

## Methodological Characteristics and Future Directions for Plyometric Jump Training Research: A Scoping Review.

**Short Title:** Scoping Review of Plyometric Jump Training Studies.

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## **ABSTRACT**

Recently, there has been a proliferation of published articles on the effect of plyometric jump training including several review articles and meta-analyses. However, these types of research articles are generally of narrow scope. Furthermore, methodological limitations among studies (e.g., lack of active/passive control groups) prevent the generalization of results and these factors need to be addressed by researchers. On that basis, the aims of this scoping review were to i) characterize the main elements of plyometric jump training studies (e.g., training protocols), and ii) provide future directions for research. From 648 potentially relevant articles, 242 were eligible for inclusion in this review. The main issues identified related to: an insufficient number of studies conducted in females, youths and individual sports (~24.0%, ~37.0% and ~12.0% of overall studies, respectively); insufficient reporting of effect size values and training prescription (~34.0% and ~55.0% of overall studies, respectively); studies missing an active/passive control group and randomization (~40.0% and ~20.0% of overall studies, respectively). Furthermore, plyometric jump training was often combined with other training methods and added to participants' daily training routines (~47.0% and ~39.0% of overall studies, respectively), thus distorting conclusions on its independent effects. Additionally, most studies lasted no longer than 7 weeks. In future, researchers are advised to conduct plyometric training studies of high methodological quality (e.g., randomized controlled trials). More research is needed in females, youth, and individual sports. Finally, the identification of specific dose-response relationships following plyometric training are needed to specifically tailor intervention programs, particularly in the long-term.

## **Key Points**

- Recently, there has been a proliferation of published articles on the effect of plyometric jump training in various populations.
- There has been relatively few studies conducted in females, youths and individual sports, with insufficient reporting of effect size values and training prescription, studies missing an active/passive control group and randomization, and most studies lasting no longer than 7 weeks.
- In the future, researchers are advised to conduct plyometric training studies of high methodological quality (e.g., randomized controlled trials) with more research needed on specific dose-response relationships, particularly in the long-term.

## **1. INTRODUCTION**

Efficient use of the stretch-shortening cycle is a key factor in jump performance with the accumulation of elastic energy in a muscle action facilitating greater mechanical work in subsequent actions [1-3]. Jump exercises are an effective means of physical conditioning for the promotion of health, injury prevention and skill-related measures of athletic performance [4-6]. Jump training is commonly associated with plyometric training and, in particular, with drills that stress the musculotendinous unit [1, 2]. In this sense, plyometric jump training involves the utilization of different types of jumping movements [7-9] that are incorporated into comprehensive strength training programs [5, 10, 11]. Numerous plyometric jump training articles have been published in peer-reviewed journals in recent years [12]. However, between the years of 2000 and 2017, scientific publications on plyometric jump training have increased 25 fold compared with any previous period [12]. This rapid expansion has been driven by the technology-related advancement of appropriate measuring devices [13, 14] and an increased awareness amongst scientists of plyometrics' potential benefits for athletic performance [15], health (e.g., improve the bone mineral density) [16-19], injury prevention [20], rehabilitation [21] and application to special populations [22-24].

Several high-quality reviews related to plyometric jump training have been published [25-28, 15, 29, 30], with a particular focus on the effects on athletic performance (e.g., agility, muscular strength, sprint, and jump performance), as well as in specific populations (e.g., male youth athletes) and various sports (e.g., soccer). Such reviews and meta-analyses generally adopt strict inclusion criteria for studies' eligibility [31, 25, 27, 32], thus reducing the limitation of potential bias. However, the application of such rigorous inclusion criteria tends to limit the number of studies in these reviews, resulting in the capturing of only some of the large number of articles that have been published. Accordingly, conclusions from reviews and meta-analyses may thus be limited [33, 34] in their facility to assess the methodological gaps and limitations among the articles that have been published.

Given the above observations, the aims of this scoping review article were to: i) characterize the main methodological features of the body of literature relating to plyometric jump training studies (e.g., participants' characteristics; training protocols), and ii) recommend future directions for plyometric jump training research. Information gathered for this scoping review could be useful for sports scientists, practitioners, and, ultimately, athletes, as it may help in the understanding of the methodological gaps and limitations in the current plyometric jump training literature. Additionally, this review may inspire the design of more high-quality studies in the field, resulting in fewer sources of bias and greater generalizability to relevant populations.

