Iran J Public Health, Vol. 54, No.11, Nov 2025, pp.2298-2312

Review Article

The Assessment of Muscle Strength for Standing Long Jump and Vertical Jump: Focusing on Muscle-Strengthening Programs: A Systematic Review and Meta-Analysis

Jeheon Moon [1], Jiho So [2], Youngju Jeon [2], *Sungmin Kim [3,4]

1. *Department of Physical Education, Korea National University of Education, Cheongju, Republic of Korea*
2. *Digital Health Research Division, Korea Institute of Oriental Medicine, Dae-jeon, Republic of Korea*
3. *Institute of School Physical Education, Korea National University of Education, Cheongju, Republic of Korea*
4. *Department of Lifesports Education, Kongju National University, Gongju, Republic of Korea*

***Corresponding Author:** Email: ksm0201@kongju.ac.kr

(Received 10 Mar 2025; accepted 15 Jun 2025)

Abstract

Background: Grip strength is often used as a proxy for systemic muscle strength due to its ease of measurement, but varying errors may occur due to measurement factors. Standing long jump and vertical jump are components of physical fitness, considered to reflect lower extremity muscle power. This systematic review aimed to evaluate the suitability of grip strength as a measure of muscle strength and its relationship to standing long jump and vertical jump performance following muscle-strengthening exercises.

Methods: Articles were selected using the PICOSD framework through a search of PubMed, Web of Science, and ScienceDirect up to Dec 6, 2024, including studies involving young, healthy adults, muscle strength improvement, and key terms such as grip strength, standing long jump, vertical jump, and resistance or plyometric training. Thirteen studies were included, comprising 496 participants. Effect sizes for grip strength, standing long jump, and vertical jump were calculated, with internal validity confirmed via publication bias and qualitative assessment.

Results: Meta-analysis of 13 articles with 32 data points revealed a significant improvement in grip strength after muscle-strengthening programs (I^2=60%, P<.01), with an effect size (ES) of -1.36 (95% CI: -2.11, -0.62). However, standing long jump and vertical jump showed no significant differences post-training (long jump: I^2=0%, P<.65; vertical jump: I^2=4%, P<.41), with small effect sizes (long jump, ES: -0.28 [95% CI: -0.51, -0.05]; vertical jump, ES: -0.35 [95% CI: -0.52, -0.19]).

Conclusion: Grip strength is a more reliable indicator of muscle strength than standing long jump and vertical jump, which mainly assess muscle strength rather than muscle strength.

Keywords: Grip strength; Standing long jump; Vertical jump; Muscle strength; Meta-analysis; Training

Introduction

Muscle strength refers to the ability of a muscle or muscle group to voluntarily exert maximum force against an external load (1). It is essential for sport-specific performance and is closely linked to the level of maximum force exerted (2). Several training methods, including traditional resistance training, plyometrics, sprinting, and sport-specific combined training, have proven effective in improving muscle strength (3). Multi-joint exercises are more effective than single-joint exercises, and free-weight exercises are superior to machine-based exercises like the Smith machine for enhancing sports performance and functional movements (2). Strengthening both upper and lower extremities improve sports performance by enhancing force transmission to the ground, as seen in sprinting and vertical jumping (4). Conversely, a decline in muscle strength can impair coordinated movement, decrease joint stability, and increase the risk of falls and reduced athletic performance (5).

Muscle strength assessment is commonly integrated into physical fitness evaluations, alongside cardiorespiratory endurance, agility, muscular endurance, flexibility, and balance. Grip strength, easily measured using a dynamometer, has become a widely accepted indicator of muscle strength in both fitness and medical contexts (6). Grip strength reflects the ability to hold or grip objects, which is crucial for daily tasks and sports requiring gripping or handling rackets (7). Although grip strength is primarily associated with forearm muscles, previous studies demonstrate significant correlations between grip strength and lower extremity strength. For instance, Bohannon, Magasi (8) reported strong correlations between grip strength and knee extension torque, with coefficients of .782 and .805 for the left and right legs, respectively. Grip strength could serve as a proxy for systemic muscle strength.

Grip strength assessments are used globally, particularly in Europe and Asia, not only for fitness evaluations but also in clinical diagnoses and monitoring recovery, especially for aging populations and disease conditions (9). Individuals with diseases like Parkinson's, rheumatoid arthritis, or chronic fatigue syndrome often show significantly reduced grip strength compared to healthy individuals (10). In addition, recent research indicates a global association between reduced handgrip strength and depression, particularly in underserved regions. Timely grip strength assessments may serve as a screening tool to identify depression risk in middle- and older-aged adults (11).

Despite its practical advantages, grip strength measurements are influenced by several factors, including posture, grip size, and body tilt during testing. Different postures during measurement can yield varying correlations with muscle groups such as shoulder abductors and elbow flexors (12). This variability highlights that grip strength provides only an indirect estimate of overall muscle strength, and it may misrepresent systemic strength under certain testing conditions. Therefore, alternative assessment methods should be considered.

Thus, grip strength is an indirect estimate of systemic muscle strength based on forearm muscle strength, and posture during grip strength testing may lead to significant variability in results. At the same time, a person could be perceived as having low muscle strength due to the grip position despite having high muscle strength. In addition, factors such as grip size and body tilt during measurement introduce additional variables. Despite numerous studies demonstrating a strong correlation between grip strength and overall muscle strength, the reliability of measured items may be uncertain. Thus, a different approach to measuring muscle strength is warranted.

Improvements in muscle strength are positively associated with muscular power, especially in the lower body. Performance tests such as the standing long jump and vertical jump are widely recognized as reliable and valid assessments of lower limb explosive strength (13, 14). These tests require participants to exert maximal force from a stationary position, making them direct indicators of neuromuscular power and coordination without the influence of external momentum (15). Compared to grip strength, which reflects localized forearm strength and can be affected by postural factors, the standing long jump and vertical jump offer more functionally relevant insights into total-body muscular performance.

