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Determining the optimal duration of plyometric training for enhancing vertical jump performance: a systematic review and meta-analysis

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Abstract

Introduction. Plyometric training is done in many ways, but countermovement jumps and squat jumps are easy and safe methods involving minimal use of equipment to increase lower body muscular power. There is enough evidence in the literature to support the notion that plyometric training increases vertical jump height. But the combination of countermovement jumps and squat jumps and its impact on vertical jump height is still unclear.

Purpose. Therefore, to examine the importance of various plyometric training techniques, this meta-analytical evaluation was created.

Materials and Methods. PubMed, MEDLINE, and Google Scholar databases were searched through August 2022. Empirical studies are expressed in the English language and issued within the last twenty-eight years. Included squat jump and countermovement jump interventions for improving vertical jump height. The studies used a training duration of a minimum of four weeks or above involving a control group included. As an approach to plyometric training that raises vertical jump height, the effects of countermovement jump and squat jump training were evaluated. To assess the level of heterogeneity, the I^2 statistics were utilized. The value of I^2 above 75% indicates significant heterogeneity and leads to the subgroup analysis method. Summary effects were calculated using standardized mean difference. With the help of the Cochrane tool, the risk of bias was assessed.

Results. The 22 study results all met the enclosure criteria. The meta-analysis indicated that the total impact of squat jumps training had high effects on vertical jump height [Effect Size = 0.96, (95% CI,0.57 to 1.35)]. A moderate degree [Effect Size = 0.91, (95 % CI,0.46 to 1.37)] of effects of countermovement jumps training on vertical jump height was reported by included interventions. Lesser than 10 weeks of plyometric training intervention duration they probably had a small effect on countermovement jumps [Effect Size = 0.79, (95 % CI, 0.30 to 1.29)].

Conclusion: Squat jumps and countermovement jumps are an efficient kind of training to increase the vertical jump height of male and female athletes, according to our study on plyometric training. Higher posttests mean differences were found in the studies including male subjects. The length of intervention has proportional effects on vertical jump height the recommended length of training should lie between 8 to 12 weeks. The effect size ranged between small to large degrees was observed in overall and subgroup analysis.

Keywords: plyometric training; muscular power; meta-analysis; vertical jumpKeywords: chronic neck pain, scapular dyskinesia, suspension system

Анотація

Діпак Кумар, Сандіп Дулл, Кулдіп Нара, Парвін Кумар. Визначення оптимальної тривалості пліометричного тренування для підвищення ефективності вертикальних стрибків: систематичний огляд і мета-аналіз

Вступ. Пліометричне тренування виконується багатьма способами, але стрибки в протилежному русі та стрибки з присідань є простими та безпечними методами, які передбачають мінімальне використання обладнання для збільшення сили м'язів нижньої частини тіла. У літературі є достатньо доказів на підтримку думки про те, що пліометричне тренування збільшує висоту вертикального стрибка. Але поєднання стрибків у протилежному русі та стрибків з присідання та його вплив на висоту вертикального стрибка досі неясно.

Мета. Тому, щоб дослідити важливість різних технік пліометричного тренування, було створено цю метааналітичну оцінку.

Матеріали та методи: Пошук у базах даних PubMed, MEDLINE та Google Scholar здійснювався до серпня 2022 року. Емпіричні дослідження викладені англійською мовою та видані протягом останніх двадцяти восьми років. Включає стрибки з присідання та стрибки проти руху для покращення висоти вертикального стрибка. У дослідженнях використовувалась тривалість навчання щонайменше чотири тижні або більше за участю контрольної групи. Як підхід до пліометричного тренування, який підвищує висоту вертикального стрибка, оцінювалися ефекти стрибків у зустрічному русі та стрибків з присідання. Для оцінки рівня неоднорідності використовували статистику I2. Значення I2 вище 75% вказує на значну неоднорідність і веде до методу підгрупового аналізу. Підсумкові ефекти були розраховані з використанням стандартизованої середньої різниці. За допомогою Кокранівського інструменту було оцінено ризик упередження.

Результати: усі 22 результати дослідження відповідали критеріям укладання. Мета-аналіз показав, що загальний вплив тренування стрибків у присіданні мав значний вплив на висоту вертикального стрибка [Розмір ефекту = 0,96, (95% ДІ, 0,57-1,35)]. Помірний ступінь [Розмір ефекту = 0,91, (95 % ДІ, 0,46 до 1,37)] впливу тренувань зі стрибків проти руху на висоту вертикального стрибка було повідомлено за допомогою включених втручань. Менше ніж 10 тижнів тривалості пліометричного тренування вони, ймовірно, мали незначний вплив на стрибки проти руху [Розмір ефекту = 0,79, (95 % ДІ, 0,30 до 1,29)].

Висновок: Згідно з нашим дослідженням пліометричних тренувань, стрибки з присідання та стрибки проти руху є ефективним видом тренування для збільшення висоти вертикального стрибка спортсменів і спортсменок. Більш високі післятестові середні відмінності були виявлені в дослідженнях, що включали чоловіків. Тривалість втручання пропорційно впливає на висоту вертикального стрибка, рекомендована тривалість тренувань повинна складати від 8 до 12 тижнів. Розмір ефекту коливався від малого до великого, спостерігався в загальному та підгруповому аналізі.

Ключові слова: пліометричний тренінг; м'язова сила; мета-аналіз; вертикальний стрибок

Аннотация

Дипак Кумар, Сандип Дхалл, Кулдип Нара, Парвин Кумар. Определение оптимальной продолжительности плиометрических тренировок для улучшения показателей вертикального прыжка: систематический обзор и метаанализ

Введение: Плиометрические тренировки выполняются разными способами, но прыжки в обратном направлении и приседания являются простыми и безопасными методами, требующими минимального использования оборудования для увеличения мышечной силы нижней части тела. В литературе достаточно данных, подтверждающих мнение о том, что плиометрические тренировки увеличивают высоту вертикального прыжка. Но комбинация прыжков в обратном направлении и прыжков в приседе и их влияние на высоту вертикального прыжка до сих пор неясны.

