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The Effects of Different Types of External Load Equipment on Muscle Activation Comparing Two Bench Press Exercises Variations

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ABSTRACT

Background: Exercise selection plays a key role in the muscle recruitment pattern of different muscles groups, and the type of external load system may affect the muscle demand due to varying joint torques. **Methods:** This study aimed to compare the muscle activation of the main muscle groups involved in the bench press performed with two different types of external resistance, a free-weight (i.e., dumbbell), and a pulley system (i.e., cable), in trained individuals. Twelve resistance-trained young adults (26±4.7 years; 26.6±2.0 kg/m^2) performed one set of 10 maximal repetitions (RM) with 75% 1RM in dumbbell bench press (DBP) and cable bench press (CBP). The muscle activity of the pectoral major (PM), anterior deltoid (AD), bicep brachii (BB), and triceps brachii (TB) was recorded with surface electromyography (EMG), and the maximal voluntary isometric contraction (MVIC) was assessed for each muscle group. The Mann-Whitney U test was used with $p \leq 0.05$. **Results:** There were no significant differences in muscle activity for PM and AD among the exercises ($p > 0.05$). However, the BB showed greater activity on the CBP ($p \leq 0.05$), and the activation of the TT was higher on the DBP ($p \leq 0.05$). **Conclusions:** The results suggest that for resistance-trained individuals, the PM and AD were similarly recruited in these two exercises. Nevertheless, the CBP was superior to the BB muscle activity, and the DBP was superior to the TB muscle activity.

Keywords: Electromyography, Resistance training, Free-weight, Pulley system, Pectoral major, Trained individuals.

INTRODUCTION

High levels of muscle strength play an important role in improving the activities of daily in several populations [1]. For athletes, the necessity to increase strength and muscle hypertrophy is critical, as the ability to produce submaximal to maximal force is often required during sports practice tasks [2]. Resistance training (RT) is the main mode of exercise used to enhance muscle adaptations, leading to significant increases in muscle strength and hypertrophy [3]. Exercise selection is a critical component of a strength training plan [4], manipulated to target a specific muscle group [5]. Additionally, the equipment used in the RT could differ either in free-weights or machines-based exercises, which both show different physiological and muscle recruitment patterns [5,6].

The bench press exercise is widely used to improve muscle strength and hypertrophy in the trunk muscles [7]. This multi-articular exercise entails a horizontal abduction of the scapular-humeral joint and an elbow extension [8], performed on the transversal plane along the longitudinal axis [9]. The primary muscle motors involved are the pectorals major (PM), the anterior deltoid (AD), the medial deltoid, and the triceps brachii (TB) [10]. However, the PM and the TB exhibit greater myoelectrical activity than AD [11].

In RT, various external load forces are generated by free-weight, machines-based, or pulley system machines. Thus, some considerations should be taken into account. In exercises with free-weights, the line of action of the resistance is always vertical. In contrast, with pulleys, the line of action of the resistance follows the cable that connects the hand of the subject to the pulley [12]. Exercises performed on machines can interfere with muscle recruitment because exercises with free-weights require greater control, leading to increased activation in the stabilizing muscles [5,10]. Also, it is assumed that the use of machines-based exercises elicits a greater overload on the primary motor muscle by reducing the action of muscle stabilizers [5,13]. This issue was verified through the reduction of AD and medial deltoid activity during the bench press on the machine. However, there were no significant differences between the bench press machine and the bench press with free-weights on the activation of PM [10]. Similar findings were observed for the PM and AD activity during the barbell bench press, dumbbell fly, and dumbbell bench press (DBP) [14]. Likewise, this was observed for the bench press performed on the smith-machine for PM and AD, although the authors found significant differences in the biceps brachii (BB) and TB among the barbell bench press and DBP [15]. On the other hand, the pulley system allows a major transfer for activities of daily living and a greater range of motion [16], which may permit a greater range of motion during the exercise. This could be beneficial for strength gains and muscle hypertrophy [17], although it does not allow a large amount of external load on the exercise [9]. The exercises involving the glenohumeral performed in the pulley system allow a greater range of motion, as the shoulder can be fully adducted at the endpoint of the concentric phase, where the PM has its largest moment arm [9].

Nevertheless, there is a lack of literature on studies that propose to evaluate muscle activation using different types of external load, especially between free-weights and pulley systems by cables, when the objective is to recruit a given muscle group. Therefore, the purpose of this study was to compare the level of muscle activity of diverse trunk muscles between two bench press exercise variations performed with different types of external load, such as free-weight (i.e., dumbbells) and pulley system (i.e., cables), in resistance-trained males.

