International Journal of Sports and Physical Education (IJSPE)
Volume 9, Issue 3, 2023, PP 1-10
ISSN 2454-6380 (Online)
DOI: https://doi.org/10.20431/2454-6380.0903001
www.arcjournals.org

Acute Effect of a Conditioning Activity on Vertical Jump Height in Trained Adult Women: A Systematic Review with Meta-Analysis

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Abstract:

Objective: *To verify the acute effect of conditioning activity protocols on vertical jump height in trained women.*

Methods: *A systematic review with meta-analysis was performed based on studies retrieved from Pubmed, SciELO, Scopus, SPORTDiscus, and Web of Science databases. The screening and eligibility of the studies were carried out by two independent evaluators and with a third researcher in case of disagreements. The result of the meta-analysis was obtained from the standardized mean difference (SMD), 95% confidence intervals (CI), and inconsistency test (I^2).*

Results: *Five studies were included in the meta-analysis. The conditioning activity intervention generated higher jumping performances than the control group/session (SMD = 0.91 [95% CI: 0.57 - 1.24]), but with high heterogeneity (I^2 = 75%). Subgroup analysis demonstrated that dynamic conditioning activities have better jump performance responses than isometrics. Conditioning activities with multiple sets increased jump performance more than single sets. Female athletes and those with more training experience appear more responsive to conditioning activity than females with lower training levels.*

Conclusion: *A conditioning activity can improve the vertical jump's acute performance in trained women. Female athletes with more training experience seem more responsive to dynamic conditioning activity, with greater volume and intensities above 70% of 1RM.*

Keywords: *Exercise; Hypertrophy; Muscle strength; Quadriceps muscle; Resistance training*

1. INTRODUCTION

The vertical jump is a motor gesture executed in several sports modalities and is highly associated with the performance of external muscle power [1]. Therefore, it is used as the main exercise in training sessions. In recent decades, the literature has observed that performing a strength exercise with high overload (in maximal or close-to-maximal intensity) before the vertical jump can enhance the latter's performance [2]. Such prior exercise is called conditioning activity (CA) [3]. On the other hand, the phenomenon associated with the acute improvement of any external muscular power exercise, such as the vertical jump, is called post-activation performance enhancement (PAPE) [4].

In addition to the variables related to CA – volume, intensity, and restinterval, among others [5]; the characteristics of the participants must also be considered to potentiate the vertical jump. Among these characteristics, sex can be an essential variable [6]. However, the small number of studies that investigated women and their methodological differences seem to provide insufficient evidence to justify any prescribing conclusion for this specific population [7,8].

A possible difference between men and women may be related to hormones' influence on potentiation, specifically, a modulation by estradiol in phosphorylation of the myosin regulatory light chain [9]. There is also evidence that women can reach peak tension in a shorter time when compared to men [10]. This characteristic may indicate a more significant potentiation of contractile properties. Performance improvement results from animbalance in the potentiation-fatigue binomial towards potentiation [11]. Since type IIB muscle fibers are more sensitive to potentiation's effect [12], women may benefit from fatigue tolerance since type I fibers prevail in their muscle tissue [13].

No previous systematic reviews with meta-analysis have examined CA's impact on vertical jump performance with samples of trained women only. This lack of information limits the knowledge of this method's effectiveness in that population. In addition, prescribing recommendations are structured from studies based mainly on male samples. Whether these recommendations can be applied to female athletes' samples is unknown. Therefore, this study aimed to determine the acute effect of CA protocols on vertical jump height in trained women and verify the influence of training level, type of contraction, and total volume of CA on vertical jump performance.

2. METHODS

2.1. Protocol and Registration

The present systematic review with meta-analysis was conducted according to the criteria and recommendations presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [14]. It was registered in PROSPERO under the identification CRD 42021206580.

2.2. Eligibility Criteria

The PICOS (participants, intervention, comparators, outcomes, and study design) approach was used to rate studies for eligibility. The sample of the included studies was composed of healthy and trained adult females between 18 and 40 years old, involved in strength/power sports and/or strength/power physical training programs, with no musculoskeletal injuries or dysfunctions. All selected studies used isometric or dynamic strength exercise, with single or multiple sets, with an external load intensity from 70% of 1RM up to maximal or supramaximal intensity. Vertical jump height was considered a performance variable and measure of interest. Studies that combined the treatment condition with other interventions (such as medication, supplementation, and electrostimulation) were excluded.