Цель. Поэтому, чтобы изучить важность различных методов плиометрической тренировки, была создана эта метааналитическая оценка.

Материалы и методы. Поиск в базах данных PubMed, MEDLINE и Google Scholar проводился до августа 2022 года. Эмпирические исследования представлены на английском языке и опубликованы за последние двадцать восемь лет. Включены приседания и прыжки с контрдвижением для увеличения высоты вертикального прыжка. В исследованиях использовалась продолжительность обучения не менее четырех недель с участием контрольной группы. В качестве подхода к плиометрической тренировке, которая увеличивает высоту вертикального прыжка, оценивались эффекты прыжков в обратном направлении и прыжков в приседе. Для оценки уровня неоднородности использовалась статистика I2. Значение I2 выше 75% указывает на значительную неоднородность и приводит к методу анализа подгрупп. Суммарные эффекты рассчитывали с использованием стандартизированной разности средних. С помощью Кокрановского инструмента оценивался риск систематической ошибки.

Результаты. Все результаты 22 исследований соответствовали критериям включения. Мета-анализ показал, что общее воздействие тренировок с прыжками в приседе оказало сильное влияние на высоту вертикального прыжка [Величина эффекта = 0,96 (95% ДИ, 0,57–1,35)]. Во включенных вмешательствах сообщалось об умеренной степени [размер эффекта = 0,91, (95% ДИ, от 0,46 до 1,37)] влияния тренировки прыжков в обратном направлении на высоту вертикального прыжка. При продолжительности плиометрических тренировок менее 10 недель они, вероятно, оказали небольшое влияние на прыжки в обратном направлении [Величина эффекта = 0,79 (95% ДИ, от 0,30 до 1,29)].

Выводы. Согласно нашему исследованию плиометрической тренировки, приседания и прыжки с контрдвижением являются эффективным видом тренировки для увеличения высоты вертикального прыжка у спортсменов мужского и женского пола. В исследованиях, в которых участвовали мужчины, были обнаружены более высокие средние различия после тестов. Продолжительность вмешательства оказывает пропорциональное влияние на высоту вертикального прыжка. Рекомендуемая продолжительность тренировок должна составлять от 8 до 12 недель. Величина эффекта варьировалась от малой до большой степени при общем анализе и анализе подгрупп.

Ключевые слова: плиометрическая тренировка; мышечная сила; метаанализ; вертикальный прыжок

Introduction

During the plyometric workout, the muscle is quickly stretched before being quickly contracted. The nervous system is getting ready to react to the cycle of stretching and shortening more swiftly [1]. That type of training can improve an athlete's speed, explosive power production, and strengthening of bone [2,3]. The main purpose of plyometrics is to improve jumping ability and jumping capability has been assumed by means of essential for effective execution in several sports [4]. The importance of jumping ability may vary per sport depending on the direction of the jump. Think about how jumping can be strategically used in team sports like basketball [5], football (soccer)[6,7], and volleyball. Vertical jump height is frequently regarded as an important performance metric [8,9]. A training program's plyometric workouts ought to be comparable to the athlete's special requirements concerning the individualities of the athletic activity in which they are participating. To encourage transfer to sport, plyometric workouts should replicate the sort of action known in that discipline, i.e. the specificity principle [10,11]. if workouts targeted running performance, such as speed bounding [12,13], the training schedule positively affected running velocity [14–16]. According to preliminary findings, Plyometric training much improved running and jumping skills as well as enhanced kicking distance[8], balance, and agility [17].

Plyometric training may develop the landing mechanics of the jump [18–20]. Which increases the strength of the muscle [21]. Training instructors and coaches who apply plyometrics in their training should be aware that while this strategy is useful, it does not confirm success in raising vertical jump height[22,23]. Equipment, gender, level of participation, diet & food, training time, recovery, economic prospects, and other events that may arise during training can all be variables to consider increasing vertical jump height [2,3,24–28]. Most authors agree that the frequency and intensity of plyometric exercise should be changed regularly based on the results of intermediate testing [29–37].

Previous review studies reported countermovement jump exercises were far better than squat jump exercises in improving vertical jump height. A meta-analytical review conducted by Goran Markovic in Zagreb Croatia revealed 4% higher outcomes of vertical jumps in the group that performed countermovement jump exercises in comparison to squat jump exercises [38]. Various factors affecting plyometric training and vertical jump height such as gender, intervention length, type of exercises, and type of sports, considerations were given for outcomes [22]. The present study identifies the gap in the previous reviews and attempts to cover the research gap. Observing the quantity and calibers of the available research literature was the aim of this systematic review., to evaluate the efficacy and effectiveness of plyometric training for improving vertical jump height in male and female players [39], and to ascertain whether this method of training could be used to enhance the motor skills of various sports.

Material and methods

Search strategy

A wide-ranging database search on the internet was accomplished via PubMed, MEDLINE, and Google Scholar, to recognize appropriate articles that examined male and female athletes' vertical jump heights after plyometric training using the squat jump and countermovement jump. The following combination of keywords was used by us: plyometric OR cycle of stretching and shortening OR squat jump OR countermovement jumps OR controlled experiments and jumping exercises. The following key phrases were combined to do a manual search: plyometric training, vertical jump, Squat jumps and counter jumps performance of men, and women athletes. Each article's reference lists were also checked to find supplementary appropriate investigations. The archival finding was confined to a journal with peer review journal papers released in English from 1996 through 2022. The Recommended Reporting Items for systematic examinations and Meta- Assessments (PRISMA) guideline was followed in accompanying this systematic review and meta-analysis.[40].

