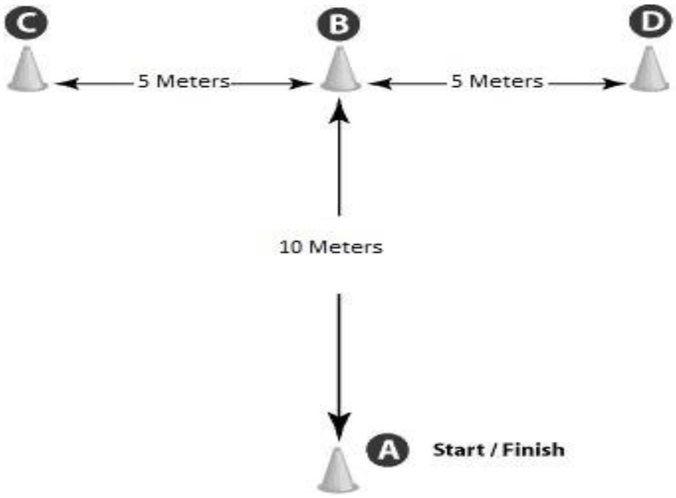
Agility T Test;

It consists of contacting the top of 4 cones arranged in a T-shape in an area of 10 meters in length and width (Figure 1). The aim is to complete a determined series in the shortest possible time by moving quickly between the contact points. Unlike other tests, the subject moves without changing the direction he/she looks from the moment he/she starts the test, and completes the 40-meter series with movements such as running forward, sliding to the right and left, and running backwards with changes of direction, Raya et al. (2013)[61].

30-Meter Sprint;

The measurement is completed by recording the time spent running with maximum effort on a 30-meter flat field with the start and finish points determined by tape after the participants warm up. The best score of the 2 trials with 2 minutes of rest is recorded Tamer, (2000)[62].

Figure 1. Agility T-Test Diagram.



Data Analysis

Data were analyzed using the SPSS program procedure in order to show the difference before and after the 6-week PT program. The Shapiro-Wilk test was used to determine whether the data were normally distributed. Since the data were normally distributed, they were analyzed using the paired sample T test. The critical value for statistical significance was accepted as $p<0.05$.

Plyometric Training Content

1. Rope Jumping
2. Going up and down on a 20 cm step board with one foot
3. Single foot ladder exercise on flat ground
4. Double foot ladder exercise on flat ground
5. Side hopping from a ladder on flat ground
6. Jumping with one foot by pulling the knees to the abdomen
7. Jumping with two feet by pulling the knees to the abdomen
8. Double foot forward jump
9. Cross jump on flat ground
10. 20 cm toe climbing stairs with the right foot
11. 20 cm toe climbing stairs with the left foot
12. 20 cm toe climbing stairs with the double foot
13. Jumping over a 30 cm cone with the left foot
14. Jumping over a 30 cm cone with the right foot

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15. Jumping over a 30 cm cone with the double foot
16. Side hopping over a 30 cm cone with the left foot
17. Side hopping over a 30 cm cone with the right foot
18. Side hopping over a 30 cm cone with the double foot hop
19. Stepping on and off the 40 cm step board with the left foot
20. Stepping on and off the 40 cm step board with the right foot
21. Jumping on the 30 cm step board with the left foot
22. Jumping on the 30 cm step board with the right foot
23. Jumping on the 40 cm step board with the double foot
24. Jumping from the floor to the vault-from the vault with the left foot 30 cm
25. Jumping from the floor to the vault-from the vault with the right foot 30 cm
26. Jumping from the floor to the vault-from the vault with the double foot
27. Depth jump from the left foot to the step board 20-30 cm
28. Depth jump from the right foot to the step board 20-30 cm
29. Depth jump from the double foot to the step board 30-40 cm
30. Jumping forward over the 30 cm cones arranged in a row with the left foot
31. Jumping forward over the 30 cm cones arranged in a row with the right foot jump
32. Jumping forward over 30 cm cones lined up one after the other with two feet
33. Jumping 30-40 cm deep with the left foot
34. Jumping 30-40 cm deep with the right foot
35. Jumping 30-40 cm deep with the double foot
36. Vertical jump at the base of the wall with the left foot
37. Vertical jump at the base of the wall with the right foot
38. Vertical jump at the base of the wall with the double foot
39. Jumping by pulling the knees to the abdomen

The PT content applied for 6 weeks is presented in Table 1. PT exercises were applied immediately after the stretching exercises. The numbers given in the exercise type column indicate the exercises in the training content, and the numbers in the jump number column indicate the number of times each movement was repeated.

