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ELECTROMYOGRAPHIC CHANGES BEFORE, DURING, AND AFTER THE STICKING POINT IN DUMBBELL BENCH PRESS

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PURPOSE: Findings from previous research indicate the electromyographic (EMG) activity of the prime mover muscles in completing a bench press is not significantly different between the pre-sticking, sticking, and post-sticking phases. However, previous research only examined EMG activity during a barbell bench press. Therefore, the purpose of this study was to examine differences in muscle activation during the pre-sticking, sticking, and post-sticking phases of a six-repetition maximum (6RM) dumbbell bench press. METHODS: Twenty-three (n = 23) resistance-trained males (age, 20.8 ± 1.2 yr; height, 179.8 ± 5.3 cm; body mass, 87.8 ± 15.5 kg; BP 6RM, 87.8 ± 13.0 lb) performed a 6RM dumbbell bench press. Wrist acceleration was used to determine the pre-sticking, sticking, and post-sticking phases. EMG data from the dominant arm pectoralis major and triceps brachii muscles during last successful repetition in the 6RM test were analyzed to compare EMG activity during each of the three phases. Statistical significance was set at \( p < 0.05 \). RESULTS: A repeated measures ANOVA revealed significant differences in the triceps brachii EMG activity between the three phases \((p = 0.02)\). A post-hoc pairwise comparison test revealed the EMG activity during the post-sticking phase \((0.477 ± 0.05)\) was significantly lower than the EMG activity during the pre-sticking \((0.564 ± 0.055)\) and sticking phase \((0.538 ± 0.061)\). EMG activity during the pre-sticking and sticking phases were not found to be significantly different from each other. A repeated measures ANOVA of the pectoralis major EMG activity showed no significant difference in EMG between the three phases. CONCLUSION: In contrast to previous research conducted with barbell bench press, there were significant differences in EMG activity of the triceps brachii between the pre-sticking, sticking, and post-sticking phases during a 6RM dumbbell bench press. Consistent with previous research, however, was a lack of difference in EMG activity of the pectoralis major between the phases while using dumbbells.

INTRODUCTION:

High intensity resistance training is a popular method of enhancing health and human performance. Resistance training intensity is defined as the effort that is expended during a training session; therefore, high intensity resistance training requires high effort (Haff & Triplett, 2007, p. 562). In performing high intensity resistance training, individuals often experience a phenomenon known as the sticking point in completing near maximal repetitions of exercises, such as the bench press (Drinkwater et al., 2007). The sticking point is defined as the time in a successful repetition where the upward movement of the weight decelerates or completely stops for a short amount of time (van den Tillaar & Ettema, 2010)). The mechanics of the sticking point are unclear. The sticking point may be due to changes in muscle mechanics (e.g., a change in muscle torque production) as the joint is moved through a range of motion while completing the repetition.

An increase in muscle activity of the pectoralis major and deltoid muscles in a 1-repetition
maximum (1RM) barbell bench press during the pre-sticking and sticking points was identified by van den Tillaar (2010). The author concluded the increase in muscle activity was due to the deltoid and pectoralis major muscles compensating for a change in the mechanical lever arms of the muscles (van den Tillaar & Ettema, 2010). However, a meta-analysis of 62 articles that included the van den Tillaar (2010) article found that there was no evidence of differences in electromyographic (EMG) activity before, during, or after the sticking point for the agonist muscles of the bench press, squat, and deadlift (Kompf & Arandjelović, 2017).

Another theory purported in the literature involves change in the mechanics of the external load (i.e., the weight being lifted). The theory states the sticking point is the weakest point in the range of motion because the lever arm of the external resistance increases, which increases the torque create by the resistance (Coburn & Malek, 2004).

The mechanics involved in the sticking point phenomenon remain unclear. However, all known published research on the topic involves weightlifting exercises performed with a barbell. No published research was found that examined changes in EMG activity while performing exercise where the extremities moved independent of each other, such as with a dumbbell bench press (DBBP) exercise. Therefore, the purpose of this study is to examine potential differences in EMG activity before, during, and after the sticking point of a six-repetition maximum (6RM) DBBP. The primary researcher hypothesized that the EMG activity of the pectoralis major and triceps brachii muscles will remain constant immediately before, during, and immediately after the sticking point of the last successful repetition in performing a DBBP.

**METHODS:**

This study was approved by the College of Saint Benedict/Saint John’s University Institutional Review Board on October 10th, 2023.