2.3. Search Strategy

Complete articles from 1961, when this topic began to be published, until August 2023, were included in the literature search. Document references were retrieved from Pubmed, SciELO, Scopus, SPORTDiscus, and Web of Science databases. The following search terms were used independently or in combination, adapted for each database, with different DeCS/MeSH combinations: “postactivaton potentiation”, “post-activaton potentiation”, “postactivation performance enhancement”, “PAP”, “PAPE”,“power”,“conditioning activity”, “conditioning stimulus”,"complex training", "contrast training",“jump”, “jumping”, “female”, “women”.

2.4. Selection Processes

The search results were initially imported into a database, where duplicates were recognized and eliminated. Two independent, blinded researchers performed both screening and eligibility processes. A third independent researcher was used in cases of conflict. Studies’ titles and abstracts were read at screening, and the references that met the criteria had their full texts analyzed for eligibility. After reading the full texts, five articles were identified that met all the requirements to be included in this review.

2.5. Assessment of Methodological Quality, Risk of Bias, and Level of Evidence

Two blinded evaluators also worked independently to assess methodological quality and risk of bias in the present review. Where there was a conflict in the outcome, a third independent researcher made the final decision. Methodological quality was assessed with the TESTEX scale [15], the tool for assessing study quality and reporting in exercise [15]. The risk of bias in the studies was assessed using the Cochrane Risk of Bias scale [16]. The Grading Recommendation Assessment, Development, and Evaluation (GRADE) tool was used to determine the systematic review's evidence level [17].

2.6. Data Extraction

For the systematic review, data were analyzed according to the studies' sample size, participants' characteristics (age, sport or training practiced), CA (exercise, volume, and intensity), main activity (performance test, volume, intensity), rest interval, and result.

The number of subjects per group (N sample), mean, and standard deviation of post-intervention results were used for the meta-analysis. In the case of performing repeated measurements at different rest intervals after the CA, only the first measurement was considered to disregard the residual effect of repeated measures, which can influence the final mean result.

In the studies with a mixed sample that separated the results of men and women, only the ones from women were included [18,19]. If the analysis had been performed jointly, the authors would have been contacted to inform women-only results. The same procedure was performed in case of absent detailed results or unreported data in studies. If the authors did not provide the raw data, the WebPlot Digitizer graph analysis tool (Version 4.5 available at: https://automeris.io/WebPlotDigitizer/), free to use, was used to calculate the mean and standard deviation of the available graphics. To this end, three measurements were performed, and their average was calculated and used for analysis. Two studies were submitted to these analyses [18,20]. When obtaining the data through graphics was impossible, the study was excluded from the analysis.

2.7. Data Analysis

The dependent variable of the present meta-analysis is continuous. Due to the heterogeneous nature of the selected studies, which may indicate that the actual effect must vary between studies, the statistical analysis adopted the random error effect model. The standardized mean difference with small sample adjustment (Hedge's G) and 95% confidence interval was also used to present individual results of each selected study. The mean and standard deviation of post-treatment measures from intervention (CA) and comparison (control) groups were considered for this calculation. Subgroup analyses were performed with a distinction between CA’s type (isometric exercise versus dynamic exercise), CA’s total volume (single set versus multiple sets), and training level (trained/moderately trained versus athletes).Statistical heterogeneity was evaluated based on the inconsistency test (I^2). All analyses above were performed using the Review Manager software (RevMan, version 5.4, The Cochrane Collaboration, 2020). A funnel plot with a standardized mean, followed by the Egger test for a random effect, was performed to identify publication bias (StatsDirect software, version 3, Wirral, UK).

3. RESULTS

3.1. Study Selection

The search strategy, inclusion criteria, and eligibility of studies included in this review are shown in Figure 1.

