Physiological concept of plyometric training to improve physical fitness of basketball players: a systematic review

Concepto fisiológico del entrenamiento pliométrico para mejorar la aptitud física de los jugadores de baloncesto: una revisión sistemática

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Abstract

Background: Increasing the physical capacity of basketball players is needed to support achievement. Good physicality is closely correlated with the resulting exercise performance. Plyometric exercise is an exercise to develop speed and strength (power) by using your own body weight.
Objective: The aim of this study was to look at how plyometric training (PT) affected basketball players' athletic performance. It also provides a theoretical basis in the application of plyometric training (PT) for basketball.
Materials and methods: Science Direct, Web of Science, and Pubmed were among the literature databases we searched for this systematic review investigation. articles that addressed basketball, plyometric training, and physical fitness that were released within the previous five years. A total of 238 published publications were found using the Web of Science, Pubmed, and Science Direct databases. Ten papers that satisfied the inclusion criteria were chosen and examined for this systematic review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were used in this study to assess standard operating procedures.
Results: Plyometric training has been shown to improve basketball players' physical fitness, according to a systematic review. It has been demonstrated that plyometric training greatly improves basketball players' physical conditioning.
Conclusions: Plyometric training is clearly proven to increase the physical fitness of basketball players. So that this can be a recommendation to be applied as a training menu for basketball athletes to support achievement.

Keywords

Plyometric traning; physical exercise; physical fitness; basketball.

Resumen

Antecedentes: Es necesario aumentar la capacidad física de los jugadores de baloncesto para lograr sus objetivos. Una buena condición física está estrechamente relacionada con el rendimiento físico resultante. El ejercicio pliométrico es un ejercicio para desarrollar la velocidad y la fuerza (potencia) utilizando el propio peso corporal.
Objetivo: El objetivo de este estudio fue observar cómo el entrenamiento pliométrico (PT) afectaba el rendimiento atlético de los jugadores de baloncesto. También proporciona una base teórica para la aplicación del entrenamiento pliométrico (PT) en el baloncesto.
Materiales y métodos: Science Direct, Web of Science y Pubmed se encontraban entre las bases de datos bibliográficas que buscamos para esta investigación de revisión sistemática. Se encontraron artículos que abordaban el baloncesto, el entrenamiento pliométrico y la aptitud física que se publicaron en los cinco años anteriores. Se encontró un total de 238 publicaciones utilizando las bases de datos Web of Science, Pubmed y Science Direct. Se eligieron y examinaron diez artículos que cumplían los criterios de inclusión para esta revisión sistemática. En este estudio se utilizaron los elementos de informe preferidos para revisiones sistemáticas y metaanálisis (PRISMA) para evaluar los procedimientos operativos estándar. Resultados. Se ha demostrado que el entrenamiento pliométrico mejora la condición física de los jugadores de baloncesto, según una revisión sistemática. Se ha demostrado que el entrenamiento pliométrico mejora en gran medida el acondicionamiento físico de los jugadores de baloncesto.
Results: Plyometric training has been shown to improve basketball players' physical fitness, according to a systematic review. It has been demonstrated that plyometric training greatly improves basketball players' physical conditioning.
Conclusiones: Se ha demostrado claramente que el entrenamiento pliométrico aumenta la condición física de los jugadores de baloncesto. Por lo que puede ser una recomendación para aplicar como menú de entrenamiento para los atletas de baloncesto para apoyar el rendimiento.

Palabras clave

Entrenamiento pliométrico; ejercicio físico; aptitud física; baloncesto.

Introduction

Basketball is a team sport performed at regular intervals characterized by quick transitions between offense and defense, and physical contact with each other. Exerting exercises like running, jumping, leg dragging, acceleration, and change of direction often occur repeatedly when basketball players perform in competitive matches (Pernigoni et al., 2021). Basketball's ensuing technical skills, including dribbling, passing, throwing, rebounding, sprinting, and defense movements influence the creation of offensive and defensive actions (Ferraz et al., 2021). Physical performance is greatly influenced by strength training as it is proven to increase strength and muscle mass (Schoenfeld et al., 2017).

It is generally accepted that maximal muscular strength and muscle cross-sectional area are positively correlated. This connection is more noticeable at large muscle mass (Taber et al., 2019). Strength and power can be increased with increased muscle mass, therefore weight gain triggered by increased muscle mass may be beneficial in exercise performance (Howe et al., 2017). Although muscular mass is crucial for athletes, training performance also depends on movement speed. Newton's second rule of motion states that force, mass, and acceleration are correlated, hence a person's muscle mass has a direct impact on their physical performance (Loenneke, 2021).

