

**Postactivation performance enhancement (PAPE) in healthy adults using a bodyweight conditioning activity: a systematic review and meta-analysis.**

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using a bodyweight conditioning activity: a systematic review and meta-analysis

## **ABSTRACT**

A systematic review and meta-analysis were conducted to review the available evidence on whether a bodyweight conditioning activity can acutely improve the outcome of a subsequent task through postactivation performance enhancement. Data sources included PubMed (National Library of Medicine), Web of Science (Clarivate Analytics), Google Scholar, SPORTDiscuss (EBSCO), Embase (Elsevier) and Thesis Global. Participants were healthy, active adults who performed either a vertical jump or a linear sprint outcome measurement. All studies were randomized control trials where the effects of a bodyweight conditioning activity were compared to a control condition. The control group followed the same course as the experimental group excluding the intervention with the intervention and outcome measurement carried out in the same session. The intervention was completed prior to the initiation of the outcome measure testing. Nineteen studies fulfilled the eligibility criteria and were included. There was a small overall effect of 0.30 (95% CI 0.14 to 0.46,  $p=0.0003$ ) in favour of using a bodyweight conditioning activity to improve the outcome of a subsequent vertical jump or linear sprint. Secondary analysis indicated that there was no difference between the vertical jump and sprint sub-group, the < 5 minutes, or 5 minutes and greater between intervention and outcome measurement sub-group or whether an intervention with the same movements or different movements was used before the outcome task sub-group. Using bodyweight conditioning activities prior to performing a maximal vertical jump or sprint may provide a small benefit in performance outcome.

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using a bodyweight conditioning activity: a systematic review and meta-analysis

## **INTRODUCTION**

Postactivation performance enhancement (PAPE) is a physical training principle which proposes that a muscle can be acutely optimized by its contractile history, which in turn affects the outcome of a subsequent task. This enhanced task is commonly associated with power-based activities which require high force production and a high rate of force development like sprinting and jumping (21). Postactivation performance enhancement has been tested in a multitude of sporting environments and different movement patterns with varying degrees of success (5). Typically, the conditioning activity for PAPE was thought to require a heavy resistance, isotonic preload stimulus (75-90% 1RM) to achieve this enhanced state (21). This required athletes to lift, push or pull heavy weights over a varying range of sets and repetitions to develop a combined effect of heightened muscle activity and consequential fatigue. Theoretically, the fatigue dispelled first, leaving the muscle in a state of acute enhancement (33).

Current literature has discussed the association between postactivation potentiation (PAP) and PAPE (39). Conventional models suggested that PAP is any acute enhancement lasting up to 20 minutes following heavy resistance training or a high intensity ballistic activity (3, 27). It is proposed that an initial contraction increases the myosin regulatory light chain (RLC) phosphorylation that supports the effects observed in PAP, including an enhancement in voluntary contractile force (47). Although part of this may be true, PAP only refers to an enhancement of an evoked twitch response, which is relatively short lived and rapidly decreases after ~1 minute (48). Postactivation performance enhancement is associated with among other things; voluntary contractions, increases in muscle temperature and several neural mechanisms unrelated to RLC phosphorylation where a muscle twitch has not been directly assessed (11,

using a bodyweight conditioning activity: a systematic review and meta-analysis

32). This study did not intend to explore these terms in detail, except to apply the correct terminology. In this study PAP will refer to reported changes in muscle twitch response while, PAPE will refer to an acute bout of high intensity voluntary exercise followed by an improvement in power, speed, and strength production (3, 51).

There is a growing interest in the PAPE effects elicited by ballistic conditioning activities including plyometrics (27). The Henneman size principle suggests that motor units are activated from the smallest, type I, fatigue resistant fibers to the larger, most powerful type IIx fibers. Selective recruitment is an exception to this principle (30, 31). By utilizing high velocity, high power movements, the smaller, type I fibers can be surpassed, activating exclusively the larger type IIa and IIx fibers extremely quickly. This form of recruitment may underpin the success seen in ballistic conditioning activities and PAPE. Seitz et al. (35) demonstrated that plyometric interventions had a greater effect on the outcome measurement compared to traditional high intensity tasks, suggesting that plyometrics may play a superior role in acutely enhancing muscle tissue, a concept reiterated by Creekmur et al. and Sharma et al. (10, 36) However Seitz et al. (35) also notes that studies investigating plyometrics are limited. Further studies have since been published and as ballistic conditioning activities including plyometrics have shown potential to induce a superior PAPE response, additional investigation is warranted.