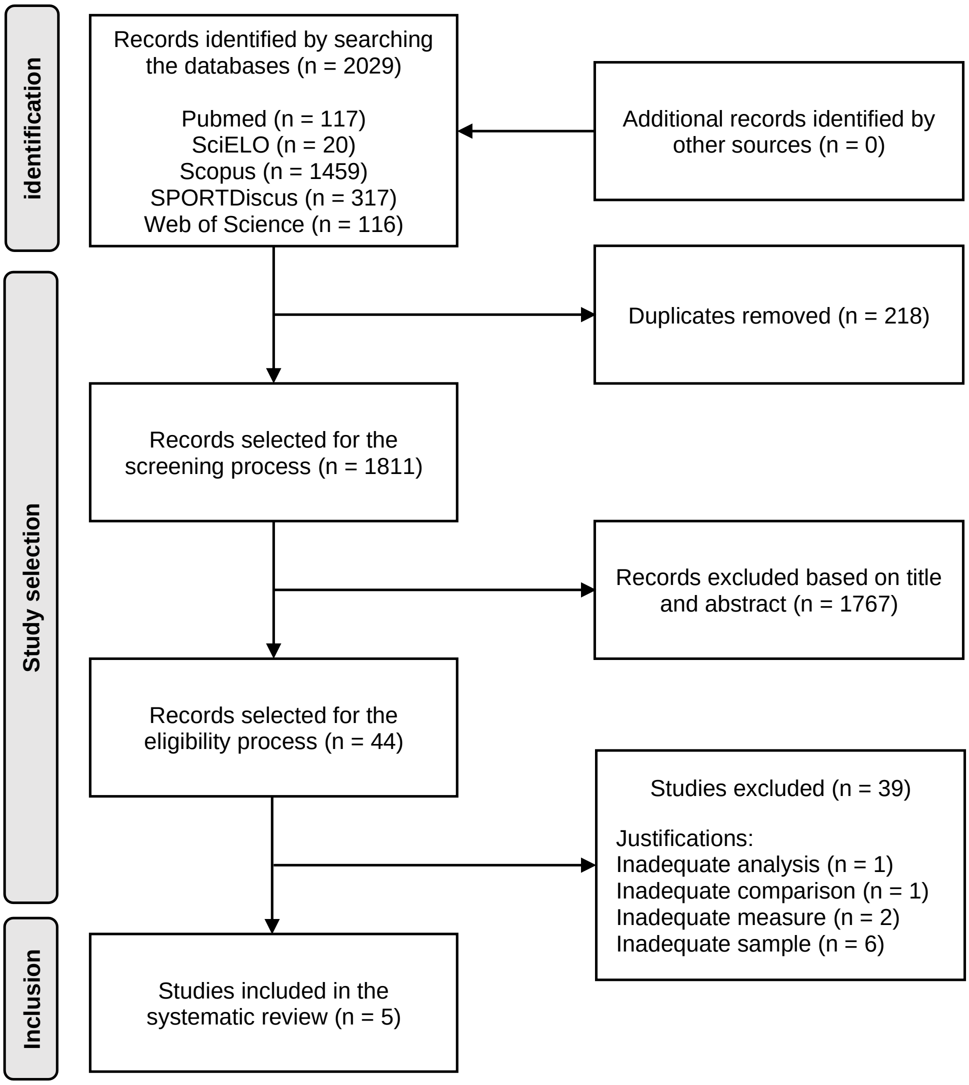

Figure1. *Study selection flowchart.*

3.2. Study Characteristics

The studies included samples of women under 30 years of age. Training levels ranged from moderately and recreationally trained to college, national, and elite athletes. The sports practiced by the participants were swimming, hockey, softball, volleyball, track and field, handball, soccer, and CrossFit. Five of the 1552 studies were selected and included in the review based on inclusion criteria (Table 1). Two included studies achieved an eight score on the TESTEX scale, two achieved a ten score, and one achieved a 12 score (Table 2). No study violated baseline equality between groups in the variable of interest (vertical jump performance).Figure 2 shows the risk of bias.

Regarding CA's type, two out of five studies used isometric exercises [18,19], and three used dynamic exercises [20-22]. Among dynamic exercise studies, all applied bilateral squats. In contrast, in isometric exercise studies, one used bilateral squat [18], and the other used the isometric midthigh pull [19]. As for CA's volume, only one study performed a single set [20], and another four performed three sets [18,19,21,22]. The number of repetitions ranged from three to four. As for the load, only one study added elastic bands to CA's overload [19]. The rest interval between conditioning and main activities presented high variability. Two studies used repeated measurements at different times after CA's execution [18,22], while three used jumping measurements in only one moment [19-21].Concerning the main activity, lower limb performance tests were performed, such as countermovement jump [19,21], squat jump [18,20,22], and squat jump with an overload (30% of 1RM squat) [21].