METHODS

Experimental approach to the problem

This randomised study with repeated measures was conducted in two sessions, each one separated by at least three to seven days. The first session was dedicated to the pre-test and a familiarisation strategy, where the exercise technique was explained to the participants, and the 10 maximal repetitions (RM) test was performed for both exercises. In the second session, a specific warm-up was done, and after that was performed a set of 10RM in the DBP and in the cable bench press (CBP), and the muscle activity of PM, AD, BB and TB was recorded, due to their major contribution to the movement (McCaw & Friday, 1994), and after a passive rest the maximal voluntary isometric contraction (MVIC) was assessed. These data were recorded using surface electromyography (EMG). The order of exercise was randomised between the participants in the familiarization session and that order was followed in the experimental session to avoid bias in the EMG results. All testing involving EMG was performed during the experimental session to prevent changes in electrode placement and to improve the reliability of the data. The subjects were advised to avoid physical exercise demanding the tested muscles groups, at least 48 hours before the test.

Participants

A convenience sample of 12 resistance-trained participants was recruited to participate in this study. All participants, aged between 18 to 30 years old, had experience in continuous resistance training for at least 1 year (minimum 3 sessions/ week) and reported implementing some bench press variation in their training routine schedule. All participants were excluded if reported any kind of musculoskeletal injury or disorder and with a history of injuries (with residual symptoms of pain, or weakness) in the trunk or upper limbs. The baseline characteristics are presented in Table 1. The participants were informed of the risks and benefits of the study before any data collection and then signed a written informed consent, and voluntarily agreed to participate in this study. All procedures were approved by the Polytechnic Institute of Beja ethics committee (CEIPBeja).

Exercise technique

For DBP the participants were positioned in dorsal decubitus on a bench with five contact points with the bench and floor (nape, shoulder girdle, glutes, and feet) holding a pair of dumbbells with a pronated grip. They were instructed to lift the dumbbells with the shoulders abducted around 60 degrees until full elbow extension and at the end of the concentric phase, the dumbbell had to be aligned with the shoulder and above the chest. During the eccentric phase, the dumbbell had to move down in a divergent mode until reached as close as possible to the chest level, always on the elbow joint. During the CBP the participants were positioned seated against a bench with 80 degrees of inclination, always with the back and glutes in contact with the bench and the feet with the floor holding the handle of the pulley in pronation with the shoulder abducted around 60 degrees. They were instructed to push the handle forward with the forearms aligned with the cable until the hands reached in front of the chest on the concentric phase. The eccentric phase was controlled until the handles reached as close as possible to the chest. All exercises were performed to the full range of movement, and each repetition lasted approximately 4 seconds, with 1–2 seconds for the concentric and 2–3 seconds for the eccentric phase. The CBP and MVIC tests were performed in a cable pulley system (Model: Black SeriesB200 functional trainer; Brand: Titanium Strength, USA). The exercise techniques of DBP and CBP are presented in Figures 1 and 2, respectively. Also, the biomechanical differences between exercises can be seen in both Figures 1 and 2.

Procedures

Familiarization and 10 RM testing

During the participants' initial visit to the laboratory, they were instructed to undergo a familiarization protocol for both exercises. In this protocol, participants received verbal and visual explanations from the researcher about the exercises' techniques. After that, several sets were completed as needed to ensure the correct technique with a light load (less than the estimated 50% of 1RM). Subsequently, the 10RM test was performed for both exercises according to the procedures used by 18 to determine the maximal load possible for performing ten consecutive repetitions with a movement tempo of 1-2 for concentric and 2-3 for eccentric phase. If more than ten repetitions were completed, an increment of 4 to 10 kg in the external load was made and after a passive rest of five minutes, the participants were instructed to make a new attempt, to minimize the fatigue effects, as recommended in previous research 19. Only three attempts were allowed for each exercise. The order of exercises was randomised at the beginning of the session to ensure the randomness of the experiment and a passive rest of 10 minutes was given between exercise tests.

Experimental testing and maximal voluntary isometric contraction

After a specific warm-up, consisting of 2 sets of 20 repetitions with 40% of 1RM, estimated with the 10RM test. The participants were instructed to perform one set of ten repetitions with 75% of 1RM. The exercise order was defined in the first session and the interval between exercises was five minutes. The movement tempo was the same as the cadence used in the 10 RM test. After 15 minutes of passive rest, the MVIC for each muscle group tested was

Table 1. Physical characteristics of the participants.

Characteristics	Mean ± SD
Age (years)	26.4 ± 4.7
Weight (kg)	84.3 ± 4.1
Height (cm)	178.3 ± 5.3
BMI (kg/m2)	26.6 ± 2.0
Resistance training experience (years)	4.6 ± 1.8
DBP 10RM (Kg)	32.0 ± 5.9
CBP 10RM (Kg)	46.9 ± 7.5

Note: The data are presented with the mean ± SD. BMI=Body mass index; RM=Maximal repetition; DBP=Dumbbell bench press; CBP=Cable bench.

