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Research article

A Comparison of Muscle Activation between Barbell Bench Press and Dumbbell Flyes in Resistance-Trained Males

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Abstract
The purpose of the study was to compare the muscle activity in the prime movers and antagonist between the barbell bench press (BBP) and the dumbbell flyes (DF) Seventeen resistance-trained men (age 22.9 ± 1.8 yrs; height 1.80 ± 0.06 m; body mass 80.0 ± 8.3 kg), with 4.8 ± 2.0 years resistance training experience, completed the study. The surface electromyographic activation was measured in four different muscles (pectoralis major, anterior deltoids, triceps brachii, and biceps brachii) during six repetition maximum loads in both exercises. To better understand eventual differences, an in-depth analysis of the fifth repetition was performed, dividing it into six phases (lower, middle, and upper phase of the descending and ascending movement). The results showed a higher muscle activation in the whole movement and the majority of the lifting phases for pectoralis major, deltoids anterior, and triceps brachii for the BBP compared to the DF (8-81 %, $p \leq 0.05$). However, the antagonist biceps brachii showed a higher muscle activation (57-86 %, $p \leq 0.05$) in the DF compared to the BBP. In conclusion, both exercises could be included in training programs, but the BBP should be emphasized because of the higher muscle activation overall. Among specific populations, were tasks based on strength and control in a horizontal shoulder flexion position with extended elbows often occurs, the DF might prove useful.

Key words: Strength training, pectoralis major, neuromuscular activation, multi-joint, single-joint.

Introduction

Exercise selection is a crucial component of resistance-training program design, and both single- and multi-joint exercises are frequently used. Single-joint exercises are often used to isolate a specific muscle or muscle group. Multi-joint exercises, however, are dependent on several muscle groups, and it is speculated that the multi-joint exercises might achieve fatigue in the synergist before the agonist, providing insufficient stimulus to the agonist (Gentil et al., 2017). Furthermore, single-joint exercises are considered to have a lower injury rate and technical demands compared to multi-joint exercises (Kraemer and Ratamess, 2004; Ratamess et al., 2009). Conversely, multi-joint exercises more closely mimic sports locomotion and daily living (Chilibeck et al., 1997).

The barbell bench press (BBP) and the dumbbell flyes (DF) are used frequently to gain strength and muscular hypertrophy in the upper-body (Baker et al., 2013; Brill et al., 2000; Castillo et al., 2012). The BBP is a multi-joint exercise that involves movement in both shoulder- and elbow joint (Van Den Tillaar and Ettema, 2010). The DF is a single-joint exercise with quite similar movement pattern in the shoulder joint with minimal movement in the elbow joint. However, little is known about the neuromuscular differences between these two exercises.

Single- and multi-joint exercises may differ biomechanically (e.g., external torque, moment arm, and kinematics), affecting the stress on the working muscles throughout the movement (Frost et al., 2010). For example, the BBP shows little to no changes in the moment arms of the shoulder during the lift (Elliott et al., 1989; van den Tillaar et al., 2012), whereas the moment arms in the DF change from the upper (short moment arm) to lower position (long moment arm) in the descending part of the lift. These changes in external torque when performing DF may result in different muscle activity throughout the movement of the prime movers (i.e., pectoralis major and deltoid anterior) when compared to the BBP.

Several studies have compared the BBP to other exercises, including pec deck (Botton et al., 2013; Rocha Júnior et al., 2007), barbell pullovers (Campos and Silva, 2014), push-ups (Calatayud et al., 2015; van den Tillaar, 2019), and shoulder press (Botton et al., 2013). However, to our knowledge, only one study has compared the BBP and the DF. Welsch et al. (2005) demonstrated similar muscle activity in the pectoralis major and anterior deltoid between the two exercises. However, the study was limited by only measuring electromyography (EMG) activity of only two muscles, analyzing only the average peak activation (100ms interval) over three non-fatigue repetitions at six repetition maximum (6RM) loads.