Table1. *Studies comparing the acute effect of conditioning activity vs. control on vertical jump height in trained women.*

Study	**N sample Age (years)**	**Conditioning activity**	**Rest**	**Main activity**	**Result (%) CA vs. CON**
Arabatzi et al. [18]	11 MT 20 ± 1	3x3s ½ MIS; RI: 2 min	20s; 4 min	3 JWC RI: 5s	9,5
Duthie et al. [21]	11 Hc, Sb Athl 24 ± 3	3x3RM ½ squat (smith); RI: NI	NI	3x3 JWC 30% 1RM RI: NI	0,0
Herring et al. [19]	15 T 22 ± 2	3x3-5s IMP; RI: 2 min	4-7 min	3 CMJ RI: 1 min	-0,3
Krčmár et al. [22]	14 Atc, Cf, Fb, Hb, Vb Athl 22 ± 2	AC-A: 3x4 squat (85% 1RM); RI: 2 min AC-B: 3x4 squat (85% 1RM) + 20% TR-EB; RI: 2 min AC-C: 3x4 squat (85% 1RM) + 30% TR-EB; RI: 2 min	5 min; 10 min	2-3 JWC 2-3 CMJ RI: 40s; 30s	JWC: 6,4 CMJ: 14,7* JWC: 11,0 CMJ: 13,9* JWC: 20,3* CMJ: 15,8*
Villalon-Gasch et al. [20]	11 Vb E-Athl 22 ± 3	½ squat - 2x12 (20kg) + 1x5 (50% 1RM) + 1x3 (90% 1RM); RI: 3 min	8 min	2 CMJ RI: 1 min	19,5*

*Athl: athletes; Atc: athletics; CA: conditioning activity; Cf: crossfit; CMJ: countermovement jump; CON: control; E-Athl: elite athletes; Fb: football; Hb: handball; Hc: hockey; IMP: isometric midthigh pull; IS: JWC: jump without countermovement; min: minutes; MIS: maximum isometric squat; MT: moderately trained; NI: not informed; RI: rest interval; RM: repetition maximum; s: seconds; Sb: softball; T: Trained; TR-EB: total resistance of elastic band; Vb: volleyball; *: significant difference (p < 0,05)*

Table2. *Results of the methodological quality assessment.*

Study	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Total
Arabatzi et al. [18]	1	0	0	1	0	2	1	2	1	1	0	1	10
Duthie et al. [21]	1	0	0	1	0	2	1	2	1	1	0	1	10
Herring et al. [19]	1	1	1	1	0	2	1	2	1	1	0	1	12
Krčmár et al. [22]	1	0	0	1	0	1	0	2	1	1	0	1	8
Villalon-Gasch et al. [20]	1	0	0	1	0	2	0	1	1	1	0	1	8

C: criterion; C1: eligibility criteria specified; C2: randomization specified; C3: allocation concealment; C4: groups similar at baseline; C5: blinding of assessor; C6: outcome measures assessed in 85% of patients; C7: intention-to-treat analysis; C8: Between-group statistical comparisons reported; C9: point measures and measures of variability for all reported outcome measures; C10: activity monitoring in control groups; C11: relative exercise intensity remained constant; C12: exercise volume and energy expenditure.

