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*Review*

# Electromyographic Activity of the Pectoralis Major Muscle during Traditional Bench Press and Other Variants of Pectoral Exercises: A Systematic Review and Meta-Analysis

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**Featured Application: Bodybuilding training professionals and users who use bench press (BP) should be aware of the implication in choosing another exercise, either to improve muscle activation or to maintain activation levels while seeking another parallel objective. Depending on the grip, we emphasize that a wide grip will have a greater involvement of the pectoralis major in both portions, but should not exceed a width of 200% biacromial distance (BAD) due to increased risk of injury. Otherwise, in the decline of the bench angle, the decrease in the clavicular portion should be considered, as opposed to an increase in the sternal portion. On the contrary, in the inclination there is a decrease in the sternal portion without having a difference in the clavicular compared to the horizontal portion. In addition, the increase in instability in the BP causes a decrease in the intensity of the load that can be moved, reducing the electromyography activity (EMG) of the pectoralis major, although it can be observed that some of these exercises have an application with different objectives due to the fact that they have a greater influence on other muscle groups with a stabilizing function. Focusing on other types of exercises, BP is the one that most involves the pectoralis major. However, other exercises such as push-ups are more accessible and obtain a similar activation when exposed to the same relative load, although it is difficult to increase the load during the exercise. Therefore, the results of our meta-analysis reflect the appropriateness of the BP for safety and efficiency.**

**Abstract:** The popularity of the bench press (BP) is justified by being one of the most effective exercises to improve strength and power in the upper body. The primary aim of this systematic review and meta-analysis was to compare the electromyography activity (EMG) of pectoralis muscle between BP and other variants of pectoral exercises (OP). *Methods:* This study was conducted according to the PRISMA. Original research articles published by March 2023, were located using an electronic search of four databases and yielded 951 original publications. This review included studies that compared the EMG activity of pectoralis muscle between BP and OP. Data were extracted and independently coded by three researchers. Finally, 23 studies were included for systematic review and meta-analysis. Meta-analysis with fixed or random effect model was performed to infer the pooled estimated standardized mean difference, depending on the heterogeneity. The studies were grouped according to the type of the comparison: grip widths, type of grip, inclination of the bench, stability, or exercise type. *Results:* The original option of BP activates the sternal portion significantly more than the variant with the inclined bench (SMD = 1.80; 95%CI 0.40 to 3.19; $p = 0.017$). Performing the exercise in an unstable situation produced significantly more activation during the concentric phase than performing the exercise in a stable situation (SMD = −0.18; 95%CI −0.33 to 3.74; $p = 0.029$). When comparing by type of exercise, greater activations are also seen in the original bench press vs. the comparisons ($p = 0.023$ to 0.001). *Conclusions:* The results suggest that the traditional bench press performed with the bench in a horizontal position, with a bar and a grip width between 150% and 200% of the biacromial distance (BAD) results from a greater EMG involvement of the pectoralis major in most variations with the same relative load. However, the sternal portion of pectoralis major showed greater activation with the declined variant of bench press.

**Keywords:** chest press; EMG; push exercises; resistance training; upper extremity

## 1. Introduction

Strength training and the use of multi-joint exercises such as bench press has multiple benefits, such as improvements in skeletal muscle health, bone mineral density, production of greater strength, power, and cardiovascular, metabolic [1–8], and mental health [2,9–17]. There are many variables that make up a strength training program, including the choice of exercises, and these depend on the objectives to be reached, as the training results in different physiological and biomechanical stimuli [18,19]. Whether for health or performance oriented purposes, and among the many types of exercises that can be performed within a strength training program, the press bench exercise is one of the most common and traditional [20–23].

The popularity of the bench press (BP) is justified by being one of the most effective exercises to improve strength and power in the upper body [24], in addition to the potential of this exercise for control in training, evaluation, and research [25,26]. The traditional BP can be executed with a free bar or with a Smith machine [27], because there are strong relationships between movement speed and 1 RM regardless of whether the exercise is performed on a Smith machine or with a free weight bar [28,29].

The main muscles involved in the movement are the pectoralis major, the anterior deltoid and the triceps brachial. Each has an integral function in the bar impulsion, and any modification in this exercise affects the development and involvement of the main musculature. Variations in the BP include bar modifications, bench inclination, grip widths, and intensity [27]. To this can be added different push exercises such as push-ups, bench press with dumbbells, exercises with pulleys, as well as different elements to optimize the result [30], being all the other variants of pectoral exercises (OP) interesting.

In the traditional BP, the width of grip is usually that which allows it to generate a greater biomechanical force in accordance with its anthropometry in order to maintain safety and avoid the risk of injury. In this way, one of the established ways to determine the traditional width is to obtain in a supine position an arm and elbow abduction at 90° while holding the bar, resulting in a grip width within a range between 150% and 200% of the biacromial distance (BAD) [31,32].

Thus, it is of interest to identify the most efficient exercises to achieve high levels of activation to stimulate muscle hypertrophy and increase muscle strength [30,33]. Electromyography activity (EMG) can measure neuromuscular activation, which is related to the efficiency of an exercise [34]. Maximal voluntary isometric contraction (MVC) was performed to identify the maximum electromyographic reference values used to normalize EMG for each exercise. In addition, interpretation of the EMG signal can be used to assist in the prescription of strength training [35]. It is generally assumed that exercises that produce greater EMG signal amplitudes have greater effects on muscle strength [36].

Given the diversity of the literature and the lack of a meta-analysis of this topic, the objective of this systematic review with meta-analysis was to compare the EMG activity of pectoralis major of the BP against OP.

## 2. Materials and Methods

The process of searching through the literature in a systematic manner and conducting a meta-analysis was carried out following the guidelines set forth by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [37], followed by the Handbook Cochrane Handbook [38] for systematic reviews of interventions.

### *2.1. Search Strategy*

This review included studies that directly compared the effect of BP and OP on pectoralis muscles EMG activity. A literature search was performed by the three reviewers (ALV; PJMP; RGSV) separately until 25 March 2023, and independently. The electronic database used were: PUBMED/MEDLINE, SPORT DISCUS and Web of Science databases, using the following Boolean search syntax: "(pectoralis muscles OR pectoral muscle) AND (exercise OR bench press OR measures OR assessment OR push movements OR push exercises OR chest press) AND (muscle activity OR electromyography OR EMG). Cohen´s Kappa was calculated to determinate the inter-rater reliability for the three authors (minimum Kappa obtained among reviewers = 0.875) and found a strong level of agreement [39]. The search strategy used in each database is detailed in Appendix A.

Additionally, the reference lists of relevant studies were screened. The authors manually cross-referenced all sources cited in the selected articles to ensure that no relevant studies were overlooked during the search and to remove any duplicate records.

### *2.2. Inclusion Criteria (Study Selection)*

The PICOS strategy was applied following the items: (a) Population: Subjects with some experience in bench press exercise; (b) Intervention or exposure: Bench press exercises; (c) Comparison: Another push pattern exercises; (d) Outcome: EMG activity of pectoralis major; (e) Study design: design experimental, cross-sectional studies, case studies, observational studies, or randomized clinical control (RCT). Thus, it was possible to establish the following inclusion criteria in a complementary way: (a) studies comparing the EMG activity of pectoralis major muscle of BP and OP; (b) EMG was recorded during the same motion and the same phase of contraction (e.g. concentric phase), so the only difference is the mode of exercise; (c) provide data concerning activation and deviations; (d) written in English, Spanish or Portuguese and published prior to March 2023; and (e) was published in a peer-reviewed journal.

The following types of studies were excluded: (a) those where EMG activity generated from the bench press exercise was not directly compared to the activity produced during the overhead press exercise; (b) those where different levels of resistance were utilized for each mode of exercise, despite the fact that the external force applied during BP and OP was not standardized across all experiments in a uniform manner (although investigators of the included studies stated that the resistance for OP was intentionally chosen to match the load used for BP); and (c) abstracts, short communications, notes, letters, and brief reports.

The data extraction process from the included studies was conducted independently by two researchers. In case of any discrepancies, a consensus meeting was held with a third researcher to resolve them. The extracted information included the author's name, year of publication, number of participants, age range, characteristics of the conventional bench press exercise and other chest exercises, the muscles assessed, and the results of the electromyography activity. This was carried out to provide a detailed characterization of the studies.

### *2.3. Assessment of Methodological Quality*

For the evaluation of the methodological quality, a Tool for the evaluation of the quality of the study and report in Exercise (TESTEX) was used. This tool is used for studies involving physical exercises. TESTEX is a 15-point scale used in experimental studies, including internal validity assessment criteria and presentation of the statistical analysis used. One point is assigned for each defined in the scale and zero in the absence of these indicators. The scale comprises the following criteria: (1) specification of inclusion criteria; (2) random allocation; (3) allocation secrecy; (4) similarity of groups in the initial or baseline phase; (5) rater blinding (for at least one key outcome); (6) measure of at least one primary completion in 85% of the allocated subjects (up to three points); (7) intention-to-treat analysis; (8) comparison between groups of at least one primary dropout (up to two points); (9) report measures of variability for all reported outcome measures; (10) monitoring of activities in control groups; (11) the relative intensity of constant physical exercise; and (12) characteristics of exercise volume and energy expenditure [40].

