Master thesis

The effects of grip width on sticking region in bench press

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Preface

I would like to thank my supervisor professor Roland van den Tillaar for his support and guidance through the process with this master thesis. I would also like to thank professor Rolf P. Ingvaldsen for his contributions in the process of coming up with an idea for the master thesis. A special thanks to the participants who took time out of their training to take part in this study.

The effects of grip width on sticking region in bench press

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Abstract

The aim of this study was to examine the occurrence of the sticking region by examining how three different grip widths affect the sticking region in powerlifters bench press performance. It was hypothesized that the sticking region would occur at the same joint angle of the elbow and shoulder independent of grip width, indicating a poor mechanical region for vertical force production at these joint angles. Twelve male powerlifters (age 27.7±8.8 years, mass 91.9±15.4kg) with a personal bench press record on a national level were recruited for the study. They were tested in one repetition maximum (1-RM) bench press with a narrow, medium and wide grip. A three-dimensional (3D) motion capture system (Qualysis, Gothenburg, Sweden) with six cameras was used to track reflective markers, creating a 3D positional measurement. The system also tracked timing, bar position and velocity. All participants showed a prominent sticking region with all three grip widths, but this sticking region was not found to occur at the same joint angles in all three grip widths. Thereby rejecting the hypothesis that the sticking region would occur at the same joint angle of the elbow and shoulder independent of grip width. The author suggests that, due to the differences in moment arm of the barbell about the elbow joint in the sticking region, there might still be a poor mechanical region for total force production that is angle specific, but not for vertical force production. Further studies measuring the lateral forces should be done to test this hypothesis.

Keywords: Bench press, Sticking region, Grip width, Joint angle, Powerlifters, Force production

Effekten av grepsbredde på sticking region i benkpress

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Sammendrag

Hensikten med denne studien var å undersøke eksistensen av sticking region ved å studere hvordan tre ulike grepsbredder påvirker sticking region i styrkeløfteres benkpressutførelse. Det ble hypotetisert at sticking region ville oppstå ved samme leddvinkel på albuen og skulderen uavhengig av grepsbredde, noe som ville indikere en dårlig mekanisk region for vertikal kraftutvikling ved disse leddvinklene. Tolv mannlige styrkeløftere (alder 27.7 ± 8.8 år, vekt 91.9 ± 15.4kg) med en personlig rekord i benkpress på et nasjonalt nivå ble rekruttert til studien. Deltakerne ble testet i en repetisjon maksimum (1-RM) benkpress med smalt, medium og bredt grep. Et tredimensjonalt (3D) motion capture system (Qyalysis, Gøteborg, Sverige) med seks kamera ble brukt til å fange reflekterende markører, og skape en 3D-posisjonsmåling. Systemet målte også timing, stangposisjon og hastighet. Alle deltakerne viste en fremtredende sticking region med alle tre grepsbreddene, men sticking region ble ikke funnet ved samme leddvinkel med alle tre grepsbreddene. Dermed ble hypotesene om at sticking region ville oppstå ved samme leddvinkel på albuen og skulderen avvist. Forfatteren foreslår at på grunn av forskjellene i stangens momentarm over albuen i sticking region kan det fortsatt være en dårlig mekanisk region for total kraftutvikling som er leddvinkel-spesifikk, men ikke for vertikal kraftutvikling. Videre studier som måler laterale krefter bør gjøres for å teste denne hypotesen.

Nøkkelord: Benkpress, Sticking region, Grepsbredde, Leddvinkel, Styrkeløftere, Kraftutvikling

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1. Introduction

The bench press is widely renowned as the best test of upper body strength, and is a part of the strength sport powerlifting. It is an enormously popular exercise, yet fairly simple to perform. In accordance to the rules and regulations set by the International Powerlifting Federation (IPF) the lift is performed lying supine on a bench with the head, shoulders and buttocks in contact with the bench surface, and the feet flat on the floor. The lift starts with straight arms, elbows locked out, the barbell is then lowered to the chest or abdominal area, before it is pushed in to straight arms and elbows locked out at the end of the lift. Each year the IPF arranges World championships in bench press, and the lift is also a part of the Special Olympics, with contestants lifting over 300kg without any supportive gear.