## **2. METHODS**

### **2.1. Search Strategy**

A literature search for published studies on the PubMed database (<https://www.ncbi.nlm.nih.gov/pubmed/?term=plyometric+training>) [35] was performed up to April 17<sup>th</sup> 2017. This search was conducted using the term ‘plyometric training’.

Considering the broad international scope of the current review, we searched for articles in all languages (e.g., fifty-four) available on the PubMed database. Only original research was included. However, to reduce the chances of excluding potentially relevant studies, seventy-two article types available on the PubMed database were included during the initial search, with no restriction for journal categories, including those found on MEDLINE. In addition, no age, sex, or publication date criteria were imposed during the initial search. Default values of the PubMed database search engine were used in search fields, PubMed commons, text availability (e.g., abstract, free full text, and full text), and participants. Manual data checking was performed to increase the precision of data collection from relevant studies.

## **2.2. Retrieved Articles Selection**

After an initial search, an account was created in the National Center for Biotechnology Information (<https://www.ncbi.nlm.nih.gov>). Through this account, the lead investigator received automatically generated emails for updates regarding the search terms used. These updates were received on a daily basis and studies were eligible for inclusion until the initiation of manuscript preparation on July 1<sup>st</sup>, 2017.

To facilitate the inclusion of a sufficiently high number of articles, many different study designs were considered. This is in line with the principles of scoping reviews [36-38], including those in the field of resistance training [5, 39]. This resulted in the accumulation of a rather broad body of research and, consequently, the reviewing of studies with different levels of quality and research questions. Several limitations were systematically identified according to standard data extraction criteria (e.g., PEDro scale) and applied to selected articles for quality assessment [40]. This is detailed in subsequent sections of this article. In line with the aforementioned principles of scoping reviews [36-38, 5, 39], both non-randomized and non-controlled studies were included [41].

*Inclusion criteria.* Included studies were those that incorporated pre- and post-intervention performance testing with  $\geq 6$  plyometric jump training sessions over a period  $\geq 2$  weeks, including plyometric jump drills as a primary component (individually; or embedded in a wider training program). Articles that used plyometric jump training with added resistance were also included. Conference contributions were considered if full-text articles were available.

*Exclusion criteria.* Articles were excluded if they were cross-sectional (transversal), a review, or a training-related study without plyometric jump training. Also excluded were retrospective studies, prospective studies, studies in which the use of jump exercises was not clearly described, studies for which only the abstract was available, case reports, studies with ambiguous study protocols, non-human investigations, special communications, repeated bout effect interventions, repeated references, letters to the editor, invited commentaries, errata, overtraining studies and detraining studies. In the case of detraining studies, if there was a training period prior to a detraining period, the study was considered for inclusion.

### **2.3. Data Extraction**

From potentially relevant retrieved articles, generic information (e.g., author's name; journal name; year) and abstracts were saved for analyses. Two investigators (RRC and CA) independently processed all data with one extracting and the other verifying. Based on previous recommendations for improving searching in PubMed [42], suggestions for plyometric jump training searches [32, 27, 29, 25] and expert opinion on methodological gaps and limitations of plyometric jump training studies, several data items were considered for extraction. A detailed outline of each of these items is provided in table 1. The items were grouped into three broad subjects for results presentation and discussion purposes: i) main general characteristics; ii) participants' characteristics; iii) key elements of plyometric jump training design.

\*\*\*TABLE 1 NEAR HERE\*\*\*

### **2.4. Eligible Articles**

From 648 articles, 406 (62.6%) were excluded (Figure 1) leaving 242 (37.4%) eligible for data extraction [43-106, 22, 107-144, 24, 145-220, 20, 221-280] (Table 2).

\*\*\*FIGURE 1 NEAR HERE\*\*\*

\*\*\*TABLE 2 NEAR HERE\*\*\*

## **3. RESULTS**

The 242 eligible articles appeared in 47 different journals. The majority (n=241) were published in English, with a clear exponential increase in number in recent years (Figure 2).