Therefore, this review aimed to explore whether standing long jump and vertical jump could effectively replace or supplement grip strength in assessing systemic muscle strength, based on findings from studies on muscle-strengthening programs.

Methods

Search Strategy

This meta-analysis study was conducted according to the reporting guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) group (16).

Inclusion and exclusion criteria

Articles were selected using the PICOSD framework through a search of PubMed, Web of Science, and ScienceDirect up to Dec 6, 2024. Keywords included “grip strength,” “standing long jump,” “vertical jump,” “resistance training,” “plyometric training,” and “training.” Inclusion criteria were: 1) young, healthy adults; 2) regular physical activity or exercise interventions; 3) studies targeting muscle strength improvement; and 4) outcomes on grip strength, standing long jump, or vertical jump. Duplicate data (e.g., plyometric vs. resistance training groups) were treated separately. Exclusion criteria were: 1) studies on the elderly; 2) reviews, meta-analyses, case studies; 3) interventions under four weeks; 4) animal studies; and 5) studies lacking mean and standard deviation data.

Data extraction

Initially, the corresponding author screened all article titles retrieved using the keywords. Two co-authors (JYJ and SJH) independently screened the titles and abstracts based on exclusion criteria, with any disagreements resolved through consultation with the corresponding author. Data extracted by KSM and MJH were cross-checked, and discrepancies were resolved by consensus to ensure accuracy.

Quality assessment of selected studies

Two reviewers used a modified Downs and Black Quality Index to assess articles on standing long jump and vertical jump performance after muscle-strengthening programs (17). The assessment form included 20 items covering reporting (nine items), internal validity (two items), external validity (four items), and selection bias (five items), with each item scored 0 or 1. Studies were categorized into three quality levels: high quality (HQ, ≥70%), moderate quality (MQ, 40%–69%), and low quality (LQ, <40%) (18). Disagreements were resolved by consulting the third reviewer (corresponding author).

Data analysis

A single researcher extracted data on sample size, participant characteristics, assessment methods, and outcomes, categorizing them into standing long jump and vertical jump records before and after muscle-strengthening programs. A meta-analysis using a random effects model was performed with R software (version 3.5; R Core Team, Vienna, Austria). Standardized mean difference, effect size, and 95% confidence intervals (CI) were calculated ($P<.05$), with effect sizes classified as small (<0.5), moderate (0.5–0.8), or large (>0.8) (19). Heterogeneity was assessed (low: 0%–25%, moderate: 25%–75%, high: 75%–100%) (19), and publication bias was evaluated using Egger’s regression test and a funnel plot (20).

Results

Search Results

Overall, 2,108 articles were identified through the literature search, of which 448 duplicate articles and 502 articles unrelated to the topic based on title and abstract review were excluded. In addition, 30 articles unrelated to training, 15 articles on other types of training, 25 articles with differences in the age range of participants, 13 articles with discrepancies in participants' characteristics, and five meta-analysis studies were excluded.

Overall, 17 articles met the inclusion criteria, with four on grip strength, four on long jump, and nine on vertical jump. Two articles covered both long jump and vertical jump, and one covered both grip strength and vertical jump. This resulted in 13 articles included in the meta-analysis. Data points included 4 from one article measuring grip strength in both hands, 2 from one article on grip strength, 2 from one article on long jump with two training methods, 6 from two articles on long jump with three methods, and 16 from five articles on vertical jump with two methods, plus additional points from other articles. In total, 33 data points from 13 articles were used for the meta-analysis. The article selection process is shown in the PRISMA flow chart (Fig. 1).

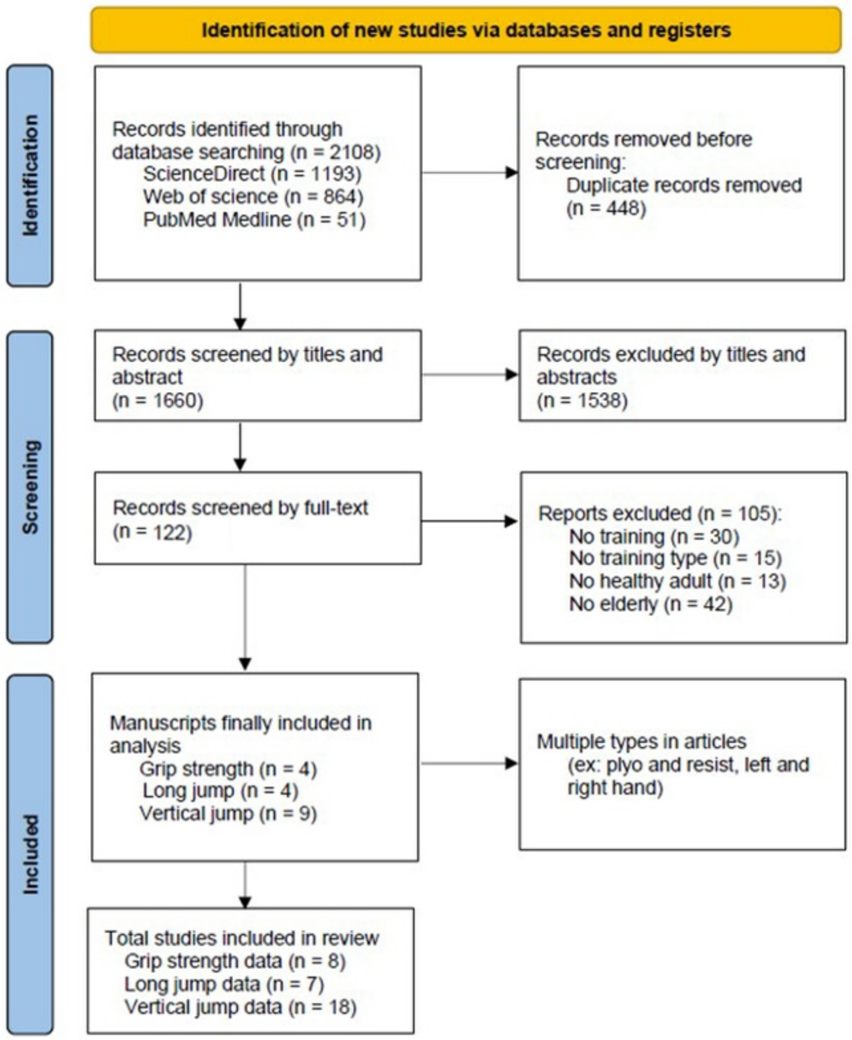

Fig. 1: PRISMA flow diagram of the article search and screening for data extraction