When performing the bench press at a heavy load Madsen and McLaughlin (1984) found that there occurs a point in the lift where the upward barbell movement decelerates or even stops before again accelerating. They named this point the sticking point, the first local minimum of the upward velocity (T_{vmin}), stating that at this position the lifters' capacity to exert force might be substantially lower than in the nearby positions. Research done by Lander et al. (1985) also found the sticking point, but instead of naming it the sticking point they named the period from peak velocity (T_{vmax}) to T_{vmin} sticking period. This definition has been seen as a more functional one when analyzing a bench press, as there is a period in which the pushing force applied by the lifter to the bar is less than the gravity of the barbell, thereby creating a period of deceleration of the barbell, not merely a point (fig. 1).

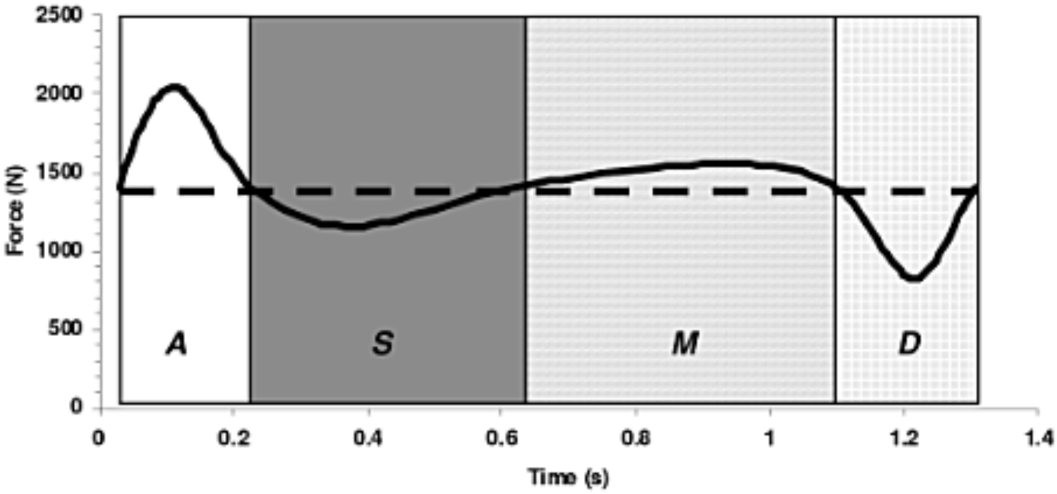

Figure 1: Typical vertical force curve in the bench press. A: Acceleration phase, S: Sticking period. M: Maximal force region, D: de-deceleration phase. From: Lander et al. (1985)

This has later also been called the sticking region (Elliot, Wilson and Kerr 1989; Hamilton, 1995; Newton et al. 1997; van den Tillaar, Saeterbakken and Ettema 2012), the definition being the region from v_{max} to v_{min}, in essence the same as the sticking period, seen as both define their term from peak velocity to first local minimum velocity. The difference being that the sticking period is hypothesized to be time dependent whereas the sticking region is hypothesized to be distance dependent.

The reason why the sticking region/period is an interesting subject for research is the fact that it occurs when performing the bench press with a heavy load. Elliot et al. (1989) found that it occurred in maximal and supramaximal loads, but not in submaximal loads (80% of 1-RM), Newton et al. (1997) only found it at loads over 90% of 1-RM and Madsen and Mclaughlin (1984) found it at maximal loads. The negative acceleration of the barbell under a heavy load has made researchers name it the weakest point in the lift (Madsen and Mclaughlin 1984) and the period where one is most likely to miss the lift (Lander et al. 1985). The latter claim has by some means been falsified; both Wilson et al. (1989) and van den Tillaar and Ettema (2009) found that although many lifters missed the lift during the sticking period, there were still many, in van den Tillaar and Ettema's (2009) research as many as 6 of 11, who pressed through the sticking period, but missed the lift later in the movement. Van den Tillaar and Ettema's (2009) explanation for this was that the loss in velocity during the sticking period results in a lower velocity after the sticking period and thereby increasing the chance of missing the lift in a later phase. So even though one does not always miss the lift in the sticking period the common idea seems to be that it can be seen as a constraint for performance in the bench press.

