# A COMPARISON OF MUSCLE ACTIVITION BETWEEN MAXIMUM PURE CONCENTRIC AND COUNTER MOVEMENT BENCH PRESSING

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The purpose of this study was to compare the kinematics and muscle activation patterns of the counter movement bench press with pure concentric lifts in the ascending phase of a successful one repetition maximum attempt for 11 recreational weight-training athletes, with special attention to the sticking region. In both conditions a sticking region occurred. However, the start of the sticking region was different between the two bench presses. In addition the muscle activity was higher in the counter movement bench press compared to the concentric one. Together with the findings of the muscle activation during the maximal lifts it was concluded that diminishing effect of force potentiation and delayed muscle activation unlikely explains the existence of the sticking region in a 1-RM bench press. Most likely, the sticking region is the result of a poor mechanical force position.

**KEY WORDS:** emg, strength, upper body, power lifting.

**INTRODUCTION:** Bench press is one of the exercises in power lifting, but also often used in general strength training for the upper body. Several studies have investigated the kinematics in bench pressing and shown that there is a sticking region during maximal lifts (Madsen & McLaughlin, 1984, Elliott, Wilson & Kerr, 1989). This region is defined from peak velocity ($v_{max}$) to the first local minimum velocity ($v_{min}$) (Lander, Bates, Swahill & Hamill, 1985). In this region, the pushing force is less than gravity on the barbell, leading to a deceleration of the barbell. However, the reason of existence of this sticking region is still unclear. Elliott et al. (1989) and Madsen and McLaughlin (1984) hypothesized that during the sticking region a poor mechanical force position occurs in which the lengths and mechanical advantages of the muscles involved were such that their capacity to exert force was reduced. Van den Tillaar and Ettema (2010) found that only the muscle activity of the major pectoralis muscles and the anterior part of the deltoid muscles significantly increased from the sticking to the post-sticking region during the upward movement. They proposed that the start of a sticking region occurs, not because of a lack of strength per se, but due to diminishing of enhanced force (potentiation induced by the immediately preceding eccentric contraction) at the start of the concentric movement. When this strength capacity is diminishing, a delayed neural reaction must occur (Walshe, Wilson & Ettema, 1998) enhancing the muscle activity level so that the resultant force matches the demands of the attempt. This process results in the overcoming of the sticking region.

In the abovementioned studies the bench press was performed with a downward and upward movement, which can cause diminishing potentiation (possibly assisted by force relaxation in the elastic components) and thereby the occurrence of the sticking region. Since in pure concentric lifts these mechanisms cannot play a role, these lifts can be used to test whether the sticking region is caused by potentiation and an accompanying delayed neural reaction (van den Tillaar & Ettema, 2010), or it is due to a poor mechanical force position (Madsen & McLaughlin, 1984; Elliott et al., 1989). Wilson et al. (1991) already showed that subjects could lift around 14% more with a counter movement bench press than with a pure concentric lift. Furthermore, they found that the force output only during the first 200ms was lower when performing pure concentric bench presses. However, they only analysed the first

0.5s of the ascending part of the lift. Furthermore, they did not explain the reason for these differences (and did not perform any EMG measurement of the involved muscles).
Therefore the aim of this study was to compare the kinematics and muscle activation of the regular free-weight bench press (counter movement) with pure concentric lifts. Since diminishing potentiation cannot occur in pure concentric lifts, the occurrence of a sticking region in this type of muscle actions would support the hypothesis that the sticking region is due to poor mechanical position. Thus, an activation pattern in the pure concentric 1RM lifts that is similar to the one during a regular one repetition maximum (1-RM) bench press would support the poor-mechanical-position hypothesis.