**Participants**

Twenty-three college-aged males (age 20.8 ± 1.2 years, height 179.8 ± 5.3 cm, body mass 87.8 ± 15.5 kg) with at least 2 years of bench press experience (training once or twice per week) participated in this study. All participants were students at Saint John’s University, Collegeville, MN at the time of the study. Participants were recruited through word of mouth, Exercise and Health Sciences department email, and a residential email.

In order to determine how many participants were needed, a priori power analysis was used. The g*power software, Version 3.1.9.6 from Heinrich Heine University Düsseldorf was used with an effect size of 0.8, an alpha value of 0.05 and a confidence interval of 0.95, the analysis determined this study requires 23 participants.

**Procedure**

Participants attended two test sessions between 3 and 12 days apart to ensure adequate recovery while also limiting time for them to develop significant amounts of muscular strength improvements.

At the start of the first session, the primary researcher explained the study to the participant and informed them of any risks and benefits associated with the study. The primary
researcher then obtained written consent from each participant. After gaining consent, the participant was weighed and reported their height, age, training age and estimated 6RM for the DBBP. Once demographic data information was collected, participants performed a series of movements to warm-up and stretch their muscles and slightly elevate their heart rate found in Table 1. Participants were also allowed to perform any other stretches that they felt necessary including band-assisted stretches. Once the participant felt sufficiently warmed up, they laid down on a bench and performed sets and rests following the information found in Table 2.

<table>
<thead>
<tr>
<th>Warm-up/Stretching</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary Biking</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Arm Circles (forwards and backwards)</td>
<td>15 seconds each direction</td>
</tr>
<tr>
<td>Over-the-head Triceps Stretch</td>
<td>15 seconds each arm</td>
</tr>
<tr>
<td>Across-the-body Triceps Stretch</td>
<td>15 seconds each arm</td>
</tr>
<tr>
<td>Pec Wall Stretch</td>
<td>15 seconds each side</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight/Rest</th>
<th>Repetitions/Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% of the estimated 6RM</td>
<td>10 repetitions</td>
</tr>
<tr>
<td>Rest</td>
<td>2 minutes</td>
</tr>
<tr>
<td>50% of the estimated 6RM</td>
<td>10 repetitions</td>
</tr>
<tr>
<td>Rest</td>
<td>2 minutes</td>
</tr>
<tr>
<td>75% of the estimated 6RM</td>
<td>8 repetitions</td>
</tr>
<tr>
<td>Rest</td>
<td>2 minutes</td>
</tr>
<tr>
<td>100% of the estimated 6RM</td>
<td>6 repetitions</td>
</tr>
</tbody>
</table>

During all warm-up sets, the primary researcher brought dumbbells to the participants in order for them not to inadvertently fatigue themselves. The primary researcher followed the protocol for spotting the dumbbell bench press as described by the National Strength and Conditioning Association for any sets above 75% of their estimated 6RM to ensure participant safety (Haff and Tripplet, 2007, p. 355). If the participant achieves 6 repetitions and is unable to perform any more repetitions, the weight lifted will be recorded as the participant’s 6RM weight. If the participant is unable to complete all 6 repetitions, the weight will be lowered by approximately 5% and, after 3 minutes of rest, the participant will attempt the 100% of 6RM trial again. If the participant is able to perform more than 6 repetitions, their weight will be increased by approximately 5% and, after 3 minutes of rest, the participant will attempt the 100% of 6RM trial again. Once a 6RM is achieved, the amount of weight lifted will be recorded.

The participant returned for the final session 3-12 days after the initial session. The participant performed the same warm-up found in Table 1. After completing the warm-up, the participant then followed the same warm-up sets and rests protocol found in Table 2 but their estimated 6RM was replaced with the recorded weight from the first session. Before the final set,
the participants were fitted with a FitLift accelerometer on their dominant wrist. The FitLift device recorded acceleration during the 6RM (FitLift, FitForm Technologies Inc, Seattle, WA). To collect EMG data, disposable EMG electrodes were placed on the participant’s dominant side sternal portion of the pectoralis major and lateral head of the triceps brachii. These electrodes were connected to a PowerLab Data Acquisition Unit by a 5-Lead Bio Amp Cable (PowerLab, ADInstruments, Dunedin, New Zealand). The primary researcher manually started both the EMG recording and the FitLift accelerometer to ensure that they were as synchronized as possible. The participant then performed repetitions of the recorded weight until muscular failure. The number of successful repetitions performed was recorded.

**Measurements**

Raw EMG activity was recorded at a frequency of 200 Hz with LabChart 8 software and converted to Root Mean Square (RMS) data.