There is a positive performance correlation between a sport and the specificity of the warm-up processes (34). Similarly, a common theme exists relating to the effectiveness of PAPE - how closely the conditioning activity relates to the subsequent task (32). Van den Tillaar et al. (46) demonstrated that specificity is an important constituent in the development of an enhanced outcome. A warm-up with activities like the subsequent task were used with significant benefit

using a bodyweight conditioning activity: a systematic review and meta-analysis

compared to an alternate non-specific warm-up. Suchomel et al. (41) propose that the intensity and velocity of the conditioning activity needs to closely mimic the levels achieved during competition or training as it is highly suggestive that this is an important component in achieving a PAPE effect. It is not uncommon for sprinters and jumpers to engage in some form of sprinting or jumping prior to competitive involvement. Research has provided an indication that using a conditioning activity very similar to the subsequent task can enhance performances within specific populations (38). In a practical example Karampatsos et al. (23, 24) observed that field event athletes achieved significantly greater throw distances after three countermovement jumps or a 20-meter sprint at maximal effort. Research also suggests that jump performance improves by using different variations of jumping as the conditioning activity (8, 20).

An initial search of PROSPERO, PubMed, JBI Evidence Synthesis, Google scholar, Web of Knowledge and SPORTDiscus was undertaken in January 2021, revealing that no comprehensive systematic review had been done on this subject. This systematic review intended to investigate whether PAPE can be achieved using a bodyweight conditioning activity in a healthy adult population. It aims to provide insight for coaches, rehabilitation specialists, and medical practitioners into the effect of bodyweight conditioning activities to enhance subsequent tasks which could improve rehabilitation outcomes, training impulses and competition performances.

## **METHODS**

### **Search strategy and study selection**

using a bodyweight conditioning activity: a systematic review and meta-analysis

The proposed systematic review was formatted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement checklist (29). The title of the review was registered in PROSPERO, registration number CRD42020152006. A full search strategy was developed for PubMed; National Library of Medicine (table 1) using text words within the titles and abstracts of relevant articles and the index terms used to describe the articles. The search strategy, including the identified keywords and index terms, was adapted for each information source. The reference list for each study selected for critical appraisal was screened for additional studies. An electronic literature search was conducted via PubMed (National Library of Medicine), Web of Science (Clarivate Analytics), Google Scholar, SPORTDiscuss (EBSCO) and Embase (Elsevier). The search strategies incorporated natural language and PubMed's controlled vocabulary: Medical Subject Headings (MeSH). Unpublished studies included Thesis Global and contacting authors. Following on from the search strategy, all found citations were compiled and uploaded into EndNote X9/2019 (Clarivate Analytics, PA, USA) and the duplicates removed. Two independent reviewers screened the titles and abstracts for assessment against the inclusion criteria for the review. Possible relevant studies were recovered in full, and their citation details captured. Two independent reviewers assessed the full text of the selected studies in detail against the inclusion criteria. Full text studies that did not meet the inclusion criteria were recorded and reasons reported in the systematic review. At each stage of the review, disagreements were resolved through discussion. The search results were reported in full in the final systematic review and presented in a PRISMA flow diagram in figure 1 (29).

### **Eligibility criteria**

## using a bodyweight conditioning activity: a systematic review and meta-analysis

This systematic review examined studies that included a healthy, active adult population where their level of participation, type of activity and training experience had been reported. This review assessed original research focusing on any bodyweight conditioning activity which attempted to elicit PAPE or to achieve an enhanced effect during a subsequent task. Types of conditioning activities included, but were not limited to, variations of the vertical jump, variations of the horizontal jump and linear sprints over different distances. The intervention needed to be completed prior to the initiation of the outcome measurement. The volume and intensity of the intervention as well as the duration between the intervention and the outcome measurement was captured when the studies were assessed. This review evaluated studies that included a control condition which was treated identically to the experimental group excluding the intervention. Both the control group and experimental groups used a reliable measurable performance outcome. This review assessed studies with the primary outcome measures being a measurable change in the score between the control group and the experimental group. Only a single outcome measurement was included per study. When multiple outcomes were measured during the same session, only the first measurement was recorded. Where available, secondary outcome measures like type, volume and intensity of the subsequent task were captured. This systematic review considered randomized controlled trials (RCT), crossover and parallel studies which were published or unpublished. These investigated the PAPE effects of a bodyweight conditioning activity on a subsequent task. Only studies published over the last 20 years were included in this systematic review due to the recent modern scientific developments within this topic and the lack of availability of studies prior to this (14). Studies which did not provide enough information to extract an effect size and were not published in English were excluded.



using a bodyweight conditioning activity: a systematic review and meta-analysis

### **Assessment of methodological quality and risk of bias**

Two independent reviewers critically appraised the eligible studies for methodological quality in the review using standardized critical appraisal instruments according to the Cochrane risk of bias tool (19). Disagreements were resolved through discussion. A value of low, high, or unknown risk of bias was provided for five domains of bias: selection bias, performance bias, detection bias, attrition bias, and reporting bias.

### **Data extraction**

Data was extracted from studies included in the review by two independent reviewers. Specific details extracted included population groups, interventions, outcomes measurements, and study methods significant to the review objective with any disagreements resolved through discussion. Authors were contacted to request missing or additional data for clarification.