**METHODS:** Eleven male participants (21.9 ±1.7 y, 80.7 ±10.9 kg, 1.79 ±0.07 m) with at least two year of bench press training experience participated in this study.. The study complied with the approval of the local committee for medical research ethics and the current ethical standards in sports and exercise research.
The participants followed a standardized protocol with bench pressing followed by two to three attempts at self-reported1-RM. When the self-reported 1-RM was successful, an attempt with an additional 2.5-5 kg was performed. When the initial attempt was unsuccessful the weight was decreased by 2.5-5 kg. Firstly the participants performed a traditional bench press (descending and ascending the barbell) with no marked pause between the down and upwards movement of the barbell. After accomplished the maximal 1-RM in this counter movement bench press the participant established the 1-RM in a pure concentric bench press. Between the two conditions the participants had rest for around 10 minutes to avoid fatigue. In the concentric condition the barbell was lying on the lowest position touching the chest on two standards. The participants had to push the barbell up as quickly as possible on a signal given by the researcher. Only the attempt in each condition with the highest weight that was lifted successfully was used for further analysis.
A linear encoder (Ergotest Technology AS, Langesund, Norway) measured the vertical displacement in relation to the lowest point of the barbell (zero distance). Velocity, force and acceleration of the barbell were calculated using respectively a five point differential and a double differential filter together with the total impulse defined as the integral of the force. The linear encoder was synchronized with the EMG recordings. Surface EMG was measured of the pectoralis major, the anterior deltoid, and the lateral and medial triceps brachii. The EMG signals were sampled at a rate of 1000 Hz. Signals were band pass filtered with a cut off frequency of 8 Hz and 600 Hz, after which the root-mean-square (RMS) was calculated. All calculations and analysis were done using commercial software (Musclelab V8.10, Ergotest Technology AS, Langesund, Norway).
To locate possible differences in muscle activity during the 1-RM bench press movement, the average RMS was calculated for each of three regions. The first region was from the lowest barbell point ($v_0$) until the maximal barbell velocity ($v_{max1}$): the pre-sticking region. The second region was from the maximal barbell velocity until the first located lowest barbell velocity ($v_{min}$): the sticking region. The last period, the post-sticking region, started at $v_{min}$ to the second maximal barbell peak velocity ($v_{max2}$), which was also called the strength region.
To assess differences in neuromuscular activity in the three regions during the traditional and pure concentric condition, a repeated 2 (condition: traditional vs. concentric) x 3 (region: pre-sticking, sticking and post-sticking) analysis of variance (ANOVA) design was used. Bonferroni post hoc analyses were conducted to determine differences. For the other kinematics (time, position, velocity force, impulse, and acceleration) a paired t-test was conducted between the two conditions. All results are presented as mean ±SD.

**RESULTS:** The average weights that successfully were lifted in the counter movement and concentric bench press by the participants at 1-RM were respectively 121.4 kg ± 29 kg, and 102.7 kg ± 21 kg.

**Table 1: Kinematics of the pure concentric (Conc) and counter movement bench press (CMBP). * indicates a significant difference between the two conditions**

| | Velocity (m/s) | | | Position (cm) | | | Time (s) | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | $v_{max1}$ | $v_{min}$ | $v_{max2}$ | $v_{max1}$ | $v_{min}$ | $v_{max2}$ | $v_{max1}$ | $v_{min}$ | $v_{max2}$ |
| Conc | .18±.07 | .03±.07 | .28±.10 | 6.1±4.0 | 13.4±6.6 | 30.3±3.6 | .60±.20 | 1.4±.7 | 3.0±1.3 |
| CMBP | .26±.08* | .03±.05 | .26±.08 | 2.2±.9* | 10.7±3.9 | 26.4±3.6* | .13±.04* | 1.0±.5 | 2.4±1.1 |

The time of the first peak velocity was significantly later in the concentric condition with no significant differences in the timing of the minimal and second peak velocity between the two conditions (table 1). The position of the barbell at the first and second peak velocity was significantly higher at these two positions in the concentric condition. However, the first peak velocity was significantly higher in the counter movement condition compared to the concentric condition (table 1). The acceleration and deceleration during the three regions were significantly higher in the counter movement condition. The total impulse during the counter movement and concentric 1-RM attempts was approximately the same (3402±2204 vs. 3414±1833 Ns)