\*\*\*FIGURE 2 NEAR HERE\*\*\*

### 3.1. General Characteristics

From eligible articles, 54.5% were classified as being insufficiently described (see table 1 for further information regarding the identification of treatment description quality).

Note: the remaining results are derived from table 2 (unless stated otherwise).

From the 242 eligible studies, 40.5% did not incorporate an active/passive control group and 19.4% did not consider any form of randomization. However, the number of eligible articles that have incorporated a randomized and controlled design have increased from 1987 to 2017, comprising up to 52.0% of relevant literature in recent years, compared to 33.3% previously. The number of participants included per study averaged 15.9 participants. From the total number of reported dependent variables (n=3982), 14.6% were deemed not clearly or quantitatively available (e.g., presented in graphical form only), whilst changes reported as effect sizes were available for only 34.0% of these (data not shown in this scoping review).

### 3.2. Participants' Characteristics

Most studies included male participants (57.2%) whilst 23.9% were female participants and 16.6% were a mixture of both sexes. Of note, the sex of participants was not clearly reported in 2.3% of the studies. Most of the studies included participants with a mean age  $\geq 18$  years old and 36.7% included youth participants, with groups' mean age equal to 19.6 years old. Participants' mean body mass, stature, and body mass index were 65.6 kg, 170.4 cm, and 22.6 kg·m<sup>-2</sup>, respectively.

The physical performance/playing level of participants was high (e.g., professional/elite athletes) in 14.9% of the studies, low (e.g., participants under medical treatment) in 8.3% of the studies, and not-clearly reported in 5.3% of the studies. Participants with moderate (e.g., non-elite/non-professional athletes) or normal (e.g., recreational athletes) physical performance or playing level featured in 46.3% of studies. Participants with mixed physical performance or playing level were included in 25.2% of studies (see table 1 for a detailed depiction of physical performance/playing level classification). With regard to the type of sport practiced, 44.2% included athletes from team sports (mostly soccer players [31.1%]), 12.0% undertook individual sports (mostly endurance runners [6.7%]), 8.7% played both individual and team sports whilst 30.1% were non-competitive (e.g., recreationally) athletes. In 5.0% of studies, this information was not clearly reported. Twelve percent of studies included participants with experience of plyometric jump training, 46.7% without experience, and 41.3% did not clearly report these details. Amongst the

included studies, 14.0% focused on training during the pre-season period of the season, 28.5% during the in-season, and 5.8% during the off-season. In 17.8% of studies, this information was not clearly reported whilst 33.9% of the studies did not include participants who were competitive athletes or who were engaged in a year-round training plan.

### **3.3. Key Elements of Plyometric Jump Training Design**

The types of plyometric jump drills were not clearly reported in 2.9% of the studies whilst 72.3% used a mixture  $\geq 2$  jump types. In addition, 24.8% employed one type of jump only. Drop jumps were included in 32.1% of studies with a combination of heights used in 17.4% and individualized prescription of heights used in 1.3% of studies. Box heights for drop jumps ranged from 10 to 110 cm.

Underfoot surface type was not clearly reported in 64.2% of studies. A proportion of 7% of studies reported either clay, wood, athletic track, cement or gymnasium-type floors. With regard to softer surfaces, 2.2% of studies reported the use of athletic mats, 7.8% utilised grass surfaces and 4.0% incorporated aquatic, elastic or sand-based surfaces. A mixture of surface types were used in 7.0% of the studies (e.g., inclined-flat; land-aquatic). In 7.0% of studies, plyometric jump training was completed using special equipment which included force plates, unstable surfaces, sledge apparatus, or similar commercially available apparatus, other than boxes or barriers. With regard to training loads, 5.2% of studies did not clearly report the number of jumps completed during the intervention period. Amongst those that did report the number of jumps, a wide range of values was observed, with 250 jumps per week as a mean. However, values varied according to training design (e.g., duration).