The degree of muscle activation elicited by an exercise is a key element to better comprehend the influence of different chest press exercises has on muscle activation in the prime movers. For specific sports (i.e., powerlifting) or movements (i.e., throwing, pressing), it could be beneficial to know where this neuromuscular stress is at its greatest regarding the range of motion (ROM) and type of muscle contraction. This could improve the specificity in the selection of upper body exercises that could be utilized towards developing overall upper body strength. However, EMG measurements have their limits (Vigotsky et al., 2018), so randomized longitudinal studies should be performed to determine the long-term benefits of different exercises.

Therefore, the aim of the study was to compare muscle activity in the pectoralis major, deltoid anterior,

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triceps brachii, and biceps brachii during training loads typical for increasing strength (6RM) in both the BBP and the DF using resistance-trained participants. A secondary aim was to provide in-depth analyses of the EMG activity, dividing repetitions into three equal parts (i.e., upper, middle, and lower phase) in the two exercises to better understand eventual differences between them. Based on the brief biomechanical analysis of the exercises, we hypothesized greater EMG activity in the pectoralis major and the anterior deltoid for the whole movement and the upper part, greater triceps brachii activity in all phases of the movement, and lower biceps brachii activity in the lower and middle phases in the BBP compared to the DF.

Methods

A within-subjects randomized, and counterbalanced crossover design was used to compare the muscle activation in the pectoralis major, deltoid anterior, biceps brachii, and triceps brachii in the BBP and the DF. The participants had two days of testing, one familiarization, and one experimental session. The 6RM loads for both exercises were determined in the familiarization session. In the experimental session, the participants lifted 6RM in both exercises with surface EMG. The exercise order was randomized prior to familiarization, and then the same order was used in the experimental session.

Participants

Seventeen resistance-trained men (age 22.9 ± 1.8 yrs.; height 180.2 ± 6.4 cm; body mass 80.0 ± 8.3 kg), with 4.8 ± 2.0 years resistance training experience completed the study. Subjects were included in the study if they were familiar with the exercises (having used both exercises frequently in their resistance-program the last six months), could perform a self-reported bench press at 1RM equal to their body weight and had no injuries prior to starting the study affecting the execution of the exercises. Subjects were fully informed (oral and in written) of the risks associated with participating in the study, and written informed consent was provided before being enrolled in the study. The subjects were free to withdraw from the study at any point without being asked any questions. All subjects were restricted from resistance training at least 48 hours before all testing. The study was approved by The Norwegian Centre for Research Data (310436) and conformed to the latest version of the Declaration of Helsinki.

Testing procedures

Initially, a familiarization session was conducted 2-5 days before the experimental test to determine 6RM in both the BBP and the DF. Before starting the 6RM testing, the participants performed a progressive warm-up. Identical warm-up procedures were conducted before the experimental tests. The loads used in the warm-up sets in the familiarization test was based on a self-reported 6RM load in the BBP. The warm-up sets consisted of 20, 12, 8, and 2 repetitions using 20, 50, 70, and 85 % of 6RM. In the experimental test, the 6RM load achieved in the familiarization test was used to determine the warm-up loads. Three to five minutes of rest was allowed between the 6RM attempts in both familiarization and experimental sessions to reduce the bias of muscular fatigue (Ratamess et al., 2007). The subject's 6RM was achieved in 1-3 attempts in both exercises. Changing exercise, the participants performed one sub-maximal (50% of 6RM) set with 3-4 repetitions to familiarize themselves with a new movement pattern (Saeterbakken and Fimland, 2013b). The order of the exercises was randomized by drawing in the familiarization test, and the same order was used during the experimental test.

When performing the BBP and the DF, the head, shoulder, and hips were supported by a bench with ~90º knee flexion (Kohler et al., 2010; Saeterbakken et al., 2011). Throughout testing sessions, the barbell and dumbbells were lowered in a controlled, but self-selected tempo. Subjects used a preferred grip in the BBP, which were noted to be kept identical in all tests. The barbell had to touch the chest lightly (no bouncing was allowed) before the elbows were fully extended (Figure 1). During the DF test, a 2-mm wide rubber band was placed on each dumbbell. In the descending part, the band was stretched and had to touch the chest to make sure the participants lowered the weights to the same position as for the BBP (Saeterbakken et al., 2011). In the DF, the elbow angle (150-160º) in the lowest position and was standardized using a protractor. The angle of the elbow joint was kept close to constant throughout the execution of the DF (Figure 2). If the subjects decreased the elbow joint angle, the 6RM attempt was terminated. Two test leaders ensured proper technique, verbal encouragement, and worked as spotters during testing.