The general characteristics of the 13 articles are summarized in Tables 1–3. Four studies were published on or before 2010, seven between 2011 and 2020, and two in or after 2021. Participants' mean age, weight, and height were 21.46±2.62 yr, 72.47±6.47 kg, and 174.53±4.63 cm, respectively. All studies used a pretest-posttest design, including 18 resistance, six plyometric, and seven combined exercises. The data quantity was sufficient for meaningful analysis based on similar systematic reviews (21), ensuring robust and reliable findings.

Table 1: Study characteristics and reported findings for grip strength articles

Study Authors, year	Sample Group/male-female	Information Age(years)/Mass(kg)/height(cm)	Training	Protocol/*intensity	Periods/Weeks
Torvinen et al. 2002 (22)	Vibration group/9m 17f	23.2±4.4/71.6 ±13.3/174.4±8 .0	1) Light squatting 2) Standing in the erect position 3) Standing in a relaxed position with slightly flexed knees 4) Light jumping 5) Alternating the body weight from one leg to another 6) Standing on the heels	1) First 2 wk: 2 min, frequency 25Hz (first minute), 30Hz(the second minute) 2) Next 1.5 months: 3 min, frequency 25Hz/60 s + 30Hz/60 sec + 35Hz/60 sec 3) Last 2 months: 4 min, frequency 25Hz/60 s + 30Hz/60 s + 35Hz/60s + 40/60s	3–5 times a week /16 wk
Alvarez et al., 2012 (23)	1) Treatment group/5m 2) Control group/5m	1) Treatment group • 23.9±6.7/70.76±7.7/172.1±4.0 2) Control group • 24.2±5.4/68.09±8.3/171.9±7.0	1) Treatment group • Maximal strength training; Explosive strength training; Golf-specific strength training 2) Control group • Golf drives, half-round, core stability, iron, wood shots, general strength training	1) Maximal strength training (3 sets×5 reps) • Horizontal bench press, seated row machine, barbell squat, seated barbell military press, seated calf extension, triceps cable push-down * 85 % of 1-RM 2) Combined exercise (3 sets×6 reps) • Horizontal bench press+plyometric push-ups, seated row machine+explosive pull-downs, barbell squat+vertical jumps over hurdles (45cm), seated barbell military press+plyometric push-ups * 70% of 1-RM 3) Golf-specific strength training (3 sets×10 reps) • Golf drives with weighted clubs, accelerated drives with acceleration tubing	5 times a week /6 wk
Quednow et al., 2015 (24)	Experimental group /4m 9f	20.2±1.3/NR/ 170.4±11.39	1) Kettlebell exercise • Regular swing, swing with goblet squat, shovel, 1-armed alternating swing, kettlebell burpees 2) Battle ropes exercises • Alternating waves, jumping jacks, parallel waves, rotational slam, jump slam	1) Kettlebell exercise (4 sets×15 s) * 25% of body weight 2) Battle ropes exercises (4 sets×15 s) * 25% of body weight	3 d a week /7 wk
Prasetyo et al., 2017 (25)	11 m	22.5±2.8/NR/ NR	Chest press, pull down, butterfly, rowing, leg extension, leg curl, seated leg press, leg lying curl, arm curl, triceps pushdown, low pulley curl, triceps extension, lower back, high pulley crunches, deadlifts	• 2–5 sets, 1–6reps * 90–100% of 1-RM	3 times a week /8 wk

Table 2: Study characteristics and reported findings for long jump articles

Study Authors, year	Sample Group/male-female	Information Age(years)/Mass (kg)/height (cm)	Training	Protocol/*intensity	Periods/Weeks
White head et al. 2018 (26)	1) Resistance group/30m 2) Plyometric group/30m	21.3±1.8/80.0 ±2.6/177.3±9.4	1) Resistance group ・ Skips, back, high knee, side slide, karaoke, lunge, backpedal, front hops, side hops, dot drills 2) Plyometric group ・ Squat, leg press, extension, leg curl, lunges, calf raises	1) Resistance group ・ Skips: 2 reps×20 times ・ Front hops, side hops: 2 reps×60 times ・ Dot drills: 4 reps×30 times ・ Others: 1reps×20 times * 70%(Wk 1–3), 75%(Wk 4–6), 80%(Wk 7–8) of 1-RM 2) Plyometric group ・ Week 1–3: 3 sets×20 reps ・ Wk 4–6: 3 sets×10 reps ・ Week 7–8: 3 sets×8 reps	2 times per week /8 wk
Dodd et al. 2007 (27)	1) Complex group 2) Heavy resistance group 3) Plyometric group	University baseball players/NR/NR	1) Complex group ・ Complex - rest - heavy resistance- rest - high velocity - rest 2) Heavy resistance group ・ Heavy resistance - rest - high velocity - rest - complex - rest 3) Plyometric group ・ High velocity - rest - complex - rest - heavy resistance - rest	1) Heavy resistance: 4 sets×6 reps ・ Squat, lunge, split squat exercises * 80–100% of 1-RM 2) High velocity: 4 sets×6 reps ・ Box jumps, depth jumps, split squat jump * 10–30% of 1-RM 3) Complex: 2 sets×6 reps ・ Heavy resistance+high velocity	3 times per week /15 wk
Kibele et al. 2009 (28)	28m/12f	1) Male ・ 23.0±2.4/77.5±8.1/182.1±6.2 2) Female ・ 22.0±1.8/60.7±5.8/167.9±6.9	・ Olympic squats, vertical jumps, 3 upper- body exercises (pulldowns, butterfly, and bench press), leg press	All exercises: 5 sets × 12 reps * Olympic squats: 75% of 1-RM * 3 upper-body exercises: 70% of 1-RM * Leg press: 70% of 1-RM	2 times per week /7 wk
Chen et al. 2022 (29)	15m	19.1±0.7/74.3 ±16.0/178.1±3.9	・ Double-leg jump, single-leg jump, side-to-side and front-to-back jumps, alternating leg jump rope	Duration: each 1 min	3 times per week /8 wk