### **Data synthesis**

The findings from the studies included were assessed, and a meta-analysis was carried out using Review Manager (RevMan) V.5.3 (Copenhagen, Denmark: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Effect sizes was expressed as a standardized mean difference, their 95% confidence intervals were calculated and presented as a forest plot. The standard chi squared and I<sup>2</sup> tests were used to test heterogeneity. Statistical analyses were performed using a fixed effects model as the heterogeneity between studies was low (44). Sub-group analysis was conducted to compare the impact of different aspects of the systematic review. Publication bias was presented for visual analysis through funnel plots.

## **RESULTS**

using a bodyweight conditioning activity: a systematic review and meta-analysis

### **Identification of studies**

Following the initial database search, 1168 individual links were retrieved. After duplicates were removed, titles and abstracts screened, and full texts assessed for eligibility, 19 studies were identified for qualitative and quantitative analysis.

### **Characteristics of the included studies**

The 19 studies identified for analysis have been summarized in table 2. All studies used a randomized controlled crossover (n=17) or parallel (n=2) design. The studies included 303 (male: n=278; female: n=25), physically active (recreational: n=5; competitive: n=14) individuals (21.3±2.6 years) from Europe (n=14), South America (n=2), Africa (n=2), and North America (n=1). All the studies included a controlled condition that was the same as the experimental condition excluding the intervention. In each study the intervention was a bodyweight conditioning activity and was concluded prior to the initiation of the outcome measurement. All the outcome measurements were either a vertical jump or a linear sprint (table 3).

### **Methodological quality and risk of bias**

The authors' judgement of risk of bias has been reported for each study in figure 2. Selection, reporting, and attrition bias was low across all the studies with performance and detection bias being very high. The risk of publication bias was not detected on visual examination of the funnel plot (figure 3).

### **Meta-analysis**

using a bodyweight conditioning activity: a systematic review and meta-analysis

From the 19 studies, 606 individual events were analyzed using standardized mean difference. The pooled results showed a small effect of 0.30 (95% CI 0.14 to 0.46,  $p=0.0003$ ) in favor of using a bodyweight conditioning activity compared to the control condition. The heterogeneity was small between the studies ( $I^2=1\%$ ) (figure 2). Sub-group analysis indicated that there were no significant differences when comparing a vertical jump 0.30 (95% CI 0.05 to 0.53) or linear sprint 0.29 (95% CI 0.07 to 0.51) outcome task ( $p=1.00$ ), the time between the intervention and the outcome measurement being less than 5 minutes 0.33 (95% CI 0.10 to 0.57) or 5 minutes and greater 0.25 (95% CI 0.03 to 0.47) ( $p=0.60$ ), and using a similar intervention 0.35 (95% CI 0.14 to 0.56) or different intervention 0.19 (95% CI -0.11 to 0.49) to the outcome task ( $p=0.40$ ).

## **DISCUSSION**

This systematic review and meta-analysis included 303 participants and 606 individual events which compared the effect of a bodyweight conditioning activity against a control condition on the outcome of a vertical jump or linear sprint. The pooled results suggested a significant, though small magnitude of change occurred in favor of the experimental group indicating that a bodyweight conditioning activity may improve the outcome in both these subsequent tasks.

When analyzing the results of a systematic review it is important to compare the outcomes to similar studies. Seitz et al. (35) reported in a systematic review and meta-analysis that investigated the outcome of jumps and sprints an effect size of 0.31 and 0.50, respectively while Wilson et al. (50) reported a similar pooled effect size of 0.38 for the outcome of 'power tasks' which likely included vertical jumps but was not clearly defined. Dobbs et al. (14) found a trivial effect of 0.08 on the outcome of vertical jumps following a variety of conditioning activities however, they pooled multiple intra-study results questioning this study's

using a bodyweight conditioning activity: a systematic review and meta-analysis

methodology. Only Seitz et al. (35) looked at a plyometric conditioning activity in a sub-group analysis indicating an effect size of 0.47 and although this was superior to a high and moderate intensity conditioning activity, the authors report limited studies available investigating plyometrics as a conditioning activity. None of these systematic reviews included characteristics or training protocols of the included studies creating challenges analyzing the different effects. Nevertheless, it seems likely that the effect of power based conditioning activities does have a small to moderate effect on a power-based outcome measurement. This is reiterated in this current study where a small but significant effect was found when using a power-based conditioning activity to enhance a power-based outcome measurement.

Previous systematic reviews and meta-analyses all looked at the outcome of power related tasks namely, jumps, sprints, change of direction, and ballistic conditioning activities including plyometric outcomes while investigating a variety of different interventions with a strong focus on resistance tasks (14, 35, 50). All these studies used a test-retest design and neglected to include any form of within study bias assessment. Our study differed in its methodological approach by using very strict inclusion criteria. Each study needed to have a controlled condition which undertook the same processes as the experimental group excluding the intervention. This was vital in mitigating any risk of the baseline testing interfering with the intervention and the outcome measurement. Only recently have studies questioned the methodology of what effect and to what extent the previous baseline testing may have on the interventions or the subsequent outcomes (3, 11, 32).