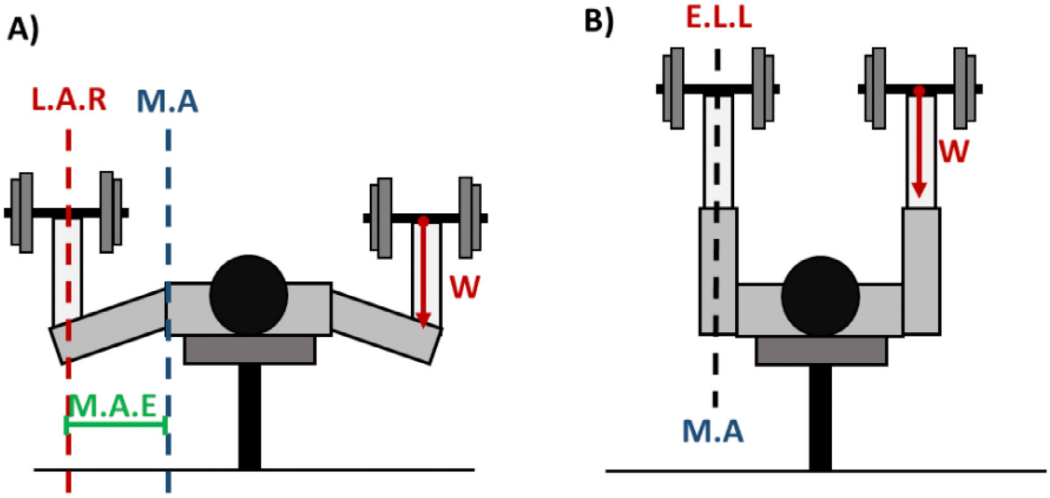

Figure 1. DBP exercise representation. A=initial phase; B=End phase; DBP=Dumbbell bench press; W=Weight force vector; M.A=Movement axis; M.A.E=Moment arm of external load; E.L.L=External load line of action.

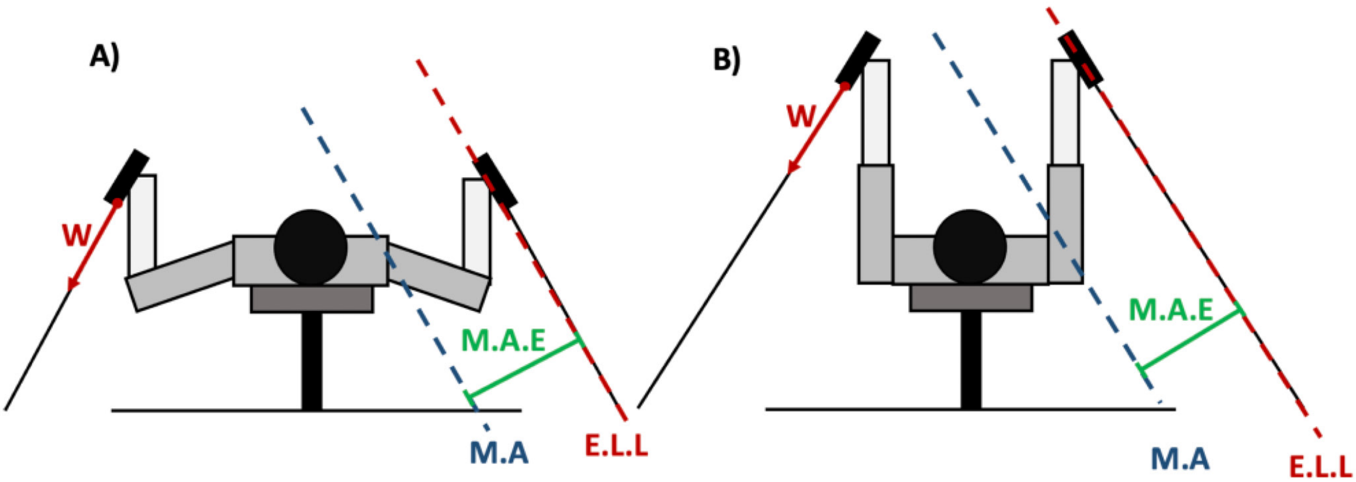

Figure 2. CBP exercise representation. A=initial phase; B=End phase; CBP=Cable bench press; W=Weight force vector; M.A=Movement axis; M.A.E=Moment arm of external load; E.L.L=External load line of action.

recorded, according to the procedures used by [20].

The MVIC was conducted to normalize the EMG data. Three maximal isometric contractions were recorded for the muscles PM, AD, TB, and BB. Each MVIC was sustained for 6 seconds against an external load at the maximal voluntary force possible with 2 minutes of passive rest between MVICs 21. The MVICs were performed with a pulley system and the weight stack of the cable pulley system was secured with straps to disable cable movement. For the PM the MVIC was recorded with the participant seated on the bench with the shoulder flexed at 45 degrees of horizontal adduction. The AD MVIC was performed while standing with the shoulder at 90 degrees of flexion. For the TB and BB, the MVIC was taken standing up with the shoulders at neutral position and the elbow at 90 degrees of flexion. A pronated grip was used for TB, and a supinated grip for BB, respectively. All subjects received strong verbal encouragement during the MVIC.