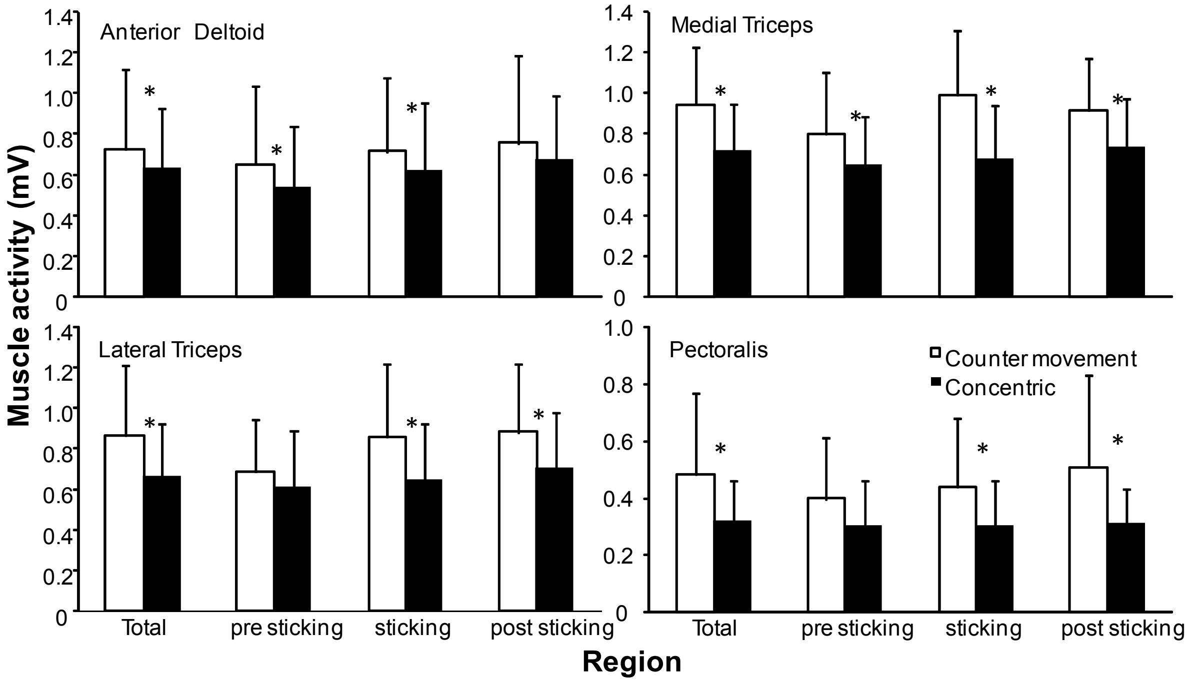


**Figure 1: Muscle activity of four muscles in the three regions in maximal concentric and counter movement bench press. *indicates a significant difference between the two conditions.**

Significantly different muscle activity was found between the two conditions in four of the six muscles ($p<0.05$). Post hoc comparisons revealed that for the lateral triceps and pectoralis the activity only was significantly higher in the sticking and post-sticking region for the counter movement bench press, while for the medial triceps the activity was significantly higher in every region. The muscle activity for the anterior deltoid muscle was only significantly higher in the pre-sticking and sticking region in the counter movement bench press (Figure 1).