In numerous studies authors have interspaced the intervention in between the outcome measurements (2, 4, 25). Although this may be a specific study objective, it also potentially

using a bodyweight conditioning activity: a systematic review and meta-analysis

skews the results as the later outcome measurements are also affected by previous outcome testing prior to the intervention. This could be highlighted as fatigue or enhancement. Therefore, each intervention was required to be performed and concluded prior to the initiation of the outcome measurement. This was to ensure that the effect was due to the intervention and could not be attributed to earlier outcome testing influencing the later outcome testing. Many of the studies investigated the effects of multiple different tasks as the outcome measurement (1, 12, 16, 22) and while multiple attempts at the same task were included, these authors felt that specificity was an integral aspect in measurement of a PAPE response. Where multiple different outcomes were measured, only the first measurement was considered due to the potential positive or negative feed-forward effect that one outcome measurement may have on the following measurement. Studies were excluded where the order of the outcome testing could not be determined. Where the outcome was measured over multiple time points only the first time point after the intervention was included (45). This was to avoid any feed-forward effects from the initial outcome testing to the latter outcome testing.

The effect of a bodyweight conditioning activity on either a vertical bias outcome measurement ( $ES=0.30$ ) or on a horizontal bias outcome measurement ( $ES = 0.29$ ) was almost identical. This does suggest that the outcome of a maximal power-based task regardless of type of action can be improved using a bodyweight conditioning activity. Although this effect is small, it is significant in both cases which has been reiterated in other studies (1, 12, ,26 36) which have all reported trivial to moderate effect sizes when comparing different power-based outcome tasks following a bodyweight conditioning activity. This would suggest athletes undertaking a bodyweight conditioning activity with either a vertical or horizontal bias would provide similar benefits in the enhancement of a subsequent power-based task. The effect of time between the

using a bodyweight conditioning activity: a systematic review and meta-analysis

bodyweight conditioning activity and the outcome measure was similar with less than 5 minutes (ES=0.33) showing a slightly greater magnitude of change compared to more than 5 minutes (ES = 0.25) though in both cases the effect size was significant. This contrasts with other studies which have indicated that ballistic condition activities including plyometrics tended to show quicker enhancements after the intervention compared to other weighted conditioning activities (35, 43). This information is slightly misleading as although most of the studies included in this meta-analysis investigated an individual time-point, three studies tested multiple time-points post intervention. As a specific study objective, only the initial outcome testing data were included to prevent any feed-forward through previous outcome testing. This may skew the outcome marginally but at least between 5 minutes and 10 minutes post intervention a small significant effect was still evident. Our study highlighted that specificity is an influential element in a PAPE outcome. Studies which compared a vertical movement or horizontal movement to a similar outcome measurement had an ES=0.35 while using an intervention different to the outcome measurement had an ES=0.19 and although not significantly different from each other the similar sub-group had a significant benefit compared to the control group while the different sub-group did not. This has been reiterated in previous studies investigating the effects of PAPE, athlete preparation and warm-up optimization. (8, 34, 46)

### **Study biases and limitations**

A moderate selection bias was present as all studies reported randomization of subjects and random allocation of group order but limited details of how this was implemented. In these studies, performance and detection bias was high and blinding the participants and the assessors would have reduced these biases however, this can be challenging in a crossover study. Three

using a bodyweight conditioning activity: a systematic review and meta-analysis

studies reported blinding of the participants and the assessor, and two studies reported blinding during the outcome measurements (6, 7, 20).

This study did not differentiate between the type of movement, including multiple variations of the vertical jump and linear horizontal movements, and volume of the bodyweight conditioning activities that were administered. If the intervention had a vertical or horizontal bias without change in direction, the study was included if it met the other inclusion criteria. This was to maintain the focus on whether a bodyweight conditioning activity could induce a PAPE regardless of the type of activity used. Another limitation was that only the initial time-point post intervention was included. As certain studies included multiple time-points and in some cases the significant effect was reported after the initial outcome measurement, the authors felt strongly that feed-forward may have either a positive or negative effect on the later outcome measurement. Where studies continued to employ the intervention while testing the outcome, the authors only included the initial outcome measurement. This was also an attempt to control the feed-forward fatigue or enhancement effect potentially created by the outcome testing and repeated intervention administration. Only nineteen eligible studies were identified for inclusion in the meta-analysis.

## **PRACTICAL APPLICATIONS**

There is substantial evidence that using a bodyweight ballistic or power-based conditioning activity including plyometrics has a small but significant benefit on the outcome of a power-based task. As these bodyweight tasks do not require any equipment or complex instruction and the enhancement effects have been reported as quickly as one minute post intervention, there seems little reason why athletes, coaches and rehabilitation specialist would not include

using a bodyweight conditioning activity: a systematic review and meta-analysis

both a maximal vertical jump or maximal linear sprints in athlete preparation for training or competition. As a recommendation, the final preparation phase should maximal vertical jumps and maximal linear sprints up to five minutes before participation.