Recording the EMG data

Surface EMG was employed to assess the muscle activity of PM, AD, BB and TB. Muscle activity was captured using the BioPlux research device (Plux wireless biosignals S.A, Lisbon, Portugal) with 12-bit analogue channels and a sampling frequency of 1000 Hz, using dual differential electrode cables. Self-adhesive double-pressure electrodes were used to collect the EMG signal, with the electrodes having an adhesive area of 4x2.2 cm, a conductive area diameter of 1 cm, and placed with a 2 cm distance between them. These electrodes were connected to active bipolar sensors emgPLUX with an amplitude gain of 1000, an analogue filter from 25 to 500 Hz, and a common mode rejection rate of 110 dB. A reference electrode was also employed for data collection. The sensors were connected via Bluetooth to a laptop through the surface EMG device.

To conduct the surface EMG, hair in the region of electrode placement was shaved, and the skin was cleaned with 70% alcohol to remove oiliness and dead cells from the skin's surface, before the electrode placement. The self-adhesive electrodes were positioned in a standing position five minutes after skin preparation. These electrodes were placed on the dominant arm side of the participants in the belly of the muscle along the direction of the muscle fibres [22,23]. The negative electrode (black) was positioned closest to the origin, while the positive electrode (red) was placed closest to the insertion, according to the manufacturer's instructions (PLUX Biosignals S.A.: https://www.pluxbiosignals.com/). The electrode placement of the PM followed Cram's manual for sternal pectoralis major 24. For the placement of the AD, TB long head, and BB the orientation was based on the European Project "Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles" (SENIAM: https://www.seniam.org/), the detailed information of electrode placement is presented in table 2. The positioning of the electrodes was verified by palpation and muscle contraction and the reference electrode was placed on the opposite side of the other electrodes [22].

EMG data analysis

The software MonitorPlux (Version 2.0) was employed to view and collect the surface EMG signal. The raw digitalized surface EMG data was filtered using a 4th order band filter between 20 Hz and 100 Hz, with a window of 1 second. The mean value, obtained through the root mean square (RMS) of each repetition in both concentric and eccentric phases, was used for data analysis. This value served as a comparative parameter with the higher intensity value found during MVIC for each of the analysed muscles [25].

The first two repetitions were excluded from the analysis, to ensure that the data obtained would not be affected by any interference, and the analysis was conducted solely with repetitions performed with a correct cadence and technique. To prevent fatigue from potentially compromising the data quality, leading to either a loss of movement tempo or harm to the exercise technique, the last two repetitions were also excluded from the analysis, according to [26], to safeguard the reliability of the data.

Statistical analysis

The mean and standard deviation (SD) were calculated for the sample characterization data and 95% confidence intervals were adopted. The normal distribution and homoscedasticity of the sample were assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The sample did not meet the criteria for normal distribution, so the non-parametric alternative of the T-test, the Mann-Whitney U test, was employed to compare the means between groups (Exercise x Muscles). The alpha criterion for significance was set at $p \leq 0.05$. The sample power calculations were not performed for this study. All data processing was carried out using the Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, Version 27.0, IBM Corp., Armonk, NY, USA). The figures were formatted with Microsoft Excel.

RESULTS

Muscle activation EMG

Figure 3 and Table 3 present the values in percentage of normalized RMS for PM, AD, BB, and TB muscles during the SPP and SPH exercises.

Table 2. Anatomical references for electrode placement.

Muscle group	Electrode placement
PM [24]	Place horizontally on the chest wall over the muscle mass that arises (approximately two cm out from the axillary fold)
AD (SENIAM)	One finger width distal and anterior to the acromion.
BB (SENIAM)	line between the medial acromion and the fossa cubit at 1/3 from the fossa cubit.
TB (SENIAM)	50% on the line between the posterior crista of the acromion and the olecranon at two finger widths medial to the line.
Reference electrode (SENIAM)	Acromion

Note: PM=Pectoralis major; AD=Anterior deltoid; BB=Biceps brachii; TB=Triceps brachii; SENIAM=Surface electromyography for the Non-Invasive Assessment of Muscles

The results indicated a higher activation of BB in the CBP (26.6% ± 2.5) compared to the DBP (19.9% ±1.6), U=35.0, $p \leq 0.05$. The analysis also showed higher activation of TB in the DBP (15.5% ±2.3) compared to CBP (10.7% ± 2.1), U=35.5, $p \leq 0.05$. The rest of the other measures were not significant ($p > 0.05$), as shown in Figure 3.

DISCUSSION

The purpose of this study was to compare the level of muscle activity in several trunk muscles between two variations of the bench press exercise with different external load profiles, free-weight (i.e., dumbbell) and pulley system (i.e., cable), to assess the differences in muscle participation. The main results showed a superior muscle activation of TB in the DBP, while the BB was more activated in CBP. However, both exercise variations demonstrated similar muscular activation of PM and AD muscles.