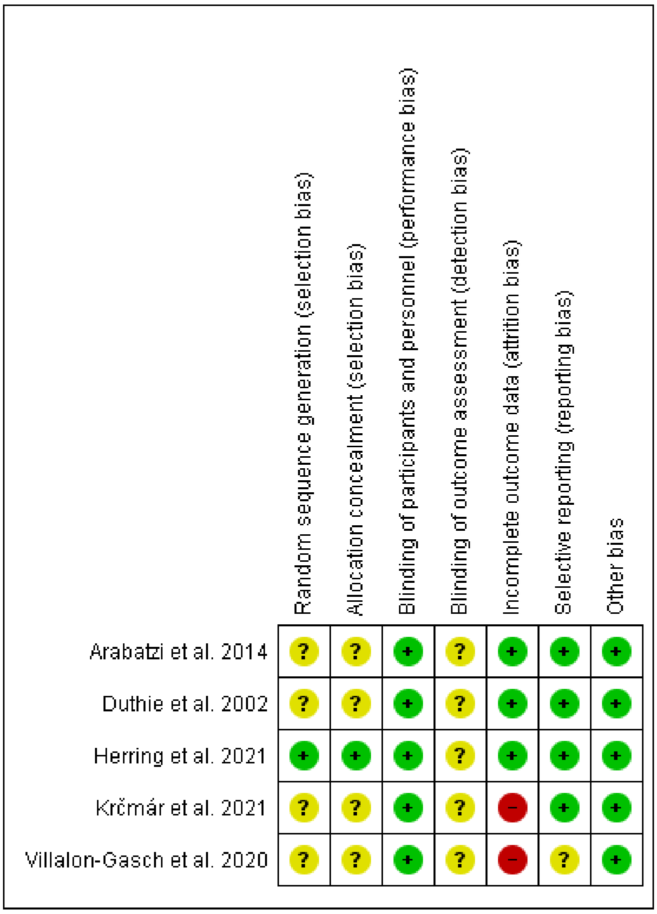

Figure2. *Risk of bias of included studies.*

3.3. Meta-Analysis Results

Eighty-five subjects underwent CAs' intervention with intensity greater than or equal to 70% 1RM, while 84 subjects constituted the comparison group (control). The standardized mean difference indicated a large and favorable effect on CA intervention (Z = 5.31, P = 0.00001, SMD = 0.91 [95% CI: 0.57 - 1.24]), with high heterogeneity (Chi^2 = 23.69, df = 6, P = 0.0006, I2 = 17%), as seen in Figure 3.

When observing responses associated with subgroups related to CA's type, a large effect favorable to dynamic exercises' intervention was identified (SMD = 1.00 [95% CI: 0.60 - 1.40]). In isometric exercise interventions, a moderate favorable effect was observed (SMD = 0.68 [95% CI: 0.06 - 1.30]). In CA's total volume subgroup, multiple series intervention had a large and favorable effect (SMD = 0.88 [95% CI: 0.53 - 1.22]). On the other hand, only one study used a single series intervention, showing a large effect (SMD = 1.37 [95% CI: -0.02 - 2.75]). Finally, in the participants' training level subgroup, a large effect favorable to intervention in athletes was identified (SMD = 1.00 [95% CI: 0.60 - 1.40]). A moderate favorable effect was observed in trained or moderately trained individuals' intervention (SMD = 0.68 [95% CI: 0.06 - 1.30]). These results can be seen in Table 3.

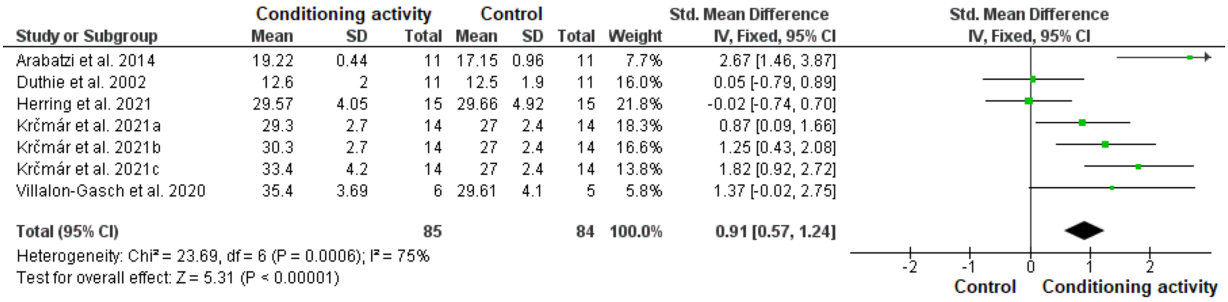

Figure3. *Effect size for vertical jump height in comparing conditioning activity vs. control.*

Table3. *Meta-analysis of subgroups.*

Subgroups		N [CA - CON] (W)	Z (P)	SMD (95% CI)	Chi², df(P)	I²
Type	Dynamic	59 - 58 (70.5%)	4.93 (0.00001)	1.00 (0.60 - 1.40)	8.86, 4 (0.06)	55%
	Isometric	26 - 26 (29.5%)	2.17 (0.03)	0.68 (0.06 - 1.30)	14.09, 1 (0.0002)	93%
Sets	Single	6 - 5 (5.8%)	1.93 (0.05)	1.37 (-0.02 - 2.75)	NA	NA
	Multiple	79 - 79 (94.2%)	4.99 (0.00001)	0.88 (0.53 - 1.22)	23.24, 5 (0.003)	78%
Training level	Athletes	59 - 58 (70.5%)	4.93 (0.00001)	1.00 (0.60 - 1.40)	8.86, 4 (0.06)	55%
	Trained	26 - 26 (29.5%)	2.17 (0.03)	0.68 (0.06 - 1.30)	14.09, 1 (0.0002)	93%