*2.4. Statistical Analysis*

The meta-analysis was performed with the R software version 3.6.0. Copyright (C) 2019 (R Foundation for Statistical Computing, Vienna, Austria). Continuous data from the mean and standard deviation from bench press and the variation exercise were used for the meta-analysis. The studies were grouped according to the type of the comparison: grip widths and type, inclination of the bench, stability, or exercise type. It was included all the comparison of the different exercise classification and type of exercise contraction reported form each article, therefore there are subsamples from each article. In certain studies, there were multiple experimental groups, which were treated as separate subgroups during the analysis. For those studies that did not report the required data, standard deviations (SD) were estimated and imputed using standard errors (SEs) and confidence intervals (CIs) where feasible. The pooled analysis was conducted using the DerSimonian-Laird (Cohen) method, and the presence of heterogeneity was evaluated using the Cochrane Q test ($Chi^2$), Higgins $I^2$, and significance (p) to decide whether to apply a fixed or random effects model for the analysis. [41]. To estimate the combined standardized mean difference (SMD), a meta-analysis was conducted using either a fixed or random effects model, based on the degree of heterogeneity observed [42,43]. DerSimonian-Laird (Cohen) was interpreted using Cohen´s [44] as small (0 to 0.29), medium (0.3 to 0.79) and large (≥0.8). The significant differences were determined at a level of $p < 0.05$. [45]. Rosenthal´s fail-safe N [46] was assessed by calculations publication bias.

## 3. Results

Through the search process, 951 publications were initially identified. A study selection flowchart is presented in Figure 1. After reviewing the titles and abstracts of the publications, certain studies were excluded, and the eligibility of the remaining articles was further evaluated through a full-text review.

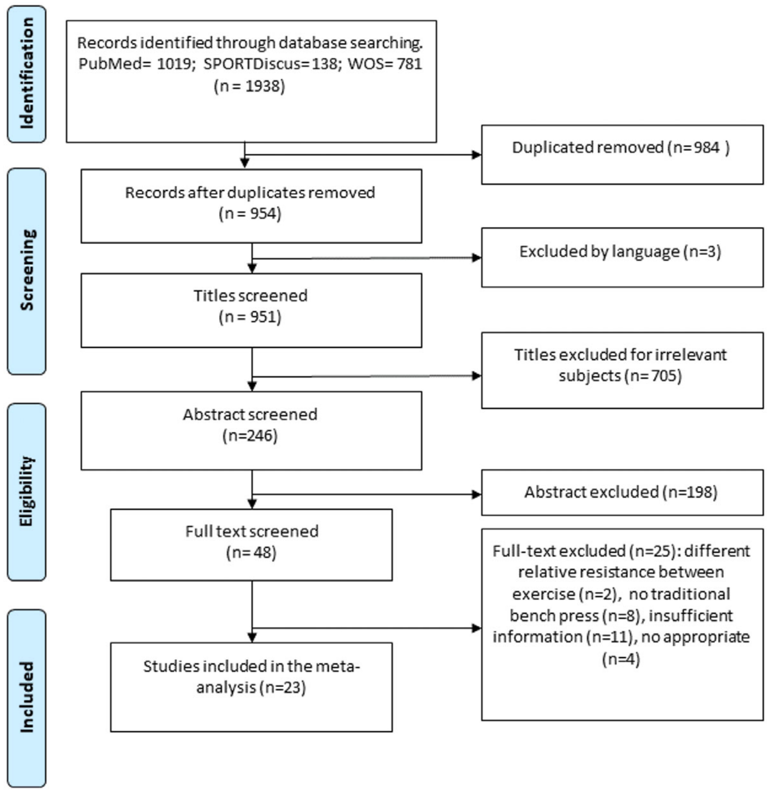


**Figure 1.** Flowchart of study.

Table 1 shows the results of the methodological quality of the studies by the TESTEX tool. According to the tool, all included studies scored above 10 points (score range: 0–15 points). The most sensitive points in the studies were: evaluator blinding, participant blinding, randomization of studies, and the form of allocation of participants.

**Table 1.** TESTEX study quality assessment.

| Study | Study Quality | | | | | Sub-Total | Study Reporting | | | | | | | | | | Sub-Total | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | (0 to 5) | 6a | 6b | 6c | 7 | 8a | 8b | 9 | 10 | 11 | 12 | (0 to 10) | (0 a 15) |
| Lehman [23] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Calatayud et al. [30] | 1 | 1 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 14 |
| Costa Crispiniano et al. [35] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Christian et al. [47] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Calatayud et al. [48] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Calatayud et al. [49] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Coratella et al. [50] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Dunnick et al. [51] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Goodman et al. [52] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 10 | 12 |
| Lauver et al. [53] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Lawrence et al. [54] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Mota et al. [55] | 1 | 1 | 0 | 1 | 0 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 13 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ostrowski et al. [56] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Pimentel et al. [57] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Sadri et al. [58] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Saeterbakken and Fimland [59] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Soncin et al. [60] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 12 |
| Welsch et al. [61] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Wang et al. [62] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Sousa et al. [63] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Costello [64] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | 12 |
| Albarello et al. [65] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |
| Barnett et al. [66] | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 11 |

Sudies that did not report the number of dropouts, but all ended with the same number of participants who started the intervention; NC: no control group. Study quality: 1 = specific eligibility criteria; 2 = type of randomization specified; 3 = hidden allocation; 4 = similar groups at baseline; 5 = raters were blinded (at least one main outcome); 6 = outcomes assessed in 85% of participants (6a = 1 point if more than 85% completed; 6b = 1 point if adverse events were reported; 6c = if exercise attendance was reported); 7 = intention-to-treat statistical analysis; 8 = statistical comparison between groups was reported (8a = 1 point if between-group comparisons are reported for the primary outcome variable of interest; 8b = 1 point if statistical comparisons between groups are reported for at least one secondary measure); 9 = point measures and measures of variability for all outcome measures that were reported; 10 = activity monitoring in the control group; 11 = relative exercise intensity remained constant; 12 = exercise volume and energy expenditure were reported.

This resulted in 23 studies included in synthesis with 6 subgroups classification [23,30,35,47–66]. Study characteristics are provided in Table 2.

