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# The Impact of PAPE Protocols on Barbell Velocity During the Bench Press in Trained Individuals: A Systematic Review

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**Abstract:** Background: Post-activation performance enhancement (PAPE) protocols are increasingly being used to acutely boost strength and power in resistance training. The objective of this systematic review was to determine how PAPE interventions influence barbell velocity in the bench press among trained individuals and address the following research question: which conditioning activities (CAs), rest intervals, and loading strategies most effectively enhance bench press velocity parameters under PAPE conditions? Methods: This systematic review, conducted according to PRISMA guidelines, searched PubMed, Scopus, SpringerNature, EBSCO, and Web of Science up to 31 January 2025 for studies involving healthy adults (18–50 years) that employed bench press or related conditioning activities intended to induce PAPE, and assessed barbell velocity (peak or mean). From pool of 111 records, 7 studies (total n = 125 males, 23–29 years old, ≥2-year training experience) met the inclusion criteria. The methodological quality of included studies was moderate (5/10 on the PEDro scale). Results: Submaximal loads (70–80% 1RM) applied for one to three short sets, with rest periods of around four to five minutes, frequently improved peak velocity (by up to 7%) and peak power (by up to 15.9%). Conversely, heavier loads (>85% 1RM) and insufficient rest tended to offset these benefits due to fatigue. Blood flow restriction or ischemic preconditioning strategies produced positive velocity outcomes mainly at lower loads (20–50% 1RM). Conclusions: These findings suggest that PAPE interventions can enhance bench press barbell velocity in trained individuals. Effectiveness, however, depends on training status, volume, load intensity, and recovery intervals. Future randomized controlled trials with larger samples, standardized reporting, and the inclusion of female athletes are recommended to refine and generalize PAPE applications for upper-body strength and power development.

**Keywords:** strength training; VBT; conditioning activity; speed; post-activation potentiation enhancement

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## 1. Introduction

The bench press exercise is undoubtedly one of the most common sights in public gyms. It serves as a foundational movement in many sports disciplines that require the development of strength and power, such as powerlifting or combat sports [1–3]. It is also recognized as one of the fundamental resistance exercises in both professional and recreational training settings [4]. Therefore, for years, the bench press has been a focal point for intensive exploration of training processes, potential benefits, contraindications, and guidelines for this movement pattern across different population groups [4,5].

Coaches and individuals with considerable experience in strength training employ various activation methods aimed at temporarily or permanently increasing performance in the context of training adaptations or achieving better sports results [6,7]. When analyzing the current scientific literature, the most common among these methods include blood flow restriction (BFR), the use of training devices such as barbell velocity trackers, and, ultimately, eliciting post-activation performance enhancement (PAPE) through these techniques [8–14].

In recent years, the PAPE effect has been classified as a distinct phenomenon, differentiating it from the post-activation potentiation (PAP) effect [15,16]. Authors of one publication comparing both phenomena hypothesized that the PAPE effect may be directly linked to neural mechanisms, which are not observed in the PAP effect [15]. The PAPE effect induces short-term modifications in the neuromuscular system, driven by processes occurring at the cellular and biochemical levels [15]. One key mechanism is the phosphorylation of myosin light chains in type II fibers, which increases the sensitivity of the actin–myosin complex to calcium ions, thereby facilitating cross-bridge formation and accelerating force development [17]. Additionally, a higher calcium ion concentration promotes faster recruitment of high-threshold motor neurons, responsible for generating greater power [18]. At the same time, beneficial changes in temperature and cellular hydration have been observed following intense muscle contractions, resulting in improved conditions for myofilament function [15]. These multi-level modulations, together with a possible increase in neural drive, lead to enhanced strength and dynamic performance across subsequent training sets, offering practical benefits for those aiming to improve power and explosiveness in specific movement patterns [17].

Researchers across various sports disciplines have been seeking the "golden mean" for inducing performance enhancement in the simplest and most efficient way possible [7]. In sports disciplines where the ability to generate force and power quickly is key (e.g., in the context of high jumps), activation exercise methodology has been based on plyometric exercises, submaximal load squats in different variations, or mechanical methods such as BFR [19,20].

Unfortunately, there is still a lack of high-quality studies that would allow for the formulation of strong hypotheses in this area.

In relation to the bench press, research to date has mainly focused on the impact of higher loads ($\geq$80% 1RM) on maximal strength or strength endurance parameters [21,22]. The PAPE effect has relatively rarely been analyzed in the context of barbell movement velocity. Meanwhile, the literature on velocity-based training (VBT) clearly indicates that monitoring barbell speed is crucial for regulating training intensity and objectively determining fatigue levels [23]. A relative increase in fatigue levels translates into poorer sports performance and achieved results, which poses a significant challenge in advanced training [1,24].

A relative decline in power and movement velocity with heavy loads may lead to a lack of progress in strength development or, ultimately, the inability to set new personal records during competitions [25].

Applying the PAPE effect as a tool to counteract this issue involves consciously using active rest periods that include a conditioning activity (CA) aimed at stimulating the neuromuscular system for more effective performance in subsequent efforts [26]. Literature suggests that even one set (or a few sets) with a high but submaximal load, performed at a specific tempo and with a precisely selected time interval between the CA and the main task, may be sufficient for short-term improvement in bench press performance parameters [27,28].