CA: conditioning activity; CI: confidence intervals; CON: control; df: degrees of freedom; N: number of subjects; NA: not applicable; SMD: standardized mean difference; W: weight

3.4. Reporting Bias

Funnel plot visual inspection (Figure 4), accompanied by the Egger test's (bias = 6.51 [95% CI = -2.42 - 15.44]) non-significant P-value (p = 0.1198), rejected the publication bias hypothesis.

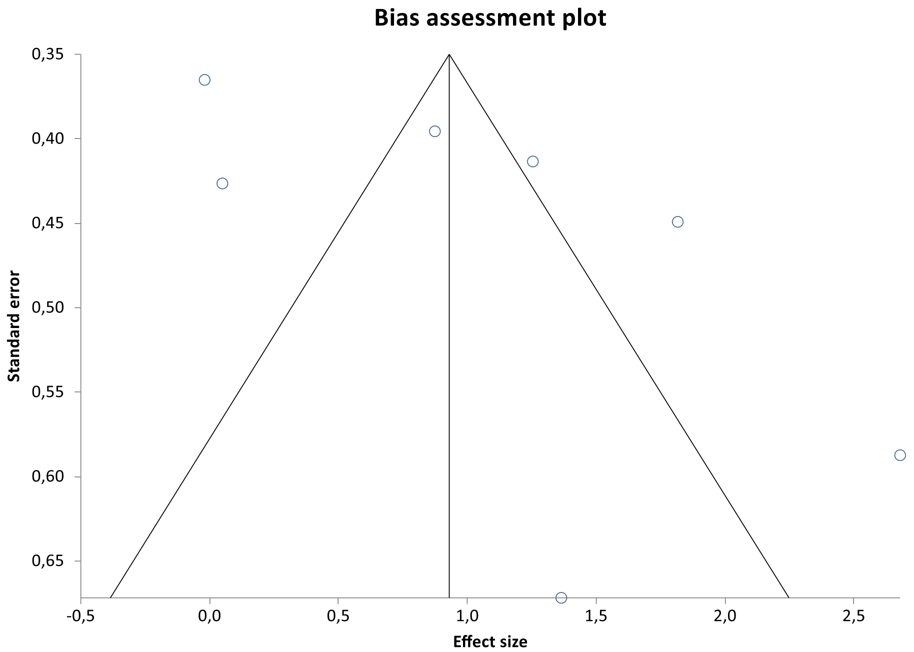

Figure4. *Publication bias of selected studies.*

3.5. Certainty of Evidence

Regarding evidence level, a low degree of certainty was observed at CA and control condition comparison for the vertical jump, according to the GRADE tool.

4. Discussion

The purpose of the present systematic review with meta-analysis was to observe CAs effect on the acute increase in vertical jump performance in trained women. A CA execution, with an intensity equal to or above 70% of 1RM and multiple series, significantly increased external lower limb muscular power in trained women compared to the control condition.

In previous systematic reviews with meta-analyses, Seitz and Haff [23] have indicated an overall favorable but small effect (SMD = 0.31) on jumping performance after performing a CA. However, the authors did not identify the part of the data comprised of women. Dobbs et al. [24], contrastingly, did not identify improvements in vertical jump performance attributed to CAs of intensity ≥ 80% of 1RM (SMD = 0.08 [95% CI: -0.04 - 0.21], P = 0.197), nor did they determine samples' sex. Furthermore, Wilson et al. [6] pointed to an overall favorable and small effect (SMD = 0.38 [95%CI: 0.21 - 0.55], P < 0.05) for muscle power in different outcomes and performance tests, for lower and upper limbs, in men (N = 113) and women (N = 16). However, in the case of women-only studies, there were no effects [(SMD = 0.2 [95% CI: -0.31 - 0.71), P > 0.05].