**Table 2.** Studies included in the study.

| Classification | Author | Year | N | Age | Population | Exercises | Phase | % BAD Grip | Muscles Tested | Value | BP EMG | ±SD | OP EMG | ±SD | VARIANT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW | Barnet and Kippers et al. [66] | 1995 | 6 | 23.7 | trained | HBP 80% RM | CON | 200 | CPM | mV | 0.361 | 0.048 | 0.474 * | 0.044 | Narrow grip 100% BAD |
| GW | Lehman [23] 1 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | CPM | % GRIP 200% BAD | 100 | 0 | 99.79 | 32.39 | Forward grip 100% BAD |
| GW | Lehman [23] 2 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | CPM | % GRIP 200% BAD | 100 | 0 | 96.87 | 44.21 | Forward grip Narrow |
| GW | Lehman [23] 3 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | CPM | % GRIP 200% BAD | 100 | 0 | 107.59 | 42.39 | Reverse Grip 100% BAD |
| GW | Lehman [23] 4 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | SPM | % GRIP 200% BAD | 100 | 0 | 82.097 | 22.613 | Forward grip 100% BAD |
| GW | Lehman [23] 5 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | SPM | % GRIP 200% BAD | 100 | 0 | 72.804 * | 34.131 | Forward grip Narrow |
| GW | Lehman [23] 6 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | SPM | % GRIP 200% BAD | 100 | 0 | 97.939 | 39.937 | Reverse Grip 100% BAD |
| GW | Soncin et al. [60] | 2014 | 10 | 26.7 | trained | HBP 8 RM | COM | 150 | SPM | %MVC | 102.49 | 18.16 | 98.72 * | 24.96 | CLOSE GRIP |
| GW | Pimentel et al. [57] | 2016 | 12 | 21.8 | recreational | HBP 10 RM | COM | 150 | SPM | %MAX RMS | 54.77 | 11 | 53.14 | 10 | CLOSE GRIP |
| GW | Calatayud et al. [49] 1 | 2018 | 18 | 31 | US | HBP 50% RM | COM | 150 | PM | %MAX RMS | 52 | 47–56 | 54 | 50–59 | Narrow grip 100% BAD |
| GW | Calatayud et al. [49] 2 | 2018 | 18 | 31 | US | HBP 50% RM | COM | 200 | PM | %MAX RMS | 49 | 45–53 | 54 * | 50–59 | Narrow grip 100% BAD |
| TG | Lehman [23] 7 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | CPM | % GRIP 200% BAD | 100 | 0 | 127.011 * | 37.93 | Reverse Grip 200% BAD |
| TG | Lehman [23] 8 | 2005 | 12 | 26.3 | WTE | HBP 12 RM | ISO | 200 | SPM | % GRIP 200% BAD | 100 | 0 | 98.06 | 35.316 | Reverse Grip 200% BAD |
| AI | Crispiniano et al. [35] 1 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | CPM | %MVC | 44.7 | 7.3 | 43.2 | 6.3 | INCLINED 45° |
| AI | Crispiniano et al. [35] 12 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | CPM | %MVC | 44.7 | 7.3 | 41.7 | 6.9 | DECLINED −30° |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AI | Crispiniano et al. [35] 3 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | SPM | %MVC | 39.3 | 7 | 40 | 6 | INCLINED 45° |
| AI | Crispiniano et al. [35] 4 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | SPM | %MVC | 39.3 | 7 | 40.1 | 8.1 | DECLINED −30° |
| AI | Crispiniano et al. [35] 5 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | SPM lower | %MVC | 41.4 | 5.5 | 37 * | 3.6 | INCLINED 45° |
| AI | Crispiniano et al. [35] 6 | 2016 | 20 | 23.2 | recreational | HBP | ISO | NO ESPECIFIC | SPM lower | %MVC | 41.4 | 5.5 | 43.3 | 4.6 | DECLINED −30° |
| AI | Lauver and Cayot et al. [53]1 | 2016 | 14 | 21.4 | trained | HBP 65% RM | CON | 150 | SPM | %MVC | 98.4 | 19.9 | 85.9 * | 19 | INCLINED 30° |
| AI | Lauver and Cayot et al. [53] 2 | 2016 | 14 | 21.4 | trained | HBP 65% RM | CON | 150 | SPM | %MVC | 98.4 | 19.9 | 71.6 * | 4.5 | INCLINED 45° |
| AI | Lauver and Cayot et al. [53] 3 | 2016 | 14 | 21.4 | trained | HBP 65% RM | CON | 150 | SPM | %MVC | 98.4 | 19.9 | 99.6 | 22.5 | DECLINED −15° |
| AI | Lauver and Cayot et al. [53] 4 | 2016 | 14 | 21.4 | trained | HBP 65% RM | ECC | 150 | SPM | %MVC | 68.5 | 15.3 | 39.3 * | 10.7 | INCLINED 30° |
| AI | Lauver and Cayot et al. [53] 5 | 2016 | 14 | 21.4 | trained | HBP 65% RM | ECC | 150 | SPM | %MVC | 68.5 | 15.3 | 27.7 * | 9.5 | INCLINED 45° |
| AI | Lauver and Cayot et al. [53] 6 | 2016 | 14 | 21.4 | trained | HBP 65% RM | ECC | 150 | SPM | %MVC | 68.5 | 15.3 | 72.7 | 19.5 | DECLINED −15° |
| AI | Lauver and Cayot et al. [53] 7 | 2016 | 14 | 21.4 | trained | HBP 65% RM | ECC | 150 | CPM | %MVC | 76.4 | 21.2 | 56.5 * | 21.2 | INCLINED 45° |
| AI | Lauver and Cayot et al. [53] 8 | 2016 | 14 | 21.4 | trained | HBP 65% RM | ECC | 150 | CPM | %MVC | 76.4 | 21.2 | 72.5 | 27.3 | DECLINED −15° |
| AI | Lauver and Cayot et al. [53] 9 | 2016 | 14 | 21.4 | trained | HBP 65% RM | 26–50% CON | 150 | CPM | %MVC | 98.2 | 20.2 | 122.5 * | 38 | INCLINED 30° |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AI | Lauver and Cayot et al. [53] 10 | 2016 | 14 | 21.4 | trained | HBP 65% RM | 26–50% CON | 150 | CPM | %MVC | 98.2 | 20.2 | 124.8 * | 34.2 | INCLINED 45° |
| AI | Lauver and Cayot et al. [53] 11 | 2016 | 14 | 21.4 | trained | HBP 65% RM | 26–50% CON | 150 | CPM | %MVC | 98.2 | 20.2 | 96.1 | 20.6 | DECLINED −15° |
| AI | Lauver and Cayot et al. [53] 12 | 2016 | 14 | 21.4 | trained | HBP 65% RM | 0–25% CON | 150 | SPM | %MVC | 119.1 | 26.7 | 101.3 * | 28.3 | INCLINED 30° |
| AI | Lauver and Cayot et al. [53] 13 | 2016 | 14 | 21.4 | trained | HBP 65% RM | 76–100% CON | 150 | SPM | %MVC | 108.9 | 45.3 | 83.1 * | 39.4 | INCLINED 30° |
| AI | Coratella et al. [50] 1 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | CPM | %MVC | 83.7 | 1.5 | 94.3 * | 5.2 | INCLINED 45° |
| AI | Coratella et al. [50] 2 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | CPM | %MVC | 83.7 | 1.5 | 75 * | 3.3 | DECLINED −15° |
| AI | Coratella et al. [50] 3 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | SPM | %MVC | 80.5 | 2.5 | 61.1 * | 1.1 | INCLINED 45° |
| AI | Coratella et al. [50] 4 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | SPM | %MVC | 80.5 | 2.5 | 88.8 | 7 | DECLINED −15° |
| AI | Coratella et al. [50] 5 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | CPM | %MVC | 62.2 | 3.2 | 31.1 * | 3.4 | INCLINED 45° |
| AI | Coratella et al. [50] 2 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | CPM | %MVC | 62.2 | 3.2 | 21.7 * | 5.6 | DECLINED −15° |
| AI | Coratella et al. [50] 6 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | SPM | %MVC | 35.7 | 2.8 | 27.3 * | 4.6 | INCLINED 45° |
| AI | Coratella et al. [50] 7 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | SPM | %MVC | 35.7 | 2.8 | 46.3 * | 4.1 | DECLINED −15° |
| AI | Albarello et al. [65] | 2022 | 30 | 28.7 | trained | HBP 60% RM | CON | 150 | CPM | RMS | 62.01 | 19.37 | 88.37 | 6.97 | INCLINED 45° |
| AI | Albarello et al. [65] | 2022 | 30 | 28.7 | trained | HBP 60% RM | CON | 150 | SPM | RMS | 87.59 | 9.3 | 54.26 | 15.89 | INCLINED 45° |
| AI | Christian et al. [47] 1 | 2023 | 20 | 24.2 M 23.8 F | trained | HBP 70% RM | COM | 190 | PM | mV | 1.53 | 0.77 | 1.55 | 0.79 | INCLINED 30° |
| AI | Christian et al. [47] 2 | 2023 | 20 | 24.2 M 23.8 | trained | HBP 70% RM | COM | 190 | PM | mV | 1.53 | 0.77 | 1.51 | 0.78 | DECLINED 30° |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | F | | | | | | | | | | | |
| AI | Christian et al. [47] 3 | 2023 | 20 | 24.2 M 23.8 F | trained | HBP 70% RM | COM | 190 | PM | mV | 1.44 | 0.62 | 1.39 | 0.63 | INCLINED 30° |
| AI | Christian et al. [47] 4 | 2023 | 20 | 24.2 M 23.8 F | trained | HBP 70% RM | COM | 190 | PM | mV | 1.44 | 0.62 | 1.52 | 0.61 | DECLINED 30° |
| TE | Welsch and Bird et al. [61] 1 | 2005 | 12 | 21.5 | Trained | HBP 6 RM | CON | 150 165 | PM | mV | 0.557 | 0.162 | 0.5 | 0.124 | Dumbbell BP |
| TE | Welsch and Bird et al. [61] 2 | 2005 | 12 | 21.5 | trained | HBP 6 RM | CON | 150 166 | PM | mV | 0.557 | 0.162 | 0.522 | 0.119 | Dumbbell fly |
| TE | Sadri et al. [58] | 2011 | 15 | 30.13 | Voluntere | HBP 75% RM | COM | NO ESPECIFIC | CPM | µv | 3802.8 | 465.92 | 3803.06 | 465.83 | DUMBBELL |
| TE | Calatayud et al. [30] 1 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 23.58 | 1.64 | STANDARD PUSH-UP |
| TE | Calatayud et al. [30] 2 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 41 * | 2.46 | ELASTIC-RESISTED PUSH UP |
| TE | Calatayud et al. [30] 3 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 30.57 | 2 | SUSPENDED PUSH-UP CLOSED EYES |
| TE | Calatayud et al. [30] 4 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 29.46 | 1.7 | SUSPENDED PUSH-UP OPEN EYES |
| TE | Calatayud et al. [30] 5 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 22.8 | 1.61 | SUSPENDED PUSH-UP PULLEY SISTEM |
| TE | Calatayud et al. [30] 6 | 2014 | 29 | 22.6 | US | HBP 50% RM | COM | 150 | SPM | %MVC | 24.63 | 2.25 | 4.11 * | 0.43 | STANDING CABLE PRESS 50% RM |
| TE | Calatayud et al. [30] 7 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 23.58 * | 1.64 | STANDARD PUSH-UP |
| TE | Calatayud et al. [30] 8 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 41 | 2.46 | ELASTIC-RESISTED PUSH UP |
| TE | Calatayud et al. [30] 9 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 30.57 | 2 | SUSPENDED PUSH-UP CLOSED EYES |
| TE | Calatayud et al. [30] 10 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 29.46 * | 1.7 | SUSPENDED PUSH-UP OPEN EYES |
| TE | Calatayud et al. [30] 11 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 22.8 * | 1.61 | SUSPENDED PUSH-UP PULLEY SISTEM |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TE | Calatayud et al. [30] 12 | 2014 | 29 | 22.6 | US | HBP 70% RM | COM | 150 | SPM | %MVC | 40.48 | 2.86 | 5.49 * | 0.52 | STANDING CABLE PRESS 70% RM |
| TE | Calatayud et al. [30] 13 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 23.58 * | 1.64 | STANDARD PUSH-UP |
| TE | Calatayud et al. [30] 14 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 41 * | 2.46 | ELASTIC-RESISTED PUSH UP |
| TE | Calatayud et al. [30] 15 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 30.57 * | 2 | SUSPENDED PUSH-UP CLOSED EYES |
| TE | Calatayud et al. [30] 16 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 29.46 * | 1.7 | SUSPENDED PUSH-UP OPEN EYES |
| TE | Calatayud et al. [30] 17 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 22.8 * | 1.61 | SUSPENDED PUSH-UP PULLEY SISTEM |
| TE | Calatayud et al. [30] 18 | 2014 | 29 | 22.6 | US | HBP 85% RM | COM | 150 | SPM | %MVC | 52.91 | 4.11 | 7.03 * | 0.63 | STANDING CABLE PRESS 85% RM |
| TE | Calatayud et al. [48] 19 | | 30 | 21.9 | US | HBP 6 RM | COM | 150 | SPM | %MVC | 52.7 | 1.85 | 52.9 | 2.55 | PUSH UP WITH ELASTIC BAND |
| TE | Soncin et al. [60] 1 | 2014 | 10 | 26.7 | trained | HBP 8 RM | COM | 150 | SPM | %MVC | 102.49 | 18.16 | 90.8 * | 16.1 | CHEST FLY |
| TE | Soncin et al. [60] 2 | 2014 | 10 | 26.7 | trained | HBP 8 RM | COM | 150 | SPM | %MVC | 102.49 | 18.16 | 57.39 * | 28.49 | SHOULDER PRESS |
| TE | Soncin et al. [60] 3 | 2014 | 10 | 26.7 | trained | HBP 8 RM | COM | 150 | SPM | %MVC | 102.49 | 18.16 | 29.5 * | 19.59 | SHOULDER ABDUCTION |
| TE | Soncin et al. [60] 1 | 2014 | 10 | 26.7 | trained | HBP 8 RM | COM | 150 | SPM | %MVC | 102.49 | 18.16 | 72.1 * | 24.06 | LYING TRICEPS EXTENSION |
| TE | Mota et al. [55] | 2017 | 10 | 23.9 | active | HBP 70% RM | CON | 200 | PM | RMS | 384.8 | 220.6 | 232.5 | 175.3 | PULL OVER |
| TE | Coratella et al. [50] 1 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | CPM | %MVC | 83.7 | 1.5 | 60.8 * | 3.2 | CHEST PRESS |
| TE | Coratella et al. [50] 2 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | CON | 150 | SPM | %MVC | 80.5 | 2.5 | 76.1 | 2.6 | CHEST PRESS |
| TE | Coratella et al. [50] 3 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | CPM | %MVC | 62.2 | 3.2 | 33.3 * | 2.1 | CHEST PRESS |
| TE | Coratella et al. [50] 4 | 2019 | 10 | 29.8 | competitive | HBP 80% RM | ECC | 150 | SPM | %MVC | 35.7 | 2.8 | 33.4 | 2.8 | CHEST PRESS |
| TE | Sousa et al. [63] | 2022 | 14 | 24.6 | Active | HBP 50% RM | COM | NO ESPECIFIC | PM | %MVC | 41.87 | 17.34 | 42.3 | 15.8 | DUMBBEL FLY STABLE SURFACE |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TE | Costello, [64] | 2022 | 24 | 19.5 | OSA | HBP 75% RM | COM | CONTROLLED | PM | mV | 206.89 | 65.25 | 222.81 | 66.84 | Swiss bar with stable load |
| SC | Goodman et al. [52] 1 | 2008 | 13 | 24.1 | trained | HBP 1 RM | CON | 160–200 | SPM | %RMS ECC | 157.6 | 16.9 | 158.1 | 9.7 | Unstable ball |
| SC | Goodman et al. [52] 2 | 2008 | 13 | 24.1 | trained | HBP 1 RM | CON | 160–200 | SPM | mV | 0.22 | 0.03 | 0.22 | 0.03 | Unstable ball |
| SC | Goodman et al. [52] 3 | 2008 | 13 | 24.1 | trained | HBP 1 RM | ECC | 160–200 | SPM | mV | 0.15 | 0.02 | 0.14 | 0.02 | Unstable ball |
| SC | Saeterbakken et al. [59] 1 | 2013 | 16 | 22.5 | trained | HBP 6 RM | COM | CHOOSE | SPM | mV | 0.555 | 0.28 | 0.448 * | 0.19 | Swiss Ball |
| SC | Saeterbakken et al. [59] 2 | 2013 | 16 | 22.5 | trained | HBP 6 RM | COM | CHOOSE | SPM | mV | 0.555 | 0.28 | 0.5 | 0.22 | BALANCE CUSHION |
| SC | Dunnick et al. [51] 1 | 2015 | 20 | 24.1 | trained | HBP 60% RM | CON | NO ESPECIFIC | SPM | %MVC | 95.87 | 19.41 | 102.24 | 23.03 | KETBELL 16 KG hung |
| SC | Dunnick et al. [51] 2 | 2015 | 20 | 24.1 | trained | HBP 80% RM | CON | NO ESPECIFIC | SPM | %MVC | 129.94 | 24.08 | 132.62 | 28.22 | KETBELL 16 KG hung |
| SC | Dunnick et al. [51] 3 | 2015 | 20 | 24.1 | trained | HBP 60% RM | ECC | NO ESPECIFIC | SPM | %MVC | 54.73 | 13.97 | 59.63 | 17.91 | KETBELL 16 KG hung |
| SC | Dunnick et al. [51] 3 | 2015 | 20 | 24.1 | trained | HBP 80% RM | ECC | NO ESPECIFIC | SPM | %MVC | 78.06 | 17.17 | 80.07 | 20.7 | KETBELL 16 KG hung |
| SC | Lawrence et al. [54] 1 | 2016 | 15 | 24.2 | trained | HBP 75% RM | COM | NO ESPECIFIC | RIGHT SPM | µv | 230 | 137 | 177 * | 114 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |
| SC | Lawrence et al. [54] 1 | 2016 | 15 | 24.2 | trained | HBP 75% RM | COM | NO ESPECIFIC | LEFT SPM | µv | 190 | 95 | 159 * | 100 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |
| SC | Ostrowski and Carlson et al. [56] 1 | 2017 | 15 | 24.2 | trained | HBP 75% RM | CON | NO ESPECIFIC | RIGHT SPM | µv | 230 | 130 | 265 | 137 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |
| SC | Ostrowski and Carlson et al. [56] 2 | 2017 | 15 | 24.2 | trained | HBP 75% RM | CON | NO ESPECIFIC | LEFT SPM | µv | 190 | 84 | 240 | 153 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |
| SC | Ostrowski and Carlson et al. [56] 3 | 2017 | 15 | 24.2 | trained | HBP 75% RM | ECC | NO ESPECIFIC | RIGHT SPM | µv | 189 | 106 | 175 | 71 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |
| SC | Ostrowski and Carlson et al. [56] 4 | 2017 | 15 | 24.2 | trained | HBP 75% RM | ECC | NO ESPECIFIC | LEFT SPM | µv | 163 | 94 | 158 | 73 | Flexible Bar and LOAD SUSPENDED BY ELASTIC BAND |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SC | Wang et al. [62] 1 | 2022 | 29 | 19.4 | US | HBP 60% RM | COM | NO ESPECIFIC | PM | mV | 2.17 | 1.12 | 2.14 | 1.21 | Smith Bench Press |
| SC | Wang et al. [62] 2 | 2022 | 29 | 19.4 | US | HBP 60% RM | COM | NO ESPECIFIC | PM | mV | 2.17 | 1.12 | 2.14 | 1.21 | Suspended by elastic |
| SC | Sousa et al. [63] | 2022 | 14 | 24.6 | Active | HBP 50% RM | COM | NO ESPECIFIC | PM | %MVC | 41.87 | 17.34 | 42.3 | 15.8 | DUMBBEL FLY UNSTABLE SURFACE |
| SC | Costello [64] 1 | 2022 | 24 | 19.5 | OSA | HBP 75% RM | COM | CONTROLLED | PM | mV | 206.89 | 65.25 | 224.4 | 52.51 | Bandbell bar with unstable load |
| SC | Costello [64] 2 | 2022 | 24 | 19.5 | OSA | HBP 75% RM | COM | CONTROLLED | PM | mV | 206.89 | 65.25 | 218.03 | 54.11 | Standard bar with unstable load |