In an attempt to enhance performance on the court, basketball players follow various training programs that focus on improving aspects such as strength, speed, and endurance (Komotska & Sushko, 2022). Technical and tactical training approaches that emphasize aspects of Athletes' physical performance can be maximized by the functional specialization of body morphology, which is a prerequisite for athlete training (Oliinyk et al., 2021). Theoretically, it must be proven that training is effective in supporting the physical performance of athletes. The right methodology and selection of good training tools have proven to be effective in supporting physical performance during training (Komotska & Sushko, 2022).

Professional scientific discussions have focused on attitudes towards integrated training, which is essentially physical training. However, this is not enough and requires a new strategic approach, generalizations based on experimental results are needed to provide practical recommendations on the importance of physical training in optimizing athlete performance (Osken & Onay, 2022). Apart from training, athletes' recuperation and the stimulation of their work capacity in different structural components of the macrocycle continue to show promise for future implementation in order to enhance athletes' physical performance (Scanlan et al., 2018). Currently, it is known that basketball players' degree of physical fitness is a priority that has an impact on the results of matches in basketball competitions. So that fitness is the most important factor that allows the athlete in certain conditions of competitive activity and highly competitive struggle to effectively and efficiently optimize the technical and tactical potential that he has (Ferraz et al., 2021). So the achievements of basketball players are never separated from the physical condition of athletes, so the problem of physical training at all stages of improving the sports performance of basketball players is very important to optimize (Cieślicka et al., 2019). Currently, there is still a lack of practical guidelines and knowledge related to the types of exercises that are effective in increasing the physical capacity of basketball players. Theoretical knowledge related to how the mechanism of exercise types in improving physical performance and physical capacity of athletes is still not fully understood.

Plyometric exercises are exercises that utilize cycles of stretching and flexing of muscles. Because of its positive benefits on athletic performance, coaches are paying more attention to and using it more frequently (Weldon et al., 2022). There are three main contraindications for people who have done some type of plyometric training in plyometric strength, plyometric endurance, and plyometric stabilization. Plyometric stabilizing exercises are intended to enhance optimal landing mechanics, postural alignment, and reactive neuromuscular efficiency. Increases in eccentric strength, dynamic joint stabilization, force output rate, and the overall neuromuscular efficiency of the human movement system are the goals of plyometric strength training (Mola & Shaw, 2024). The contractile component of actin and myosin cross-bridges with sarcomeres is essential for motor control and force output during plyometric activities. By pre-stretching the muscle-tendon unit's inherent length-tension curve, plyometric activities enhance the ability of muscle fibers to produce more tension and the resulting force production (Singh et al., 2024).

The ability to sprint is crucial for success in the basketball game (Figueira et al., 2021). Sprint training, overspeed training, endurance sprinting, weight training, and plyometric training are some of the training techniques used to enhance sprinting performance (Anversha et al., 2024). Basketball players need to be able to accelerate, decelerate, and change direction quickly while keeping perfect form. The effectiveness of the neuromuscular system determines agility. To increase agility, plyometric exercises that focus on a variety of movements are essential (Noyes & Barber-Westin, 2019). Plyometric workouts, as emphasized by Patir et al., 2021 Athletes now employ aerobic capacity as an exercise method to increase their strength and explosiveness in a variety of sports. A major component of the human body's overall energy capacity is aerobic capacity, which is a sign of a wide range of metabolic activities. The ability of an organism to use the most oxygen possible at any given time is indicated by its maximal oxygen absorption (VO2 max), a measure of aerobic intensity (Singh et al., 2024).

Based on previous research data shows that basketball athletes who have been given plyometric training interventions conducted three times a week for 6 weeks prove an increase in physical fitness (Demir & Dağlıoğlu, 2022). But it is still not explained exactly how the physiological response of the human body when doing plyometric training. It is important to understand the physiological mechanisms that occur in order to explain definitively and scientifically the stages of the mechanism and be able to prove empirically what happens when athletes do plyometric training. A clear explanation of physiological mechanisms is still minimal literature and certainly confusing because of the complexity of body mechanisms during sports. Therefore, this systematic review will explore in depth how plyometric exercises can improve the physical fitness of basketball athletes. As well as exploring how the mechanisms that occur in the body when performing plyometric exercises.