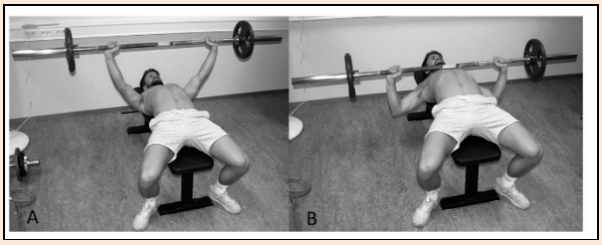

Figure 1. Barbell bench press. Top (A)- and bottom (B) position of the barbell bench press.

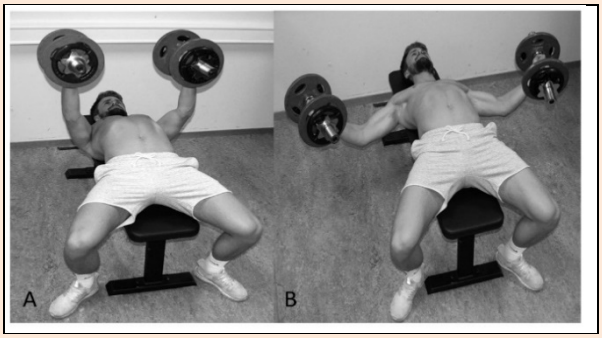

Figure 2. Dumbbell flyes. Top (A)- and bottom (B) position of the dumbbell flyes.

Electromyography

Surface EMG (Musclelab 4020e, Ergotest Technology AS, Langesund, Norway) determined muscle activation in the

pectoralis major, anterior deltoids, biceps brachii, and triceps brachii. EMG signals were sampled using gel-coated electrodes (Dri-Stick Silver circular sEMG Electrodes AE-131, NeuroDyne Medical, USA), with an 11 mm contact diameter and a 20mm center-to-center distance. Electrodes were placed on the belly of the muscle along the estimated direction of the muscle fiber. Before electrode placement, the skin was shaved, abraded, and washed with alcohol according to the recommendations by SENIAM. The electrodes were placed on 4 locations: the pectoralis major (~4 cm medial to the axillary fold), anterior deltoid (1.5cm distal and anterior to the acromion), triceps brachii (long head, ~3 cm medial and on 50% on the line between the acromion and olecranon) and biceps brachii (one-third of the distance from the fossa cubit on the line between the fossa cubit and the medial acromion) (Anderson and Behm, 2004; Goodman et al., 2008; Saeterbakken and Fimland, 2013b). All EMG data were collected in the same session to ensure identical positioning of the electrodes in both exercises

To minimize external noise, the raw EMG signal was amplified and filtered using a preamplifier (rejection rate of 100 dB) located close to the sampling point. The EMG signals were band-based filtered using a fourth-order Butterworth filter with a cut-off frequency of 8-600Hz. The EMG signal was converted to root mean square (RMS) EMG signals using a hardware circuit network (frequency response 0 - 600 kHz, averaging constant 100 ms, total error ± 0.5%). The RMS-converted signal was re-sampled at a 100 Hz using a 16-bit analog-to-digital converter (AD637). A linear encoder (ET-Enc-02, Ergotest Technology AS, Langesund, Norway) was connected to the barbell and dumbbell, to identify the different repetitions, the different parts, and the different phases based on the trajectory of the equipment (barbell/dumbbell) during each 6RM attempt. The encoder had a resolution of 0.075 mm and a sampling frequency of 100 Hz. The mean RMS EMG value of all six repetitions in each condition was used for further analysis. Additionally, the fifth repetition was divided into upper, middle, and lower phases of the descending and ascending part (total of six phases) (Saeterbakken and Fimland, 2012; 2013a). These phases were classified by splitting the range of motion into three identical lengths.