* $p < 0.05$, compared with BP values. Abbreviations: GW = grip width; TG = type of grip; AI = angle of inclination; TE = type of exercise; SC = stability condition; WTE = weight training experience; US = university student; RM = repetition maximum; BP = bench press; HBP = horizontal bench press; OP = other modalities of pectoral exercises or bench press; CON = concentric; ECC = eccentric; ISO = isometric; COM = complete; BAD = biacromial of distance; PM = pectoralis major; CPM = clavicular pectoralis major; SPM = sternocostal pectoralis major; MVC = maximum voluntary isometric contraction; mV = millivolts; µV = microvolts; RMS = root mean square; SD = standard deviation; OSA = off season athletes; M = male; F = female.

Table 3 show the pooled analysis of activation between subgroup analysis.

**Table 3.** Differences of activation between subgroup analysis.

| Group | Studies | SMD | SMD (95% CI) | $I^2$ | t | *p*-Value |
|---|---|---|---|---|---|---|
| **Grip Width** | | | | | | |
| *Normal vs. narrow* | | | | | | |
| Clavicular | [66], [23] $^{1,2,4}$ | −0.38 | −1.85; 1.10 | 59.6 | −0.82 | 0.473 |
| Sternal | [23] $^{5,6,8}$, [57], [60] | 0.49 | −0.15; 1.14 | 32 | 2.12 | 0.101 |
| **Angle of inclination** | | | | | | |
| *Horizontal vs. declined* | | | | | | |
| Sternal | [50] $^{4,8}$, [35] $^{4,6}$, [53] $^{3,6}$ | −0.75 | −1.85 a 0.36 | 74.9 | −1.74 | 0.143 |
| Clavicular | [50] $^{2,6}$, [35] $^{2}$, [53] $^{8,11}$ | 2.03 | −2.03; 6.53 | 90.6 | 1.46 | 0.218 |
| *Horizontal vs. inclined* | | | | | | |
| Sternal | [50] $^{3,7}$, [35] $^{3,5}$, [53] $^{1,2,4,5,12,13}$ [65] $^{1}$ | 1.80 | 0.40;3.19 | 87.6 | 2.87 | 0.017 |
| Clavicular | [50] $^{1,5}$, [35] $^{1}$, [53] $^{7,9}$ [65] $^{1}$ | 0.36 | −3.03; 3.74 | 92.6 | 0.26 | 0.81 |
| **Stability condition** | | | | | | |
| *Stable vs. unstable* | | | | | | |
| Concentric | [51] $^{1,2}$, (52 $^{1,2}$), (41$^{1,2}$) | −0.18 | −0.35; −0.03 | −0 | −3.02 | 0.029 |
| Eccentric | [51] $^{3,4}$, (52 $^{3}$), (41 $^{3,4}$) | 0.02 | −0.34; 0.37 | −0 | 0.12 | 0.911 |
| Complete | [59] $^{1,\ 2}$, [59] $^{2}$, [54] $^{1,2}$, [62], [63] $^{1,2}$, [64] $^{1,2}$ | −0.047 | −0.29; 0.20 | 8.3 | −0.43 | 0.675 |
| **Type of exercise** | | | | | | |
| *Bench press vs. other variants type* | | | | | | |
| Sternal | [30] $^{1–18}$, [39], [50] $^{2,4}$, [60] $^{1–4}$ | 4.04 | 1.74; 6.35 | 98 | 3.62 | 0.001 |
| Clavicular | [50] $^{1,3}$, [58], [62] | 4.53 | −4.22; 13.27 | 94.9 | 1.65 | 0.198 |
| *Bench Press vs. all push up variants* | [30] $^{1–5,7–11,13–17}$,[48], [62] | 3.01 | 0.46; 5.57 | 98.4 | 2.52 | 0.023 |
| *Bench Press vs. other variants no push ups* | [30] $^{6,12,18}$, [50]$^{1–4}$, [55], [58], [60] $^{1–4}$, [61] $^{1,2}$ | 4.53 | 1.40; 7.65 | 95.9 | 3.09 | 0.008 |