Table 3: Study characteristics and reported findings for vertical jump articles

Study Authors, year	Sample Group/ male-female	Information Age(years)/Mass (kg)/height (cm)	Training	Protocol	Periods/ Weeks
Whitehead et al. 2018 (26)	Resistance group Plyometric group/30m	21.3±1.8/80.0 ±2.6 /177.3±9.4	1) Resistance group: back, high knee, side slide, karaoke, lunge, backpedal, front hops, side hops, dot drills 2) Plyometric group: squat, leg press, extension, leg curl, lunges, calf raises	1) Resistance group: Skips: 2 reps×20 times / Front hops, side hops: 2 reps×60 times / Dot drills: 4 reps×30 times / Others: 1 rep×20 times * 70%(Wk 1–3), 75%(Wk 4–6), 80%(Wk 7–8) of 1-RM 2) Plyometric group: Week 1–3: 3 sets×20 reps / Wk 4–6: 3 sets×10 reps/Week 7–8: 3 sets×8 reps	2 times per week /8 wk
Dodd et al. 2007 (27)	Complex group Heavy resistance group Plyometric group	University baseball players/NR/NR	1) Complex group: complex-rest-heavy resistance-rest-high velocity-rest 2) Heavy resistance group: heavy resistance-rest-high velocity-rest-complex-rest 3) Plyometric group: high velocity-rest-complex-rest-heavy resistance-rest	1) Heavy resistance: 4 sets×6 reps / Squat, lunge, split squat exercises * 80–100% of 1-RM 2) High velocity: 4 sets×6 reps / Box jumps, depth jumps, split squat jumps * 10–30% of 1-RM 3) Complex: 2 sets×6 reps / Heavy resistance+high velocity	3 times per week /15 wk
Torvinen et al. 2002 (22)	Vibration group /9m 17f	23.2±4.4/71.6 ±13.3/174.4±8.0	Light squatting, standing in the erect position, standing in a relaxed position with slightly flexed knees, light jumping, alternating the body weight from one leg to another, standing on the heels	1) First two weeks: 2 min, frequency 25Hz(first minute), 30Hz(second minute) 2) Next 1.5months: 3 min, frequency 25Hz/60s+30Hz/60s+35Hz/60s 3) Last 2months: 4 min, frequency 25Hz/60s+30Hz/60s+35Hz/60s + 40/60s	3–5 times a week /16 wk
Thompson et al. 2015 (4)	Training group /17m 17f	22.8±3.0/75.9 ±14.7/173.3±9.9	Barbell deadlift training	5 sets×5 reps * weight to perform 5 sets of 5 times * add 0.45–2.2 kg if possible 5 reps per set * Remove 0.45–2.2 kg if not possible 5 reps per set	2 times per week /10wk
Khazaei et al. 2023 (30)	Functional exercise group/9f Resistance exercises group/8f	21.7±3.0/NR/ 167.2±6.1	1) Functional exercise group: Burpees, barbell squats+standing calf raise, alternate push up on a medicine ball, snatch, clean and jerk, lunge+holding medicine ball, kettlebell single-leg deadlift 2) Resistance exercises group: Smith squat, barbell chest press, leg extension, lat pull-down, lying leg curl,	· First week: 3 sets×14 reps · Second week: 3 sets×12 reps · Third week: · Fifth week: 3 sets×12 reps · Sixth week: 4 sets×6 reps · Seventh week: 5 sets×6 reps · Eighth week:	3 times per week /8 wk

Table 3: Continued…

			machine shoulder press, cable lateral raise	4 sets×10 reps • Fourth week: 4 sets×10 reps	5 sets×6 reps	
Keerthi et al.2016 (31)	Experimental group/16f Plyometric group/19f	1) Experimental group 21.0±2.0/63.9±4.6/174.5±5.4 2) Plyometric group 19.9±4.7/66.8±15.1/175.0±7.1	1) Experimental group: Special training program 2) Plyometric group: Benches, depth and lay-up jumps	10 sets×11 reps		3 times per week /8 wk
Alvarez et al. 2012 (23)	Treatment group /5m Control group/5m	1) Treatment group 23.9±6.7/70.8±7.7/172.1±4.0 2) Control group 24.2±5.4/68.1±8.3/171.9±7.0	1) Treatment group Maximal strength training: Golf drives, core stability, maximal strength program, general strength training. Explosive strength training: Golf drives, combined weights and plyometrics program, general strength training Golf-specific strength training: Golf drives, half-round, core stability training, Golf-specific strength exercises, wood shots, general strength training 2) Control group Golf drives, half-round, core stability, iron wood shots, general strength training	1) Maximal strength training(3 sets×5 reps): Horizontal bench press, seated row machine, barbell squat, seated barbell military press, seated calf extension, triceps cable push-down * 85% of 1-RM 2) Combined exercise(3 sets×6 reps): Horizontal bench press+plyometric push-ups, seated row machine+explosive pull-downs, barbell squat+vertical jumps over hurdles(45cm), seated barbell military press+plyometric push-ups * 70% of 1-RM 3) Golf-specific strength training(3 sets×10 reps): Golf drives with weighted clubs, accelerated drives with acceleration tubing		5 times a week /6 wk
Griffiths et al. 2019 (32)	Traditional training /15m Explosive training /15m	1) Traditional training 21.0±1.0/77.4±1.7/178.7±1.3 2) Explosive training 23.0±1.0/76.1±2.1/175.3±1.3	Smith machine squats, knee extension, knee flexion, hip extension, hip flexion, heel raises, chest press, and pull-down in that order. 1) Traditional training: 2s eccentric and 2s concentric repetition duration 2) Explosive training: Maximal intended velocity for both concentric and eccentric phases	3sets * 80% of 1-RM		2 times per week /6 wk