The idea of the sticking period or sticking region as a weakness in the lift has resulted in a lot of research being done with the aim of trying to explain why it occurs. In time there has been established two main models of explaining the occurrence of it. One is based on the hypothesis that it occurs due to the loss of enhanced force at the start of the ascent (Elliot et al. 1989; Newton et al. 1997; van den Tillaar and Ettema 2009; 2010). The argument being that there is a portion of elastic energy being released in the eccentric phase, or/and that there is a potentiation of the contractile elements of the muscle, during the eccentric phase, that results in improved force development at the start of the lift. When this improved force development stops, the bar loses velocity and the sticking period starts. Van den Tillaar and Ettema (2010) claimed that when the potentiation diminishes the activity of the prime movers has to be enhanced to avoid a full stop, but this activity enhancement has a certain “neural delay” thereby creating the sticking period. This model of explaining the sticking region/period uses the term sticking period, the reason being as mentioned earlier that this model bases its explanation on the assumption that the sticking region/period is time-dependent; the sticking period occurs at a certain time in the lift.

The other explanation model is based on the idea that the sticking region/period is a mechanically disadvantageous region for force development (Madsen and McLauglin 1984; Elliot et al. 1989; van den Tillaar et al. 2012). Thereby using the term sticking region, as they believe it occurs at a certain distance from sternum. The reason for this mechanically disadvantageous region is hypothesized to be either the muscle length or the internal or external moment arms. Within this model of explanation there has been found that the external moment arms are more advantageous in the sticking region than in the region before, and less advantageous than in the region after (Elliot et al. 1989). Thereby rejecting the hypothesis that less advantageous external moment arms are the reason for the sticking region.

When it comes down to comparing the two explanation models, newer research suggests that the “neural delay” is not the main reason for the sticking region. Van den Tillaar et al. (2012) did research testing the sticking region with a full bench press and an isometric bench press at 12 different heights from sternum. Even though one did not have any eccentric movement in the isometric bench press there was still a prominent region with lower force output, a sticking region. This was in consensus with Madsen and Mclaughlin´s (1984) first hypothesis claiming that the mechanical poor region for force production was caused by the involved muscles length or moment arms. Van den Tillaar et al. (2012) suggested that the force-curve during a near maximal and maximal bench press could be seen as the force-length curve of the muscle. Thereby hypothesizing that the muscle lengths are the cause of the sticking region. One possible way to see if this hypothesis is true is to test the bench press with different grip widths and see if the sticking region occurs at the same joint angle, in the shoulder and elbow, independent of distance or time from the sternum. The joint angle would here represent the length of the muscle; same joint angle would equal same muscle length.

Past research on grip width has primarily been done on strength and muscle activation differences. Madsen and Mclaughlin (1984) and Wagner et al. (1992) found that one is significantly stronger with a wide grip compared to a narrow grip, this is in consensus with the general understanding in strength training environments. Many researchers have also found that there is significantly higher triceps activation with a narrow grip compared to a wide grip (Barnett, Kippers and Turner 1995; Lehman 2005; McLaughlin, 1985), and the opposite with pectoralis major activation, wide grip creating higher activation than the narrow grip. A good explanation for this has not been found, but Barnet et al. (1995) tried to explain it, based on an explanation first set forth by Bigland-Richie et al. (1974): They suggested that the greater stretch of the pectoralis major muscle in wide grip bench-pressing, and triceps in narrow grip, will cause for a greater activation-demand seeing as the force-output in each motor unit will be reduced due to a disadvantageous muscle length.

The only study found mentioning sticking region and grip width is Wagner et al. (1992), who tested the bench press with six different grip widths, stating that the sticking region began at a significantly higher point for a grip width of 169% of bi-acromial distance (BAD), than for a grip width of 270% of BAD. This may be an argument for the hypothesis that the sticking region occurs at the same joint angle, independent of distance from sternum, seen as the same joint angle in the elbow with a wider grip would equal a lesser distance from sternum. However, in this study no joint angles were measured or moment arms on the shoulder or elbow joint. This makes it difficult to state if the sticking region occurs at the same joint angles. Therefore the aim of the present study was to examine the occurrence of the sticking region by examining how three different grip widths affect the sticking region in powerlifters bench press performance. It was hypothesized that the sticking region would occur at the same joint angle of the elbow and shoulder independent of grip width, indicating a poor mechanical region for vertical force production at these joint angles.