Figures 2–7 show the forest plots of the analyses performed on pectoral activation. Each of them includes all the measurements made within each item. In this case, it is shown how some articles only include one piece of data while other articles include a greater number of pieces of data. This is due to the fact that some articles make several measurements assessing different phases or different percentages of RM.

A total of four studies compare pectoral activation produced at different grip widths [23,57,60,66]. Two studies analyze the activation in clavicular pectoralis and three studies the activation in the sternal pectoralis. Pooled analysis shows that the original exercise BP (medium grip distance) activate the clavicular (SMD = −0.38; 95%CI = −1.82; 1.10) and sternal portion (SMD = 0.49; 95%CI = −0.75; 2.20) of the pectoral as well as the narrow grip. The variability among effects is presented in the forest plot in Figure 2.

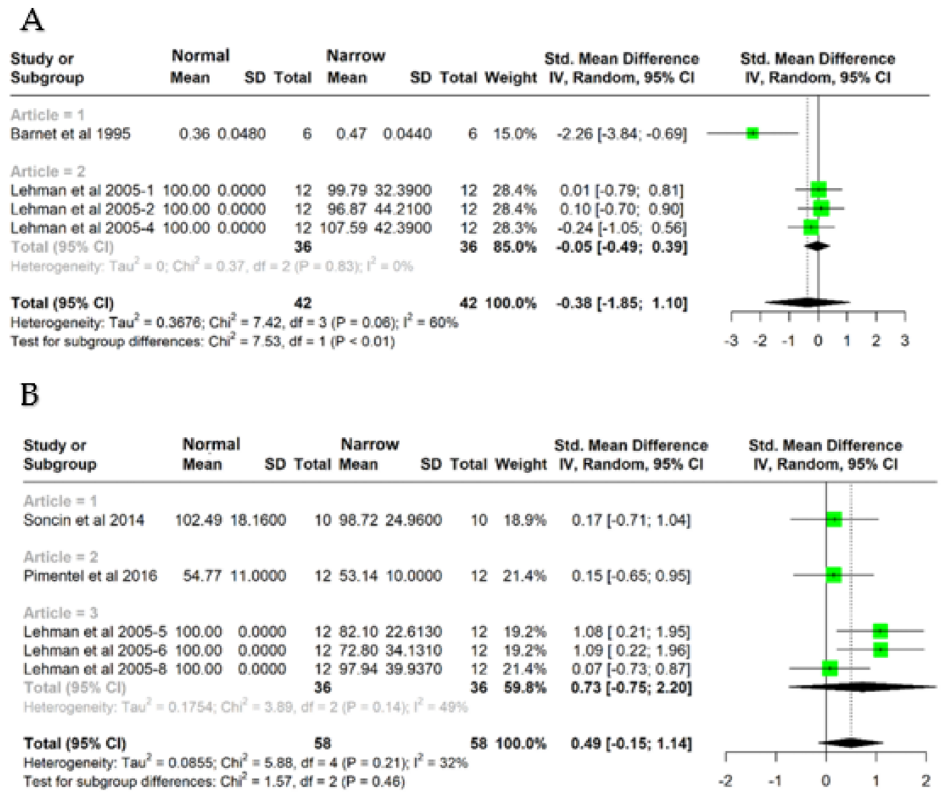


**Figure 2.** (**A**) Forest plot for muscle activation in grip width in clavicular pectoralis. (**B**) Forest plot for muscle activation in grip width in sternal pectoralis.

In relation to the declined angle there are three studies analyze the activation of the clavicular portion and another three analyze the activation of the sternal portion. No differences were shown in the pectoral activation (clavicular or sternal portion) when compared with the activation in the exercise performed without decline (Figure 3). In relation to the activation of the pectoral taking into account the inclination of the bench, there are four studies included in the present meta-analysis [35,50,53,65], three studies analyze the activation of the clavicular portion and another three analyze the activation of the sternal portion. The analysis shows that the BP variant with the inclined bench activates less the sternal portion (significantly) (SMD = 1.80; 95%CI 0.40 a 3.19; $p = 0.017$). No differences were found in clavicular portion. The variability among effects is presented in the forest plot in Figure 4.

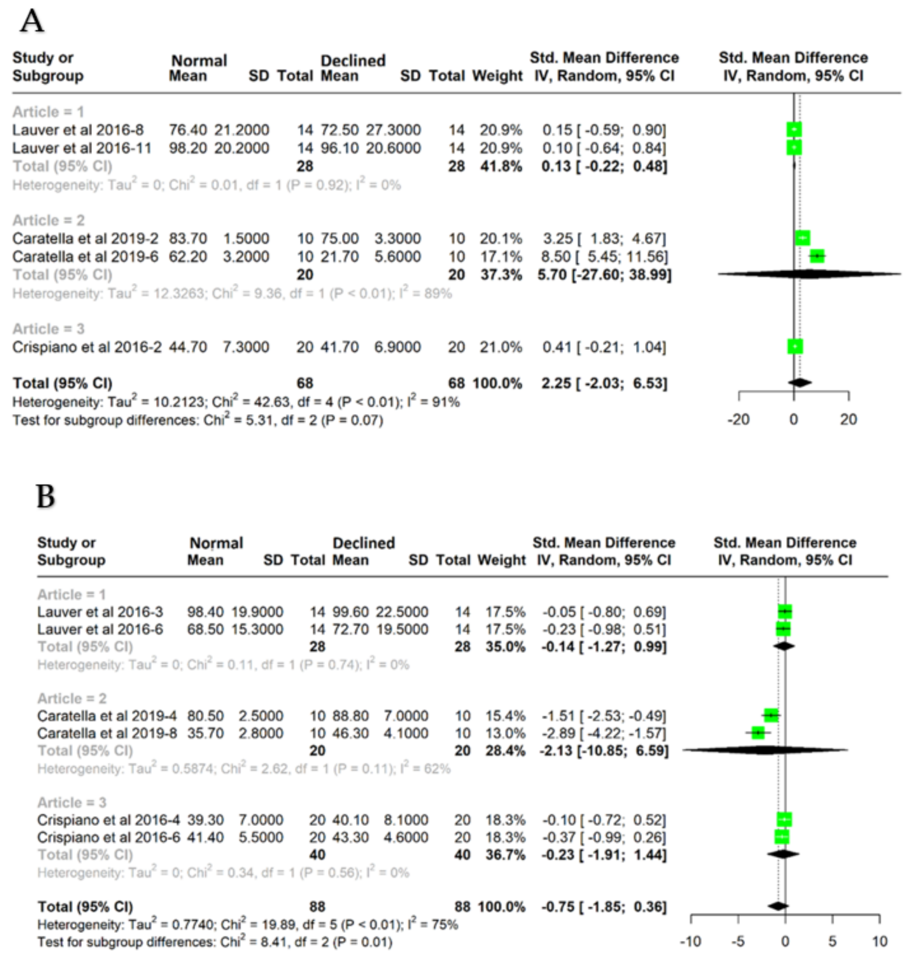


**Figure 3.** (**A**) Forest plot for muscle activation in Angle of declination in clavicular pectoralis (**B**) Forest plot for muscle activation in Angle of declination in sternal pectoralis.