A concern is the lack of a control group or condition in experimental designs of post-activation potentiation and PAPE studies. Often, such studies involve verifying the effect of a specific CA intervention on a selected outcome [25-27] or the comparison between two or more specific interventions [28-30]. The control condition is critical to ensure findings are attributed to CA execution. Its absence constitutes a significant limitation in the experimental design. Any activities performed before or during the test (such as warm-up and baseline tests) can have a cumulative potentiation or fatigue effect, affecting performance [31-33].

Another factor that corroborated to the lack of potentiation in uncontrolled trials is the execution of measurements at different rest intervals within the same intervention. This characteristic was identified in three studies included in this meta-analysis, presenting both positive [18, 22] and adverse effects [19] and seems to be frequent in PAPE studies [34-36]. Also, rest intervals in such studies do not match the literature recommendation of 8 to 12 minutes [37], which may have generated a predominance of muscle fatigue during the jump execution.

In the comparison between CA's type, a large effect favoring intervention was observed in dynamic CA studies (SMD = 1.00 [95% CI: 0.60 - 1.40]) and a moderate effect in isometric CA studies (SMD = 0.68 [95% CI: 0.06 - 1.30]). An isometric stimulus may not mimic specific recruitment orders for movement since motor units' recruitment can be task-dependent [38]. Furthermore, isometric CAs may be more likely to improve fiber contractile performance, while dynamic CAs seem more efficient in increasing PAPE in similar dynamic motor tasks [4,5].

When comparing CA's total volume, only one study used a single set CA (SMD = 1.37 [95% CI: -0.02 - 2.75]) [20]. On the other hand, a large effect favorable to intervention was observed in studies containing multiple sets CAs (SMD = 0.88 [95% CI: 0.53 - 1.22]). This result agrees with Seitz and Haff's [23] findings, which also described moderate effects in favor of multiple series (SMD = 0.69 [95% CI: 0.39 - 0.98)]. However, they also found effects favorable to single series, although small ones (SMD = 0.24 [95% CI: 0.17 - 0.3]). Likewise, Wilson et al. [6] found favorable effects for both interventions: moderate effects for multiple series (SMD = 0.66 [95% CI: 0.36 - 0.95]) and small for single series (SMD = 0.42 [95% CI: 0.37 - 0.44]). Therefore, CA's volume must be controlled to achieve an ideal scenario of a faster fatigue dissipation rate for PAPE to prevail [11].

When comparing subjects' training levels, a large effect favorable to intervention was observed in studies carried out with athletes (SMD = 1.00 [95% CI: 0.60 - 1.40]), and a moderate effect was identified in studies carried out with trained or moderately trained individuals, but not athletes (SMD = 0.68 [95% CI: 0.06 - 1.30]). The athlete's physiological profile associated with each sport's demand (individual versus collective, speed versus resistance, cyclic versus intermittent) can be a factor in influencing PAPE's responses [39]. However, this moderator is not always considered, especially in studies that contain athletes from different sports modalities [13, 33].

Some limitations must be considered when it comes to PAPE evidence. The large variability between studies hampers comparisons. Differences in methods and procedures, training protocol characteristics (exercise selection, intensity, volume, rest interval, and others), and sample particularities (age, sex, training time, sport, and type of stimulus performed) are determinant factors. Therefore, extrapolation and comparison between results must be cautious, especially in the female population.

5. Conclusion

A CA can improve the vertical jump's acute performance in trained women. Regarding the training protocol, female athletes with more training experience seem more responsive to dynamic CAs, with greater volume (3 sets) and intensities above 70% of 1RM. Thus, in the sports environment, where quick results and performance improvements are often needed in the short and medium term, CA protocols and complex training seem to be coherent interventions. However, more studies with trained women are necessary to elucidate the best dose-response relationship in CA characteristics (volume, intensity, rest time, and exercise type).

ACKNOWLEDGMENTS

The study was partially funded by a doctoral scholarship from the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) granted to Soares ALC (Process: 260003/014681/2022) and a PROCIÊNCIA research grant from the Universidade do Estado do Rio de Janeiro (UERJ), awarded to Gomes PSC.

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Citation: *Ana Clara Vale Lopes et al. "Acute Effect of a Conditioning Activity on Vertical Jump Height in Trained Adult Women: A Systematic Review with Meta-Analysis" International Journal of Sports and Physical Education (IJSPE), vol 9, no. 3, 2023, pp. 1-10. DOI:* https://doi.org/*10.20431/2454- 6380.0900301*.