A very important component here is the timing between the conditioning activity and the execution of the target effort, which has varied in studies from 3 to even 10 min. Opti-

mizing this interval largely depends on individual factors, such as training level, current state of the nervous system, and previous experience with high-intensity training [7].

Key determinants of concentric phase performance in the bench press include power output and barbell velocity parameters. The PAPE effect can effectively influence all these metrics; however, there is currently limited scientific literature defining optimal durations for the conditioning activity or describing a clear protocol for selecting methods that elicit this effect.

For instance, some studies have employed sets with 70–80% 1RM combined with short (3–4 min) or moderate (5–8 min) rest intervals, resulting in peak velocity increases by more than ten percent in the subsequent set [29,30]. Others have used blood flow restriction (BFR) with slightly lower loads (20–50% 1RM), aiming to stimulate motor units through tissue hypoxia and thus increase barbell velocity in subsequent attempts [31–33]. However, the results of these experiments are often inconsistent, which further complicates the ability to draw uniform conclusions.

From a practical training perspective, the choice of the optimal method for inducing the PAPE effect should consider not only the current phase of the training cycle but also the type of target effort (short and intense sets vs. longer strength endurance efforts), as well as the individual specificity of the athlete (e.g., training level, potential health limitations). Although the PAPE concept is not entirely new, it has only recently gained popularity in bench press research, highlighting the need for an updated and synthesized understanding of the current scientific evidence.

Despite the growing number of publications on this phenomenon, there is still a lack of a consistent and detailed systematic review synthesizing knowledge on the effects of PAPE protocols on barbell velocity in the bench press among trained individuals (including advanced and elite athletes). Previous studies have often been fragmentary, discussing PAPE effects in various exercises (e.g., jumps, squats) while neglecting the bench press. Moreover, there is a lack of comprehensive analysis of differences in outcomes based on rest intervals, applied loads, number of sets, and the presence (or absence) of a control group. Therefore, the objectives of this systematic review are as follows:

- To identify and compile available studies assessing post-activation performance enhancement (PAPE) protocols in the bench press among trained individuals (paying particular attention to advanced and recreationally trained populations).
- To analyze the impact of the applied conditioning activities (CAs) on barbell velocity (peak velocity, mean velocity), and—where data are available—on power parameters (peak power, mean power).
- To determine the key moderating factors influencing the effectiveness of PAPE protocols, such as the type of CA, rest interval between CA and the target effort, applied load magnitude, number of sets, and participants' training experience.

## 2. Methods

### 2.1. Literature Search

The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1). The review registration was performed a posteriori on 1 April 2025. The review has been registered in OSF database: https://doi.org/10.17605/OSF.IO/R9X2Y. One of the authors (K.K.) searched the Scopus, PubMed, SpringerNature, EBSCO, and Web of Science databases for studies up to 31 January 2025 involving the PAPE effect and measurements of barbell movement velocity in the bench press. The following keyword combinations were used in each database. The focus was on ensuring the highest possible relevance to the selected topic in order to filter out publications unrelated to the subject matter.