Plyometric jump training was added to the habitual training of participants in 38.5% of studies. In 20.5% of studies, part of the habitual training strategy of participants was replaced with plyometric jump training; however, 22.1% of the studies did not clearly report the approach taken on this issue. Approximately 18.9% of the studies recruited subjects who were not involved in habitual physical training. Plyometric jump training was combined with other methods of training as part of an intervention in 47.1% of studies but no clear information was identified in 2.5% of the studies. Most of the studies that applied a combination of plyometric jump training with other methods used resistance (29.7%), speed (14.3%), and agility (8.0%) training. Other training methods that were used in combination with plyometric jump training were sport-specific, balance, electrostimulation, stretching, core, footwork, endurance, coordination, and high-intensity interval training methods. Most commonly, two or more of these methods were used in combination with plyometric jump training.

Training duration ranged from 2 to 96 weeks. Most studies applied  $\leq 7$  weeks of training (mode), with a mean number of 8.3 weeks observed. However, there was high variability for this statistic with a standard deviation of 7.2 weeks. With regard to training frequency, 5.6%, 50.6%, 28.5%, 1.6%, and 0.4% of the studies used one, two, three, four, and six sessions per week, respectively. From the included studies, 12.9% used a combination of training frequencies, more commonly two and three sessions per week. Some groups were submitted to a range of training frequencies ranging from zero up to five sessions per week. Plyometric jump training intensity was not clearly reported for 42.0% of the included studies while 52.0% reported it as maximal using criteria such as height, distance, reactive strength index, optimal power, percentage of one repetition maximum, time, voluntary effort, velocity, rate of execution, force, or a mixture of these. Training intensity was submaximal in 6.0% of studies and this was quantified using similar measures such as percentage of one repetition maximum, height, distance, velocity, and rating of perceived exertion.

A proportion of 17.7% of the studies did not feature progressive overload as an element of programme design and 6.7% did not present clear information relating to this factor. Individual overload techniques (e.g., volume-based; technique-based; intensity-based) were applied in 34.2% of the studies whereas 41.4% of studies used a mixed model of progression, combining two or three individual overload techniques during the training program. Information relating to the tapering of training was not reported in 11.1% of the studies. Conversely, 15.5% applied a tapering strategy but 73.4% did not present clear information with respect to this factor.

The rest time between sets and/or exercises was not clearly reported for 42.4% of the studies. The rest interval extended from zero to 600-s, with a mean of 119-s, a standard deviation of 80-s, and a mode of 120-s. With regard to the rest period between plyometric jump repetitions, 79.3% of the studies did not clearly specify the interval (if any) between plyometric jumps. For those that reported the duration, this ranged from 4-s to 120-s, a mean of 13-s, a standard deviation of 8-s, and a mode of 15-s. The rest period between training sessions was not clearly reported in 45.6% of the studies. Among those studies that reported this value, 48 and 72 hours were the most common rest period durations reported, with intervals ranging from 24 hours to 168 hours.

#### **4. DISCUSSION**

The aims of this scoping review article were to: i) characterize the main methodological features of the literature relating to plyometric jump training studies; ii) provide recommendations for future plyometric jump training research. The main results allowed a comprehensive characterization of the main methodological features of the literature of plyometric jump training

studies. In the following paragraphs a discussion is provided on the implications of the identified elements and future directions for plyometric jump training research (table 3).

\*\*\*TABLE 3 NEAR HERE\*\*\*

#### 4.1. Main General Characteristics

From the 242 eligible articles ~51% were not described in sufficient detail meaning that their findings could not be effectively leveraged for future research or practice. Accordingly, just under 50% of the studies in this review demonstrate the quality of description required to leverage their findings for future research and practice. Examples of insufficiently described study features relate to the omission of one or more basic treatment descriptors such as training duration, frequency, intensity, exercise type and number of prescribed sets and repetitions. Moreover, around 40% of the included studies did not incorporate a control group *per se* and approximately 25% were non-randomized or did not clearly report information relating to this design element. However, randomization and controlled design implementation has become more common, increasing from 33.3% to 52% of published articles in recent years. This seems to indicate that the growing number of published articles is mirrored by a concurrent improvement in the methodological design of plyometric jump training interventions. With regard to the reporting of results, around 15.0% of dependent variable changes were not clearly described, often being presented in graphical form only whilst effect size changes were reported for just 34% of dependent variables. Given the growing consensus with regard to the importance of effect sizes in intervention studies [281], investigators should consider not only the null-hypothesis test but also the magnitude-based inference analysis [282]. In relation to this issue, p-values could be argued to be pernicious given the binary nature of their associated conclusions which relate to the statistical terms ‘*significant*’ and ‘*non-significant*’ [283]. In addition, the adequate classification of participants categories according to training experience and level (e.g., professional athlete) should be considered by researchers [284].