Table 3: Continued…

Arabatzi, et al. 2010 (33)	Weight-lifting group/9 m Plyom-etrics group/9 m Com-bined group/9 m	20.3±2.0/85.2 ±6.8/184.8±8. 3	1) Weightlifting group: snatch from a squat position, high-pull, power clean, half-squat, clean and jerk 2) Plyometric group: double-leg hurdle hops, alternate single-leg hurdle hops, double-leg hops, half-squats 3) Combined group: Snatch from a squat position, high-pull, power clean, half-squat, clean and jerk, and 4 PL drills: double-leg hurdle hops, alternate single-leg hurdle hops, double-leg hops, half-squats	1) Weightlifting group • First 2 wk: 4 sets×4 reps * 75 % of 1-RM • Week 3, 4: 4 sets×6 reps * 80% of 1-RM • Last 4 wk: 4 sets×4 reps * 80–90 % of 1-RM 2) Plyometrics group • First 2 wk: 4 sets×6 reps • Week 3, 4: 6 sets×6 reps • Last 4 wk: performance speed has increased 3) Combined group • First 2 wk: 4 sets×6 reps/4 sets×6 reps • Week 3, 4: 4 sets×6 reps/6 sets×6 reps • Last 4 wk: 4 sets×4 reps/intensity increased	3 times per week /8 wk

The quality assessment results are presented in Table 4. The mean qualitative score of the included studies was 15.07 points (75.36%), with 11 high-quality studies (4, 22-24, 26, 27, 29, 30, 32) and three moderate-quality studies (25, 28, 31, 33).

Table 4: Quality assessment of the included studies

References	Items																				Score	Percentage (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Torvinen et al. (22)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	0	15	75
Quednow et al. (24)	1	1	1	1	0	1	1	0	0	0	1	1	0	0	1	1	0	0	1	1	12	60
Prasetyo et al. (25)	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	0	16	80
Whitehead et al. (26)	1	1	1	0	1	1	1	0	0	1	1	0	1	1	0	1	1	1	1	1	15	75
Dodd et al. (27)	1	1	1	1	1	0	0	1	1	1	0	0	1	0	1	1	0	1	0	1	13	65
Kibele et al. (28)	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	15	75
Chen et al. (29)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	16	80
Thompson et al. (4)	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	17	85
Khazaei et al. (30)	1	1	1	1	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1	1	15	75
Keerthi et al. (31)	1	0	0	0	1	1	0	1	1	0	1	0	1	0	1	1	0	1	1	1	12	60
Griffiths et al. (32)	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19	95
Alvarez et al. (23)	1	1	0	1	1	0	1	0	1	1	1	1	0	1	1	1	1	0	1	1	15	75
Arabatzi et al. (33)	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	17	85

Grip strength

Eight data points from four studies on grip strength using muscle-strengthening programs were included, with programs ranging from 6 to 16 wk (four resistance and one combined program). One study used data from two groups, while two assessed grips strengths in both hands. These studies involved 60 participants (mean age: 22.8 yr), with group sizes ranging from <10 to 21–31 participants. Seven of eight studies reported increased hand strength. The data showed high heterogeneity (I^2=60%, P<.01), and the effect size was statistically significant at -1.36 (95% CI: -2.11, -0.62) (Fig. 2).

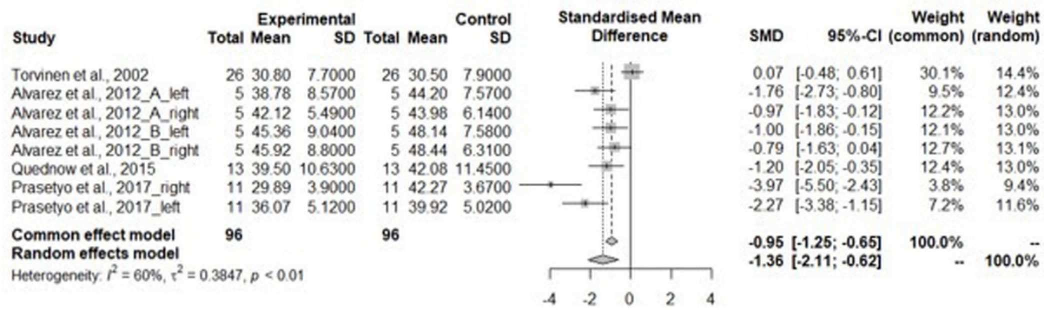

Fig. 2: Comparison outcome of grip strength by the strength training

Standing long jump

Seven data points from four studies assessing standing long jump through muscle-strengthening programs were included. The programs comprised resistance (n=4), plyometric (n=2), and combined (n=1) training, lasting 7 (n=1), 15 (n=1), and 8 (n=2) wk, respectively. One study included two groups and another three groups, totaling 146 participants (mean age: 21.4 yr). One of the seven studies reported improved standing long jump performance. No significant heterogeneity was found (I^2=0%, P=.65), with an effect size of -0.28 (95% CI: -0.51, -0.05) (Fig. 3).