RMS EMG values were not normalized as the aim of the study was to compare the muscle activity within subjects between two quite similar exercises, and the relative muscle activation values from normalization would not provide any further information. Often when comparing EMG data taken during an exercise (i.e., dynamic bench press) and an MVC (isometric chest flyes), the exercise EMG sometimes surpasses the MVC EMG (Neto et al., 2020).

All data (EMG of each muscle, velocity, vertical displacement, and time from the linear encoder) was collected and synchronized using a multi-channel single data acquisition system (Musclelab 4020e, Ergotest, Norway).

Statistical analysis

Statistical analyses were performed using SPSS (v22, Chicago, IL, USA). The data were checked for normality using a Shapiro-Wilk test. Where the variables were normally distributed, a paired *t*-test was used to determine differences in EMG activity. Wilcoxon signed-rank test was used with non-normally distributed EMG data. All p-values were adjusted using the Holm-Bonferroni correction ($\alpha = \frac{\alpha}{m-i+1}$) to correct for multiple pairwise comparisons to avoid potential type I-errors (Holm, 1979). All parametric data are presented as mean ± 95% confidence intervals (CI) and with Cohen's *d* effect size (ES) calculated from the mean differences between the conditions and divided the results by the pooled standard deviation. For the non-parametric tests, the z-score divided by the square root of the total sample size was used (r statistic). ES was considered small, medium, and large at 0.2, 0.5, and 0.8, respectively (Cohen, 1988) whereas r-values of <0.3 was consider small, 0.3-0.5 medium and >0.5 large. For the non-parametric data, the median and the 25-75 percentile interquartile range are presented. Statistical significance was accepted at $p \leq 0.05$. All data are presented as mean ± standard deviation or 95% CI.

Results

Pectoralis major

Mean RMS EMG activity in the pectoralis major was 16% higher in the BBP compared to the DF (Figure 3) during the whole movement ($p = 0.027$, ES = 0.36). Comparing phases, the BBP elicited greater activation in the upper (42%, $p = 0.002$, ES = 1.06), middle (21%, $p = 0.032$, ES = 0.43) and lower (23%, $p = 0.002$, ES = 0.37) phases of the descending part compared to the DF (Figure 4). However, during the ascending part, only the upper phase in the BBP elicited higher pectoralis major activation (34%, $p < 0.001$, ES = 0.94) compared to the DF, whereas similar activation was observed in the middle and lower phases.

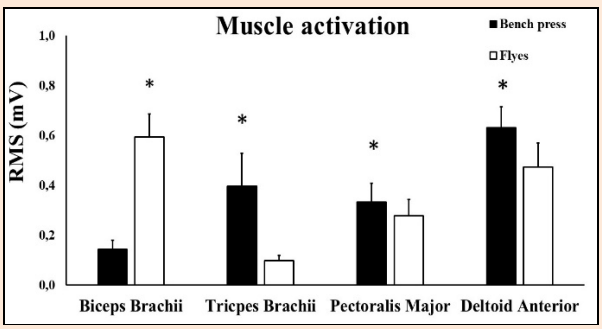

Figure 3. Overall muscle activation for both exercises. The mean and 95% confidence interval for RMS EMG for each muscle and exercise condition during the whole movement.

Anterior deltoids

Mean RMS EMG activity in the anterior deltoids was 25% ($p = 0.007$, ES = 0.84) higher in the BBP in comparison to the DF (Figure 3). Higher anterior deltoid activation was observed in the middle (14%, $p = 0.024$, ES = 0.37) and upper phases (46%, $p < 0.001$, ES = 1.54), but not in the lower (8%, $p = 0.078$, ES = 0.18) phase of the ascending part of the BBP compared to the DF (Figure 5). In the descending part, only the middle phase (30%, $p = 0.010$, ES

= 0.97) produced higher anterior deltoid activation in the BBP compared to the DF, whereas no differences were observed in upper or lower phase (28 %, p = 0.109, ES = 0.25; 9 %, p = 0.110, ES = 0.67).