Table 1. Plyometric training table

Week	Exercise type	Number of jumps	Number of sets	Total number of jumps
Week 1	1.2.3.4.5.6.7.8.9.10.11.12	20.10.10.10.10. 5.5.5.5.10.10.5	2	210

Week 2	1.2.3.4.5.6.7.8.9.10.11.12	20.10.10.10.10. 5.5.5.5.10.10.5	2	210
Week 3	1.2.3.4.5.6.7.8.13. 14.15.16.17.18	20.10.10.10.10. 5.5.5.5.5.5.5.5.5	2	210
Week 4	1.3.4.8.13.14.15.16.17.18.19 20.21.22.23.24.25.26.29	20.10.10.5.5.5.5.5. 5.5.5.5.5.5.5.5.5.5.5	2	240
Week 5	1.16.17.18.19.20.21.22.23.2. 25.26.27.28.29.30.31.32.35	20.5.5.10.10.10.5. 5.5.5.5.5.5.5.5.5.5.5	2	250
Week 6	1.12.13.14.15.24.25.26.27.2. 29.32.33.34.35.36.37.38.39.	20.10.5.5.5.5.5.5.5. 5.5.5.5.5.5.5.5.5.10	2	240

3. FINDINGS

Height, weight, age and body mass index (BMI) of the students in the study are presented in Table 2.

Table 2. Height (cm), weight (kg), age (years) and BMI (kg/m2) of the students (n=30)

Parameter	Height, cm	Weight, kg	Age, years	BMI, kg/m2
Mean	152,43	50,56	12,76	20,40
Standard Deviation	7,01	6,86	0,66	2,04

BMI: weight (kg)/height squared (m²)

The height and weight values of the students in the study were measured as 152.43±7.01 cm and 50.56±6.86 kg, respectively, their age was determined as 12.76±0.66 years, and their body mass index was calculated as 20.40±2.04 (Table 2).

Table 3. Vertical jump values of the students in the study.

Variable		x̄	S	T	*p
Vertical Jump	Pretest	2,2653	11,20570	-2,513	0,018
	Posttest	2,2740	10,66286		

A related sample T-test was applied to determine the difference between the vertical jump scores of the students in the study before and after the PT program and the results are presented in Table 3. As seen in Table 3, there is a statistically significant difference between the Vertical Jump pre-test and post-test (*p<0.05). This difference is in favor of the post-test average. Therefore, PT increased the vertical jump score in sedentary students and was determined to be effective.

Table 4. Agility t-test values of the students in the study.

Variable		x̄	S	T	*p
Agility t-test	Pretest	15,1850	1,76071	2,987	0,006
	Posttest	14,9323	1,94924		

A related sample T-test was applied to determine the difference between the Agility T-Test scores of the students in the study before and after the PT program, and the results are presented in Table 4.

As seen in Table 4, there is a statistically significant difference between the pre-test and post-test of the Agility T-Test (*p<0.05). This difference is in favor of the post-test average. Therefore, PT reduced the Agility T-Test completion time in sedentary students and was determined to be effective.

Table 5. 30-Meter Sprint values of the students in the study.

Variable		x̄	S	T	*p
30Meters Sprint	Pretest	6,2693	0,52182	4,653	0,000
	Posttest	5,9857	0,59261		

A related sample T-test was applied to determine the difference between the 30-Meter Sprint scores of the students in the study before and after the PT program, and the results are presented in Table 5.

As seen in Table 5, there is a statistically significant difference between the 30-Meter Sprint pre-test and post-test (*p<0.05). This difference is in favor of the post-test average. Therefore, PT reduced the 30-Meter Sprint completion time in sedentary students and was determined to be effective.

4 DISCUSSION

In our study, a PT program was applied to children with no sports experience for 6 weeks, and the vertical jump, agility T-test and 30-meter sprint scores were examined before and after the program. According to the pre- and post-tests, it was observed that the vertical jump, agility T-test and 30-meter sprint scores changed at a statistically significant level (*p<0.05).