Materials and methods

Study Design

For this type of systematic review investigation, researchers conduct a comprehensive search through journal databases such as Science Direct, Web of Science, and Pubmed. These platforms are considered the best in the world for compiling papers that have a strong scientific basis and impact. Duplicate articles are removed in this initial search process. Further filtering of search results is done based on predetermined inclusion and exclusion criteria.

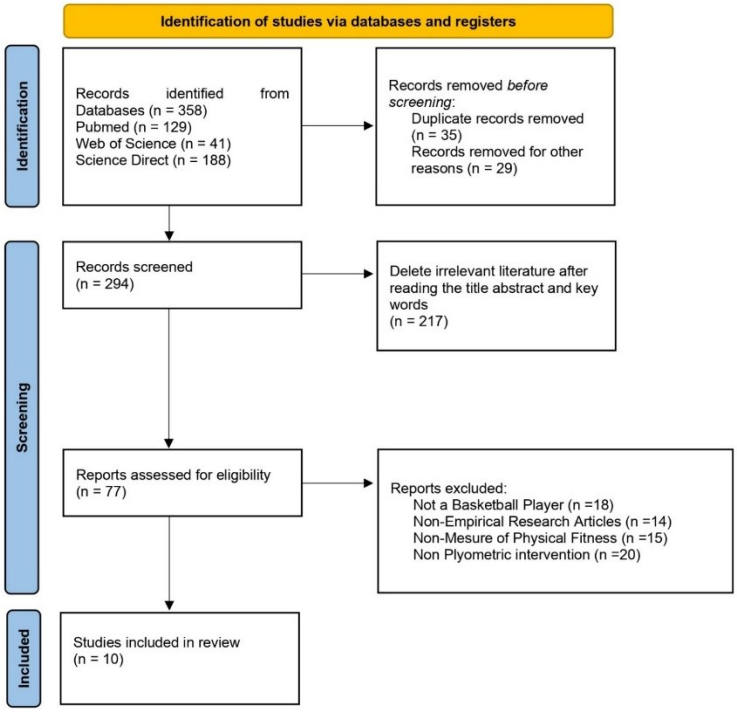
Eligibility criteria

The inclusion criteria for this study were developed by reviewing papers discussing plyometric training, basketball players, physical fitness published in the last five years. Furthermore, our analysis excluded journals that did not meet scientific validity standards or were not included in trusted search indexes such as Web of Science, Pubmed, or Science Direct.

Procedure

Full text, abstract, and title of the papers were added to the Mendeley database after verification and review. In the first stage, 358 publications were found using Science Direct, Pubmed, and Web of Science databases. For the second screening stage after conducting title suitability screening, 294 papers that met the requirements were selected. In the third stage after reading the title, abstract, and keywords resulted in 77 papers. In this last stage we have read the entire article and determined based on suitability, the sample should be basketball players, the study should be original, the parameters should be physical fitness, and the exercise intervention used should be plyometric training. At this point, we organized the items based on their overall suitability. Ten papers that met the inclusion criteria were selected for analysis after a thorough review and observation process. The operational criteria in this investigation was to comply with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) evaluation.

Figure 1. PRISMA flowchart of the article selection process



Results

Table 1. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
(Paes et al., 2022)	Randomized controlled trial	Thirty-six young basketball athletes	14 - 15 years	Plyometric training: 1. The exercise starts with a 10-minute warm-up. 2. Plyometric training is done before basketball training begins. 3. Plyometric training consists of idea leaps, split squat jumps, high knee jumps, side jumps, countermovement jumps, serial forward hops, single-leg lateral hops, and vertical jumps. 4. Training was conducted for 6 weeks.	Male experimental group 1. 20 meter sprints have increased significantly. 2. Illinois agility test also experienced significant improvement. Female experimental group 1. 20 meter sprint had significant improvement. 2. Illinois agility test did not improve significantly.
(Sánchez-Sixto et al., 2021)	Randomized controlled trial	Thirty-six female basketball players	22 - 23 years	Plyometric training: 1. The exercise starts with a 7-minute warm-up. 2. The workout consists of drop jump, and jump. 3. All exercises were performed 12 sessions over 6 weeks of intervention. Combined training: 1. Latihan dimulai dengan pemanasan selama 7 menit. 2. Latihan terdiri dari full squat, dan jump. 3. Semua latihan dilakukan 12 sesi selama 6 minggu.	1. Combined and pliometric exercises increase jump height. 2. Improvement in jumping performance is higher when combined exercises are used.
(Cherni et al., 2021)	Randomized controlled trial	Twenty-seven	20 - 21 years	Plyometric training: 1. An adaptation session	1. There was a significant