Eligibility criteria

The randomized controlled trials issued during the previous twenty-eight years in English had been taken into contemplation in this systematic review. The consisted of applicants were soccer, basketball, handball, volleyball, badminton, football, gymnasts, and collegiate male and female athletes of any age group (no binding). A minimum of four weeks of plyometric exercise and the presence of a control group were prerequisites for the synthesis of data to encompass the study. The control groups either did not exercise or participated in any regular sports activity without plyometric training. The involved articles have to specify the vertical jump height as the result metric for at least one of the squat jump and countermovement jump movement patterns.

Follows exclusion were implemented: (1) studies did not use proper training plans for respondents; (2) those academic papers that weren't authored in English; (3) studies did not show the control group; (4) studies with a combined of plyometric, weight training and resistance training in directive to minimize the consequences of combination training; (5) Studies that were uncontrolled, cross-sectional, and (6) where the results did not distinguish between males and females did not produce distinct outcomes.

Data Extraction

Two reviewers each separately gathered the information on subjects containing (age, gender, sample size,) enlightenment a description of the intervention (exercise kind, extent, length, and frequency range, session) study design and study outcomes, and method (randomization and distribution concealment) One author worked on this (R. PH), Despite the fact that S. LE, an additional author, reviewed the extracted data for accuracy and completeness. One author (J-PB) evaluated the content's quality. A third reviewer or agreement was used to resolve disagreements. Reviewers did not know the writers, organizations, or script journals.

Risk of Bias Assessment

Using the Cochrane technique separately, the risk of bias was evaluated by two authors (R. PH & S. LE) [41,42]. This tool assesses the risk of bias by evaluating each of the seven criteria: sequential generation, allocated, deception, participant and staff illuminating, concealment of outcome assessment, inadequate outcome data, selective reporting, and additional sources of bias. The risk of bias was graded as (1) low, (2) unclear, or (3) high on each of the criteria. The consensus was reached through conversation after discrepancies were double-checked with a third reviewer (J. PB).

Data synthesis

The degree of training effects was assessed using effect size calculation as per the equations given below. Cohen's d is one of the most commonly used effect size measures. It is particularly useful when comparing the means of two groups or conditions. Cohen's d is calculated by taking dividing the variation between the two groups' mean differences by the combined standard deviation (see Equation 1, and 1.1). A minimum of two studies having similar assessment outcomes were used for subgroup analysis. A random effect method was used to determine the pooled effect of countermovement jump and squat jump training on vertical jump height performance. The degree of the size of the calculated effects ranged as follows: small (0.2), medium (0.5), and large (0.8) [43]. The current version, the review manager 5.4 tool was used for the above-cited method of data synthesis [44,45].

Equation 1

$$D = \frac{\overline{X}_1 - \overline{X}_2}{SD_{Pooled}}$$

Where, D = raw mean difference, n_1 and n_2 are the sample size in group one and group two, S_1 and S_2 are the standard deviation in group one and group two.

Equation 1.1

$$SD_{Pooled} = \sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}}$$

Heterogeneity also called inconsistency in systematic reviews refers to the variability or diversity among the results of separate studies that are included in the analysis. Statistical strategies include a meta-analysis used to combine the findings from numerous independent studies on a particular research question to obtain an overall estimate of the effect size or association. Heterogeneity is an important consideration in meta-analysis because it can impact the construal and generalizability of the results. To assess the degree of heterogeneity, researchers commonly use statistical tests such as Cochran's Q test or the I^2 statistic (see equation 1.2). The Cochran's Q test determines whether the apparent variations between research are merely the result of chance, while the I^2 statistic quantifies the amount of total variability that is due to heterogeneity rather than chance (see equation 1.3). Higher values of I^2 indicate greater heterogeneity. The I^2 statistics were used to analyze the degree of heterogeneity, which was then categorized as follows: Low heterogeneity is defined as I^2 of 0% to 24%, moderate heterogeneity is defined as I^2 of 25% to 49%, substantial heterogeneity is defined as I^2 of 50% to 74%, and considerable heterogeneity is defined as I^2 of 75% to 100% [44,46]. The I^2 test was used to determine how much of the observed variation reflected a meaningful difference in effect size and how much of the changes in findings might have been explained by chance alone [46]. It was suggested that this ratio be represented by the statistics I^2, which might act as a proxy for the signal-to-noise ratio. It is calculated as:

Equation 1.2
$$I^2 = \left(\frac{Q - df}{Q}\right) \times 100\%$$

Equation 1.3
$$Q = \sum_{i=1}^{k} w_i (Y_i - M)^2$$

Where "w_i" is stands for study weight," Y_i" is denote the study effects size, "M" is the summary effect and, "k" is the total number of studies.

When a meta-analysis only has a few trials or studies with a small number of participants, this test's accuracy is reduced because of its low power, $P \leq .10$ was regarded to designate significant heterogeneity [44].

Outcome measures

Study Selection

Overall, 366 articles were classified from the database search during the research years 1996 to 2022. 124 studies were left after replacement were detached and articles with poor topics and summaries were eliminated. After the screening by two independent reviewers 50 full-text manuscripts were evaluated for eligibility criteria. 22 papers were eventually chosen for the last round of screening and included in the quantitative synthesis (meta-analysis) (Fig. 1).