2 Methods

2.1 Subjects

12 healthy male powerlifters at the age of 19 - 41, with a bench press record on a national level were recruited for the study. National level was defined as having lifted the same as, or more than, the qualification weight for the national championships in their weight class and category. Amongst the subjects were National, Nordic and European champions in powerlifting. In accordance to the Helsinki declaration all participants signed a consent form.

Table 1: Characteristics of the participants

	Minimum	Maximum	Mean	SD
Age (yrs)	19	41	27.73	8.82
Bodyweight (Kg)	77.5	127	91.85	15.41
Wide grip width (cm)	61	81	74.54	9.75
Medium grip width (cm)	40.5	62.5	56.79	6.04
Narrow grip width (cm)	31	47	39.17	3.51

2.2 Procedure

The subjects were randomly assigned an order in which they were to perform the three grip widths. The three grip widths being; wide defined as preferred competition grip, narrow defined as bi-acromial distance, and medium in the middle of the two. After a general warm-up, including as many reps as the subject wanted with just the barbell, the subjects conducted a standardized warm-up protocol with the first grip width. The protocol was as follows: 8 reps at 40% of the self-estimated one repetition maximum (1-RM$_{est}$), 6 reps at 60% of 1-RM$_{est}$, 3 reps at 70% of 1-RM$_{est}$ and 2 reps at 80% of 1-RM$_{est}$. The 1-RM$_{est}$ was the weight that the subject himself estimated to be his one repetition maximum at that grip width. After the warm-up protocol the subjects were tested at 95% of 1-RM$_{est}$ and 100% of 1-RM$_{est}$, if the 100% lift was successful the weight was raised by 2.5kg or 5kg, depending on the lifters feedback, until a miss or a near miss lift. Three attempts were performed in total with each grip width; the highest completed lift was used for further analysis.

After the first 1-RM was established the lifter was instructed to perform a warm-up set with 3 reps at 80% of 1-RM$_{est}$ at the second grip width. This set was supposed to work as an adaptation set to the new width. After the set the lifter performed the same testing routine as with the first grip width. The same procedure was conducted with the last grip width, one adaptation set at 80% of 1-RM_{est}, and then a 95% and 100% test, plus possible increases if the lift was not a maximum lift. The lifter got 3-5 minutes of rest between each attempt.

The subjects performed the bench press as according to the rules and regulations set by the IPF, except that the requirement for a full stop on the chest was removed, they were allowed to touch and press, but no bounce was allowed.

2.3 Measurements

A three-dimensional (3D) motion capture system (Qualysis, Gothenburg, Sweden) with six cameras was used to track reflective markers, creating a 3D positional measurement. The markers were placed, one on each side of the body, on the lateral tip of the acromion, on the lateral and medial epicondyle of the elbow, on the ulna, and on the radius. There were also placed two markers on the middle of the bar, 20 cm apart, to track bar displacement.

The points of the lift that were used for further analysis were: the start of the ascent (v_0), first peak velocity (v_{max}), first local minimum velocity (v_{min}) and second peak velocity (v_{max2}). These points constitute the start points of the different regions of the lift, v_{max} being the start of sticking region, v_{min} the start of post-sticking region (and thereby also the end of sticking region), and v_{max2} the start of the deceleration phase. Timing, barbell position, velocity, joint angles and resultant moment arms on the elbow and shoulder joint were calculated at these points in Matlab (6.1). Joint angles (shoulder flexion and abduction and elbow extension) were estimates of the anatomical angles calculated from lines formed between the centers of the reflective markers (fig. 2).