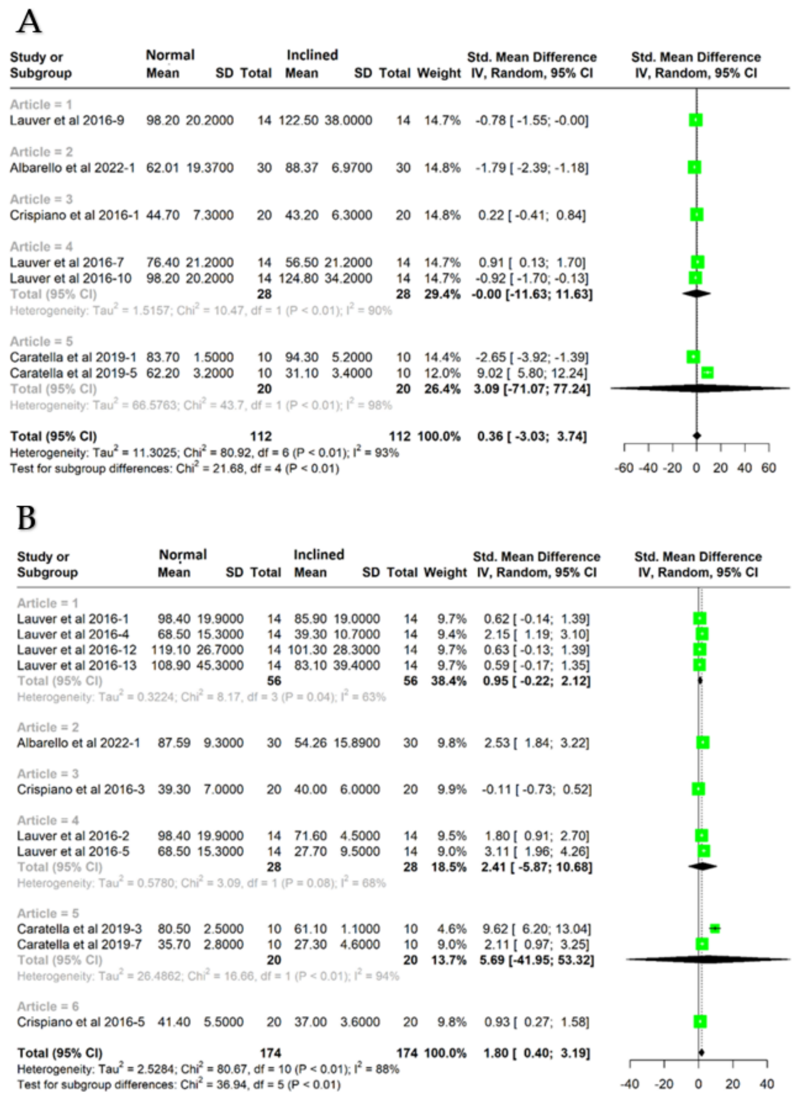


**Figure 4.** (**A**) Forest plot for muscle activation in Angle of inclination in clavicular pectoralis (**B**) Forest plot for muscle activation in Angle of inclination in sternal pectoralis.

In relation to the analysis comparing the activation of the pectoral muscle in a stable situation vs. an unstable situation, Figure 5A shows the analysis for the activation of the pectoral muscle in the concentric phase, Figure 5B for the eccentric phase and Figure 5C for all joint action. Six studies compare the original option of BP with an unstable exercise variant [50,51,54,56,59,64]. No difference in chest activation was shown for eccentric phase or complete exercise; however, an unstable condition produced significantly more activation during the concentric phase than performing the exercise in a stable situation (SMD = −0.18; 95%CI −0.33 to 3.74; $p = 0.029$).

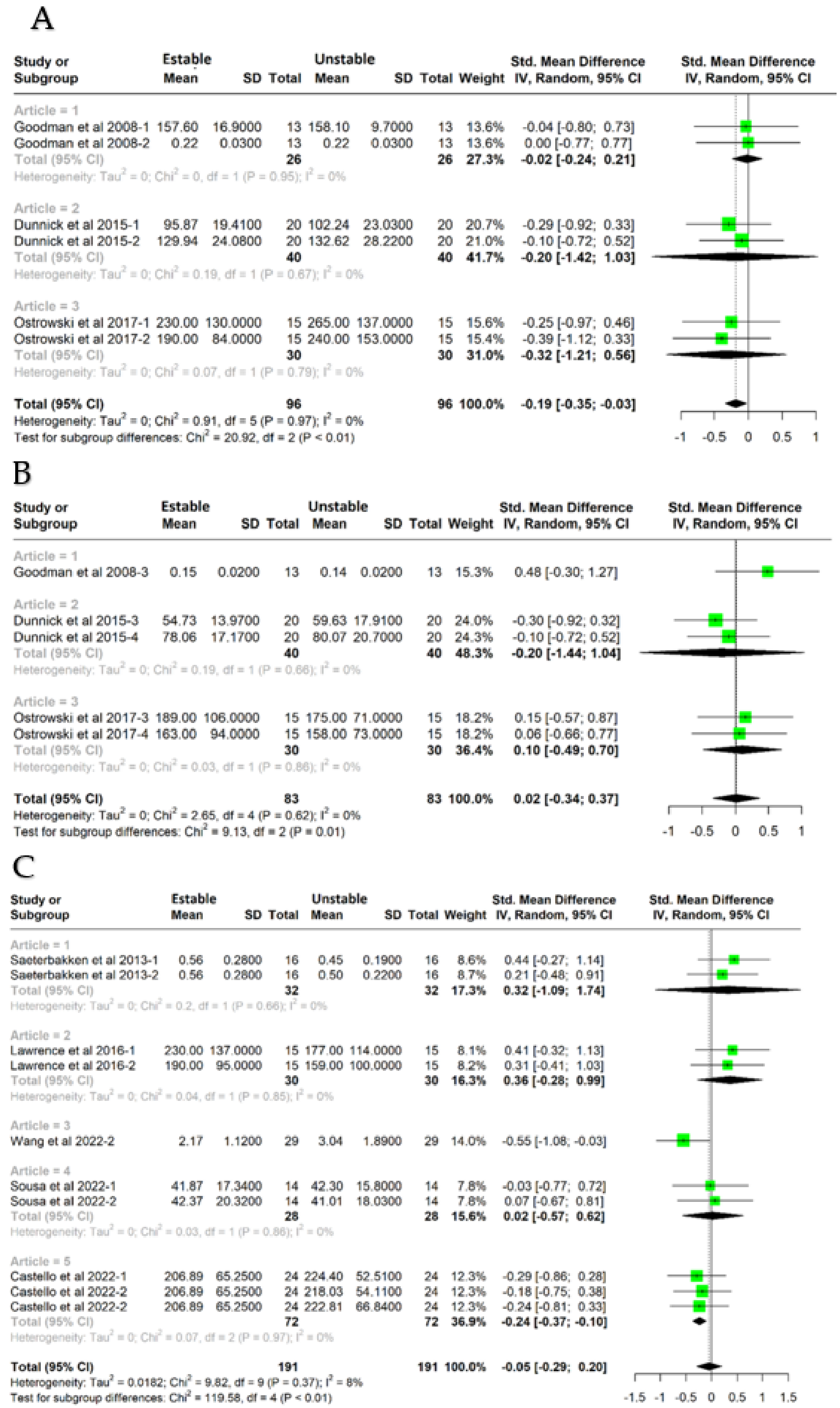


**Figure 5.** (**A**) Forest plot for muscle activation in Stability condition in concentric phase. (**B**) Forest plot for Stability condition in eccentric phase. (**C**) Forest plot for muscle activation in Stability condition of complete exercise.

In relation to the analysis on the activation of the pectoralis, comparing the PB exercise with any other exercise, in Figure 6A the activation of the clavicular pectoralis is shown and in Figure 6B the activation of the sternal pectoralis. A total of six studies compare the activation of the pectoral in the traditional BP with another exercise type (push-ups [30,48,62], dumbbell [50,58], elastic resistance [30], chest press [50], and others [58,60]).

The analysis shows that there is no significant difference in the activation of the clavicular portion when comparing the PB with another exercise; however, there is a greater activation in the sternal pectoralis in the variable exercise (SMD = 4.04; 95% ICI 0 = 1.74; 6.35) (Figure 6). Likewise, there is also a greater activation in general both in the push up vs. BP exercise (SMD = 3.01; 95% CI = 0.46; 5.57). As when comparing other exercises to push up (SMD = 4.53; 95%CI = 4.40; 7.65) (Figure 7).

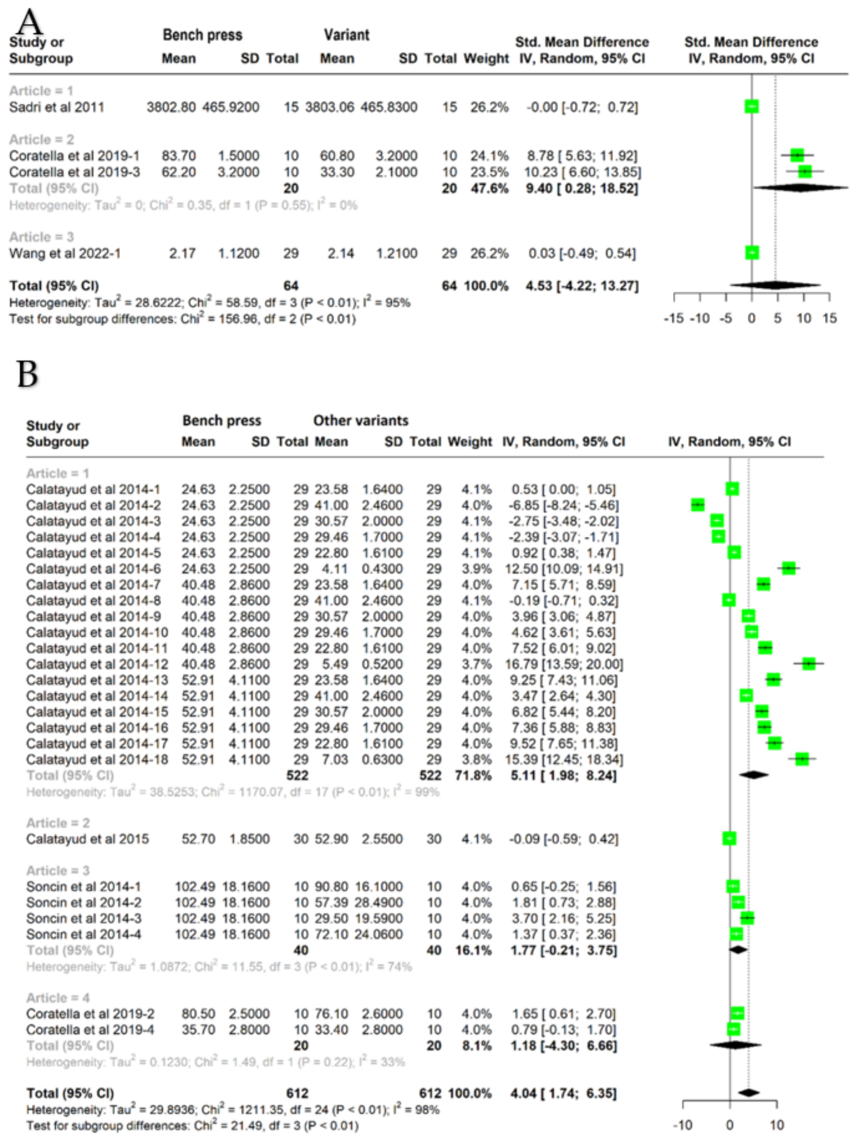


**Figure 6.** (**A**) Forest plot for muscle activation in Type of exercise in clavicular pectoralis. (**B**) Forest plot for muscle activation in Type of exercise in sternal pectoralis.