Study Characteristics

Between 1996 and 2022, all research papers that fulfilled the requirements for enclosure were printed in English. Table No. 2 provides a thorough explanation of studies incorporated in the analysis. The 22 studies' overall total number of subjects was 1023 individuals, and each study's average sample size ranged from 5 to 33 subjects per group. The involvement of interventions in included studies was as follows; one study gives 5 weeks of training [48], four studies give 6 weeks of training [49–52], one study give 7 weeks of training [53], seven studies give 8 weeks training [54–60], two studies give 10 weeks training [36,37], 3 studies give 12 weeks training [33,34]. In these studies, 4 interventions included female subjects and 14 interventions included male participants. To investigate the influence of countermovement, jump training, and squat jump training on vertical jump height thirteen studies had 5 to 8 weeks of training length and five studies had 10 to 12 weeks of training length. In sixteen studies data will be measured in centimeters and two studies data will be measured in meters. two to three alternating training sessions per week was the most preferred training frequency; one study has given 6 to 8 sessions per week [53]. Plyometric training sessions lasted between 20 to 120 minutes. One study, however, employed a plyometric exercise programme that required 30 jumps each week (10 jumps on alternate 3 days) for 6 months. [49].

Statistical analysis

Summary of Squat Jump

The squat jump training group's overall effect on the vertical jump is favorable. Sixteen effects (73%) were greater than zero. The mean effect size *Cohen's d* for overall effects size was 0.96 [95% CI, 0.57 – 1.35; Z = 4.88, (P < 0.00001)]. More specifically, the squat jump training is associated with higher vertical jump compared to the control group.

A moderate but significant amount of heterogeneity [Tau = 0.56; chi–square = 79.97, df = 19 (P < 0.0001) I^2 = 76%] and risk of bias were observed in overall study effects to detect the inexplicable variances between study estimates, method of subgroup analysis was approached to explain the heterogeneity.

The pooled effects of the first subgroup i.e., males and females separately reported in the table no 3. The overall effects in male subgroups favor the squat jump training group the mean effect size was 1.06 [95% CI, 0.57 – 1.55; Z = 4.27 (P < 0.0001)]. While the overall effects in the female sub-group also favor the squat jump training. The mean effect size was 0.59 [95% CI, 0.24 – 0.95; Z = 3.28 (P < 0.001)].

Similarly, the pooled effects of the second subgroup i.e., intervention length group 5 to 8 weeks and 10 to 12 weeks separately reported in the forest plot (fig -3) the overall effects in intervention length of 5 to 8 weeks subgroups favor the squat jump training group. The mean effect size was 0.79 [95 % CI, 0.38 – 1.20: Z = 3.75 (P < 0.0002)]. While the overall effects in the intervention length 10 to 12 weeks subgroups give preference to the squat jump training group. The mean effect size was 1.65 [95 % CI 0.63 – 2.67; Z = 3.17 (P < 0.002)].

There are no subgroup effects by gender of the participants. The test for subgroup difference does not indicate a significant difference in training effects between the subgroups of male and female participants (Table 4).

Results

Summary of countermovement jump

The countermovement jump has a positive overall effect on the countermovement jump training group. Seventeen effects (77%) were greater than zero. The mean effect size of Cohen's *d* for overall effects size was 0.91[95% CI 0.46 – 1.37; Z = 3.93, (P < 0.0001)]. Countermovement jump training, in particular, is related to a greater vertical jump in comparison to the control group.

A moderate but significant amount of heterogeneity [Tau = 0.90; chi–square = 117.91, df = 20 (P < 0.00001) I^2 = 83%] and risk of bias were observed in overall Study effects to detect the unexplained differences between study estimates, method of subgroup analysis was approached to explain the heterogeneity.

The pooled effects of the first subgroup i.e., males and females separately reported in the forest plot (fig – 4). The overall effects in male subgroups favor the countermovement jump training group the mean effect size was 1.12 [95% CI 0.59 – 1.66; Z = 4.09 (P < 0.0001)]. While the overall effects in the female sub-group also favor the countermovement jump training. The mean effect size was 0.14 [95% CI 0.49 – 0.76; Z = 0.43 (P < 0.67)].

Similarly, the pooled effects of the second subgroup i.e., intervention length group 5 to 8 weeks and 10 to 12 weeks separately reported in the forest plot (fig – 5) the overall effects in intervention length of 5 to 8 weeks subgroups favor the countermovement jump training group. The mean effect size was 0.79 [95 % CI 0.30 – 1.29: Z = 3.15(P < 0.002)]. While the overall effects in the intervention length of 10 to 12 weeks subgroups give preference to the countermovement jump training group. The mean effect size was 1.35 [95 % CI 0.11 – 2.58; Z = 2.14 (P < 0.03)].