		elite female basketball players		was conducted 3 days prior to the intervention. 2. Exercise was conducted 2 sessions per week for 8 weeks. 3. Exercises consisted of bounding jumps, hurdle jumps, drop jumps.	increase in squat jump after the intervention
(Demir & Dağlıoğlu, 2022)	Randomized controlled trial	24 male basketball players	18 – 36 years	Plyometric training: 1. The exercise begins with a warm-up first. 2. Exercise is done 3x a week for 6 weeks. 3. The exercises consisted of Medicine ball bench press, plyometric push-up, overhead slam, nordic hamstring curl, box jump, squat jump, and lateral jump.	1. There were significant improvements in T-Test, agility, balance, vertical leap, shuttle run, and speed.
(Aksović et al., 2020)	Randomized controlled trial	33 young basketball players	15 – 16 years	Plyometric training: 1. The exercise begins with a warm-up first. 2. Exercise is done 2x a week for 10 weeks. 3. The exercises consisted of Lunge jumps, tuck leaps, ankle jumps, countermovement jumps, squat jumps, and single-leg jumps.	1. There was a significant increase in sprint speed in basketball athletes after the intervention of plyometric training.
(Reinoso et al., 2024)	Randomized controlled trial	16 female basketball players	11 – 12 years	Plyometric training: 1. The exercise begins with a warm-up first. 2. Exercise is done 2x a week for 12 weeks. 3. The exercises consisted of squat jump and countermovement jump.	1. There was a significant increase in jumping capacity after plyometric intervention.
(Radu et al., 2024)	Randomized controlled trial	One hundred seventeen female basketball players	10 and 12 years	Plyometric training: 1. The exercise begins with a warm-up first. 2. Exercises are conducted for a duration of 90 minutes per session. 3. Exercises were performed 2x a week for 24 weeks. 4. The exercises included in the experimental program were arranged based on their specifications as follows: for coordination, 22 exercises were applied (coded C1-C22); for pliometrics, 29 exercises were practiced (coded P1-P29); and there were 15 combined coordination-pliometric exercises (coded C-P1-C-P15).	1. There is a significant increase in the maximum jump height of basketball athletes after intervention.
(Buğa & Gencer, 2022)	Randomized controlled trial	48 male basketball players	12 – 15 years	Plyometric training: 1. The exercise starts with a 10-minute warm-up. 2. Exercises were conducted for 8 weeks. 3. Exercises consisted of toe jump, double foot left-right jump on the line, leap and stretch in place, leap by step, pulling one knee to chest, double feet knee to chest, squat jump, split squat jump.	1. There was a significant increase in agility and vertical jump in basketball players after plyometric training intervention.
(Anversha et al., 2024)	Randomized controlled trial	64 male basketball players	15 years	Plyometric training: 1. The exercise starts with a 10-minute warm-up. 2. Exercise is performed 3x a week for 8 weeks. 3. Exercises included sideways ankle hops, kangaroo jumps, vertical jumps, hexagon drills, zig-zag drills, forward	1. There were significant improvements in agility, sprinting performance, and leg explosiveness after an 8-week plyometric training intervention.

				jumps over cones, sideways jumps over cones, barrier jumps, box jumps, single-leg squat jumps with pauses, alternating step-up jumps, single-leg medial jumps, single-leg medial jumps.	
(Pechlivanos et al., 2024)	Randomized controlled trial	Twenty-nine male basketball players	21 years	Plyometric training: 1. The exercise begins with a warm-up first. 2. Exercise is done 3x a week for 4 weeks. 3. Exercises include knees flexed and knees extended.	1. Plyiometric training with flexed knees was shown to significantly improve squat jumps and countermovement jumps. 2. Plyometric training with knees extended is proven to significantly improve drop jump ability.

Discussion

This study sought to ascertain how plyometric training affected basketball players' physical fitness levels. The results of the study prove that plyometric training consisting of countermovement jump, side jump, idea leaps, split squat jumps, high knee jumps, horizontal jumps, single-leg lateral hops, serial forward hops, and single-leg vertical jumps on basketball players is proven to improve the ability of 20 meter sprint speed (Paes et al., 2022). The results of another study with full squat, and jump interventions on basketball players conducted for 12 training sessions proved to significantly increase jump height (Sánchez-Sixto et al., 2021). Plyometric exercises performed 2 sessions per week for 8 weeks consisting of bounding jumps, hurdle jumps, drop jumps from the research data also provide a significant increase in squat jump ability after intervention (Cherni et al., 2021). So that the physical condition of basketball players is proven to be improved by the plyometric training method.