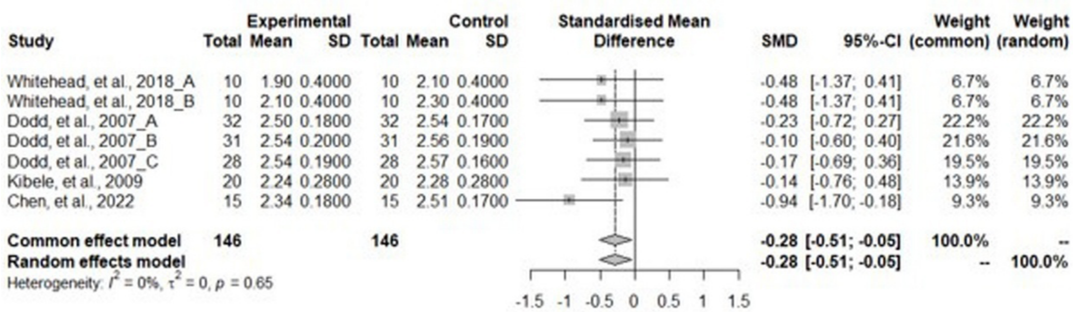

Fig. 3: Comparison outcome of long jump by the strength training

Vertical jump

Eighteen data points from nine studies assessing vertical jump through muscle-strengthening programs were included. The programs involved resistance (n=10), plyometric (n=4), and combined (n=5) training, lasting 6–16 wk. Five studies included two groups and two studies three groups, totaling 290 participants (mean age: 21.21 yr). Two of 18 studies reported improved vertical jump performance. No significant heterogeneity was found (I^2=4%, P=.41), with an effect size of -0.35 (95% CI: -0.52, -0.19) (Fig. 4).

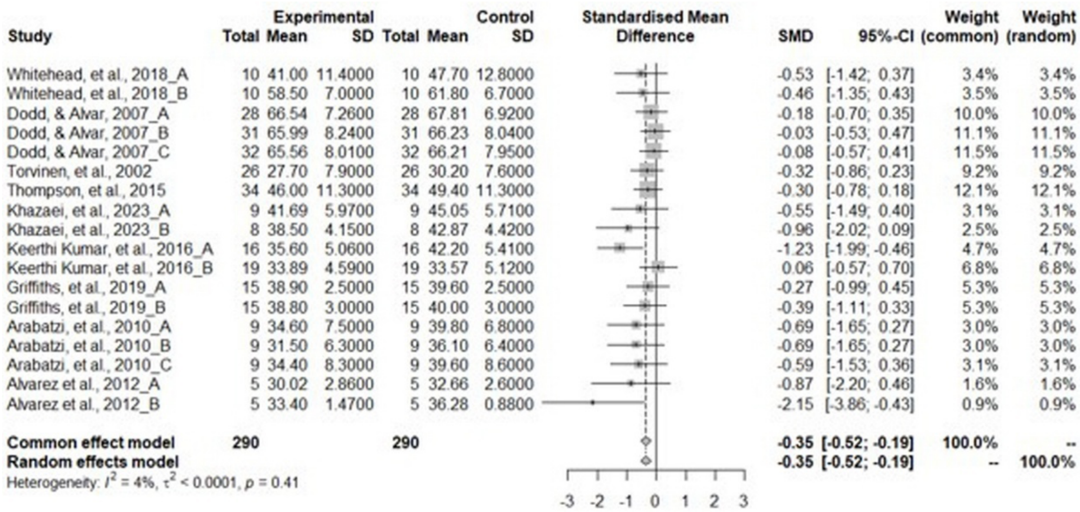

Fig. 4: Comparison outcome of vertical jump by the strength training

Risk of bias

Funnel plots showed an even distribution among studies, suggesting minimal publication bias. Egger's regression test, conducted for vertical jump studies (≥10 results), revealed no bias (*P*=.27). Tests were not performed for grip strength and long jump due to insufficient data points (Fig. 5).

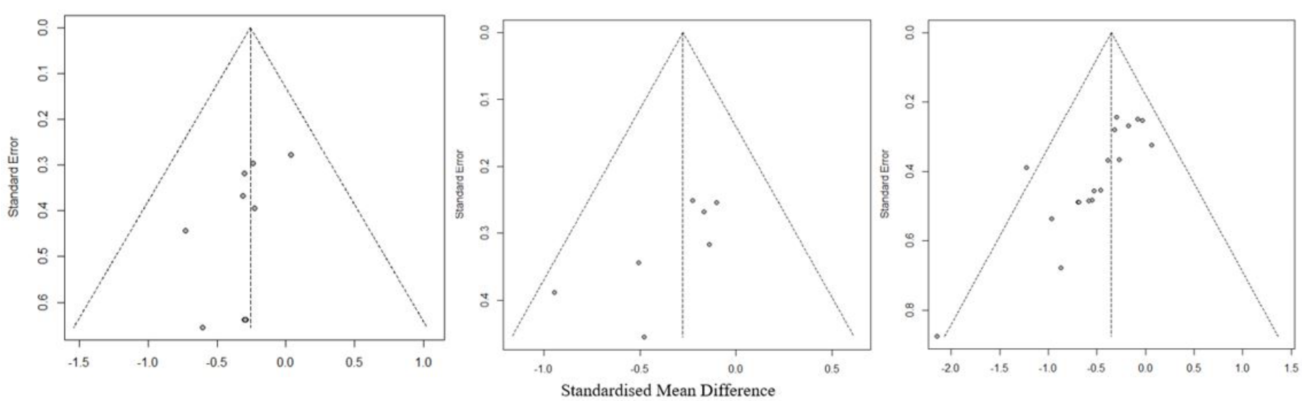

Fig. 5: Funnel plots for publication bias

Discussion

This review aimed to determine whether grip strength is suitable for assessing muscle strength, based on previous studies evaluating standing long jump and vertical jump performance after muscle-strengthening programs. Among the 13 articles included in the meta-analysis, four studies were published on or before 2010, seven between 2011 and 2020, and two after 2021. Muscle-strengthening programs included resistance training (n=18), plyometric training (n=6), and combined training (n=7).

Among grip strength studies, resistance training programs (n=4) were most common, with one study on alternative resistance-related training. A meta-analysis was conducted using eight data points. Grip strength is widely considered a marker of physical muscle strength (5, 8). Since muscle strength refers to the ability to lift maximal loads, exercise programs targeting strength can significantly enhance athletic performance (25). Many studies in the meta-analysis reported improved grip strength following training. Prior research indicated that long-term lower extremity muscle-strengthening programs could maintain or improve grip strength (5), with notable improvements seen after high-intensity training, particularly in the dominant hand. Moreover, short sessions about 20 min, three times a week can effectively enhance grip strength (24). Personalized programs based on fitness assessments are also important (10). In the included studies, participants consistently trained three times per week for at least four weeks, suggesting that consistent lower extremity strengthening can meaningfully improve grip strength (5, 6).