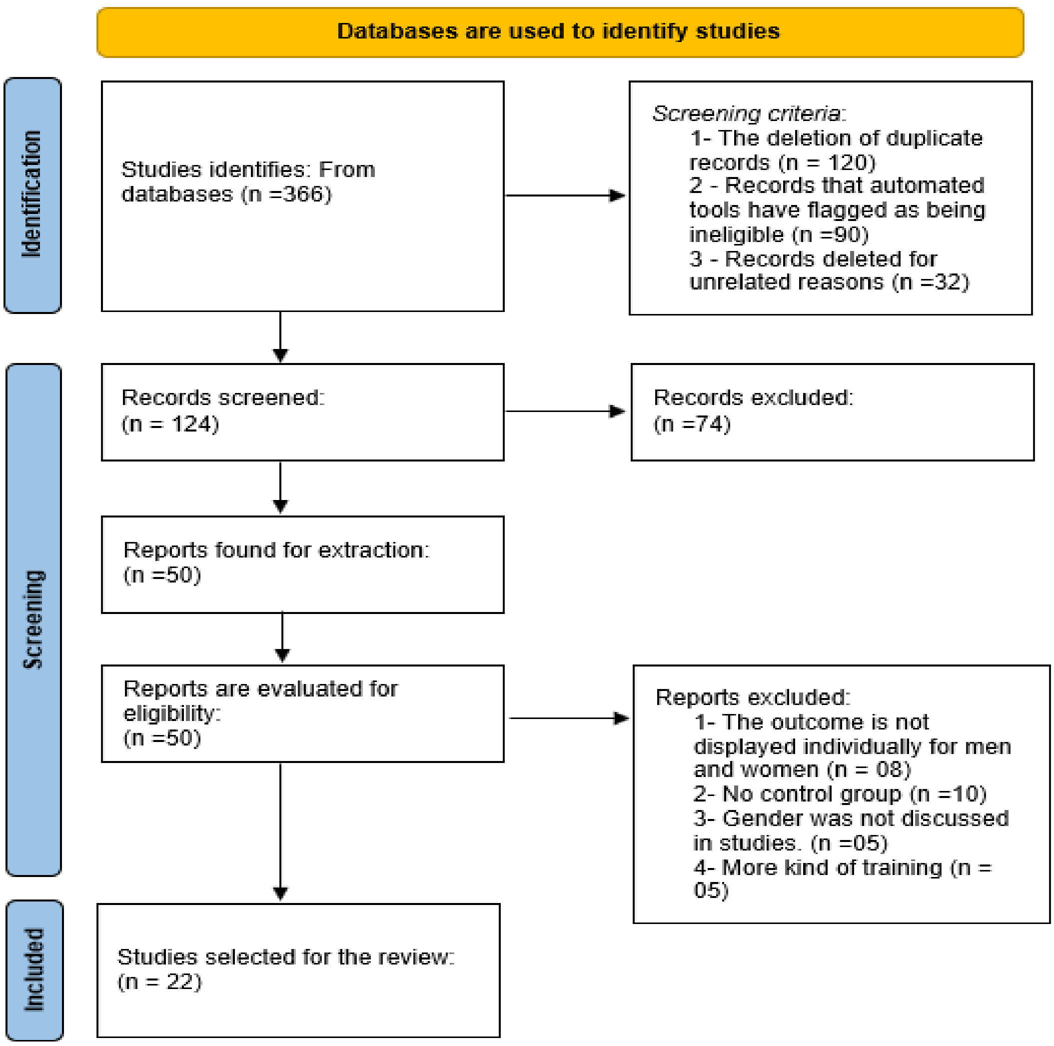

Fig. 1. The study selection is depicted in a flowchart. (retrieved from:[47])

Table 1

Studies Characteristics

Study	Age	Gender	Sports Type	Country	T/W*	Frequency*	Duration*
Holcomb et al. 1996[55]	NR	Male	NR	Alabama	8	3	NR
Gehri et al. 1998[35]	18-20	Both	Basketball	USA	12	3	20-30
Maffiulrtti et al. 2002[49]	21-23	Male	Volleyball	Italy	6	3	120
Toumi et al. 2004[54]	19-22	Male	NR	USA	8	3	120
Toumi et al.2004[54]	19-22	Male	NR	USA	8	3	120
Kubo et al.2007[33]	22	Male	NR	Japan	12	3	NR
Ronnested et al.2008[61]	NR	Male	Soccer	Norway	7	6	NR
Campo et al.2009[34]	22.8	Female	Soccer	Belgium	12	3	NR
Meylan et al.2009[57]	13.1	NR	Soccer	Switzerland	8	-	90
Khlifa et al.2010[37]	19-23	Male	Basketball	Italy	10	2	90
Khlifa et al. 2010[37]	19-23	Male	Basketball	Italy	10	3	90
Chelly et al.2014[56]	17.41	Male	Handball	Canada	8	3	90
Chelly et al.2015[36]	11.9	Male	Track athletes	Canada	10	3	90
Sozbir 2016[50]	NR	Male	NR	Turkey	6	2	NR
Ozmen et al.2017[52]	12.5	Both	Badminton	Turkey	6	NR	NR
Mazurek et al.2018[48]	20.2	Male	Handball	Poland	5	NR	NR
Mazurek et al.2018[48]	20.2	Male	Handball	Poland	5	NR	NR
Bogdanis et al.2019[59]	7-9	Female	Gymnasts	Greece	8	2	NR
Bogdanis et al.2019[59]	7-9	Male	Gymnasts	Greece	8	2	NR
Padron-Cabo et al. 2021[60]	13	Male	Soccer	Spain	8	NR	NR
Hammami et al. 2021[58]	17	Male	Handball	Tunisia	8	5	120
Stankovic et al.2022[51]	NR	Female	Football	Serbia	6	3	90

*frequency = training session/week, *duration = length of each training session in minutes, *T/W = training per weeks
*NR = not reported.