The results of research on other basketball players prove that plyometric training 3x a week for 6 weeks with a menu of medicine ball bench press, Nordic hamstring curl, overhead slam, box jump, squat leap, lateral jump, and plyometric push-up proved to be able to provide significant improvements in flexibility, balance, vertical jump, shuttle run, speed, and T-Test (Demir & Dağlıoğlu, 2022). Sprint speed can also be improved with plyometric training. It is proven that there is a significant increase in the sprinting ability of basketball athletes after plyometric training intervention 2x a week for 10 weeks with the type of exercise consisting of squat jump, single leg jump, counter movement jump, ankle jumps, tuck jumps, lunge jumps (Aksović et al., 2020). So there are indeed many beneficial effects that result from plyometric training, especially in basketball player athletes.

Other research' findings demonstrate that there is a substantial increase in jumping capacity after plyometric intervention 2x a week for 12 weeks with the type of exercise consisting of squat jump and countermovement jump (Reinoso et al., 2024). Other research' findings also demonstrate that basketball players' maximal jump height significantly increases following a 24-week intervention of plyometric training that lasts 90 minutes twice a week (Radu et al., 2024). The results of other studies prove the same thing that plyometric training consisting of toe jump, double foot left-right jump on the line, leap and stretch in place, leap by step, pulling one knee to chest, double feet knees to chest, squat jump, split squat jump and performed for 8 weeks is proven to significantly increase agility and vertical jump in basketball players (Buğa & Gencer, 2022).

There were significant improvements in agility, sprinting performance, and leg explosive power after an 8-week plyometric training intervention consisting of exercises including sideways ankle hops, kangaroo jumping, vertical jumping, hexagon and zigzag drills, leaping forward and sideways over a cone, barrier jumping, box jumping, alternating step-up leaps, single-leg medial hops, and single-leg squat jumps with a pause performed 3x a week for 8 weeks (Anversha et al., 2024). So that it is known that the significant impact of plyometric training on increasing the physical fitness of basketball athletes. This is certainly a concern for coaches to be able to apply this type of training in improving the physical performance of basketball athletes. It is very necessary for coaches to understand the importance of this plyometric training theoretically and practically.

Physiological Concept of Plyometric Exercise in Improving Physical Fitness

It is known that plyometric training is significantly able to increase the physical fitness of basketball players. However, it is also necessary to understand how and what happens in the body when doing

plyometric training and why it can have an impact in enhancing players' physical health. Sole et al., 2021 revealed that there was a significant increase in muscle mass, total leg muscle volume, thigh muscle volume, thigh circumference, and calf circumference after performing plyometric exercises. Other research results from Kim et al., 2022 also proved that the improvement of physical attributes including muscle power, strength, and agility, was also triggered by plyometric training for 8 weeks, in addition to the reduction of muscle damage. Bedoya et al., 2015 implies that as teenage athletes are going through a period of active physical development, using plyometric exercises during this time may encourage muscle neural adaptation, improving the athlete's body's efficiency for situations requiring quick movements. Furthermore, the workouts enhance neuromuscular coordination, enabling more effective use of physical fitness traits including agility, speed, and jumping.

Davies et al., 2015 demonstrated that plyometric exercise enhanced activity automation and motor patterns; these modifications may boost neuronal efficiency and enhance neuromuscular function. Following eight weeks of plyometric training, there were no appreciable variations between the groups regarding the muscle injury indicators CK and LDH. Possibly as a result of an adaptive reaction to the activity, their levels actually dropped. Muscle injury markers may have decreased rather than risen since all subjects, regardless of group, were skilled baseball players and the control group engaged in general exercise as opposed to no regular exercise. The level of activity may have an impact on changes in CK and LDH (Koch et al., 2014). These indicators may significantly rise in people who don't follow a training regimen or after detraining, whereas they may fall in people who are well-trained due to the constant training regimens (Kim et al., 2022). In addition, other research results conducted by Kurgan et al., 2020 demonstrated that one plyometric exercise session can cause an initial post-exercise anti-inflammatory response by raising IL-6 levels five minutes after exercise and lowering TNF-α an hour after exercise.