PT; It is the most efficient method frequently preferred for developing agility, speed and explosive strength, and is a training type used to increase the explosive strength and power components of athletes, Chu, (1998)[63]. In the study examining the effects on neural activation of knee extensors during isometric, concentric and eccentric contractions, it was stated that PT applied for 6 weeks and 3 sessions per week increased the maximum voluntary contraction (MVC) power and neural activation of the quadriceps muscle, regardless of the contraction mode, Behrens et al. (2016)[64] Our study is parallel to this study on neural activation.

It has been reported that short-term PT has positive effects on sprint and jumping power, which are important determinants of match-winning moves in football, Asadi et al. (2018)[65] In the study investigating the effects of jumping exercises with and without stretch-shortening cycle movements on physical conditioning components in pre-adolescent male football players, it was reported that jumping exercises using SSC were generally more effective in improving speed and muscle strength performance measurements in young athletes, however, it was stated that jumping exercises without SSC negatively affected change of direction performance in young athletes, Bouguezzi et al. (2020)[66] Our study is parallel to the results of this study.

As a result of 28 studies of medium to high methodological quality, it was reported that PT improved muscle strength, linear sprint speed, change of direction speed, balance and muscle power in basketball players regardless of gender and age, and that the development increased linearly with age, Ramirez-Campillo et al. (2022)[67] In terms of time efficiency, it is recommended to use the low-volume PT model in order to improve the representative features of athletic performance. In the study related to this recommendation, the effects of 8 weeks (2 sessions per week) of low- and high-volume PT in-season in children aged 12-14 were compared on physical condition measurements in pre-adolescent male football players, and similar performance increases were observed in sprint time, change of direction and jumping ability measurements between the low and high-volume PT groups, Chaabene and Negra, (2017)[68]. The results of this study show similar performance increases with our study in the same age group.

The results of different meta-analyses show that PT is an effective method for improving jumping performance in children aged 10 to 18 years, which supports the view that PT can improve lower extremity explosiveness, Moran et al. (2017)[69]; Oxfeldt et al. (2019)[70]. In a study involving badminton players aged 12-13 years, it was stated that squat jump height increased significantly in the PT group compared to the control group, and agility increased significantly by a value of 6%, but there was no improvement in the control group, Ozmen and Aydogmus, (2017)[71]. Our results are parallel to this study conducted with the same age group.

In studies conducted with sedentary children; to determine whether pre-adolescent boys have plyometric trainability, 45 children aged 10-11 were divided into 2 groups as regular football training and football + plyometric training and trained twice a week for 12 weeks, the results showed that the children had significant plyometric trainability and that football training led to greater performance gains when supported by a PT protocol, Michailidis et al. (2013)[29]. The results of the study are parallel to our results. In the study examining age-related changes in plyometric-based double- and single-legged jump performance, it was reported that the double-legged countermovement jump (CMJ) and single-legged CMJ (SCMJ) scores of 143 sedentary boys aged 7-15 increased with a similar trend with age, Hioki et al. (2023)[72]. The results of the study are similar to our study and show that younger children, namely 5th and 6th grade students, can also participate in plyometric training.

Marta et al. reported that suspension training (ST) in which 118 sedentary children aged 10-11 participated was effective compared to the control group, while plyometric training provided more gains than ST. It has been suggested that 8 weeks of ST or PT is effective in improving variables related to strength and power in healthy, sedentary children. Based on the results, it has been stated that it can be considered as an alternative to traditional resistance training and can be applied in school-based programs, Marta et al. (2022)[73]. The results of the study are consistent with our aim in the study and show similar results.

In a study in which 29 girls and 32 boys aged 7-8 who attended physical education classes were divided into two groups, one group was subjected to plyometric-based movements in a 15-minute warm-up period for 8 weeks, while the other group was subjected to regular warm-up activities. It has been reported that children who warm up based on plyometrics have significant increases in motor performance skill proficiency, upper and lower body muscle strength, and that the inclusion of a plyometric-based program in the warm-up phase of physical education classes can increase motor performance skills and muscle strength even in pre-adolescent (under 12 years of age) primary school students, Sortwell et al. (2021)[74]

Conclusion and Recommendation

As a result; plyometric training is effective on measured variables of physical fitness in sedentary children. It is parallel to literature studies that include sedentary and active sports children. Considering the decrease in children's physical fitness levels over time, choosing plyometric training as a warm-up in primary school physical education classes and as an activity in secondary school can contribute to increasing physical fitness as a practical and fun method.

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