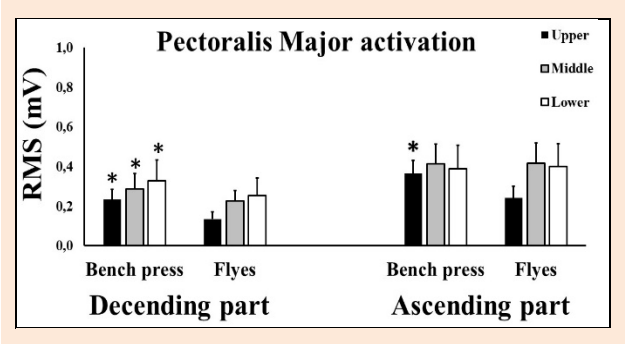

Figure 4. Muscle activation in different phases. Mean RMS EMG activity in different phases (lower, middle and upper) in pectoralis major for the barbell bench press and the dumbbell flyes. Values are means with 95% confidence interval. * indicates a significant difference (p ≤ 0.05) between the two exercises.

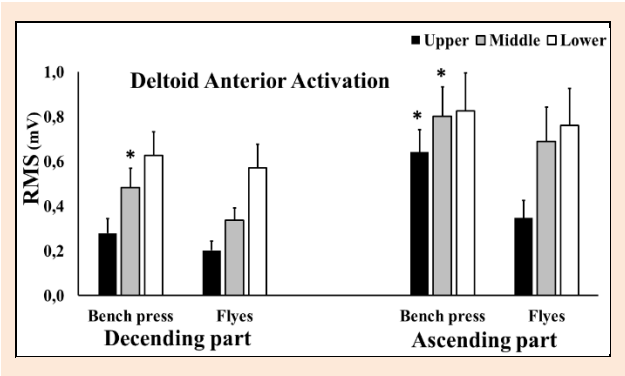

Figure 5. Muscle activation in different phases. Mean RMS EMG activity in different phases (lower, middle and upper) in deltoid anterior for the barbell bench press and the dumbbell flyes. Values are means with 95% confidence interval. * indicates a significant difference (p ≤ 0.05) between the two exercises.

Triceps brachii

Mean RMS EMG activity of the BBP elicited 75% (p = 0.003, ES = 1.47) greater activation of the triceps brachii than the DF in the whole movement (Figure 3). The BBP produced greater triceps brachii activation in all phases in both the descending (upper = 62%, p = 0.017, ES = 0.88; middle = 72%, p = 0.025, ES = 1.03; lower = 67%, p = 0.038, ES = 0.99) and the ascending part (lower = 81%, p = 0.010, ES = 1.55; middle = 84%, p = 0.008, ES = 1.75; upper 75%, p = 0.013, ES = 1.35) compared to the DF (Figure 6).

Biceps brachii

Mean RMS EMG activity in the biceps brachii of the whole movement was higher in the DF (76%, p < 0.001, ES = 3.07) compared to the BBP (Figure 3). The DF elicited greater biceps brachii activation in all phases of the descending part (upper = 57%, p = 0.004, ES = 1.30; middle = 71%, p < 0.001, ES = 2.39; lower = 62%, p < 0.001, ES = 1.94) and the ascending part (lower = 83%, p < 0.001, ES = 3.06; middle = 86 %, p < 0.001, ES = 2.86; upper 69%, p = 0.002, ES = 1.56) compared to the BBP (Figure 7).

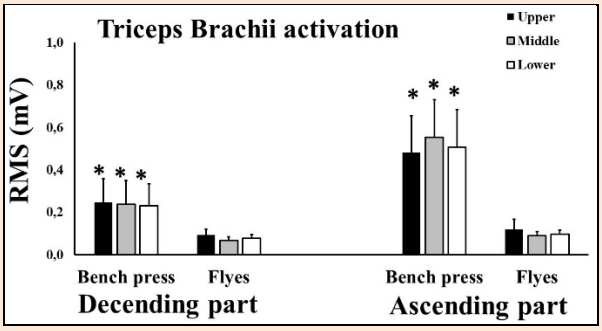

Figure 6. Muscle activation in different phases. Mean RMS EMG activity in different phases (lower, middle and upper) in triceps brachii for the barbell bench press and the dumbbell flyes. Values are means with 95% confidence interval. * indicates a significant difference (p ≤ 0.05) between the two exercises.