Table 3

Shows summary of effects of squat jump training about male and female subgroups analysis

Study	Squat Jump			Control			Weight	SE* (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Male								
William 1996	49	6.1	12	45.4	6.5	12	5.30%	0.55 [-0.27, 1.37]
Nicola 2002	37.6	6.1	10	36.6	5.9	10	5.10%	0.16 [-0.72, 1.04]
Hechmi 2004	37.1	1.8	30	34.2	2.1	30	6.00%	1.46 [0.89, 2.04]
Hechmi T 2004	39.5	1.4	30	36.1	1.9	30	5.90%	2.01 [1.38, 2.64]
Kubo 2007	26.6	4.8	5	20.7	4	5	3.60%	1.21 [-0.21,2.62]
Bent 2008	32.8	1.7	7	29.6	1.4	6	3.60%	1.90 [0.50, 3.29]
Cesar 2009	30.5	3.2	14	30.1	4.1	11	5.40%	0.11 [-0.68, 090]
Raidh Khalifa 2010	40.28	0.92	9	38.08	1.05	9	4.10%	2.12 [0.91, 3.33]
Raidh Khalifa 2010	41.54	1	9	37.08	1.24	9	3.00%	3.77 [2.10, 5.44]
Mohamed 2014	0.44	0.04	12	0.39	0.03	11	5.00%	1.35 [0.43, 2.28]
Mohamed 2015	0.24	0.03	14	0.2	0.02	13	5.10%	1.51 [0.64, 2.38]
Krzystof 2018	0.39	0.08	12	0.4	0.08	12	5.30%	-0.12 [-0.92, 0.68]
Krzystof 2018	0.4	0.03	14	0.41	0.04	14	5.50%	-0.27 [-1.02, 0.47]
Geogory 2019	17.5	3.5	17	16.3	4	17	5.70%	0.31 [-0.37, 0.99]
Hammami 2021	38	3	17	28.9	4.5	15	4.90%	2.35 [1.42,3.28]
Alexis 2021	21.47	4.08	10	21.31	3.42	10	5.10%	0.04 [-0.84, 0.92]
Subtotal			222			214	78.6%	1.06 [0.57, 1.55]
Female								
Danial1998	29.38	6.42	10	27.5	7.47	10	5.10%	0.26 [-0.62, 1.14]
Tarik 2017	20.18	3.63	11	15.98	2.76	9	4.80%	1.23 [0.25, 2.21]

Geogory2019	19	3.2	33	17.3	3.4	33	6.20%	0.51 [0.02, 1.00]
Mima 2022	28.98	3.73	12	26.29	4	12	5.30%	0.67 [-0.16, 1.50]
Subtotal			66			64	21.40%	0.55 [-0.27, 1.37]
Overall			288			278	100%	0.96 [0.57, 1.35]
Male	Tau²=0.75; χ²=74.70,df=15(P<0.001);I²=80%, Z=4.27(P0.0001)							
Female	Tau ²=0.00; χ²=2.33,df=3(P=0.51);I²=0%, Z=4.88(P<0.001)							
Total	Tau²=0.56; χ² =79.97,df=19(P0.00001);I²=76%, effect: Z=4.88(P<0.001), sub-group difference: χ²=2.31,def=1(P=0.13),I²=56.8%							

SE* = Summary of Effects

Table 4

Shows the summary of the effects of squat jump training on the intervention length of male and female subgroups

Study	Squat Jump			Control			Weight	SE* (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Male								
William 1996	49	6.1	12	45.4	6.5	12	5.30%	0.55[0.27,1.37]
Nicola 2002	37.6	6.1	10	36.6	5.9	10	5.10%	0.16[0.72,1.04]
Hechmi 2004	37.1	1.8	30	34.2	2.1	30	6.00%	1.46[0.89,2.04]
HechmiT2004	39.5	1.4	30	36.1	1.9	30	5.90%	2.01[1.38,2.64]
Bent 2008	32.8	1.7	7	29.6	1.4	6	3.60%	1.90[0.50,3.29]
Cesar2009	30.5	3.2	14	30.1	4.1	11	5.40%	0.11[0.68,0.90]
Mohamed2014	0.44	0.04	12	0.39	0.03	11	5.00%	1.35[0.43,2.28]
Tarik 2017	20.18	3.63	11	15.98	2.76	9	4.80%	1.23[0.25,2.21]
Krzystof2018	0.39	0.08	12	0.4	0.08	12	5.30%	-0.12[0.92,0.68]
Krzystof2018	0.4	0.03	14	0.41	0.04	14	5.50%	-0.27[1.02,0.47]
Geogory2019	17.5	3.5	17	16.3	4	17	5.70%	0.31[0.37,0.99]
Geogory2019	19	3.2	33	17.3	3.4	33	6.20%	0.51[0.02,1.00]
Hammami 2021	38	3	17	28.9	4.5	15	4.90%	2.35[1.42,3.28]
Alexis 2021	21.47	4.08	10	21.31	3.42	10	5.10%	0.04[0.84,0.92]
Mima2022	28.98	3.73	12	26.29	4	12	5.30%	0.67[0.16,1.50]
Subtotal			241			232	79.10%	0.79[0.38, 1.20]
Female								
Danial 1998	29.38	6.42	10	27.5	7.47	10	5.10%	0.26[0.62,1.14]
Kubo 2007	26.6	4.8	5	20.7	4	5	3.60%	1.21[0.21,2.62]
RaidhKhalifa2010	40.28	0.92	9	38.08	1.05	9	4.10%	2.12[0.91,3.33]
RaidhKhalifa2010	41.54	1	9	37.08	1.24	9	3.00%	3.77[2.10,5.44]
Mohamed 2015	0.24	0.03	14	0.2	0.02	13	5.10%	1.51[0.64,2.38]
Subtotal			47			46	20.90%	1.65[0.63, 2.67]
Overall			288			278	100%	0.96[0.57, 1.35]
Male	Tau²=0.49; χ²=59.31 ,df=14(P<0.001);I²=76% Z=3.75(P=0.0002)							
Female	Tau²=0.97;= χ²15.66,df=4(P=0.004);I²=74% Z=3.17(P=0.002)							
Total	Tau²=0.56; χ²=79.97,df=19(P<0.001);I²=76%, effect: Z=4.88(P<0.00001),Sub-group difference ; χ² =2.35,df=1(P=0.13),I²57.5%							

SE* = Summary of Effects

Table 5

Shows a summary of the effects of countermovement jump in male and female subgroups