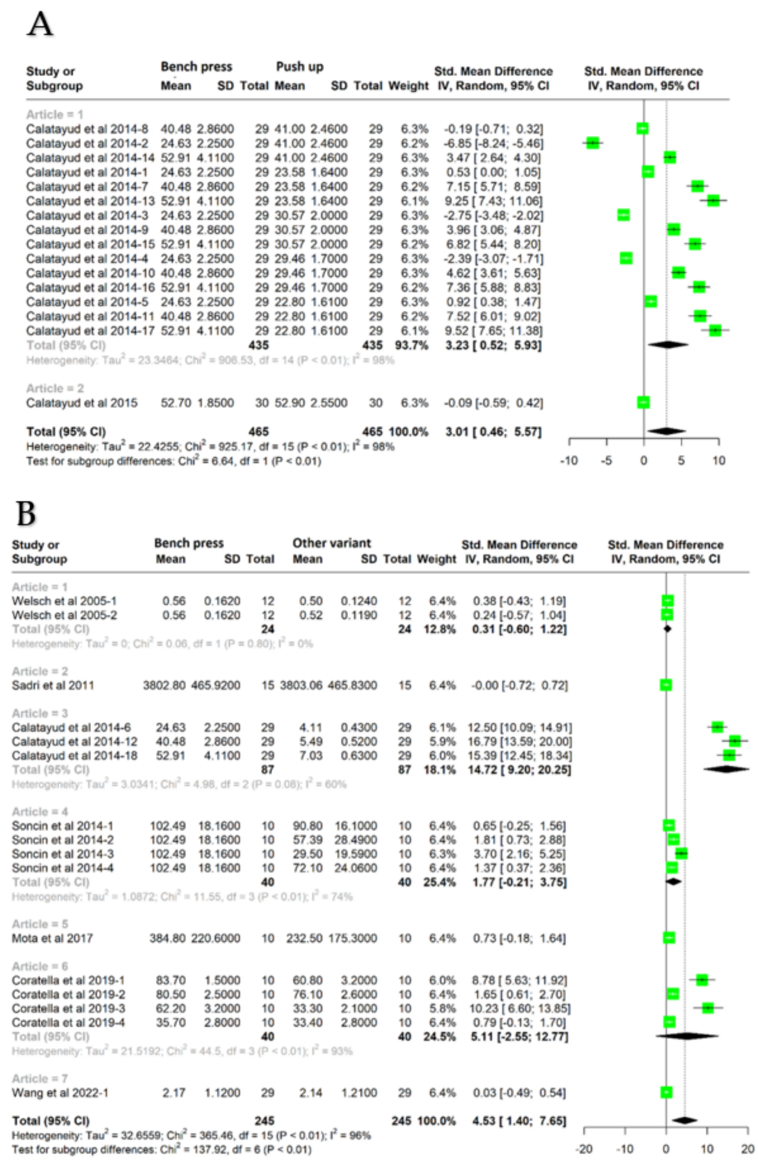


**Figure 7.** (**A**) Forest plot for muscle activation in bench press vs. push up. (**B**) Forest plot for muscle activation in Bench Press vs. other exercise no push up.

## 4. Discussion

This is the first systematic review with meta-analysis that analyses the activation of the pectoralis major in different variations of the bench press exercise. There are three systematic reviews on BP [20,67,68]. These studies categorized the included studies by grips, bench tilt, and exercises with greater instability such as the use of dumbbells, at the same that the present. However, they did not show a clear answer on the EMG activity between one modification or another.

Several articles go into detail and try to clarify the difference in activation in the grip width of BP [23,49,57,60,66], even highlighting the importance of a meta-analysis for a better conclusion [49]. In this case, following the inclusion criteria and the scientific literature, we established as a reference for the meta-analysis a normal grip between 150% and 200% of BAD, since several authors found no difference between these ranges of BAD [31,49] and more specifically the sternocostal portion [66]. Furthermore, other authors take a grip with 200% BAD as standard to normalize the activation values and be compared with different grip widths [23]. Thus, grips less than 150% BAD were considered a narrow grip.

In regard with sternal portion [23,57,60], narrow grip shown significantly lower activation compared to the standardized normal grip. Particularly in line with our results, Clemons and Aaron [31], found that a 190% BAD grip obtained higher levels of activation in the pectoralis than a narrow grip located between 100% BAD and 130% BAD. Similarly, Lheman [23] showed that a narrow grip (distance of one hand width between the two hands) the sternocostal portion was activated significantly less than during a 200% BAD, while with 100% BAD it was also activated less, but not significantly. In contrast, other researchers have not found variation in activation of the sternal portion between different grip widths [66,69]. However, it should be noted that the data from Saeterbakken´s study [69] are presented as a mean of activation across different bench conditions (inclined, horizontal, and declined), and thus the specific activation from narrow grip cannot be isolated, which is why it was not included in the meta-analysis.

In regards with clavicular portions [23,66], the analysis shown that the EMG activity is similar in normal width and narrow grip. This coincides with the results of several studies [23,69], which observed similar activity of the clavicular pectoris during the different grip widths. It should be noted that not all authors are in line with the results of this analysis. Barnett et al. [66], showed increased activation of the clavicular pectorals in the 100% BAD grip, compared to 200% BAD, although the study does not specify in which bench inclination option these results were shown. Calatayud et al. [49] found differences in the pectoralis major between narrower grips than 200% BAD, although this study did not show specific between the clavicular and sternal pectorals, but the result was the mean of both portions so it may interfere, hence the non-inclusion in the meta-analysis.

When examining variations in grip such as switching from a pronation to a supination grip [23], the pooled analysis indicates that the sternal portion of the pectoralis is activated similarly in both types of grip. However, it is important to note that this conclusion is based on data from a single article, as there are few studies that have focused specifically on analyzing the differences in activation between different grip types. Conversely, it was found that the clavicular portion of the pectoralis is significantly more active in the supination grip variant compared to the original prone grip variant.

Combining the grip width in the two forearm positions, Lehman [23] showed no influence on electrical activation, specifically in the clavicular portion of the pectoralis major. This author points out the lack of knowledge about the reason why the clavicular portion of the pectoralis major increases its activity when the forearm is supinated.

While activation is an important factor to consider, there is also a need to consider the risk of injury associated with different types of grip. Multiple studies have demonstrated that using a grip equal to or greater than 200% BAD results in increased shoulder abduction, with angles approaching 90 degrees that can potentially be harmful to the glenohumeral joint. Additionally, performing this exercise with such a grip increases the likelihood of both chronic and acute injuries due to its high volume and common use in training [70–75]. Similarly, a narrow grip could produce a tendency for the elbow to rotate in the mid-plane, increasing the risk of injury [67]. Therefore, along with the results of this meta-analysis, a grip greater than 100% BAD and less than 200% BAD will maintain a similar activation of the pectoralis major, in addition to reducing the risk of injury by reducing abduction at an angle, approximately 45°, in this grip width [73]. These factors may indicate the proper grip type to generate sufficient muscle activation to obtain hypertrophy, increase muscle strength, and prevent injuries.

The pectoralis muscle activation was compared between different inclination benches. The concept has been created that a greater inclination in the BP means a greater incidence with respect to the activation of the clavicular portion of the pectoralis major, as opposed to a detriment of the sternal portion [67].

In relation to the declined variant, the meta-analysis showed that the declined BP shown significantly less clavicular portion activation and high sternal portion activation than horizontal BP [35,50,53]. These results are in line of results of previous research, such as those of Barnett et al. [66], that showed significant differences in favor of the sternal pectoral and other studies that showed similar levels of activation [50,53,69]. In this question Barnett et al. [66] only found significant differences in the grip of 200% BAD, while with a narrow grip of 100% BAD they did not find this significance, so we must take into consideration the results of Saeterbakken et al. [69], since it presents the same with the average of different widths of grip, thus being able to be influenced.

The inclined variant of the BP indicated significantly less activation of the sternal portion compared to the horizontal BP [35,50,53]. These data are in line with the findings of several authors where they showed a detrimental effect on the activation of the sternal portion as the slope increased [50,66,74,75]. In contrast, the clavicular portion showed no significance against the significant results found by Coratella et al. [50], and Lauver et al. [53] found specifically only during 26 to 50% of the contraction movement, therefore it is important to analyze each of the variations in the different times of the movement. On the other hand, in relation to the results of this meta-analysis, Barnett et al. [66], found no difference in the clavicular portion with respect to the execution of an inclined and horizontal press. In the same line, Saeterbakken et al. [69], did not observe differences in the activation, although it is necessary to consider the angle of inclination (25°), which is inferior to the rest of articles [35,50,53]. It is possible to mark a minimum range of inclination to be able to influence in a superfluous way in the clavicular portion, although it should also be taken into consideration that angles greater than 45° can cause the opposite effect and decrease the involvement of the pectoralis major [76]. In this sense, the bench angle interferes with the activation between the pectoral muscle portions and increases the participation of other muscles such as the deltoids when there is an inclination of 45 degrees. This must be considered for the prescription of exercises according to the planned objective.