Although some limitations are difficult to address (e.g., subjects’ blinding), investigators should strive to conduct more randomized and controlled studies whilst also being mindful that the nature of the control condition will depend heavily on the applied setting in which the study is conducted. For example, researchers must consider the use of physically active control groups in an athletic setting and whilst passive controls are more appropriate in a clinical setting. When using a control group is not possible, a washout period or a cross over design might serve as a potential alternative in a field setting though this may be a suboptimal approach in youth athletes who are physically maturing at a fast rate. Studies should include adequate sample sizes which can sustain high rates of participant attrition and descriptions of utilised methods should be detailed to the degree that

studies could be replicated without need for recourse. If necessary, study details should be included in a supplemental file. Results should be comprehensively reported and should include effect sizes and associated inferences.

#### **4.2. Participants' Characteristics**

As in similar research fields [285], relatively few (<25%) plyometric jump training studies included females, either adult or youths. Most of the included studies recruited participants with a mean age of around 18 years and less than 37% of the included studies involved youth groups. Amongst the studies that included youth participants, biological age was reported only in around 37% of study groups, an important research gap previously identified [5]. This limitation is compounded by the utilization of different measures of maturity across studies making it difficult to compare results. This could be viewed as a critical limitation among plyometric jump training interventions performed in youths because biological age seems to influence adaptations to plyometric jump training interventions [25]. Similarly, only one group with a mean age of over 65 years was identified. This is concerning given that modified jump exercises for older adults may be a good alternative [22] to *conventional* jumps. Regarding anthropometric data, most studies were conducted in healthy-weight participants. Some studies included overweight and obese participants [62, 61] whilst others reported changes in participants' body composition [94, 132, 159, 175, 210] or anatomical adaptations related to reduced injury risk (e.g., tendon hypertrophy) [286-288, 139]. Although usually seen as a training method to induce neural-related adaptations, plyometric jump training deserves further consideration as a training strategy to induce musculoskeletal [4] and body composition adaptations.

Only around 15.0% of the included studies were conducted in participants with a high-level of athletic performance or sport playing level. This may be due to the unwillingness of professional or elite athletes' coaches to modify their training schedule. Similarly, although plyometric jump training may have potential relevance as a rehabilitation therapy [107, 180, 226, 116, 146, 178, 61, 62, 96, 24, 201], only around 8% of the included studies were conducted in participants with a low-level of athletic performance or playing level. Moreover, the moderating effect of sports practice is relatively uncertain amongst individual sports as only around 12% of the included studies have been conducted in athletes who were engaged in such activities. Nevertheless, it does seem that plyometric jump training offers beneficial adaptations to participants with different athletic performance or playing levels and in various sports disciplines. Regarding plyometric jump training experience, although some reviews and meta-analyses reported no effects of previous experience on sprint [29], maximal strength [30], vertical jump [28], and agility [27] adaptations after a plyometric jump training intervention, others reported the opposite [26]. Moreover, as of yet, no controlled comparative research has been conducted and around 41.0% of included studies did not clearly report on this issue. However, it

is reasonable to expect that previous experience with jump training (e.g., long-jumpers) could impact on the degree of adaptation in high-level athletes because their ceiling for adaptation could be lower.

Cross-sectional studies have shown that plyometric jump training is applied regularly during athletes' competitive season [289-297]. Its application on a year-round basis might reduce the occurrence of injuries, most notably among youth athletes [298]. However, based on this review, the identification of cases in which the application of plyometric jump training was conducted in a year-round fashion proved difficult. Moreover, only 48.0% of the included studies applied plyometric jump training at some point of the participant's season (e.g., in-season), without a long-term follow-up in order to compare its effects during other moments of the season (e.g., pre-season).