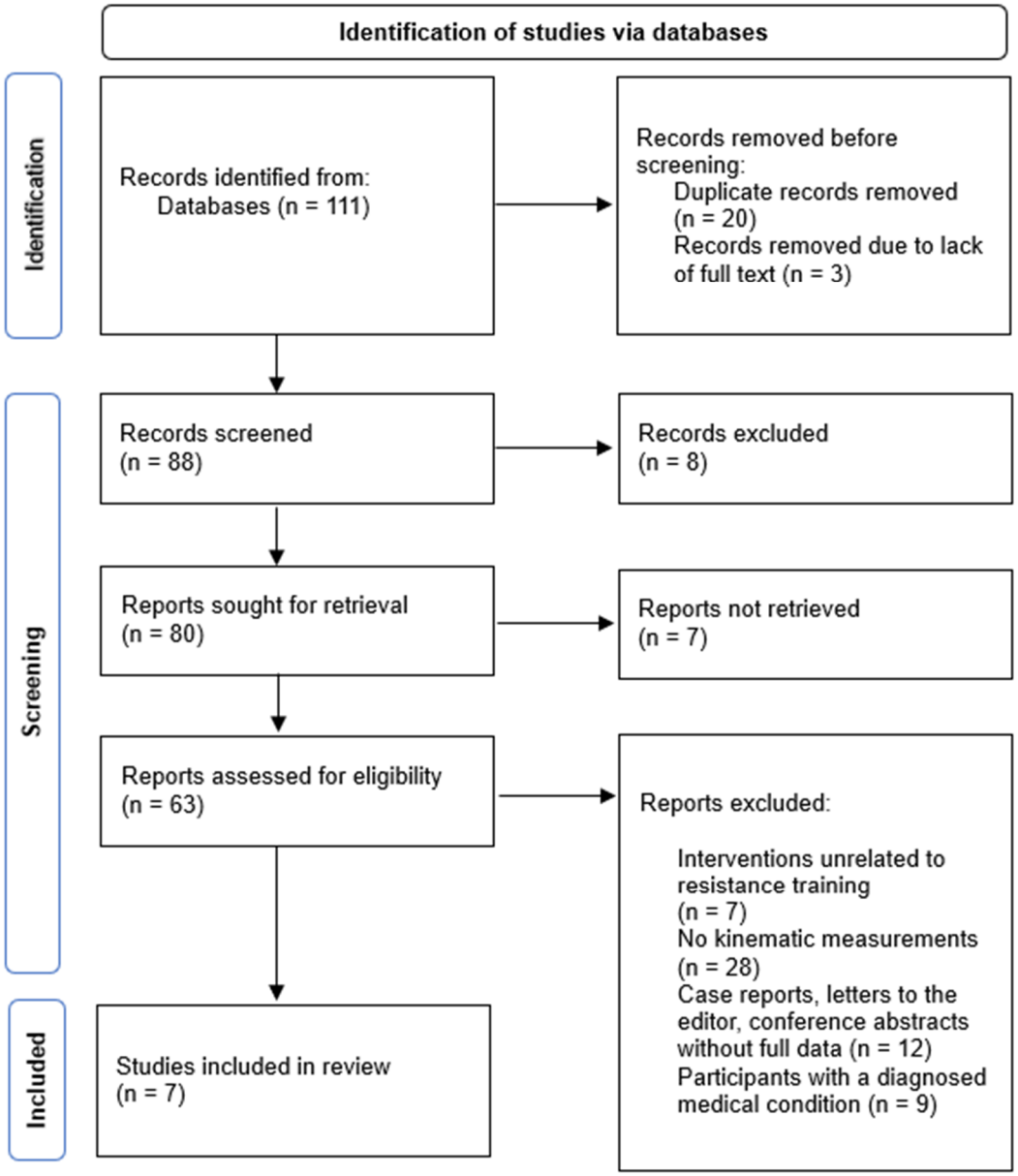



**Figure 1.** PRISMA flow chart.

The following keywords were used for the search:

("post-activation potentiation" OR "postactivation performance enhancement" OR pape OR "post-activation" OR "postactivation") AND ("barbell velocity" OR "movement velocity" OR "lifting velocity" OR "bar velocity" OR "velocity-based training" OR vbt) AND ("bench press" OR "bench" OR "powerlifting" OR "resistance training" OR "strength training") AND ("advanced athletes" OR "trained individuals" OR "resistance-trained" OR "strength-trained" OR "powerlifters")

### *2.2. Data Extraction*

The screening and data extraction process was carried out by two authors (K.K. and Ł.R.) and included variables such as training experience level, study outcomes, applied measurements, and sample size. Duplicates were removed manually. Any discrepancies were discussed with the third author (T.A.) regarding the inclusion of data in the overall analysis until a consensus was reached. The methodological quality of the studies was assessed using the Physiotherapy Evidence Database (PEDro) scale.

### 2.3. Study Identification and Selection

The review included studies that met the criteria developed based on the PICO model (Table 1). Only publications in English were included, with no specific time range for the publication date up to 31 January 2025. Publications that were excluded included case reports, letters to the editor, conference abstracts lacking full data, and those for which the full text was not available.

**Table 1.** Inclusion and exclusion criteria based on the PICOS framework.

| | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| Population | - Adults aged 18–50, healthy, with no contraindications to resistance training.<br>- Participants with experience in strength training (recreational or professional athletes). | - Individuals with contraindications to resistance training or with serious health issues that could affect the reliability of the results. |
| Intervention | - Various types of resistance training protocols or methods focusing on the bench press and their impact on movement kinematics.<br>- Interventions include the measurement of barbell velocity (e.g., mean or peak), power (mean/peak power), and/or other kinematic parameters during the bench press. | - Studies in which the intervention does not involve strength/resistance training.<br>- Protocols that do not focus on the bench press as the primary exercise.<br>- Lack of kinematic measurements. |
| Comparison | - No intervention, a different type of physical activity, or a different resistance training protocol (e.g., bench press with different loading parameters), provided the study includes a control or comparison group.<br>- Alternatively, a comparison of different protocols (e.g., with and without additional activation methods). | - |
| Outcome | - Changes in barbell velocity parameters.<br>- Changes in power parameters. | - Lack of complete data preventing interpretation of the results. |

### 2.4. Effect Measures

In this systematic review, the primary outcome variables were the kinematic parameters of the bench press, specifically:

- Peak velocity (PV)—the peak velocity of the barbell.
- Mean velocity (MV)—the average velocity of barbell movement in a given set or repetition.
- Peak power (PP)—the peak power output during the movement.
- Mean power (MP)—the average power generated in a set or repetition.

Due to the heterogeneity of the studies and the limited ability to conduct a full meta-analysis (stemming from the lack of a unified measurement protocol and varying methods of reporting results), the main effect measures presented in the included studies were:

Change in mean values—e.g., an increase in PV (m/s) following a PAPE protocol compared to a control condition or baseline values.

Percentage change (%Δ)—most commonly reported in the original publications, e.g., “+7% PV” or “+15.9% PP” relative to the baseline.