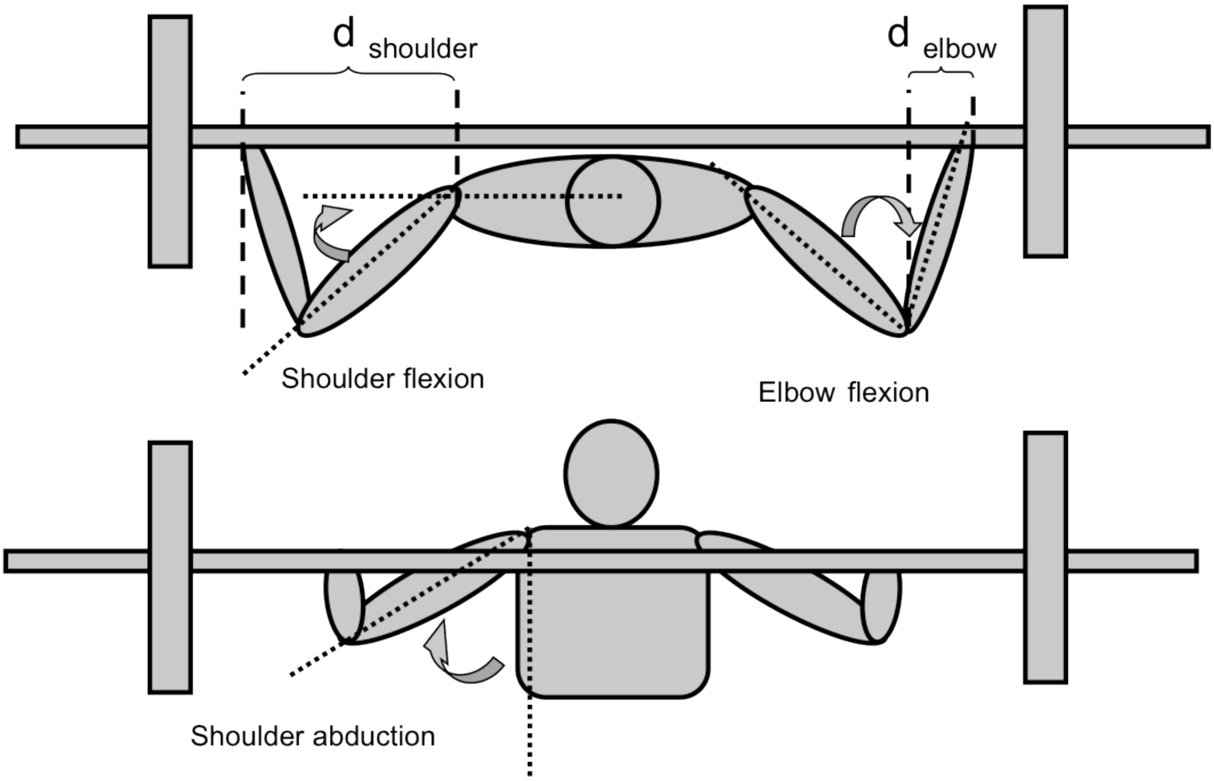

Figure 2: The joint angles and moment arms which were measured during the bench press. Adapted from van den Tillaar and Ettema (2009)

2.4 Statistical analysis

A one-way ANOVA with repeated measures was used with Bonferroni post-hoc tests to assess differences in kinematics. When the assumption of sphericity was violated, the Greenhouse-Geisser adjustments of p-values are reported. For the analysis of resultant moment arms a two-way ANOVA 3*4 repeated measures design with Bonferroni post-hoc tests was used. The significance level was set at $p \leq 0.05$. Statistical analysis was performed in SPSS version 21.0 (SPSS, Inc., Chicago, IL). All results are presented as means ± standard deviations if not otherwise stated. Effect size was evaluated with η^2(Eta partial squared) where $0.01<\eta^2<0.06$ constitutes a small effect, a medium effect when $0.06<\eta^2<0.14$ and a large effect when $\eta^2>0.14$(Cohen, 1988).

3 Results

The highest successful loads lifted by the participants with narrow, medium and wide grip were 122.1±19.4 kg, 126.5±21.6 kg and 131.5±22.9 kg. There was no significant difference between 1-RM in narrow and medium grip ($p=0.146$), but there was a significant difference in wide grip compared to medium and narrow ($p\leq0.029$).