During the DBP, there is a greater activation of the AD and PM, followed by the recruitment of the TB and the BB [15,27,28]. Moreover, this exercise showed a delay onset muscle soreness in PM, as an increase in muscle thickness immediately after the exercise bout [6]. Concerning muscle activation, measured through the surface EMG in the muscles PM, AD, TB, and BB during DBP, a higher muscle activity of BB was observed in comparison with the TB [15,28]. For the AD and PM muscles, it was the AD that presented the greatest activation during the DBP [28], aligning with similar findings to our results. Through the kinetic analysis of the DBP, it was verified that when using dumbbells instead of barbell, there is greater instability, causing an increase in the internal torque produced by the stabilizing muscles of the shoulder, which could lead to an activation of the long head of the BB [29]. This may be the main explanation for the BB activation found in DBP. In another study focused on evaluating the muscle activation of PM, AD, and TB in DBP, it was found that PM exhibited the highest activation with significant differences among the other muscles [27]. These results differ from the findings in the present study, where AD showed higher activation, although without significant differences compared to PM. Performing exercises in the pulley system favours a greater range of motion compared to the bar or machines and has a greater transfer to activities of daily living [16]. The authors also compared the muscle activity using surface EMG in PM, AD, TB, BB, rectus abdominis and external oblique abdominal during the standing CBP, it was found that AD exhibited the highest EMG signal, followed by TB, PM and lastly by BB [16]. Although the CBP exercise was performed standing, the results were similar to our results, where the AD had greater activation than PM, however, without significant difference between them. Nevertheless, for BB and TB, the results were different, since in our study BB showed a greater tendency of activation than TB. In another study where the muscle activity of the rectus abdominis, erectors of the spine, external oblique abdominal, PM, and AD was recorded during the standing and unilateral CBP exercise, AD exhibited the greatest activation, albeit without statistical differences.

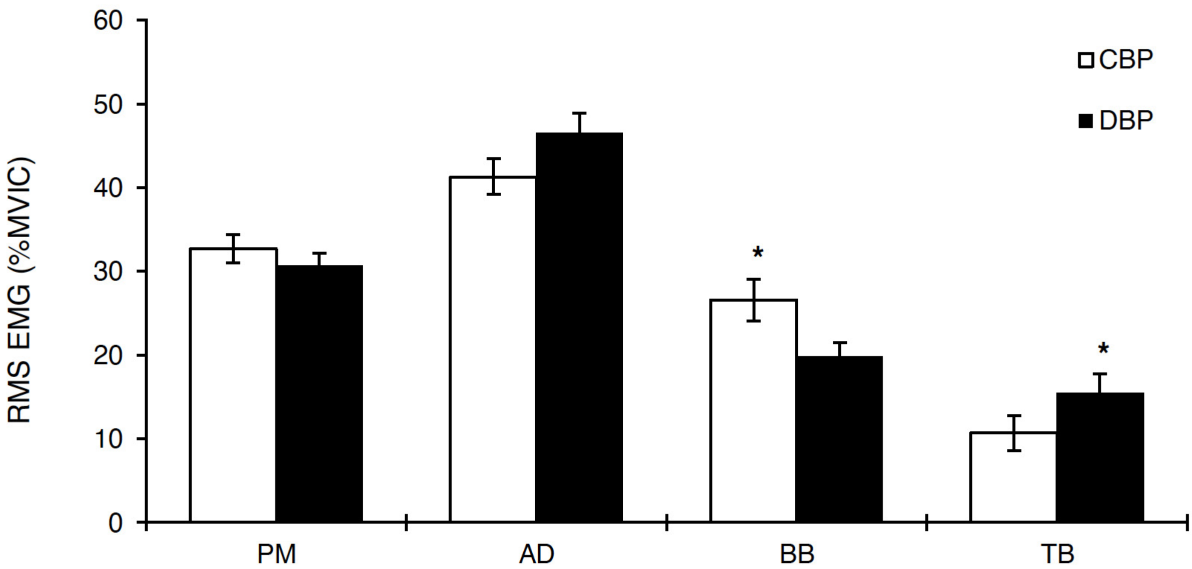

Figure 3. RMS EMG normalized values (%MVIC) during the DBP and CBP for all tested muscle groups. *Represents $p \leq 0.05$ between DBP and CBP. RMS=Root mean square; EMG=Electromyography; MVIC=-Maximal voluntary isometric contraction; PM=Pectoralis major; AD=Anterior deltoid; BB=Biceps brachii; TB=Triceps brachii; DBP=Dumbbell bench press; CBP=Cable bench press.

Table 3. Values of muscular activation using EMG with normalized RMS for the different muscles analysed.