#### **4.3. Key Elements of Plyometric Jump Training Design**

To assess the specific effects of plyometric jump training in isolation with its effects as a part of a wider training program, researchers must clarify whether interventions are carried out with, without, or in place of, other forms of physical activity [189]. Despite this, nearly 22.0% of the included studies did not report if plyometric training was added *to* an existing training program or if it *replaced* part of a program. Relatedly, 39% of the included studies reported that plyometric training was added to a program whilst ~47.0% of the included studies reported that it was added to another training method as part of an intervention (resistance, sprint, agility, balance, electrostimulation, stretching, core, footwork, endurance, coordination and high-intensity interval training). Considering this, researchers should aim to strengthen their methodological approaches by clarifying if the effects of interventions occur because of plyometric jump training only or are due to a combination with another training method within or without a regular program of physical preparation. In this way, researchers could consider replacing part of athletes' habitual training with plyometric jump training, avoiding the introduction of other training methods to prevent the distortion of results.

Most of the included studies combined two or more types of jump drills, which, from a practical perspective, is considered to be a sound approach to optimizing adaptations [91, 88]. Despite this, from a research perspective, the prescription of multiple jump types within a single intervention could confound the independent effect of a single jump type, for example, a drop jump. Accordingly, more research is needed to assess the specific effects of different plyometric jumps types with researchers being encouraged to apply programs that have little, if any, variation in the prescribed jump drill. Although ~25.0% of the included studies sought to assess the effect of a single type of plyometric jump, these studies did not compare the effect of one type of jump versus another. Moreover, very few investigations have compared the effects of different jump intensities (e.g., drop jump heights) [246] or the effects of intensity distribution (e.g., polarized plyometric training), whilst only three included studies

individualized the prescription of jump training. Although it is beyond the scope of the current review to provide a detailed description of the dependent variables analyzed amongst included articles, it is worth mentioning that only three studies analyzed the effect of plyometric jump training on injury rates [20, 222, 249]. Relatedly, injury incidence was not associated with participation in plyometric jump training programs, including those that incorporated drop jumps, thus underlining the apparent safety of plyometric jump training.

The type of training surface used for plyometric jump training may affect the speed of the stretch-shortening cycle that is performed (e.g., fast vs. slow), thus implying different biomechanical and physiological effects [299, 300] and possibly different adaptations. However, the surface type was not clearly reported for most (64.2%) of the included studies. The use of soft surfaces was reported by less than 15% of the included studies and, in most cases, their use was related to the specific nature of athletes' competition surface (e.g., grass surface for soccer players) [280]. Plyometric jump training was completed using special equipment in around 7% of the included studies. The utilization of special equipment to aid plyometric jump training adaptations is still a matter of debate, especially with regard to the usefulness of unstable surfaces compared to stable surfaces [301]. Noticeably, only one study quantified (e.g., by means of the restitution coefficient) the hardness of training surface [138]. It is particularly noteworthy that authors do not typically acknowledge this factor which could be justifiably considered a key aspect of plyometric program configuration.

Different physiological and physical performance traits (e.g., agility; speed) exhibit different temporal responses to plyometric jump training [27, 30, 28, 29, 22, 302]. In this sense, training duration should be adjusted to the type of trait that is being targeted by the coach or athlete. However, most of the included studies lasted just 7 weeks or less. Therefore, the long-term effects of plyometric jump training are difficult to characterize based on evidence from the current body of available literature. In addition, the applied training volume varied widely among studies with optimal values still yet to be determined. Although plyometric jump training volume recommendations have been provided for some physical performance traits [29, 30, 28], a general lack of consensus might partially explain the wide variation in current opinion. Training volume should be closely considered for both athletic performance enhancement and injury prevention purposes [303] as relevant doses could differ [272]. The weekly distribution of plyometric training frequency of included studies ranged from one to six sessions per week, with around 79% of the included studies applying 2 to 3 sessions per week. Some studies compared the effects of different training frequencies and revealed that this factor might not be as important as the overall training volume [45, 204, 211]. This corroborates the findings of some meta-analyses [27, 304] yet contrasts with those of others [28, 30, 29].