Acceleration of the weight was recorded at a rate of 60 Hz on the FitLift mobile app. and exported to an Excel file on a notebook computer. The last successful repetition was identified by matching the fluctuations in accelerometer data to the corresponding repetition. The concentric phase of the last successful repetition was then broken into three phases: pre-sticking phase (PrSP), sticking phase (SP), and post-sticking phase (PoSP) as described by van den Tillaar (2010). PrSP was the period of time from the most positive instantaneous acceleration until the time when the acceleration first becomes negative. SP was from the first negative acceleration to the time the acceleration next became positive. PoSP was from time the acceleration became positive with the same time length as the second period (van den Tillaar & Ettema, 2010).

Using the time stamps automatically generated from the accelerometer data, the primary researcher collated the accelerometer information with the EMG data to find an average RMS EMG activity for each of the three phases for both the triceps brachii and pectoralis major.

**Statistical Analysis**

To determine differences in muscle activity during the DBBP, a one way repeated-measures analysis of variance (ANOVA) was used. When the sphericity assumption was violated, the Greenhouse-Geisser estimates of sphericity were used. Post-hoc pairwise tests were used to identify differences between phases. Statistical significance was set at $p < .05$. Partial eta-squared values were reported to reflect the magnitude of the differences between for each phase (small = 0.01, medium = 0.06, and large = 0.14) (Cohen, 1988). Cohen’s effect sizes ($d$) were calculated with the following criteria: $0 < 0.19$ as insignificant, $0.20 < 0.49$ as small, $0.50 < 0.79$ as medium, and $0.80+$ as large (Cohen, 1988).

**RESULTS:**

A repeated-measures ANOVA was performed to examine the effect of time (prior to, during, and after the sticking phase) on the EMG activity for the triceps brachii and pectoralis major. The means and standard deviations for the EMG activity are presented in Tables 3 and 4.
Table 3. Descriptive statistics for Triceps Brachii EMG.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PrSP</td>
<td>0.56</td>
<td>0.06</td>
</tr>
<tr>
<td>SP</td>
<td>0.54</td>
<td>0.06</td>
</tr>
<tr>
<td>PoSP</td>
<td>0.48</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 4. Descriptive Statistics for Pectoralis Major EMG.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PrSP</td>
<td>0.70</td>
<td>0.06</td>
</tr>
<tr>
<td>SP</td>
<td>0.70</td>
<td>0.06</td>
</tr>
<tr>
<td>PoSP</td>
<td>0.67</td>
<td>0.07</td>
</tr>
</tbody>
</table>

For the triceps brachii, Mauchly’s test indicated that the assumption of sphericity had been met, $\chi^2(2) = 1.06, p = .590$. The effect of time on EMG activity was significant at the .05 level, $F(2), (44) = 4.38, p = .018$, partial $\eta^2 = .17$.

Post-hoc pairwise comparisons with a Least Significant Difference adjustment indicated that EMG activity in the triceps brachii was significantly lower at the PoSP than at the PrSP, ($p = .015$) and SP, ($p = .035$) see Figure 1. There was no significant difference between EMG activity between the PrSP and SP, ($p = .395$).

Post-hoc pairwise comparison test revealed the EMG activity during the PoSP (M = 0.477, SD = 0.05) was significantly lower than the EMG activity during the PrSP (M = 0.564, SD = 0.055; $d = 1.655$) and SP (M = 0.538, SD = 0.061; $d = 1.094$).

For the pectoralis major, Mauchly’s test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 9.86, p = .007$, and therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.73$). The effect of time on EMG activity was not significant at the .05 level, $F(1.455), (32.01) = 0.81, p = .419$, partial $\eta^2 = .04$, see Figure 2.

![Figure 1. Mean RMS EMG activity (mV) of the triceps brachii lateral head during the PrSP, SP, and PoSP of a 6RM DBBP (* indicates $p<.05$).](image1)

![Figure 2. Mean RMS EMG activity (mV) of the sternal pectoralis major during the PrSP, SP, and PoSP of a 6RM DBBP.](image2)
DISCUSSION:

The purpose of this study was to examine potential differences in EMG activity between the pre-sticking, sticking, and post-sticking phases of a 6RM DBBP. The primary researcher’s hypothesis was partially supported by the data collected. The EMG activity of the pectoralis was not significantly different between the PrSP, SP, and PoSP phases of the DBBP which supported the hypothesis. However, a significant difference in triceps brachii EMG activity was identified between the PoSP and PrSP, and between the PsSP and SP which did not support the hypothesis.