Muscles	CBP	DBP	Δ (%)	*p*
PM (%)	32.7 ± 1.7	30.7 ±1.5	2.0	0.083
AD (%)	41.3 ± 2.1	46.5 ±2.4	5.2	0.260
BB (%)	26.6 ± 2.5	19.9 ±1.6	6.7	0.033*
TB (%)	10.7 ± 21	15.5 ±2.3	4.8	0.035*

*Note: Data are presented as mean ± SD. * - represents p≤0.05. Δ – represents the percentual of variation between exercises. RMS = Root mean square; EMG = Electromyography; PM = Pectoralis major; AD = Anterior deltoid; BB = Biceps brachii; TB = Triceps brachii; DBP = Dumbbell bench press; CBP = Cable bench press.*

The core muscles also showed a higher level of activation than PM, possibly due to the exercise being performed standing and unilaterally, creating a greater instability and a twisting force in the trunk [30]. Despite the differences in exercise execution, the results showed a similar tendency to our results. The results of our study could be explained by the presence of a greater moment arm during the end phase of the concentric muscular action in the pulley system, despite the larger moment arm occurring between the initial and end phases of the movement, which is the point when the line of action of the cable is perpendicular to the performer's hand 9. Additionally, a significant activation of BB was found in the CBP, likely attributed to the exercise being performed on the pulley system, where the force of the weight aligns with the direction and senses of the cables [12]. As the direction of the weight vector is oblique to the movement, it induces a torque in the elbow joint, forcing it to perform an extension against this force. In opposition to this force, the BB acts by generating an isometric elbow flexion force [31], However, further studies are needed to evaluate the myoelectric response of the BB in exercises performed with cables.

When comparing the two exercises, despite both showing significant activation of BB, it was in the CBP exercise where the greatest activation was found, approximately 6.7% higher than in the DBP, with significant differences. Regarding TB, it was in the DBP where this muscle presented significantly greater activation, about 4.8% more than in the CBP. However, for the PM and AD, there were no significant differences in muscle activity among exercises. Nevertheless, AD showed higher mean values of normalised RMS. Thus, the results suggest that both exercise variations recruit PM and AD muscles with similar magnitude, indicating their equal efficiency in activating these muscles These results can be explained by the kinetics of movement, where a larger moment arm for a given muscle leads to a greater torque produced by the muscle for the same magnitude of external force [12]. This higher torque results in a greater force produced by the muscle, positively correlated with the magnitude of muscle activation measured by EMG [32]. Nevertheless, more studies are needed to confirm the results of the present study, as this is the first study, to our knowledge, which analysed these two variations, the dumbbells and pulley system with cables. However, when compared to other exercises some evidence supports our findings. One study compared the muscular activation by surface EMG between standing CBP and machine-based bench press performed with 8RM showing that both exercises are equally effective in recruiting PM and AD, with no differences in EMG levels. Although, the machine-based bench press showed a higher activity on TB muscle while the CBP revealed a greater activation of BB muscle in the standing CBP [16]. Despite of one exercise being performed on a disc-guided machine instead of dumbbells, the results were similar to our findings, when compared with the standing CBP. Another research which assessed the EMG during 1RM of the unilateral standing CBP and the barbell bench press found that unilateral standing CBP promoted higher, but not significant, activity in AD compared to the barbell bench press in contrast the barbell bench press showed a higher activation in PM [30]. Lastly, another paper evaluated the EMG of PM, AD, TB, and BB in the DBP, barbell bench press and machine-based bench press for several sets of 10RM, demonstrating that DBP elicited greater activity of BB than the other two variations. Specifically for PM, the muscle activity was only higher than the barbell bench press, TB showed larger activation in the barbell bench press and in the machine-based bench press when compared with DBP, and for the AD, there were no differences between the exercises in the first set [28]. The findings of all these studies are in line with our results, showing a similar response and pattern in EMG activity of PM, AD, TB, and BB during the motor task of pushing against various external load types. Despite these consistent trends, it is important to note that more research is required to draw more conclusions.

This investigation has some limitations that should be considered before drawing conclusions. The sample consisted of healthy resistance-trained subjects, and it's important to acknowledge that individuals with different characteristics (such as varying ages, training levels, health conditions, etc.) may respond differently. Thus, further research is needed to evaluate these different populations. Besides that, the calculation of sample power was not performed, then the statistical power may be affected. Additionally, our results focused on analysing acute levels of EMG, and therefore, conclusions regarding chronic adaptations, such as hypertrophic responses or muscular strength adaptations, should not be made. Longitudinal research is necessary to assess these adaptations over time. To our knowledge, this was the first study aiming to compare these two exercises with different types of external load kinematics, which makes it challenging to draw strong conclusions. Future research in this field is needed to explore other exercises and muscle groups to enhance our understanding of the effects and differences in biomechanics, kinesiology, and chronic adaptations when using either free-weights or pulley systems.