## **CONCLUSION**

This systematic review and meta-analysis demonstrated that a PAPE response can be induced by a bodyweight conditioning activity prior to undertaking a subsequent task. There was no significant difference between doing a vertical jump or a linear sprint as an outcome measure or doing the outcome measurement less than 5 minutes or more than 5 minutes after the intervention. There was no difference whether the outcome was the same or different to the conditioning activity although it was moderately more beneficial to use a vertical bias conditioning activity to enhance a vertical power-based activity and similarly for horizontal condition activities and linear sprints. Due to the simplistic nature of using a bodyweight intervention, coaches and athletes are encouraged to employ these before undertaking maximal vertical jumps or linear sprints.

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### **Conflicts of interest**

The authors declare no conflict of interest

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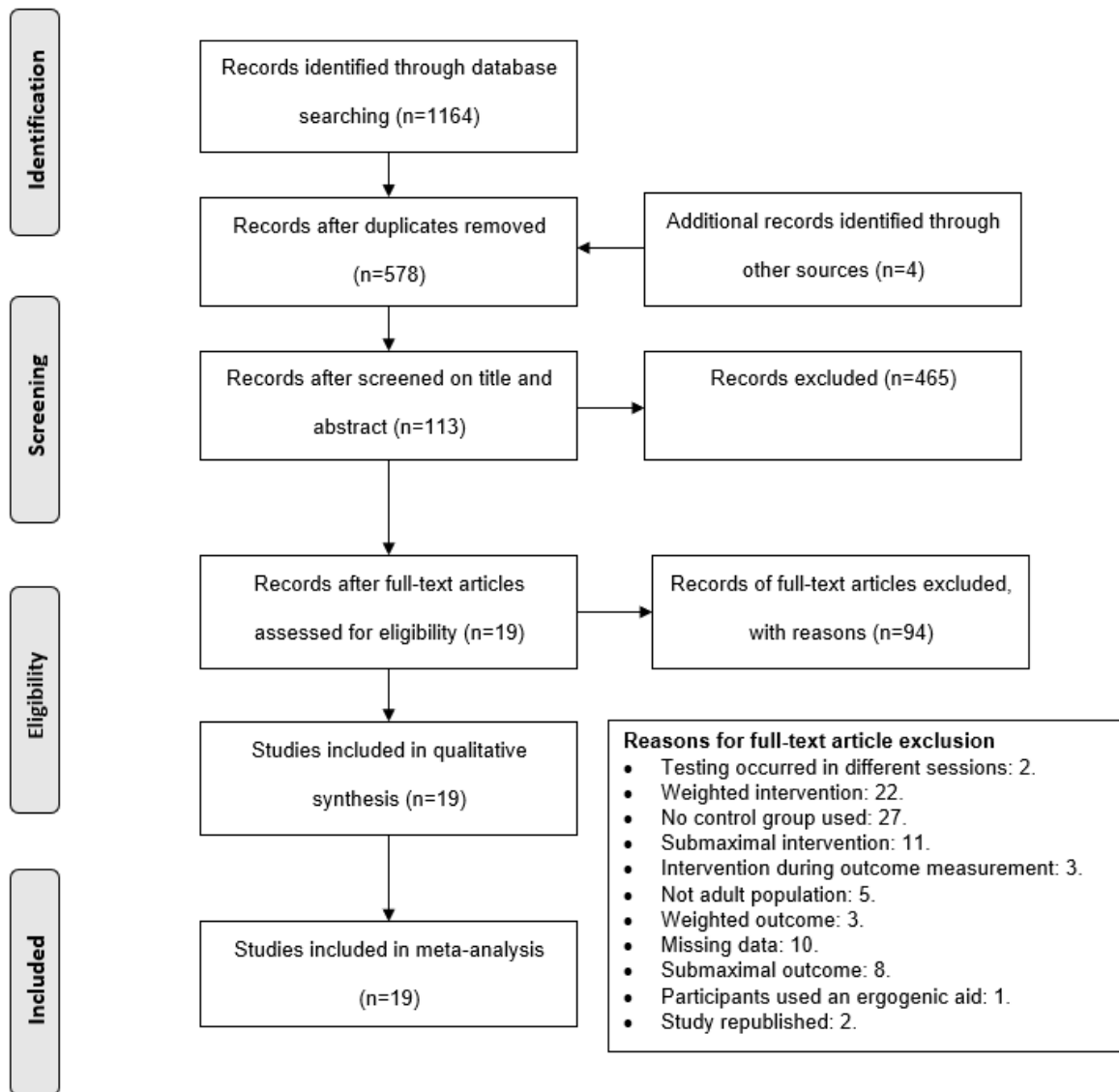
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**Appendix**