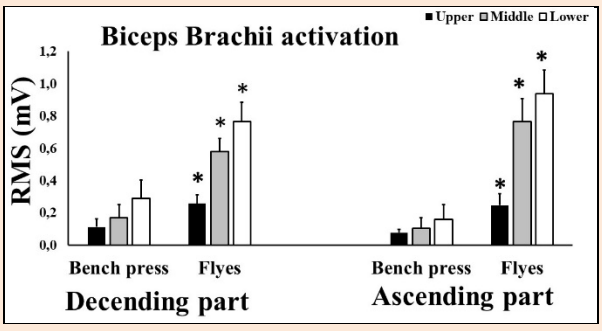

Figure 7. Muscle activation in different phases. Mean RMS EMG activity in different phases (lower, middle and upper) in biceps brachii for the barbell bench press and the dumbbell flyes. Values are means with 95% confidence interval. * indicates a significant difference (p ≤ 0.05) between the two exercises.

The subjects used 18.7 ± 2.4 seconds and 23.5 ± 3.2 seconds in total lifting 6RM in the BBP and the DF (p < 0.001, ES = 1.67). The intraclass correlation coefficient of the 6RM loads in the BBP and the DF between the familiarization session and experimental session was 0.993 and 0.914, respectively. The total 6RM loads in the BBP and the DF was 88.5 ± 16.0kg and 40.5 ± 7.7kg (p < 0.001, ES = 3.82).

Discussion

The main findings showed that the BBP had a higher muscle activation in pectoralis major, anterior deltoids, and triceps brachii compared to the DF for the whole movement, in addition to the majority of the lifting phases. In contrast, biceps brachii had higher activation in the whole movement and phases during the DF compared to the BBP.

As hypothesized, greater pectoralis major and anterior deltoid activation were observed in the whole movement during the BBP. Even though the relative intensity was similar (i.e., 6RM loads) between the exercises, the absolute loads (amount of kilograms) lifted were quite dissimilar. This, together with the differences in external moment arm, can most likely explain the EMG results during the phases. The critical region for a successful and unsuccessful repetition in both exercises are early in the lower ascending phase (van den Tillaar and Ettema, 2009; van den Tillaar et al., 2012). In this phase, the external moment

arm in the DF is much longer compared to the BBP and can explain the similar muscle activation between the exercises in the lower phase. The major difference in absolute loads (DF~40kg vs. BBP~90kg) between the exercises, together with a large change in the external moment arm during the ascending phase in the DF, alters the total resistance (reduced external torque) during the middle and upper in a much larger extent compared to the BBP. In contrast, the external moment arm for the BBP is much more similar throughout the lifting phases, which would explain the requirement to maintain a higher muscle activation throughout the whole movement, especially the middle and upper phase, compared to the DF. All this may result in reduced muscle activation as the relationship between external loading (i.e., % of 1RM), and neural drive has been demonstrated previously in both isometric and dynamic contractions (Alkner et al., 2000; McBride et al., 2010).

The EMG findings in the present study for the pectoralis major and deltoid anterior were in contrast to the only comparable study examining the BBP and the DF (Welsch et al., 2005). Welsch et al. (2005) and colleagues demonstrated no differences between the two exercises. However, Welsch and colleagues (2005) examined three non-fatiguing repetitions using 6RM loads, which could explain the different findings. Furthermore, Welsch et al. (2005) only examined the average peak (100ms interval per repetition) EMG activation for the ascending phase of the three repetitions, which further reduces the similarities between the different findings. Using the peak and not the average or RMS values for muscle activation decreases the ecological validity as doublets/triplets spikes may cause non-stationary values (i.e., in the turn-over from eccentric to concentric muscle contraction or in a specific range of motion were the muscle filaments overlap maximally). Analyzing peak EMG values or mean integrated EMG activity may cause differences in the subsequent level of muscle activity (Hildenbrand and Noble, 2004; Warden et al., 1999) and for some muscles, a poor to moderate relationship between the two methods ($r = 0.10 – 0.70$) has been observed (Hibbs et al., 2011).