PRACTICAL APPLICATIONS

Therefore, if the goal is to stimulate the PM and the AD, both exercises will be good options for coaches to include in their training plans. Coaches should pay attention to this aspect and consider incorporating both exercises when calculating set-volume, not only for the PM muscle but also for the AD muscle. Recent literature suggests that in multiarticular exercises, which argues that the training volume should be fractionated by the muscles involved in the movement, not just focusing on the primary muscles. However, to calculate the training volume the magnitude of stress caused by the exercise on the muscles and EMG data should be considered, and both play an important role in determining that stress [33]. Therefore, the results of this study are valuable to coaches and physiotherapists when they are selecting the exercises for PM, as there are other muscles recruited simultaneously. Such as, the BB and the TB in the two bench press variations analysed, may influence the muscular action or movement, in fatigue mechanisms and force production. Coaches and physiotherapists can use this information to tailor exercises to individual goals and needs.

CONCLUSIONS

For resistance-trained subjects, the exercises DBP and CBP elicited similar levels of muscle activity between PM and AD, suggesting that both exercises may equally recruit both muscle groups. Additionally, the DBP was superior to CBP in TB activity, while the CBP caused greater activation of BB compared to the DBP. Overall, when comparing both exercises, the DBP required superior muscle activity and force production of TB muscle, whereas the CBP required superior muscle activity and force production of BB muscle.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHORS CONTRIBUTIONS

Conceptualization, M.R, R.M, L, N. Data collection, M.R. Data analyses, M.R, RM. Writing-Original Draft Preparation, M.R, R.M. Writing-Review & Editing, M.R, R.M, L, N. All authors have read and agreed to the published version of the manuscript.

REFERENCES

1. Rantanen T, Avlund K, Suominen H, Schroll M, Frändin K, Pertti E. Muscle strength as a predictor of onset of ADL dependence in people aged 75 years. Aging Clin Exp Res. 2002;14:10-15. https://pubmed.ncbi.nlm.nih.gov/12475129/
2. Maughan RJ, Watson JS, Weir J. Strength and cross-sectional area of human skeletal muscle. J Physiol.

1983;338(1):37-49. https://doi:10.1113/jphysiol.1983.sp014658
3. Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of Low- vs. High-Load Resistance Training on Muscle Strength and Hypertrophy in Well-Trained Men. J Strength Cond Res. 2015;29(10):2954-2963. https://doi:10.1519/JSC.0000000000000958
4. Solstad TE, Andersen V, Shaw M, Hoel EM, Vonheim A, Saeterbakken AH. A Comparison of Muscle Activation between Barbell Bench Press and Dumbbell Flyes in Resistance-Trained Males. J Sports Sci Med. 2020;19(4):645-651. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7675616/
5. American College of Sports Medicine. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009;41(3):687-708. https://doi:10.1249/MSS.0B013E3181915670
6. Ferreira D V, Ferreira-Júnior JB, Soares SRS, et al. Chest Press Exercises With Different Stability Requirements Result in Similar Muscle Damage Recovery in Resistance-Trained Men. J Strength Cond Res. 2017;31(1):71-79. https://doi:10.1519/JSC.0000000000001453
7. Castillo F, Valverde T, Morales A, Pérez-Guerra A, de León F, García-Manso JM. Maximum power, optimal load and optimal power spectrum for power training in upper-body (bench press): a review. Rev Andal Med Deport. 2012;5(1):18-27. https://doi:10.1016/S1888-7546(12)70005-9
8. van den Tillaar R, Ettema G. The “sticking period” in a maximum bench press. J Sports Sci. 2010;28(5):529-535. https://doi:10.1080/02640411003628022
9. Campos Maurício. Biomecânica Da Musculação. Sprint; 2000.
10. McCaw ST, Friday JJ. A Comparison of Muscle Activity Between a Free Weight and Machine Bench Press. The Journal of Strength & Conditioning Research. 1994;8(4). https://journals.lww.com/nsca-jscr/Fulltext/1994/11000/A_Comparison_of_Muscle_Activity_Between_a_Free.11.aspx
11. Stastny P, Gołaś A, Blazek D, et al. A systematic review of surface electromyography analyses of the bench press movement task. PLoS One. 2017;12(2):e0171632. https://doi:10.1371/journal.pone.0171632
12. Ruivo R, Soncin R. Treino de Força - Seleção de Exercícios e Sua Análise Cinesiológica e Biomecânica. (Ruivo R, ed.). Independently published; 2021.
13. Lander JE, Bates BT, Sawhill JA, Hamill J. A comparison between free-weight and isokinetic bench pressing. Med Sci Sports Exerc. 1985;17(3):344-353. https://journals.lww.com/acsm-msse/Abstract/1985/06000/A_comparison_between_free_weight_and_isokinetic.8.aspx
14. Welsch EA, Bird M, Mayhew JL. Electromyographic Activity of the Pectoralis Major and Anterior Deltoid Muscles During Three Upper-Body Lifts. The Journal of Strength and Conditioning Research. 2005;19(2):449. https://doi:10.1519/14513.1
15. Saeterbakken AH, van den Tillaar R, Fimland MS. A comparison of muscle activity and 1-RM strength of three chest-press exercises with different stability requirements. J Sports Sci. 2011;29(5):533-538. https://doi:10.1080/02640414.2010.543916
16. Signorile JF, Rendos NK, Heredia Vargas HH, et al. Differences in Muscle Activation and Kinematics Between Cable-Based and Selectorized Weight Training. J Strength Cond Res. 2017;31(2):313-322. https://doi:10.1519/JSC.0000000000001493
17. Pallarés JG, Hernández-Belmonte A, Martínez-Cava A, Vetrovsky T, Steffl M, Courel-Ibáñez J. Effects of range of motion on resistance training adaptations: A systematic review and meta-analysis. Scand J Med Sci Sports. 2021;31(10):1866-1881. https://doi:10.1111/sms.14006
18. Simão R, Farinatti P de TV, Polito MD, Maior AS, Fleck SJ. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. J Strength Cond Res. 2005;19(1):152-156. doi:10.1519/1533-4287(2005)19<152:IOEOOT>2.0.CO;2
19. Kraemer WJ. A Series of Studies—The Physiological Basis for Strength Training in American Football: Fact Over Philosophy. The Journal of Strength and Conditioning Research. 1997;11(3):131. https://doi:10.1519/1533-4287(1997)011<0131:ASOSTP>2.3.CO;2
20. Campos YAC, Vianna JM, Guimarães MP, et al. Different Shoulder Exercises Affect the Activation of Deltoid Portions in Resistance-Trained Individuals. J Hum Kinet. 2020;75:5-14. https://doi:10.2478/hukin-2020-0033
21. 21. Ekstrom RA, Soderberg GL, Donatelli RA. Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface EMG analysis. Journal of Electromyography and Kinesiology. 2005;15(4):418-428. https://doi:10.1016/j.jelekin.2004.09.006
22. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography and Kinesiology. 2000;10(5):361-374. https://doi:10.1016/S1050-6411(00)00027-4
23. Behm DG, Leonard AM, Young WB, Bonsey WAC, MacKinnon SN. Trunk Muscle Electromyographic Activity With Unstable and Unilateral Exercises. The Journal of Strength and Conditioning Research. 2005;19(1):193. https://doi:10.1519/1533-4287(2005)19<193:TMEAWU>2.0.CO;2
24. Criswell E. Electrode Placements. In: Cram’s Introduction to Surface Electromyography. 2nd ed. Jones and Bartlett Publishers; 1998:307-309.
25. Castelein B, Cagnie B, Parlevliet T, Cools A. Superficial and Deep Scapulothoracic Muscle Electromyographic Activity During Elevation Exercises in the Scapular Plane. Journal of Orthopaedic & Sports Physical Therapy. 2016;46(3):184-193. https://doi:10.2519/jospt.2016.5927
26. Rocha Júnior V de A, Gentil P, Oliveira E, Carmo J