**Figure 1:** Flow chart of study selection for the analysis on whether a bodyweight conditioning activity can acutely improve the outcome of a subsequent task through postactivation potentiation.

using a bodyweight conditioning activity: a systematic review and meta-analysis

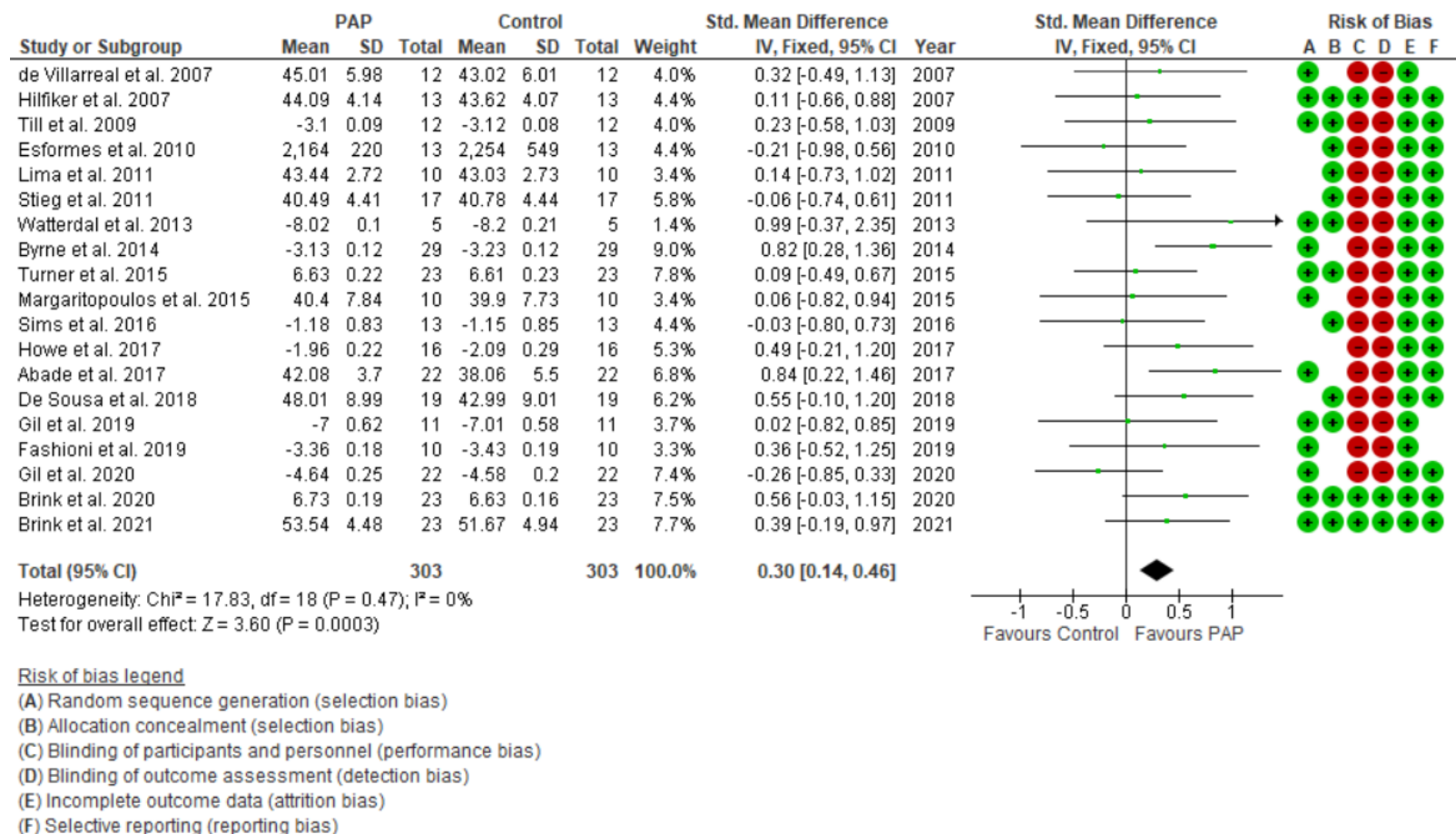
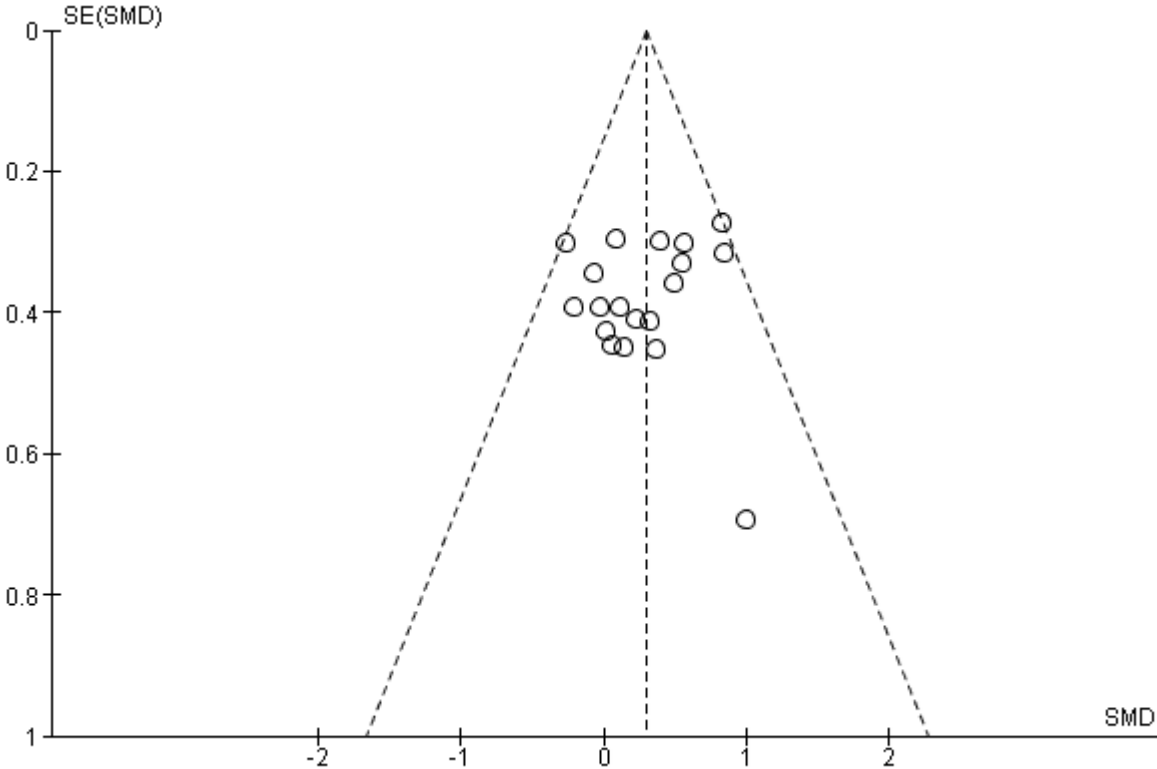