Where statistical significance values were provided by the authors of the source studies, a $p$-value < 0.05 was considered the threshold for significance. Since the majority of studies reported PAPE effects in the form of percentage increases or decreases in barbell velocity or power, no standardized effect size measure (e.g., Cohen's d, Hedges' g) was calculated.

Unfortunately, data presented as 95% confidence intervals (CI) were rare in the original articles, making it difficult to precisely define the range of measurement uncertainty (Table 2).

**Table 2.** PEDro scale for the included studies.

| PEDro Items | Krzysztofik et al. (2022) [34] | Krzysztofik and Wilk (2020) [27] | Ribeiro et al. (2021) [29] | Salagas et al. (2022) [30] | Wilk et.al. (2020) [33] | Jarosz et al. (2021) [31] | Wilk et al. (2020) [32] |
|---|---|---|---|---|---|---|---|
| 1. Randomization | + | + | + | + | + | + | + |
| 2. Allocation concealment | - | - | | - | - | - | - |
| 3. Comparability at baseline | + | + | + | + | + | + | + |
| 4. Patient blinding | - | - | - | - | - | - | - |
| 5. Therapist blinding | - | - | - | - | - | - | - |
| 6. Assessor blinding | - | - | - | - | - | - | - |
| 7. At least 85% follow-up | + | + | + | + | + | + | + |
| 8. Intention to treat | - | - | - | - | - | - | - |
| 9. Between-group comparisons | + | + | + | + | + | + | + |
| 10. Point Measures and variability | + | + | + | + | + | + | + |
| **Total** | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 |

PEDro items: 1. Randomization; 2. allocation concealment; 3. comparability at baseline; 4. patient blinding; 5. therapist blinding; 6. assessor blinding; 7. at least 85% follow-up; 8. intention to treat analysis; 9. between-group statistical comparisons; 10. point measures and measures of variability. Marks: (+), item fulfilled; (-), item not fulfilled.

In cases where the effects of different types of conditioning activities (e.g., traditional bench press, occlusion variants, cambered bar bench press, etc.) were analyzed, the differential effect (effect size) was usually presented as the percentage increase or decrease in specific parameters (PV, PP, MV) relative to baseline or control values. This allows for a qualitative comparison between intervention variants and supports conclusions about the effectiveness of PAPE protocols.

### *2.5. Assessment of Study Quality*

The PEDro scale was used to assess the quality of the included studies. Two authors (Ł.R. and K.K.) independently evaluated the methodological quality of each publication. In cases where difficulties arose in classifying a study, discussions were held with a third author (T.A.) to reach a consensus. The maximum possible score on the PEDro scale is 10 points. Studies scoring more than 6 out of 10 are generally considered to be of "high" or "moderately high" methodological quality. According to current literature, these thresholds may vary in interpretation. The detailed scoring criteria, along with an analysis of the included publications, are presented in Table 2.

## 3. Results

### 3.1. Risk of Bias Analysis

The overall PEDro score range for the included studies is presented in Table 2. The methodological quality for all seven included studies was rated at 5 out of 10, indicating a moderate level of methodological quality.

### 3.2. Characteristics of the Study Participants Included in the Review

In total, the studies included 125 male participants aged between 23 and 29 years, with training experience ranging from 2 to 12.7 years. The body mass of individual participants collectively ranged from 77.2 to 94.3 kg. The studies included in the review focused exclusively on strength-trained populations, with one-repetition maximum (1RM) values ranging from 95.8 to 168.5 kg. The vast majority of participants (85%) were classified as advanced or high-level recreational lifters, while the remaining 15% had at least two years of training experience. None of the studies included female participants [27,29–34].

### 3.3. Bench Press Variations as Conditioning Activities

In four studies, different variations in the bench press were used as conditioning activities (CA) in the context of the PAPE effect [30–32,34]. These included the following: standard bench press with 80% 1RM performed until a 10% drop in mean velocity [34], non-traditional barbells such as the cambered bar (CMB) and reverse cambered bar (RCMB) [34], blood flow restriction (BFR) bench press at 70–90% arterial occlusion pressure (AOP) [27,31], and combined protocols (IPC + PAPE) using 90% 1RM loads [30].

The highest increases in peak velocity (PV) and peak power (PP) were observed with the standard bench press (STD), reaching +7.0% and +15.9%, respectively [34]. The use of non-traditional bars (CMB and RCMB) resulted in smaller gains: PV +2.2–2.6%; PP +5.6–7.3%. Blood flow restriction (BFR) with light loads ranging from 20 to 50% 1RM increased PV by 5.99–17%, but no effect was observed at $\geq$60% 1RM [31,33]. Ischemic preconditioning (IPC) improved mean velocity (MV) by 6.5–9% in the initial sets; however, the combination of IPC + PAPE did not demonstrate a synergistic effect [30].

### 3.4. The Impact of Rest Interval and Load Modifications

It was shown that adjusting the rest interval within the range of 4 to 10 min does not significantly affect PV/PP values, which are key components of barbell movement velocity [27]. Rest periods shorter than 3 min were associated with decreased performance in subsequent sets, such as a −6.4% drop in PV in the third set during BFR protocols [33]. No significant changes in PV/PP were observed when loads exceeded >80% of 1RM [30].