Previous studies comparing different lifting phases, where the moment arms changing throughout the range of motion, have demonstrated differences in muscle activation in multi-joint exercises (squat, lunges, deadlift) (Andersen et al., 2018; 2019; Saeterbakken et al., 2014; 2019). Therefore, analyzing the average peak EMG activity for the whole repetition or only descending or ascending parts (Goodman et al., 2008; Saeterbakken et al., 2011; Welsch et al., 2005) might mask the several peak EMG activity periods and the influence of external moment arms changing throughout the ROM.

As hypothesized, the BBP demonstrated greater muscle activity in the triceps brachii in the whole movement and phases compared to the DF. These differences are most likely the result of differences in the execution of the exercises. During the BBP, both hands are connected through the barbell, which allows the triceps to extend the elbow converting lateral forces into vertical movement of the barbell during the concentric part of the lift, and therefore contributing to force production in the vertical direction (Duffey and Challis, 2011; Saeterbakken et al., 2011). In contrast, there is no extension of the elbow in the DF, and the triceps brachii function as a co-contractor together with the biceps brachii to stabilize the elbow during the lift.

The use of independent dumbbells increases the instability in the elbow joint when compared to the use of a barbell in BBP. Therefore, the primary task for the biceps brachii in the DF is probably not to generate force but to stabilize and maintain a constant angle in the elbow joint. These speculations and our findings could be supported by Saeterbakken and colleagues (2011), who compared chest press with barbell and dumbbells (i.e., arm flexion) and observed greater biceps brachii activation in the dumbbell bench press compared to barbell bench press most likely due to the use of independent dumbbells which require stabilizing and maintaining of the elbow joint position (laterally) during the lift. Further, it should be acknowledged that the biceps brachii can function as a synergist in the two exercises since it has been shown to assist in the adduction of the arm (Furlani, 1976). Importantly, it has been demonstrated that bi-articulated muscles are more activated, performing a contraction in one joint when the muscles are extended in the other joint (Kwon and Lee, 2013). Therefore, it is possible that the biceps brachii, functioning as a shoulder adductor, is more important when the elbow is extended during the DF compared to the BBP. Finally, in the BBP, the biceps brachii acts like an antagonist, and a contraction could prevent or slow down an elbow extension (Baratta et al., 1988).

There are some limitations that need to be addressed. EMG signals interpreted during dynamic movement can be a complicated issue because of the possible relative shift of the electrodes, signal non-stationarity, and fluctuations in the conductivity properties of the skin (Farina, 2006). Furthermore, it is always an inherent risk that surface EMG measurements might include muscle activity from adjacent muscles (i.e., cross-talk). However, all the EMG data were collected in the same session, and there was no requirement to replace any of the electrodes. Further, the current study only included resistance-trained males. Thus, the findings cannot be generalized to other populations.

Conclusion

In conclusion, the BBP showed a higher muscle activation in pectoralis major, anterior deltoids, and triceps brachii compared to the DF. However, biceps brachii showed a higher muscle activation in the DF compared to the BBP. If the primary aim of the training is maximal mechanical stress (i.e., loading) and muscle activity of the prime movers, the authors recommend the use of barbell bench press and not dumbbell flyes.

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of the country in which they were performed. The authors have no conflict of interest to declare.

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Key points

- The findings of the present study demonstrated that performing the BBP activates the agonists and synergists, to a greater extent than the DF. The DF, on the other hand, activated the arm flexors (biceps brachii) to a greater extent than the barbell bench press.
- Lower external loads were lifted with the DF than the BBP. Therefore, the authors recommend the BBP for athletes or others engaged in resistance training.
- For variation, both exercises should probably be included in the program but with an emphasis on majority of the volume focused on the BBP due to the higher muscle activation overall.
- The DF could prove quite useful among specific populations and tasks where strength, stabilization, and control in a horizontal shoulder flexion position with extended elbows is desirable.

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