Figure 2: Primary analysis of studies measuring a bodyweight conditioning activity against a control



using a bodyweight conditioning activity: a systematic review and meta-analysis



**Figure 3:** Funnel plot for assessing publication bias in studies measuring a bodyweight conditioning activity against a control

using a bodyweight conditioning activity: a systematic review and meta-analysis

Table 1: Search strategy: Search of Medline PubMed

<b>Search</b>	<b>Query</b>	<b>Records retrieved</b>
#1	"postactivation"[Text Word] OR "post-activation"[Text Word]	984
#2	"warmup"[Text Word] OR "warm-up"[Title/Abstract] OR "warm-up"[Text Word]	2853
#3	"jump*"[Text Word] OR "sprint*"[Text Word]	33654
#4	"plyo*"[Text Word]	873
#5	Search: #2 OR #3 OR #4	36209
#6	Search: #1 AND #5	215
#7	Search: #6 Filters: English	214
#8	Search: #7 Filters: Humans	141

using a bodyweight conditioning activity: a systematic review and meta-analysis

Table 2: Characteristics of the included studies

<b>Study</b>	<b>Location</b>	<b>Sex</b>	<b>Age</b>	<b>Study designs</b>	<b>Level of competition</b>	<b>Sport</b>	<b>Warm up</b>
<b>Abade et al. (1)</b>	Portugal	M22	18±1	RCT crossover	Competitive	Soccer	Maximal
<b>Brink et al. (7)</b>	South Africa	M23	24±5	RCT parallel	Competitive	Soccer	Submaximal
<b>Brink et al. (6)</b>	South Africa	M23	24±5	RCT parallel	Competitive	Soccer	Submaximal
<b>Byrne et al. (9)</b>	Ireland	M29	20±4	RCT crossover	Competitive	Variety	Submaximal
<b>De Sousa et al. (12)</b>	Brazil	M19	24±1	RCT crossover	Competitive	Basketball	Submaximal
<b>de Villarreal et al. (13)</b>	Spain	M12	23±3	RCT crossover	Competitive	Volleyball	Submaximal
<b>Esformes et al. (15)</b>	Wales	M13	22±3	RCT crossover	Competitive	Variety	Submaximal
<b>Fashioni et al. (16)</b>	UK	M10	23±4	RCT crossover	Recreational	Soccer	Submaximal
<b>Gil et al. (17)</b>	Portugal	M22	19±2	RCT crossover	Recreational	PA	Submaximal
<b>Gil et al. (18)</b>	Portugal	M11	25±6	RCT crossover	Recreational	PA	Submaximal
<b>Hilfiker et al. (20)</b>	Switzerland	M13	22±4	RCT crossover	Competitive	Snow sport	Submaximal
<b>Howe et al. (22)</b>	UK	M13 F3	19±2	RCT crossover	Recreational	PA	Submaximal
<b>Lima et al. (26)</b>	Brazil	M10	21±3	RCT crossover	Competitive	Sprinting	Submaximal
<b>Margaritopoulos et al.</b>	Greece	M5 F5	19±1	RCT crossover	Competitive	Karate	Submaximal