Study	Countermovement jump			Control			Weight	SE* (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Male								
William 1996	54.2	6.5	10	49.5	7.5	10	4.80%	0.64[0.26,1.55]
Nicola 2002	42.5	6	10	42.3	7.2	7	4.70%	0.03[0.94,1.00]
Hechmi 2004	42.5	1.3	30	37.3	1.9	30	5.10%	3.15[2.38,3.93]
Hechmi T 2004	42.8	2.1	30	39.3	1.7	30	5.40%	1.81[1.20,2.41]
Kubo 2007	31.4	5	5	23.2	4.6	5	3.60%	1.54[0.03,3.05]
Bent 2008	36.7	1.9	7	36	2	6	4.40%	0.33[0.77,1.44]
Cesar 2009	37.2	4.5	14	34.6	4.4	11	5.00%	0.56[0.24,1.37]
Raidh Khalifa 2010	49.03	1.14	9	43.69	1.46	9	3.20%	3.88[2.18,5.59]
Raidh Khalifa 2010	47.2	1.07	9	44.1	1.22	9	4.00%	2.57[1.25,3.90]
Mohamed 2014	0.46	0.04	12	0.41	0.03	11	4.80%	1.35[0.43,2.28]
Mohamed 2015	0.25	0.03	14	0.21	0.03	13	5.00%	1.29[0.45,2.14]
Kerim 2016	36.06	1.77	12	35.36	1.55	12	5.00%	0.41[0.40,1.22]
Krzystof 2018	0.44	0.09	12	0.45	0.09	12	5.00%	-0.11[0.92,0.69]
Krzystof 2018	0.46	0.05	14	0.47	0.06	14	5.10%	-0.18[0.92,0.57]
Geogory 2019	17.8	4.6	17	17	4.5	17	5.30%	0.17[-0.50,0.85]
Hammami2021	40.6	2.7	17	30.9	4.6	15	4.70%	2.55[1.59,3.51]
Alexis2021	22.4	4.36	10	21.25	3.74	10	4.90%	0.27[-0.61,1.15]
Subtotal	-	-	232	-	-	221	80.10%	1.12[0.59, 1.66]
Female								
Danial1998	32.15	7.59	7	30.5	7.2	7	4.50%	0.21[0.84,1.26]
Silvia 2009	25.6	1	10	26.2	0.09	10	4.80%	-0.81[1.73,0.11]
Geogory 2019	20.1	2.9	33	18.1	3.2	33	5.60%	0.65[0.15, 1.14
Mima 2022	22.97	2.85	12	22.29	2.85	12	5.00%	0.23[-0.57,1.03]
Subtotal	-	-	62	-	-	62	19.90%	0.14[-0.49,0.76]
Overall	-	-	294	-	-	283	100%	0.91[-0.49,1.37]
Male	Tau^2=1.04; χ^2=98.96, df=16(P<0.001) I^2=84%, Z=4.09(P0.0001)							
Female	Tau^2 =0.24; χ^2 =7.52, df=3(P=0.06);I^2=83%, Z=0.43(P=0.67)							
Total	Tau^2=0.90; χ^2=117.91, df=20(P<0.001); I^2=83%, Z=3.93(P<0.0001) subgroup difference : χ^2=5.51,df=1(P=0.02),I^2=81.9%							

SE* = Summary of Effects

Table 6

Shows a summary of the effects of countermovement jump about intervention length of male and female subgroups

Study	Countermovement jump			Control			Weight	SE* (95% CI)
	Mean	SD	Total	Mean	SD	Total		
Male								
William 1996	54.2	6.5	10	49.5	7.5	10	4.80%	0.64[0.26,1.55]
Nicola 2002	42.5	6	10	42.3	7.2	7	4.70%	0.03[-0.94,1.00]
Hechmi 2004	42.5	1.3	30	37.3	1.9	30	5.10%	3.15[2.38,3.93]
Hechmi T 2004	42.8	2.1	30	39.3	1.7	30	5.40%	1.81[1.20,2.41]
Bent 2008	36.7	1.9	7	36	2	6	4.40%	0.33[-0.77,1.44]
Cesar 2009	37.2	4.5	14	34.6	4.4	11	5.00%	0.56[-0.24, 1.37]
Mohamed 2014	0.46	0.04	12	0.41	0.03	11	4.80%	1.35[0.43,2.28]
Kerim 2016	36.06	1.77	12	35.36	1.55	12	5.00%	0.41[-0.40, 1.22]
Krzystof 2018	0.44	0.09	12	0.45	0.09	12	5.00%	-0.11[-0.91,0.69]
Krzystof 2018	0.46	0.05	14	0.47	0.06	14	5.10%	-0.18[-0.92, 0.57]
Geogory 2019	17.8	4.6	17	17	4.5	17	5.30%	0.17[-0.50, 0.85]
Geogory 2019	20.1	2.9	33	18.1	3.2	33	5.60%	0.65[0.15,1.14]
Hammami 2021	40.6	2.7	17	30.9	4.6	15	4.70%	2.55[1.59,3.51]
Alexis 2021	22.4	4.36	10	21.25	3.74	10	4.90%	0.27[-0.61,1.15]
Mima 2022	22.97	2.85	12	22.29	2.85	12	5.00%	0.23[-0.57,1.03]
Subtotal			230			240	74.90%	0.79[0.30, 1.29]
Female								
Danial 1998	32.15	7.59	7	30.5		7	4.50%	0.21[-0.84,1.26]
Kubo 2007	31.4	5	5	23.2		5	3.60%	1.54[0.03,3.05]
Silvia 2009	25.6	1	10	26.2		10	4.80%	-0.81[-1.73, 0.11]
Riadh Khalifa 2010	49.03	1.14	9	43.69		9	3.20%	3.88[2.18,5.59]
Riadh Khalifa 2010	47.2	1.07	9	44.1		9	4.00%	2.57[1.25,3.90]
Mohamed2015	0.25	0.03	14	0.21		13	5.00%	1.29[0.11,2.58]
Subtotal			54			53	25.1%	1.35[0.11, 2.58]
Overall			294			283	100.0%	0.91[0.46, 1.37]
Male	Tau^2 =0.78; χ^2=83.33, df=14(P<0.001); I^2=83%, Z=3.15(P=0.002)							
Female	Tau^2=1.98; χ^2=34.27, df=5(P<0.001) I^2=85%, Z=2.14(P=0.03)							
Total	Tau^2=0.90; Z χ^2=117.91, df=20(P<0.00001); I^2=83%, Z=3.93(P<0.0001), subgroup difference: χ^2=0.66, df=1(P=0.42), $I^2$0%							