For the standing long jump, the meta-analysis included four data points from resistance programs, two from plyometric programs, and one from another resistance-related program. For the vertical jump, there were 10 from resistance, four from plyometric, and five from combined or other programs. The effect size for the standing long jump was low (-0.28) and for the vertical jump was -0.35. No significant changes were observed in seven of eight data points for the standing long jump and 17 of 18 for the vertical jump. This may be due to the exercise programs' limited sets, repetitions, and speeds. Resistance exercises improve muscle functions such as strength, power, endurance, and growth, depending on load, repetitions, exercise type, rest periods, and number of sets (25). Effective resistance training typically involves 1–5 repetitions at 75%–90% of 1RM for power, six repetitions at ≥85% of 1RM for strength, 6–12 repetitions at 67–85% of 1RM for hypertrophy, and 12+ repetitions at ≤67% of 1RM for endurance (34). However, some studies targeting standing long jump used 12 repetitions or continuous 1-minute exercises, indicating endurance rather than strength focus. Vertical jump studies often used light weights (10%–30%) or moderate repetitions (10–12 reps), which may not have effectively developed strength or power. Consequently, muscle endurance, not strength or power, was likely emphasized (5). Exercise speed also plays a crucial role in muscle function development, but most articles did not regulate speed; only Dodd and Alvar (27) incorporated high-speed exercises with light weights. Without controlled speed despite low repetitions, no significant improvements were observed in jump performance. Thus, adjusting both load and speed is critical for improving standing long jump and vertical jump through strength programs.

Plyometric exercise, a form of resistance training, enhances balance, coordination, agility, and power via rapid, high-load muscle contractions (35). The stretch-shortening cycle intense eccentric contraction followed by immediate concentric contraction is central to plyometric training (36). Typically, plyometric programs involve quick, jump-based movements (37) and can significantly improve performance with appropriate progression, aiming for about 400 jumps per day (38). This can enhance both physical ability and muscle strength (39). However, the plyometric programs in the analyzed studies often involved lower intensity and more repetitions, focusing more on technique than strength or power. While beneficial for general fitness, such protocols may not significantly enhance quick, forceful movements like jumps and may even increase injury risk (39). Plyometric training's effectiveness is heavily dependent on the individual's baseline strength and power levels, and programs need to be tailored accordingly to achieve optimal performance outcomes. Effective plyometric training for improving jump performance requires carefully planned intensity, duration, and frequency (40). Although prior studies showed significant muscle power improvements through plyometric exercise, this meta-analysis found that plyometric training had minimal effects on enhancing standing long jump and vertical jump. This discrepancy could be explained by the varying training loads and the potential for technique over load focus in the analyzed protocols, which may limit improvements in explosive power.

This study had several limitations. The meta-analysis covered only three sports with few articles and various resistance training types, limiting analysis of specific training characteristics. Thus, caution is needed when interpreting the effect sizes. Although grip strength is widely used for muscle strength assessment due to its convenience, its focus on upper extremity muscles questions its validity as a systemic measure. This study highlights the need to explore alternative, more accurate methods for assessing overall muscle strength in practical settings. In the meta-analysis of grip strength, moderate heterogeneity was observed (I^2 = 60%), possibly due to individual variability in training responses. This may reflect the influence of factors such as upper limb usage, baseline strength, and intervention characteristics. Additionally, the inclusion of only 'young, healthy adults' was to control for confounding factors, but this limits the generalizability of the findings to broader populations. Future research should include more diverse groups, such as older adults and individuals with varying health conditions, to better understand the applicability of the results.

Conclusion

The meta-analysis included studies that assessed handgrip strength, standing long jump, and vertical jump using resistance training, plyometric exercises, or other resistance-related training programs to improve physical muscle strength.
Assessment of grip strength in young adults before and after muscle strength training in most studies revealed improved grip strength. However, the results showed no statistically significant differences between the standing long jump and the vertical jump. Grip strength is more indicative of muscle strength among physical factors, while standing long jump and vertical jump, primarily testing power, may not effectively assess muscle strength components. Given the inherent association of the standing long jump and vertical jump with muscle strength and power, enhancing performance may necessitate exercise repetitions and speed adjustments to improve muscle power.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This work was supported by the National Research Council of Science & Technology (NST) Aging Convergence Research Center (CRC22014-500).

Conflict of interest

The authors declare that there is no conflict of interests.

References

1. Brooks, GA, Fahey TD, Baldwin KM, *Exercise physiology: human bioenergetics and its applications*. 5th ed. 2005, Boston: McGraw-Hill, USA.
2. Suchomel, TJ, Nimphius S, Stone MH (2016). The importance of muscular strength in athletic performance. *Sports Med*, 46:1419-1449.
3. Silva, JR, Nassis GP, Rebelo A (2015). Strength training in soccer with a specific focus on highly trained players. *Sports Med Open*, 1:17.
4. Thompson BJ, Stock MS, Shields JE, et al (2015). Barbell deadlift training increases the rate of torque development and vertical jump performance in novices. *J Strength Cond Res*, 29 (1):1-10.
5. Alam, MM (2021). The effectiveness of a week-long free weight training intervention for grip strength and grip endurance time in young adults. *EC Clin Med Case Rep*, 4:01-07.
6. Oh, YH, Moon JH, Kong MH, et al (2017). The association between hand grip strength and health-related quality of life in Korean adults. *The Korean Journal of Sports Medicine*, 35 (2):103-111.
7. Chang, H-Y, Chou K-Y, Lin J-J, et al (2010). Immediate effect of forearm kinesio taping on maximal grip strength and force sense in healthy collegiate athletes. *Phys Ther Sport*, 11 (4):122-127.
8. Bohannon, RW, Magasi SR, Bubela DJ, et al (2012). Grip and knee extension muscle