(28)

using a bodyweight conditioning activity: a systematic review and meta-analysis

<b>Sims et al. (37)</b>	UK	M13	19±1	RCT crossover	Recreational	PA	Submaximal
<b>Stieg et al. (40)</b>	USA	F17	19±1	RCT crossover	Competitive	Soccer	Submaximal
<b>Till et al. (42)</b>	UK	M12	18±1	RCT crossover	Competitive	Soccer	Submaximal
<b>Turner et al. (45)</b>	UK	M23	21±1	RCT crossover	Recreational	PA	Maximal
<b>Watterdal et al. (51)</b>	Sweden	M5	24±2	RCT crossover	Competitive	MD running	Submaximal

RCT, randomized controlled trial; M, male; F, female; PA, physically active; MD, middle distance.

using a bodyweight conditioning activity: a systematic review and meta-analysis

Table 3: The intervention and outcome protocols of the included studies

<b>Study</b>	<b>Intervention</b>	<b>Outcome measurement</b>	<b>Time between intervention and outcome measurement</b>
<b>Abade et al. (1)</b>	Maximal Vertical and horizontal movement - 4 sets of 5 jumps over 40 cm barriers followed by agility ladder 10 steps	Vertical jump height - 2 maximal attempts	6 min
<b>Brink et al. (7)</b>	Maximal vertical jumps - 2 maximal CMJ (2min)	Vertical jump height – 2 maximal attempts	2 min
<b>Brink et al. (6)</b>	Maximal sprint - 2 maximal 20m sprint (2min)	Linear sprint – 2 maximal attempts (20m)	2 min
<b>Byrne et al. (9)</b>	Maximal vertical movement - 3 maximal depth jumps	Linear sprint – 1 maximal attempt (20m)	1 min
<b>De Sousa et al. (12)</b>	Maximal vertical jump - 6 sets of 6 CMJ 10s between reps 2 min between sets	Vertical jump height - 1 maximal attempt	5 min
<b>de Villarreal et al. (13)</b>	Maximal vertical jump - 3 x 5 drop jumps	Vertical jump height - 1 maximal attempt	5 min
<b>Esformes et al. (15)</b>	Maximal horizontal & vertical jumps - performed 6 alternate bounds, 6 right speed hops, 6 left speed hops, 6 vertical bounds	Vertical jump power output (W) – 3 maximal attempts	5 min
<b>Fashioni et al. (16)</b>	Maximal sprints & vertical jumps - 2 straight sprinting, 2 tuck jumps into sprints, 2 reaction sprints	Linear sprint – 1 maximal attempt (20m)	5 min

## using a bodyweight conditioning activity: a systematic review and meta-analysis

<b>Gil et al. (17)</b>	Maximal vertical jumps - 2x5 depth jumps (70cm)	Linear sprint – 1 maximal attempt (30m)	10min
<b>Gil et al. (18)</b>	Maximal vertical jumps - 2x5 depth jumps (70cm)	Linear sprint – 1 maximal attempt (50m)	5min
<b>Hilfiker et al. (20)</b>	Modified vertical jumps - 5 modified drop jumps (60cm)	Vertical jump height – 3 maximal attempts	1 min
<b>Howe et al. (22)</b>	Maximal vertical & horizontal jumps - Hurdle hops x6, Lateral hurdle hops x10, CMJ x 5, depth jump x10 (20cm), Broad jump x 5	Linear sprint – 3 maximal attempts (10m)	4 min
<b>Lima et al. (26)</b>	Maximal vertical jumps - 2x5 depth jumps (75cm)	Vertical jump height – 1 maximal attempt	5 min
<b>Margaritopoulos et al. (28)</b>	Maximal vertical jumps - 3x5 tuck jumps (30sec)	Vertical jump height – 1 maximal attempt	5 min
<b>Sims et al. (33)</b>	Maximal vertical jumps- 3x20 pogo jumps	Linear sprint – 3 maximal attempts (10m: 30-40m)	8min
<b>Stieg et al. (40)</b>	Maximal vertical jumps - 6 depth jumps	Vertical jump height – 3 maximal attempts	10min
<b>Till et al. (42)</b>	Maximal vertical jumps - 5 Tuck jumps	Linear sprint – 3 maximal attempts (20m)	4 min
<b>Turner et al. (45)</b>	Maximal horizontal jumps - 3 x 10 alt leg bounds	Linear sprint velocity – 1 maximal attempt (20m)	2min
<b>Watterdal et al. (51)</b>	Maximal horizontal sprint - 1 x 50m sprint	Linear sprint - 1 maximal attempt (60m)	10 min

CMJ, countermovement jump.