These variations between authors [31,35,49,50,53,57,66,69] may be due to modifications in the placement of the electrodes by the classification or division of the major pectoral according to different criteria. Since an electrode placement in the horizontal fibers of the sternal portion did not show significant changes between the different angles of the bench, while a significantly lower activation was observed in the inclined press if the electrode placement was carried out in the low or descending fibers of the sternal portion [35].

In training sessions, it is common to modify the traditional bench press (BP) in various ways, such as increasing instability, with the expectation of achieving different results. However, it is important to note that the outcomes of such modifications may not always align with the intended objectives. In this study, variations that introduced instability were performed with the same relative load and executed in the same plane and trajectory to prevent any changes in the results [51,56,68]. No differences were obtained in any of the subgroups and phases of contraction (concentric–eccentric) analyzed, in the execution of the press bench with different materials that could increase the instability. These changes to an unstable surface can be effective as long as the objective of execution is to obtain a greater involvement of the stabilizing muscles, due to a greater activation of these muscle groups in exercises with greater instability [51,59,68,77].

In addition, one should not forget the increased risk of accidents in unstable environments, especially in inexperienced athletes, who may not be knowledgeable about the changes in lifting load due to increased instability in execution, having no effect on increased force production [68,78–81]. Furthermore, not only is the modification of a BP usually used as an exercise to stimulate the pectoralis major muscles in a different way, also different pushing exercises are selected for very different purposes, most of them trying to implicate the pectoralis major in a similar way to the traditional BP and even increase its involvement [69].

In the results of the analysis in relation to the comparison with the push up variant [30,69], it showed a greater effect on the activation of the pectoral in the traditional BP. However, the difference in the relative load between the subgroups should be considered, because the activation was greater when pushups were performed suspended or with an elastic resistance in comparison with BP at 50% RM, changing direction from 70% RM [30]. In regard with other variants no push up, traditional BP activated pectoralis major significantly more than the variants [30,50,55,58,60,61]. However, if we focus on a specific subgroup whose variant is BP performed with dumbbells, these differences are not shown and the activation is similar [58,61]. In fact, the execution with dumbbells could have a greater range of movement, but as can be seen in the study by Welsch et al. [61], and also in the study by Solstad et al. [82], the % of activation of the pectoralis major during the complete contraction is greater in the traditional BP executed with a bar. The pectoralis major can be worked to a greater extent by achieving a higher rate of activation during the BP movement. This study highlights the need to monitor the activation range throughout the entire movement, rather than just relying on the absolute or normalized electrical activation value. Additionally, variations in pushing exercises that yield similar levels of pectoralis major activation but involve different movements can lead to significant neuromuscular adaptations [83]. These variations are important because they can induce muscle strength gains due to new neural adaptations.

In synthesis, the selection of the exercise or its modifications has to be in accordance with the needs of the training, whose main criterion is the work of a muscle, and to know that any modification of the same one can differ, although whose execution follows similar patterns of movement. In addition, appropriate execution of the bench press is important for pointing to specific muscles and preventing injuries, as demonstrated by Algra [20].

Data regarding performance markers related to muscle activation at different tilts, stability conditions and different exercises were found in some of the articles included in this review. Saeterbakken and Fimland [59] analyzed muscle strength from 1-RM in addition to muscle activation without difference in these two variables comparing stable (flat bench) and unstable (exercise ball) conditions. Goodman et al. [52] found different results, with greater strength from 6-RM and pectoralis EMG activity on a stable bench compared to a Swiss ball. Crispiano et al. [35] analyzed this same two variables, but in different tilt conditions (horizontal, inclined, and declined). No differences were found in muscle strength to all tilt conditions. EMG activity of lower part of pectoralis major was lower in inclined bench press, without difference in sternal and clavicular portions to all conditions. Calatayud et al. [48] compared EMG activity during 6-RM bench press and elastic band push-up. At baseline, there was no difference at EMG between 6-RM bench press and band push-up and the two groups showed similar gains in strength tests after the training period.

Although a strength of this study is that it is the first meta-analysis and provides a novel clarification on the effectiveness of the BP, there are some limitations. First, certain limitations may influence comparisons of EMG range of movement, such as the difference in the degree of freedom of each of the articulations implicated, the uncontrolled range of movement between different variants, the different absolute load between variants that is usually limited by muscles distinct from the pectoralis major with a stabilizing function. Even the size of the pectoralis major of each subject, may not be sufficient for the electrodes to have a sufficient surface area discriminated between the clavicular and sternal portion, which a reduced dimension of the musculature may produce that this division is not being made correctly.

## 5. Conclusions

In this study, it was found that the traditional BP performed with the bench in a horizontal position, with a grip width between 150% and 200% of the bi-acromial distance (BAD), results in greater activation of the pectoralis major in most variations compared to the same relative load. However, the declined variant leads to greater activation of the sternal portion. Therefore, the declined variant of the BP can be considered an exercise that allows for a significant increase in intensity, which is a key factor in muscle activation. It is important to note that modifying the exercise may have a justified reason, such as targeting other muscles or diversifying training, but it can also decrease the activation of the pectoralis major. These findings highlight the importance of choosing the appropriate variation of the BP to achieve specific training goals while maximizing muscle activation.

Based on the results of the systematic review and meta-analysis on the activation of the pectoralis major in different variations of the bench press exercise, the following practical recommendations can be made for trainers and researchers:

1. Grip width: A grip width between 100% BAD and 200% BAD is recommended as it results in similar activation of the pectoralis major with a reduced risk of injury compared to wider grips. Narrower grips result in significantly lower activation of the sternal portion of the pectoralis major.
2. Forearm position: The forearm position has little effect on the electrical activation of the clavicular portion of the pectoralis major. However, supination of the forearm increases the activation of the clavicular portion of the pectoralis major.
3. Inclination bench: A greater inclination in the bench press exercise results in greater activation of the clavicular portion of the pectoralis major and less activation of the sternal portion. Therefore, the choice of inclination of the bench press exercise should depend on the training goal and the muscle activation required.
4. Declined bench: The declined bench press exercise results in significantly less activation of the clavicular portion and more activation of the sternal portion of the pectoralis major compared to the horizontal bench press. Therefore, the declined bench press exercise is recommended for targeting the sternal portion of the pectoralis major.
5. Risk of injury: A grip width greater than 200% BAD increases the risk of shoulder abduction, which can result in chronic or acute injury. Similarly, a narrow grip can increase the risk of injury by causing rotation of the elbow in the mid-plane. Therefore, trainers should consider the risk of injury when selecting the grip width for their clients.

By following these recommendations, trainers can tailor their exercise programs to optimize the activation of the pectoralis major while minimizing the risk of injury. Researchers can also use these recommendations to design studies that compare the activation of the pectoralis major in different variations of the bench press exercise.

## 6. Patents

The results of this study were taken into account for the design of a new machine that will more effectively and safely activate the pectoralis muscle, with the following registered patent: Publication n° ES1296848 (U); request n° U202231979; (http://invenes.oepm.es/InvenesWeb/detalle?referencia=U202231979) (accessed on 1 April 2023).

**Author Contributions:** Conceptualization, P.J.M.-P.; methodology, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; software, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; validation, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; formal analysis, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; investigation, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; resources, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; data curation, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; writing—original draft preparation, A.L.-V., N.G.-G., R.G.d.S.V., and P.J.M.-P.; writing—review and editing, N.G.-G., R.G.d.S.V., and P.J.M.-P.; visualization, A.L.-V., N.G.-G., F.J.O.-C., R.G.d.S.V., and P.J.M.-P.; supervision, P.J.M.-P.; project administration, P.J.M.-P.; funding acquisition, P.J.M.-P. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Universidad Católica San Antonio de Murcia (protocol code CE111908), and is part of the project ref: CFE/CO/05-17.

**Informed Consent Statement:** Not applicable.

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## Abbreviations

| | |
|---|---|
| AI | angle of inclination |
| BAD | biacromial of distance |
| BP | bench press |
| COM | complete |
| CON | concentric |
| CPM | clavicular pectoralis major |
| ECC | eccentric |
| GW | grip width |
| HBP | horizontal bench press |
| ISO | isometric |
| mV | millivolts |
| MVC | maximum voluntary isometric contraction |
| OP | other modalities of pectoral exercises or bench press |
| PM | pectoralis major |
| RM | repetition maximum |
| RMS | root mean square |
| SC | stability condition |
| SD | standard deviation |
| SPM | sternocostal pectoralis major |
| TE | type of exercise |
| TG | type of grip |
| US | university student |
| WTE | weight training experience |
| μV | microvolts |

## Appendix A. Search Strategy

| PubMed/Medline | SPORTDiscus | Web of Science |
|---|---|---|
| (pectoralis muscles OR pectoral muscle) AND (exercise OR bench press OR measures OR assessment OR push movements OR push exercises OR chest press) AND (muscle activity OR electromyography OR EMG) | (pectoralis muscles OR pectoral muscle) AND (exercise OR bench press OR measures OR assessment OR push movements OR push exercises OR chest press) AND (muscle activity OR electromyography OR EMG) | (pectoralis muscles OR pectoral muscle) AND (exercise OR bench press OR measures OR assessment OR push movements OR push exercises OR chest press) AND (muscle activity OR electromyography OR EMG) |

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