strength reflect a common construct among adults. *Muscle Nerve*, 46 (4):555-558.
9. Innes, E (1999). Handgrip strength testing: A review of the literature. *Aust Occup Ther J*, 46 (3):120-140.
10. Kamarul, T, Ahmad TS, Loh W (2006). Hand grip strength in the adult malaysian population. *J Orthop Surg (Hong Kong)*, 14 (2):172-177.
11. Oh JW, Kim SM, Lee D, et al (2023). Reduced grip strength potentially indicates depression: Investigating multicontinental databases. *J Affect Disord*, 323:426-434.
12. Mandalidis, D O'Brien M (2010). Relationship between hand-grip isometric strength and isokinetic moment data of the shoulder stabilisers. *J Bodyw Mov Ther*, 14 (1):19-26.
13. Markovic, G Mikulic P (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Med,* 40:859-895.
14. Maulder, P Cronin J (2005). Horizontal and vertical jump assessment: reliability, symmetry, discriminative and predictive ability. *Phys Ther Sport*, 6 (2):74-82.
15. Nuzzo, JL, McBride JM, Cormie P, et al (2008). Relationship between countermovement jump performance and multijoint isometric and dynamic tests of strength. *J Strength Cond Res*, 22 (3):699-707.
16. Moher, D, Liberati A, Tetzlaff J, et al (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*, 151 (4):264-269.
17. Kaur, M, Ribeiro DC, Theis J-C, Webster KE, Sole G (2016). Movement patterns of the knee during gait following ACL reconstruction: a systematic review and meta-analysis. *Sports Med*, 46:1869-1895.
18. Xie, P-P, István B, Liang M (2022). Sex-specific differences in biomechanics among runners: A systematic review with meta-analysis. *Front Physiol*, 13:994076.
19. Cohen, J. *Statistical power analysis for the behavioral sciences*. 2013: routledge.
20. Kim, H-Y Lee M-N (2019). Effects of non-pharmacological interventions for preoperative anxiety in surgical patient: a systematic review and meta-analysis. *J Korean Acad Fundam Nurs*, 26 (4):248-259.
21. Ren, Z, Zhang X, Wei Y, et al (2024). Association between breakfast consumption frequency and handgrip strength and standing long jump: A systematic review and meta-analysis. *Front Psychol*, 15:1451799.
22. Torvinen, S, Kannus P, Sievänen H, et al (2002). Effect of four-month vertical whole body vibration on performance and balance. *Med Sci Sports Exerc*, 34 (9):1523-1528.
23. Alvarez, M, Sedano S, Cuadrado G, Redondo JC (2012). Effects of an 18-week strength training program on low-handicap golfers' performance. *J Strength Cond Res*, 26 (4):1110-1121.
24. Quednow, J, Sedlak T, Meier J, et al (2015). The effects of high intensity interval-based kettlebells and battle rope training on grip strength and body composition in college-aged adults. *Int J Exerc Sci*, 8 (2):3.
25. Prasetyo, Y Nasrulloh A (2017). Weight training with pyramid systems to increase the leg and back muscular strength, grip strength, pull, and push strength. *Man India*, 97 (24):193-201.
26. Whitehead, MT, Scheett TP, McGuigan MR, et al (2018). A comparison of the effects of short-term plyometric and resistance training on lower-body muscular performance. *J Strength Cond Res*, 32 (10):2743-2749.
27. Dodd, DJ Alvar BA (2007). Analysis of acute explosive training modalities to improve lower-body power in baseball players. *J Strength Cond Res*, 21 (4):1177-1182.
28. Kibele, A Behm DG (2009). Seven weeks of instability and traditional resistance training effects on strength, balance and functional performance. *J Strength Cond Res*, 23 (9):2443-2450.
29. Chen, C-F Wu H-J (2022). The effect of an 8-week rope skipping intervention on standing long jump performance. *Int J Environ Res Public Health*, 19 (14):8472.
30. Khazaei, L, Parnow A, Amani-Shalamzari S (2023). Comparing the effects of traditional resistance training and functional training on the bio-motor capacities of female elite taekwondo athletes. *BMC Sports Sci Med Rehabil*, 15 (1):139.
31. Keerthi Kumar, M Sundar Raj U (2016). Effect of plyometric and weight training programs on vertical jump in female basketball players. *Int J Phys Educ Sports Health*, 3 (3):25-27.

32. Griffiths, B, Grant J, Langdown L, et al (2019). The effect of in-season traditional and explosive resistance training programs on strength, jump height, and speed in recreational soccer players. *Res Q Exerc Sport*, 90 (1):95-102.
33. Arabatzi, F, Kellis E, De Villarreal ES-S (2010). Vertical jump biomechanics after plyometric, weight lifting, and combined (weight lifting+ plyometric) training. *J Strength Cond Res*, 24 (9):2440-2448.
34. Bompa, TO Buzzichelli C, *Periodization-: theory and methodology of training*. 2019: Human kinetics.
35. Faigenbaum, AD, McFarland JE, Keiper FB, et al (2007). Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. *J Sports Sci Med*, 6 (4):519-25.
36. Fernandez-Fernandez, J, De Villarreal ES, Sanz-Rivas D, Moya M (2016). The effects of 8-week plyometric training on physical performance in young tennis players. *Pediatr Exerc Sci*, 28 (1):77-86.
37. Newton, RU, Häkkinen K, Häkkinen A, et al (2002). Mixed-methods resistance training increases power and strength of young and older men. *Med Sci Sports Exerc*, 34 (8):1367-1375.
38. Wathen, D (1993). Explosive/plyometric exercises. *Training*, 25 (2):122.
39. Davies, G, Riemann BL, Manske R (2015). Current concepts of plyometric exercise. *Int J Sports Phys Ther*, 10 (6):760-86.
40. Silva, AF, Clemente FM, Lima R, et al (2019). The effect of plyometric training in volleyball players: A systematic review. *Int J Environ Res Public Health*, 16 (16):2960.