### 3.5. Main Findings

The use of low-volume conditioning activities (CA), consisting of one to three sets with loads ranging from 70 to 80% 1RM and rest intervals of 4 to 5 min, maximizes the benefits related to barbell movement velocity parameters. Excessive training volume, as well as loads exceeding >85% 1RM combined with inappropriate rest periods, lead to fatigue that counteracts the PAPE effect. The use of occlusion techniques and their variations (BFR, IPC) is effective when applied with low loads. A comprehensive analysis of the included studies is presented in Table 3.

**Table 3.** Characteristics of the studies included in the systematic review.

| Reference | Participants | Control Group | Familiarization | Warm Up | Time from Warm-Up to CA | Conditioning Activity | Peak Velocity Improvement [%] | Peak Power Improvement [%] | Mean Power Improvement [%] | Mean Velocity Improvement [%] | Number of Repetitions | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Krzysztofik et al. (2022) [34] | 10 males: Age: 26 ± 3; BM: 93.2 ± 9.4 kg Training experience: 6.3 ± 2.4 years; BP 1RM: 1.54 kg ± 0.2 kg/bm BP 1RM/BM = 1.54 | Yes | Three preliminary sessions were conducted: 1RM tests (standard, cambered, and reverse cambered bars) and trials to determine a 10% mean velocity loss threshold. | Standard protocol: 5 min of upper-body ergometer exercise; two sets of torso and shoulder rotations, push-ups, etc. Warm-up sets performed at 30%, 50%, and 70% of 1RM. | A 5 min interval was applied between the end of the warm-up and the start of the conditioning activity (CA). | One set of bench press at 80% 1RM was performed until a 10% drop in mean velocity. This was performed across three separate sessions using different barbell types: standard (STD), cambered (CMB), and reverse cambered (RCMB). | CTRL: +2.3% STD: +7.0% CMB: +2.6% RCMB: +2.2% | CTRL: +4.2% STD: +15.9% CMB: +7.3% RCMB: +5.6% | No data available. | No data available. | CA: variable number of repetitions (until a 10% velocity drop); BPT: two repetitions. | Among the tested variations, the greatest increase in peak velocity and peak power during bench press throw (BPT) was observed following the standard bench press (STD) used as the conditioning activity (CA). Shorter (RCMB) or deeper range of motion (CMB) resulted in a smaller effect compared to STD. |
| 2. Krzysztofik And Wilk (2020) [27] | 24 males: Age: 24.5 ± 2.6 BM: 84.8 ± 8 kg Training experience: 6.3 ± 2.5 years BP 1RM: 105.8 ± 9.9 kg BP 1RM/BM = 1.25 | Yes | One preliminary session was conducted: 1RM testing followed by three sets of three repetitions of the bench press at 70% 1RM, with 4 min rest intervals. | 5 min on an upper-body ergometer (100 W) followed by two circuits of exercises (squats, torso rotations, push-ups), then 15/10/5 repetitions at 20/40/60% of 1RM. | Baseline test (three repetitions at 70% 1RM) followed by conditioning activity (in either the PAPE or CONT group) then a 4 min rest interval. | Three sets of five plyometric push-ups (1 min rest between sets). CONT group: 4 min on an upper-body ergometer. | +5.1% (in the 1st set after the CA) | +7.3% (in the 1st set after the CA) | +2.6% (in the 1st set) | +4.4% (in the 1st set) | Main test (BP): three repetitions in each of the three sets. | An increase in barbell power and velocity was observed in the first set following plyometric push-ups. However, in subsequent sets (second and third), the values dropped below baseline levels. No such fluctuations were noted in the control group. This suggests that a 4 min rest interval is sufficient for a one-time improvement, but does not sustain the effect across multiple sets. |
| 3. Ribeiro et al. (2021) [29] | 22 males: Age: 23.50 ± 2.15; BM: 77.23 ± 8.93 kg Training experience: At least 2 years BP 1RM: No data available | No data | 1RM was determined using the load–velocity relationship through progressively increasing loads. | Two sets (six repetitions each) with loads corresponding to 40% and 80% of the target 80% 1RM (1 min rest between sets); followed by 5 min of rest. | 5 min | Three sets of six repetitions at 80% 1RM in the bench press (each set separated by a 3 min rest interval). | Approx. +1% improvement (across the entire training session); PV for the 1st set was not reported separately. | No data available. | Approx. +18% increase in the 1st set (not statistically significant). | Approx. +10.6% increase (from 0.47 to 0.52 m/s in the first set). | Six repetitions in each of the three sets (basic training block). | The greatest increase in mean velocity (MV) was observed in the first set following the specific warm-up (statistically significant difference). No significant differences were found in peak velocity (PV) or average power across the entire training session; the improvement was most pronounced during the initial repetitions. The authors concluded that a submaximal warm-up (40% + 80% of the target load) facilitates faster attainment of higher barbell velocity in the first sets. |