Plyometric jump training intensity has been defined as the amount of stress placed on involved muscles and connective tissue and joints during a given exercise [305]. Commonly, athletes perform drop jumps from progressively increasing heights for a more intense training stimulus [306, 307, 145, 308]. Indeed, it has been shown that there is greater muscle activity in drop jumps from a 60-cm box height than from a 40-cm [309] or 20-cm box height [306]. However, these assertions are not without opposition [310-314]. Considering this, although training intensity is a key factor to acknowledge in exercise prescription [11], plyometric jump training lacks consensus on optimal markers of intensity. Relatedly, the intensity of plyometric jump training was not clearly reported in around 42% of included studies. Moreover, when reported, in several cases the description of how intensity was achieved was difficult to derive or was reported using highly varied criteria such as height, distance, reactive strength index, optimal power, percentage of one repetition maximum, time, voluntary effort, velocity, rate of execution, force, rating of perceived exertion or a mixture of these factors.

Progressive overload implicates a gradual increase of the stress placed upon the body during exercise training and is considered to be one of the fundamental principles of training [11, 87]. However, 23.2% of included studies did not incorporate an element of progressive overload or failed to report clear information relating to this factor. While around 33% of the included studies used a one-dimensional form of overload (e.g., volume-, technique- or intensity-based), approximately 41% used a mixed model of progression. However, the difference between the effects of various progression models adopted in the literature still requires elucidation. After an overload period, the application of a training taper has been identified as a key strategy [315-318]. This generally consists of reducing the training volume towards the end of a program or prior to a competition (or assessment) period [317]. However, only 15.5% of the included studies incorporated a taper strategy. Moreover, around 85% of the included studies did not apply a taper or failed to report it. On that basis, the effects of a taper as part of a plyometric training protocol need to be further examined.

Although evidence has been provided on the acute effects of rest time between plyometric jump repetitions [319] and sets/exercises [320], studies which directly investigate this are scarce [102]. Indeed, the rest time between repetitions and sets/exercises was not clearly reported for 79.3% and 42.4% of the included studies, respectively. When this information was reported, there were wide variations in the rest intervals utilized. Considering that the required rest period may depend on factors such as the duration of the effort [321, 322] and participants' ages [323], the wide variety of rest intervals used among the included studies may be explained by the various type of jump drills and the wide age range of participants. Regarding rest between training sessions, the most commonly used period was 48 to 72 hours. Even though anecdotal reports recommend that plyometric jump training sessions should not be performed on consecutive days [324], there is a lack of experimental studies that have addressed

this issue [120]. Factors such as training experience, habituation to plyometric jump drills, age and intensity could be considered when rest periods between sessions are assessed [4].

Aside from several strengths (e.g., the number of analyzed studies; the broad spectrum of items extracted from studies), this review has some limitations. Factors such as the volume of plyometric jumps completed as a warm-up, the training attendance rate, and the coach-to-trainee ratio during interventions were not considered as review criteria. In addition, given the broad aim of this review, only the term '*plyometric training*' was used in the search strategy.

## **5. CONCLUSION**

From 648 potentially relevant articles, 242 were eligible for data extraction with 26 variables from each allowing a comprehensive characterization of the main methodological features of the literature relating to plyometric jump training. This was based on the initial identification of ~6292 elements through database searching. The implications of study design features for future directions in plyometric jump training research were described. To our knowledge, this one of the most extensive and comprehensive review studies conducted so far regarding plyometric jump training.

For investigators working in the field of plyometric jump training, a primary goal is to mobilize institutional, political and government bodies, in addition to coaches and athletes, to increase awareness about the importance of this type of physical training activity. Benefits derived from plyometric jump training may include improvement of neuromuscular, metabolic, and cardiovascular markers as well as body composition and proxies of athletic performance. This can be achieved in both females and males as well as in pediatric and geriatric populations, sedentary participants and competitive athletes, both in preventive and rehabilitative therapy settings. Investigators involved in the relevant field should strive to increase funds available for research and should also look to foster international and multicenter collaboration toward a better understanding of the benefits that can be derived from this type of training strategy. This can be achieved through the promotion of a higher quality of research output. Overall, through this scoping review, several methodological elements have been recognized that should be addressed in future studies.

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