SE* = Summary of Effects

Discussion

This study evaluates the effects of squat jump and countermovement jump training programs on vertical jump height performance of the different types of disciplines. The findings of this systematic review and meta-analysis validated the value of plyometric exercise for athletes. The plyometric training effects on the squat jump and countermovement jump performance ranged from minor to very large. Studies included different cultures and across the globe such as the USA, Italy, Alabama, Turkey, Canada, Norway, Switzerland, Belgium, Serbia, Tunisia, Japan, Greece, Spain, Poland. subjects belong to different disciplines i.e., basketball, volleyball, handball, track events, soccer, football, badminton, gymnasts, untrained, health volunteered, college students, and physical education students have included the present meta-analysis.

Our meta-analytical results are consistent with earlier research that investigated the effects of plyometric training on vertical jump height in male and female volunteers from various fields [17,36,49,53]. When we looked at research done in the past to examine the effects of plyometric exercise, we found that it improves vertical jump height[2,29,32,62]. The effects of various jump patterns' vertical jump performance on plyometric training vary. Jumps with countermovement, squats, and drops were all anticipated.[2,18,63,64]. It has been proposed that plyometric training is greater success in enhancing performance in jumps that use the brief stretch cycle of muscle because it improves the elastic properties of the muscle-tendon unit as well as the neuronal the involved motor units' firing patterns and order [4,63,65–67].

The duration of training interventions consisted of studies extended from 5 to 12 weeks and 2 to 6 days of training were given in one week, in which 2 to 15 sessions were given in a one-week training. A total of 1143 subjects (experimental group n-582 and control group n-561) have participated in 22 RCTs (randomized controlled trials). Most of the studies were based on moderate to high int ensity[37,49,51,55,58,60,61]. high intensity-based training was most helpful for increasing the vertical jump height . 2 to 6 days of training were given in one week, in which 2 to 15 sessions were given for a week of training 20 to 120 min. The plyometric training effect may also be influenced by an athlete's background and current training status. Compared to untrained and professional athletes, amateurs and trainee athletes will likely respond more quickly and have an increase in jump performance.

The meta-analyses that were carried out in this review applied non-plyometric training groups (control) that did not distinguish between physically active and inactive participants (e.g., only pre and post-data were taken from the control group), as well as between subjects in the control group who were physically engaged daily. Different sorts of equipment and environments were used in the plyometric approaches that were examined. While the study [68] revealed that the benefits of plyometric training in jumping performance are stronger for interventions of 10 weeks or more, 14 of the 17 investigations lasted less than 10 weeks. Additionally, variations in plyometric leaps, total jumps, and workout intensity are seen among studies.

The studies including vertical jump height concerning squat jump and countermovement jump exercises were taken from previous studies to review the effect of plyometrics training on vertical jump height. Two subgroups were created in SJ (1-squat jump gender group & 2-intervention length group and in addition, two subgroups in countermovement jump (1-counter movement jump gender group & 2-intervention length group) for primary outcome analysis and closer scrutiny Subgroup squat jump males after the data analysis show that there was a significant effect of squat jump training on male athletes for increasing vertical jump height fig-1. Along with this, a study in the subgroup squat jump male also shows that squat jumps have no significant effect[48] In this study, handball male players were given 5 weeks of plyometric training, after the results of which it was found that the training period was too short that's why there was no significant effect observed). Along with this, we get to see significant effects in the study group female, which suggests that squat jump can increase vertical jump height in women.

Limitations

The outcomes of this analysis should be explained with some limitations. The insufficient findings made it difficult to reach specific conclusions. Some consist of studies involving somewhat small intervention groups. Most of the studies did not describe the intensity of the training intervention. Therefore, the possible relationship between intensity and the related factor of plyometric training is still unclear. In addition, just four research featured young athletes, making it insufficient to employ chronological age as a moderator variable in the study. Another drawback was that the majority of the papers included in this study had low ('poor') quality of methodology ratings. It is challenging to come to any firm findings due to the few studies that have been conducted. The number of subjects in included interventions was also not sufficient (min-05, max-30). The smaller number of participants decreases the validity of obtained outcomes. It is advised that more study enhances the caliber of their study designs by inspecting the impact of plyometric training on jump efficiency.

Conclusion

The present study shows that countermovement jumps and squat jump in plyometric training improve the vertical jump height of male and female athletes. while a high degree of effect was observed in the studies containing male subjects. Large effects were observed in countermovement jump in comparison to squat jump training. The effectiveness of plyometric training also seems to depend on the length of the interventions. Greater improvements in vertical jump performance are produced by longer training weeks. Finally, plyometric exercise can be used as a beneficial training method to improve athletes' vertical jump height performance in many different kinds of sports.

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Conflict of Interest

The writers don't have any conflicts of interest

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