**Table 3.** *Cont.*

| Reference | Participants | Control Group | Familiarization | Warm Up | Time from Warm-Up to CA | Conditioning Activity | Peak Velocity Improvement [%] | Peak Power Improvement [%] | Mean Power Improvement [%] | Mean Velocity Improvement [%] | Number of Repetitions | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4. Salagas et al. (2022) [30] | 12 males: Age: 25.8 ± 6.0; BM: 79.7 ± 8.9 kg Training experience: No data available BP 1RM: 95.8 ± 13.3 kg) BP 1RM/BM = 1.20 | Yes | Two preliminary sessions: 1. 1RM testing 2. Measurement of full arterial occlusion pressure (AOP) | Standard warm-up (5 min on a stationary bike, 5 min of dynamic stretching) + specific warm-up: two sets with submaximal load (50–75%). | Approx. 0.5–10 min (depending on the protocol: IPC/PAPE/combination). | Three experimental conditions: IPC—5 min occlusion at 100% AOP, then 5 min reperfusion; PAPE—one set of three reps at 90% 1RM; IPC + PAPE—one set of three reps at 90% 1RM, then 5 min IPC. All groups then performed four sets (12 s each) of bench press at 60% 1RM with maximal velocity. | +7.8% (IPC) and +8.5% (PAPE) compared to CTRL (average across four sets), while the PAPE + IPC condition showed no significant difference from CTRL. | No data available. | No data available. | IPC in sets 1–3: + 6.5–9% vs. CTRL; PAPE in sets 2–4: + 6.7–8.9% vs. CTRL; PAPE + IPC only in set 1: +5.8% vs. CTRL. | Main part (after CA): 12 s of work per set at 60% 1RM. The number of repetitions was variable (each participant performed as many reps as possible within 12 s). | Short-term occlusion (5 min) improved both mean and peak barbell velocity in sets 1–3 (higher than control), with a lower RPE. A single set of three reps at 90% 1RM (PAPE) enhanced barbell velocity, particularly in sets 2–4. The combination of IPC + PAPE produced an effect only in the first set. |
| 5. Wilk et al. (2020) [33] | 12 males: Age: 23.2 ± 2.66; BM: 75.3 ± 6.33 kg Training experience: 5.7 ± 2.93 years; BP 1RM: 101.8 ± 13.9 kg) BP 1RM/BM = 1.35 | Yes | Three preliminary sessions, including 1RM testing, along with familiarization with BFR and movement tempo. | 5 min on a stationary bike + general upper-body warm-up, followed by basic preparatory sets leading up to 1RM testing. | Immediately before the set (I-BFR), continuous during rest (C-BFR), or no BFR (NO-BFR). | I-BFR: Occlusion at 70% AOP applied before each set and removed after reps; 3 min rest without occlusion. C-BFR: Continuous occlusion at 70% AOP maintained throughout (~23 min). Both protocols: eight sets × two reps, loading from 20% to 90% 1RM (10% increments). | At loads of 20–50% 1RM: approx. +12–17% PV compared to control (for both I-BFR and C-BFR). At ≥60% 1RM—no increase observed. | No data available. | No data available. | No increase observed. Additionally, BFR did not reduce mean velocity (MV) at higher loads. | No fixed number of repetitions—each set performed to failure. | Both intermittent occlusion (I-BFR) and continuous occlusion (C-BFR) increased peak barbell velocity (PV) at low to moderate loads (20–50% 1RM) by 12–17% compared to the control condition. No differences were observed in mean velocity (MV). Occlusion had no negative impact on barbell velocity at loads ≥60% 1RM. |
| 6. Jarosz et al. (2021) [31] | 10 males: Age: 26.3 ± 4.7; BM: 89.8 ± 6.3 kg; BP 1RM: 142.5 ± 16.9 kg Training experience: 7.8 ± 2.7 years BP 1RM/BM = 1.59 | Yes | One preliminary session: 1RM testing along with familiarization with the BFR protocol and AOP measurement. | General warm-up followed by a specific warm-up (sets with 20 kg, 40%, and 60% 1RM). | 3 min | Eight sets of bench press (20–90% 1RM, increasing by 10% each set), with ischemia applied during rest intervals at 80% AOP. | +5.99% (at 20% 1RM) +10.74% (at 50% 1RM) (no significant differences observed at other load levels). | No data available. | No data available. | No. significant improvement (Δ ~4.2% at 20% 1RM, $p = 0.088$) | One repetition per set (velocity measured at a given load). | Ischemia applied during rest intervals increased peak barbell velocity at light loads (20% and 50% 1RM), but had no effect on mean velocity. The effect diminished at higher loads (60–90% 1RM). |