The pectoralis major EMG activity was not significantly different between the PrSP, SP, and PoSP. The lack of difference is possibly because the pectoralis major attachment is close to the stable part of the body that is not moving during the lift (i.e. torso). The shorter distance from the stable body could mean there is less variability in the movement that pectoralis major is responsible for during a DBBP. These findings are consistent with the Kompf & Arandejelović meta-analysis that found no significant differences in EMG between the three phases during a barbell bench press (2017).

The triceps brachii EMG activity was significantly less in the PoSP compared to PrSP, and SP phases. The differences may be from the participant’s ability to move the upper extremities independently of one another due to the nature of the DBBP. The independent movement allows the elbow to extend while keeping the weight over or near the humeroulnar joint axis of rotation, thus improving the mechanical advantage of the triceps brachii and reducing muscle activity.

A different way of interpreting the results is that the PrSP and SP were significantly higher than the PoSP. In this scenario, it is likely that during the PrSp and SP, the elbow joint needed to be more stabilized causing the triceps brachii to be more active and EMG activity increased. In order to achieve this greater stability, the antagonist to the triceps brachii which is mainly the biceps brachii also had to be active which brings about co-contraction. According to an article by Koo et al., (2023) higher amounts of co-contraction allow for greater stability of a joint. Since EMG of the antagonist elbow flexor muscles was not measured during in this study, the amount of co-contraction cannot be determined.

Another potential reason for the triceps brachii EMG activity being significantly different between the phases is that it is further away from the stable body of the participant. The triceps brachii attachment is further away from the stable body which could mean that there is more variability in the muscle activity of the triceps brachii.

The significant difference that was found for the triceps brachii EMG activity during a DBBP differs from the Kompf & Arandejelović’s 2017 meta-analysis using a barbell. One possible explanation for the difference in results is while performing a barbell bench press, the hands are in a set place and therefore the position of the hands relative to the humeroulnar joint cannot be adjusted to reduce the moment arm of the barbell’s weight. In performing the DBBP, the neuromuscular system has more freedom of joint motion and can position the weight to
maximize mechanical advantage in extending the elbow. The participants’ lifting experience may also be a factor in the efficiency of the neuromuscular system performing the lift. An individual who has lifted weights before will better know how their body works and what it takes to lift the weight efficiently were as a less experienced individual has not gone through the trial-and-error process as much.

There were few limitations of the current study. One limitation was the FitLift accelerometer and PowerLab Data Acquisition Unit needed to be started independently of each other. Starting the accelerometer and electromyograph separately caused small amounts of error that was not corrected for in the data analysis. Due to the possible error, the three phases of the lift could potentially be a few hundredths of a second different than what was reported. To correct for error in future studies, an accelerometer and EMG software should have exact time stamps instead of a relative time based off when the equipment is started.

Another limitation was that two locations were used for the initial 6RM and the data collection 6RM. During the first test session, participants performed the sets in a non-controlled environment in which music was often playing and other people in the area. For the second day, participants moved to a more controlled environment with no music and nobody near them. Since data was only used from the controlled environment, the data should be consistent but the amount of weight the participants could have lifted may have slightly varied due to the different external factors.

While methodology was slightly different than Van den Tillar’s 2010 article, the PrSP, SP, and PoSP were defined the same way which allows for Van den Tillar’s findings to be compared to the results of this study. One thing to note is that the sticking phase occurred later in the concentric phase of the DBBP (0.65 s) compared to the barbell bench press (0.2 s) (van den Tillaar & Ettema, 2010). Another difference was the amount of time that the sticking point lasted for in the DBBP (0.61 s) compared to the barbell bench press (0.9 s) (van den Tillaar & Ettema, 2010). The reason for the differences in duration and timing of the sticking point with the barbell bench press and DBBP are unknown.

Future studies should directly examine the differences in EMG activity between barbell bench press and DBBP using the same participants to better understand the difference in mechanics of the two lifts during the PrSP, SP, and PoSP.

Future studies should also assess the EMG activity of more shoulder and elbow joint muscles to assess the role of co-contraction of muscles around the joints as a contributing factor to differences in EMG activity with the DBBP and barbell bench press.

CONCLUSION:

In contrast to previous research conducted with barbell bench press, there were significant differences in EMG activity of the triceps brachii between the pre-sticking, sticking, and post-sticking phases during a 6RM dumbbell bench press. Consistent with previous research,
however, was a lack of difference in EMG activity of the pectoralis major between the phases while using dumbbells.

REFERENCES