do. Comparação entre a atividade EMG do peitoral maior, deltóide anterior e tríceps braquial durante os exercícios supino reto e crucifixo. Revista Brasileira de Medicina do Esporte. 2007;13(1):51-54. https://doi:10.1590/S1517-86922007000100012
27. Silva S, Gonçalves M, Leme M, Bérzin F. Supino Plano com Halteres: Um Estudo Eletromiográfico. Motriz. 2001;7(1):1-5. https://www1.rc.unesp.br/ib/efisica/motriz/07n1/SarahSilva.pdf
28. Farias D de A, Willardson JM, Paz GA, Bezerra E de S, Miranda H. Maximal Strength Performance and Muscle Activation for the Bench Press and Triceps Extension Exercises Adopting Dumbbell, Barbell, and Machine Modalities Over Multiple Sets. J Strength Cond Res. 2017;31(7):1879-1887. https://doi:10.1519/JSC.0000000000001651
29. Krosshaug T. Revealing “secrets”of strength training exercises with kinetic analyses. In: 8th International Conference on Strength Training (ICTS 2012). Norwegian School of Sport Sciences; 2012:81-83.
30. Santana JC, Vera-Garcia FJ, McGill SM. A Kinetic and Electromyographic Comparison of the Standing Cable Press and Bench Press. The Journal of Strength and Conditioning Research. 2007;21(4):1271. https://doi:10.1519/R-20476.1
31. Kleiber T, Kunz L, Disselhorst-Klug C. Muscular coordination of biceps brachii and brachioradialis in elbow flexion with respect to hand position. Front Physiol. 2015; https://doi:10.3389/fphys.2015.00215
32. Disselhorst-Klug C, Schmitz-Rode T, Rau G. Surface electromyography and muscle force: Limits in sEMG–force relationship and new approaches for applications. Clinical Biomechanics. 2009;24(3):225-235. https://doi:10.1016/j.clinbiomech.2008.08.003
33. Schoenfeld B, Grgic J, Haun C, Itagaki T, Helms E. Calculating Set-Volume for the Limb Muscles with the Performance of Multi-Joint Exercises: Implications for Resistance Training Prescription. Sports. 2019;7(7):177. https://doi:10.3390/sports7070177