**Table 3.** *Cont.*

| Reference | Participants | Control Group | Familiarization | Warm Up | Time from Warm-Up to CA | Conditioning Activity | Peak Velocity Improvement [%] | Peak Power Improvement [%] | Mean Power Improvement [%] | Mean Velocity Improvement [%] | Number of Repetitions | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7. Wilk et al. (2020) [32] | 10 males: Age: 29.8 ± 4.6; BM: 94.3 ± 13.6 kg; Training experience: 12.7 ± 6.8 yrs; BP 1RM: 168.5 ± 26.4 kg BP 1RM/BM = 1.79 | Yes | One preliminary session: 1RM testing along with familiarization with the BFR protocol (60% AOP). | General warm-up (5 min on an ergometer) followed by a specific warm-up (15/10/5 repetitions at 20/40/60% 1RM). | 5 min | Three sets × three repetitions of bench press at 70% 1RM with BFR (90% AOP) or without (CONT). | BFR: +6.8% (set 2 vs. 1) −6.4% (set 3 vs. 2) CONT: +10.3% (set 2 vs. 1) +8.6% (set 3 vs. 1) | BFR: +7.8% (set 2 vs. 1) −6.4% (set 3 vs. 2) CONT: +7.4% (set 2 vs. 1) +7.9% (set 3 vs. 1) | BFR: +4.5% (set 2 vs. 1) −4.2% (set 3 vs. 2) CONT: +4.4% (set 2 vs. 1) +2.7% (set 3 vs. 1) | BFR: +5.8% (set 2 vs. 1) −7.3% (set 3 vs. 2) CONT: +2.4% (set 2 vs. 1) +2.4% (set 3 vs. 1) | Three repetitions in each of the three sets (target test). | BFR increased peak power and velocity in set 2, but a decline was observed in set 3. The CONT group maintained improvements in both sets 2 and 3. Differences in the kinetic profile of the PAPE effect between conditions were statistically significant ($p < 0.05$). |

BP—bench press; BM—body mass; CA—conditioning activity; CMB—cambered barbel; RMCB—reversed cambered barbell; BPT—bench press throw; STD—standard barbell conditioning activity; BP 1RM—bench press one rep max; CTRL, CONT—control group; AOP—arterial occlusion pressure; IPC—ischemic preconditioning.

## 4. Discussion

This systematic review aimed to evaluate the effectiveness of selected post-activation performance enhancement (PAPE) protocols in improving barbell velocity during the bench press in trained individuals. The collected data indicate that there are multiple ways to induce short-term improvements in upper-body strength–speed parameters; however, the outcomes of individual studies often differ due to varied research designs and procedures. The following sections discuss the PAPE-inducing strategies identified in the review, the moderating factors influencing their effectiveness, and potential areas for future research.

### *4.1. Velocity Parameters*

The primary focus of this analysis was the assessment of barbell movement velocity—specifically, peak velocity (PV) and mean velocity (MV)—following the application of various types of conditioning activities (CAs). Most of the studies included (Table 3) confirm that achieving the PAPE effect in the bench press is possible, provided that several key conditions are met. Regarding the intensity range of the CA, it was shown that loads between 70 and 80% of 1RM, applied in short sets (e.g., one–three sets), were most often associated with significant increases in movement velocity in subsequent sets. For example, a +7.0% increase in PV and +15.9% increase in peak power (PP) were observed following a standard bench press at 80% 1RM [34]. In contrast, loads of ≥85–90% 1RM require more careful management of rest periods and training volume, as excessive load and fatigue may cancel out the potential PAPE effect. This is supported by the findings of Wilk et al. [33], where higher BFR loads failed to improve PV. In terms of training volume, performing too many sets or taking rest intervals that are too short may lead to fatigue accumulation, thereby neutralizing the PAPE effect. In studies by Krzysztofik and Wilk [27], a one-time increase in velocity and power was clearly observed in the first set after applying plyometric push-ups, but the effect disappeared in the following sets. A similar trend was observed in protocols utilizing blood flow restriction (BFR): increases in velocity were noted with light loads and in the first set, followed by declines as volume increased [32].

Furthermore, rest intervals shorter than 3 min were shown to be insufficient, especially when heavier loads were used, resulting in reductions in PV or MV values [33]. On the other hand, rest periods of 4–5 min, or even up to 8–10 min, have been shown to yield positive outcomes [27,28]. The final choice of rest duration should be tailored to the athlete's training level and the specific demands of the session. Some sources suggest that the strongest PAPE response occurs within a narrow "time window" of 3–8 min following the CA [6,7,15].

Among the analyzed studies, the most effective CA variant for short-term increases in barbell velocity during the bench press was the standard bench press using a similar load (approximately 70–80% 1RM and in the repetition range of 2 to 6), which resulted in PV improvements of up to +7% [34]. Equipment modifications (e.g., cambered bar) led to slightly smaller gains. Upper-body plyometric elements, such as explosive push-ups, also showed effectiveness, but typically only in the first of several sets [27].

### *4.2. The Role of Blood Flow Restriction (BFR)*

The use of blood flow restriction (BFR) and ischemic preconditioning (IPC) has garnered significant interest among researchers aiming to enhance barbell velocity. Although this mechanism is often considered in the context of post-activation potentiation (PAP) or muscular hypoxia during volume-based training, current findings also explore its potential as a PAPE-inducing tool. Several studies have reported a clear increase in peak velocity (PV) (+5.99–17%) during the initial sets performed with ischemia applied either during rest intervals or immediately before barbell attempts [31,33]. However, this effect tended to disappear once loads exceeded 60% of 1RM. It is likely that, within this intensity range,

rapid muscular fatigue becomes dominant, overshadowing the potential benefits of hypoxia. When using BFR at higher loads (≥70% 1RM), only a transient increase in velocity or power was observed—typically in the second set—followed by a decline in subsequent sets [32]. This suggests that BFR does not consistently provide long-lasting performance enhancement and may contribute to fatigue accumulation when heavier loads are used. IPC, on the other hand, demonstrated positive effects when applied in short rest intervals (5 min of occlusion followed by 5 min of reperfusion), particularly in the first bench press sets (+6.5–9% MV compared to control) [30]. Interestingly, combining IPC with a PAPE protocol (high intensity at 90% 1RM) did not prove to be effective over multiple sets—the positive effect was mainly observed in the first set and diminished thereafter.