Marzouki et al., 2022 discovered that plyometric training regimens can enhance physical fitness, which can have an effect on children's health. It has been demonstrated that plyometric training enhances agility, strength, and speed (Hariyanto et al., 2022). The stretch-shortening cycle used in plyometric activities consists of an eccentric after a muscular strain immediately by a concentric contraction (Munshi et al., 2022). Exercises involving plyometrics include explosive jumps, hops, bounds, and skips (Morris et al., 2022). Regular physical activity and exercise can improve a person's quality of life (e.g., having more energy reserves in the muscles, improved mood, feeling more relaxed, sleeping better, improving cognitive function, and raising the body's metabolism) (Park & Park, 2022).

How plyometric training can increase physical fitness depends on a number of things. In order to maintain muscle and organism growth, we must first recognize that insulin and insulin-like growth factor 1 (IGF1) are powerful anabolic hormones. These hormones attach to particular receptors (IGF1 and insulin receptors), which trigger a sequence of phosphorylation events that alter proteins, enzymes, or transcription factors in either a positive or negative way (Sartori et al., 2021). Along with glucose uptake and energy production, this route controls protein synthesis, degradation, cell division, and survival. Mice's muscles overexpress locally acting IGF1 isoforms, indicating that localized IGF1 expression promotes muscle growth and repair (Musarò et al., 2001). It has been discovered that variables such as increased IGF-1 levels, protein synthesis, angiogenesis, and muscle satellite cell proliferation are targeted by exercise-induced muscle hypertrophy (Larsson et al., 2019). Furthermore, it has been demonstrated that IGF-1 stimulates cell proliferation to improve the strength and form of muscle fibers (Ascenzi et al., 2019). Skeletal muscle growth has been shown to be mediated by IGF-1/IGF-1R through a number of mechanisms, including the PI3K/Akt signaling pathway (Yoshida & Delafontaine, 2020). In this animal study, exercise dramatically improved the composition and function of skeletal muscle, and this improvement was closely linked to the activation of the IGF-1/IGF-1R-PI3K/Akt signaling pathway (Li et al., 2022). Thus, it is clear that IGF-1 contributes significantly to muscle development and hypertrophy, which affects athletes' capacity for physical performance.

By encouraging cell division and proliferation, insulin-like growth factor-1 (IGF-1) works as a mediator to lessen organ dysfunction brought on by illness (Ahmad et al., 2020). Furthermore, the development of muscle mass and strength, metabolic regulation, and skeletal muscle regeneration are all strongly associated with IGF-1 (Yoshida & Delafontaine, 2020). According to earlier research, exercise can improve muscle mass and function by raising IGF-1 expression in skeletal muscle under pathological situations (Ribeiro et al., 2019; Sellami et al., 2019; Feng et al., 2022). According to a recent study, healthy

people can enhance muscle hypertrophy by secreting enough IGF-1 and activating the phosphatidylinositol 3-kinase (PI3K)/protein kinase B (Akt) signaling pathway (Yoshida & Delafontaine, 2020). The results of previous studies have indeed proven that IGF-1 is increased after physical exercise which has an impact on muscle hypertrophy and increased muscle mass (Ayubi et al., 2024). Thus, frequent plyometric training has been demonstrated in this study to improve basketball players' physical fitness, and plyometric training as a type of exercise has numerous health benefits. Plyometric training is therefore strongly advised when instructors are trying to help athletes perform better physically.

Strenght and Limitations

The advantage of this systematic review is that it only looks at randomized controlled trials, which is the most reliable type of scientific evidence as there is no possibility of ambiguous causal relationships. In addition, the samples taken were focused on humans and specifically on basketball players so that all samples could show homogeneous data and not be mixed with other categories such as samples using non-basketball players.

The limitation that we encounter is the lack of discussion and discussion related to how plyometric exercise in increasing physical fitness through physiological review and how the mechanism underlies the increase in physical fitness in basketball players by plyometric exercise. Therefore, this review is considered important to do in order to add insight and repertoire of knowledge related to how the effect of plyometric training on increasing physical fitness and how the underlying mechanism is explained theoretically and scientifically so that the results of the study can be a recommendation for coaches to use plyometric training in order to increase athletes' physical fitness which has an impact on physical performance during competition.

Conclusions

Based on the related articles that we found, it can be said that regular plyometric training can have an impact on increasing the physical fitness of basketball athletes. This increase is triggered by increased muscle mass and increased muscle hypertrophy. So that physical performance can increase which will have an impact on ability and performance during competition.

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