**DISCUSSION:** In both conditions a sticking region occurred. However, the start of the sticking region was different between the two bench presses. In addition the muscle activity was higher in the counter movement bench press compared to the concentric one. However, the total impulse was the same for the two bench presses. The occurrence of a sticking region in the concentric bench press, even when it started later than in the counter movement bench press, indicated that the proposed theory (van den Tillaar & Ettema, 2010) about diminishing effect of potentiation, and a delayed muscle activation is unlikely the reason for existence of the sticking region. The sticking region started when the barbell was at 2.2 cm (counter movement) and 6 cm (pure concentric) from the sternum and ended at 11 and 13 cm from the sternum which was also found in earlier studies (e.g. Madsen & McLaughlin, 1984; Elliott et al., 1989; Wilson, Elliott & Wood, 1991; van den Tillaar et al. 2009) indicating that around these heights the barbell is in a poor mechanical position to conduct maximal force by the participants. However, no joint angles of the elbow and shoulder were measured, which could give more information about the occurrence of the sticking region; if this sticking region is dependent upon leverage and always occur at the same angles for the participants, which should be included in future studies before stating that the occurrence of the sticking region is the result of is a poor mechanical position to conduct maximal force.

The participants lifted around 20 kg more with the counter movement bench press compared to the concentric lifts, which was also found in earlier studies (Wilson et al., 1991). However, the total impulse was the same between the counter movement and concentric bench press indicating the participants had to conduct the same amount of force over time during the lifts. Even with this increased weight the initial acceleration was higher in the counter movement bench resulting in a higher first peak velocity. However, deceleration was also higher in these lifts, which probably was caused by diminishing potentiation of the contractile elements (Walshe et al. 1998) and effect of elastic elements (Elliott et al., 1989). Furthermore, the difference in lifted weight was mainly caused by the significantly increased muscle activity of in four of the six muscles in the counter movement bench press (Figure 1). This was in accordance with the findings of Walshe et al (1998) in squatting who concluded that higher active muscle state results in more force output in a counter movement than in a pure concentric movement.

In earlier studies it was hypothesized that during the sticking region the lengths and mechanical advantages of the muscles involved were such that their capacity to exert force was reduced in this period (Madsen & McLaughlin, 1984; Elliott et al, 1989). However, in none of the prime movers (pectoralis, triceps and deltoid muscle) the muscle activity decreased from the pre- to the sticking region (Figure 1) indicating muscle activity is not inhibited in the sticking region.

**CONCLUSION:** The kinematics in the ascending part of maximal 1-RM bench press between counter movement bench press and a pure concentric bench press revealed that both conditions had a sticking region. Together with the findings of the muscle activity during the maximal lifts it was concluded that diminishing effect of force potentiation and delayed muscle activation unlikely explains the existence of the sticking region in a 1-RM bench press. Most likely, the sticking region is the result of a poor mechanical force position.

**REFERENCES:**


Elliott, B.C., Wilson, G.J., & Kerr, G.K. (1989). A biomechanical analysis of the sticking region in the bench press. *Medicine and Science in Sports and Exercise*, 21, 450-462.

Lander, J.E., Bates, B.T., Swahill, J.A., & Hamill, J. (1985). A comparison between free-weight and isokinetic bench pressing. *Medicine and Science in Sports and Exercise*, 17, 344-353.

Madsen, N., & McLaughlin, T. (1984). Kinematic factors influencing performance and injury risk in the bench press exercise. *Medicine and Science in Sports and Exercise,* 16, 376-381.

van den Tillaar, R. & Ettema, G. (2009). A comparison of kinematics and muscle activity between successful and unsuccessful attempts in bench press. *Medicine & Science in Sports & Exerc*ise *41(11)*, 2056-2063.

van den Tillaar, R. & Ettema, G. (2010). The "sticking period" in bench press. *Journal of Sports Sciences* 28, 529-535.

Walshe, A.D., Wilson, G.J., & Ettema, G.J. (1998). Stretch-shorten cycle compared with isometric preload: contributions to enhanced muscular performance. *Journal of Applied Physiology*, 84, 97-106.

Wilson, G.J., Elliott, B.C., & Wood, G.A. (1991). The effect on performance of imposing a delay during a stretch-shorten cycle movement. *Medicine and Science In Sports And Exercise*, 23, 364-370.