Both BFR and IPC may serve as useful tools for eliciting immediate improvements in velocity during resistance exercises performed at low to moderate intensities. However, at higher loads or when exercises are repeated over multiple sets, these benefits are quickly neutralized by fatigue.

### *4.3. Individual Factors in the Context of the PAPE Effect*

The collected findings clearly suggest the usefulness of PAPE protocols for short-term improvement in barbell velocity. However, several individual factors must be considered in practical training settings. The studies included in this review primarily involved male participants with at least two years of resistance training experience, most of whom were classified as advanced lifters (with bench press 1RM values reaching up to 168.5 kg) [32]. According to the conclusions of Seitz and Haff and Tillin and Bishop, athletes with higher strength levels are more resistant to fatigue and may more easily benefit from the PAPE effect compared to less-trained individuals. Similar observations were made by Tsolakis et al., who reported that a higher level of relative strength played a key role in achieving performance gains in power output among trained men [18,35,36]. In less experienced individuals—or conversely, elite athletes from strength sports—different responses to the same protocol may occur. It is likely that more highly trained individuals require a stronger stimulus or more precisely controlled rest intervals to achieve a measurable PAPE effect. Another important factor is the type of warm-up used. Several of the analyzed studies showed that a well-structured submaximal warm-up (e.g., short sets at 40% and 80% of the target load) can elicit an immediate increase in mean velocity (MV) during the first training set. This response often aligns with the principles of PAPE, where performance is enhanced immediately following a conditioning activity [29]. However, to maintain such effects over longer sequences of exercises, closer control over training volume and rest duration is required.

Some studies found no clear advantage between shorter rest intervals (3–4 min) and longer ones (6–8 min), but much evidence suggests that a 4–5 min interval may be sufficient to reduce fatigue while maintaining elevated neuromuscular readiness. Reducing this rest to 1–2 min generally diminishes the beneficial effect—especially when high loads are involved [27,30].

The specificity of the sport discipline also plays a critical role in the context of PAPE. In sports focused on maximal strength (e.g., powerlifting), the stimulus intensity must be high enough while avoiding premature fatigue. In contrast, disciplines that combine strength and power (e.g., combat sports, basketball) may benefit more from velocity-focused modifications at moderate loads. Some studies suggest that optimizing movement velocity can facilitate repeated actions, such as strikes or throws, which are essential in these disciplines [2,3].

### 4.4. Limitations of the Study

All studies included in this review received a PEDro score of 5 out of 10, indicating a moderate level of methodological quality. This highlights several issues:

Lack of randomized assignment to different CA protocols—in some studies, participants self-selected into specific interventions or completed the protocols in a fixed order.

Inconsistent outcome reporting—some authors reported only percentage differences in PV or PP without providing precise effect sizes (e.g., Cohen's d, Hedges' g) or confidence intervals.

These limitations underscore the need for further high-quality research involving control groups and larger sample sizes. Such studies would allow for more precise identification of cause-and-effect relationships and contribute to the development of standardized guidelines for implementing PAPE protocols in the bench press.

### 4.5. Recommendations for Future Research

In future research, conducting more comprehensive meta-analyses is recommended, provided there is greater consistency across protocols in terms of the type of CA, load intensity, rest duration, and number of sets. Studies including female participants, novice trainees with limited training experience, or direct comparisons between elite powerlifters and recreational lifters in the context of the bench press would also be highly valuable.

## 5. Conclusions

In summary, it is recommended to implement PAPE protocols in bench press training to enhance barbell velocity. Despite the limited number of studies and moderate methodological quality (PEDro = 5/10), the findings suggest that a relatively short-term speed improvement can be achieved under several key conditions. First, it is crucial to select an appropriate load, usually in the range of 70–80% 1RM, performed in one–three short sets of two–six repetitions. Second, the rest interval between the conditioning activity (CA) and the target effort should be around 4–5 min, which helps minimize fatigue and maintain the PAPE effect at least in the first set. Third, techniques such as plyometric exercises or occlusion strategies (BFR, IPC) can further support movement velocity, but mainly at lower loads (20–50% 1RM). At higher intensities (>85% 1RM) or insufficient recovery, the benefits of PAPE may be negated by accumulating fatigue. The training level of participants plays a significant role—more advanced individuals seem to benefit more effectively from brief protocols based on submaximal loads. Implementing these recommendations in practice can yield considerable advantages for further development of strength and movement dynamics in the bench press, but requires careful selection of training parameters and consideration of individual athlete characteristics.

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