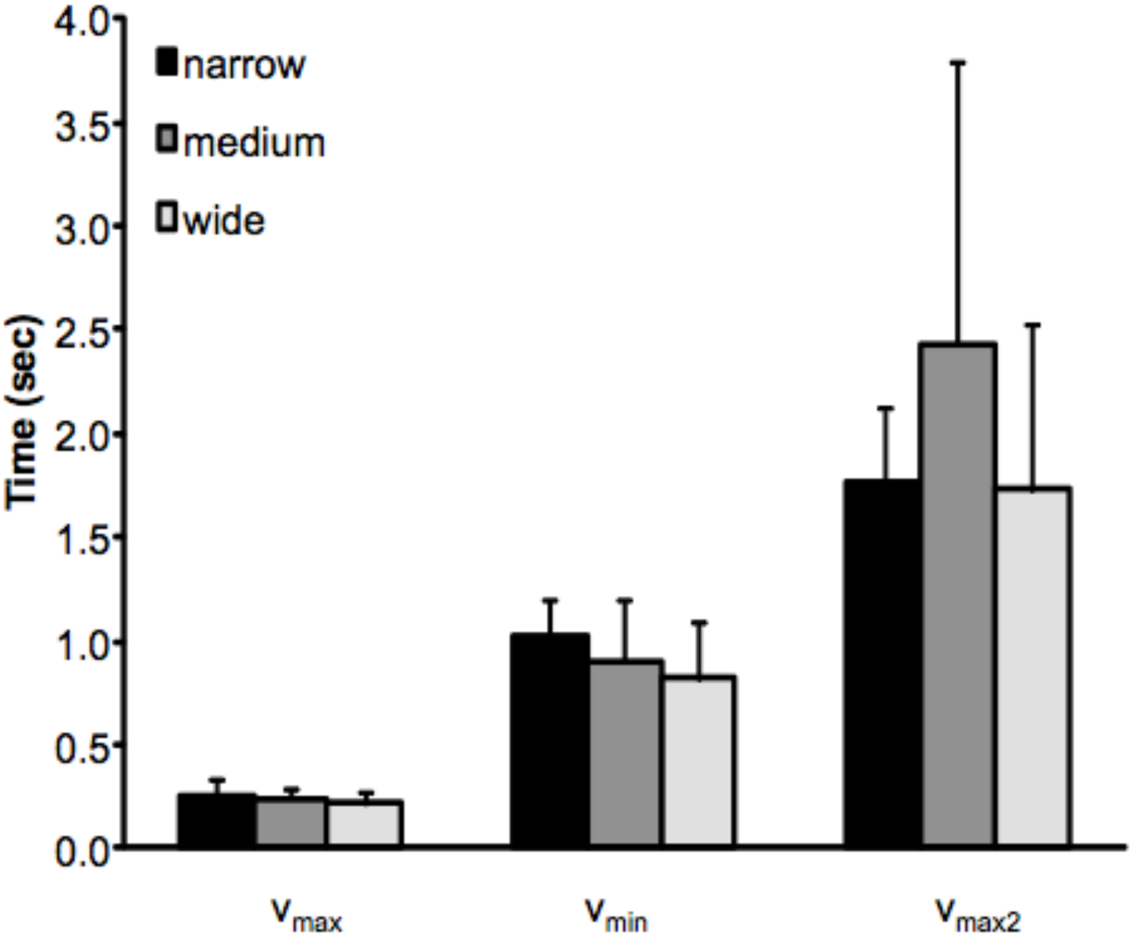

Figure 3: Time of occurrence of v_{max}, v_{min} and v_{max2} with the three different grip widths.
* Indicates a significant difference compared to both the other two grip widths
† Indicates a significant difference between these two grip widths

No significant differences were found for the time of occurrence at v_{max}, v_{min} and v_{max2} between the three grip widths ($F_{2,22} \leq 2.434$, $p \geq 0.111$, $\eta^2 \leq 0.181$, fig. 3). However, velocity at v_{max} was significantly different between the three grip widths ($F_{2,22}=23.606$, $p<0.0001$, $\eta^2=0.682$, fig. 4) with no significant differences of velocity at v_{min} and v_{max2} ($F_{2,22} \leq 3.102$, $p \geq 0.065$, $\eta^2 \leq 0.220$, fig. 4). Post hoc comparisons showed that velocity at v_{max} was significantly higher ($p\leq0.001$) with the narrow grip compared to the other two grip widths (fig. 4).

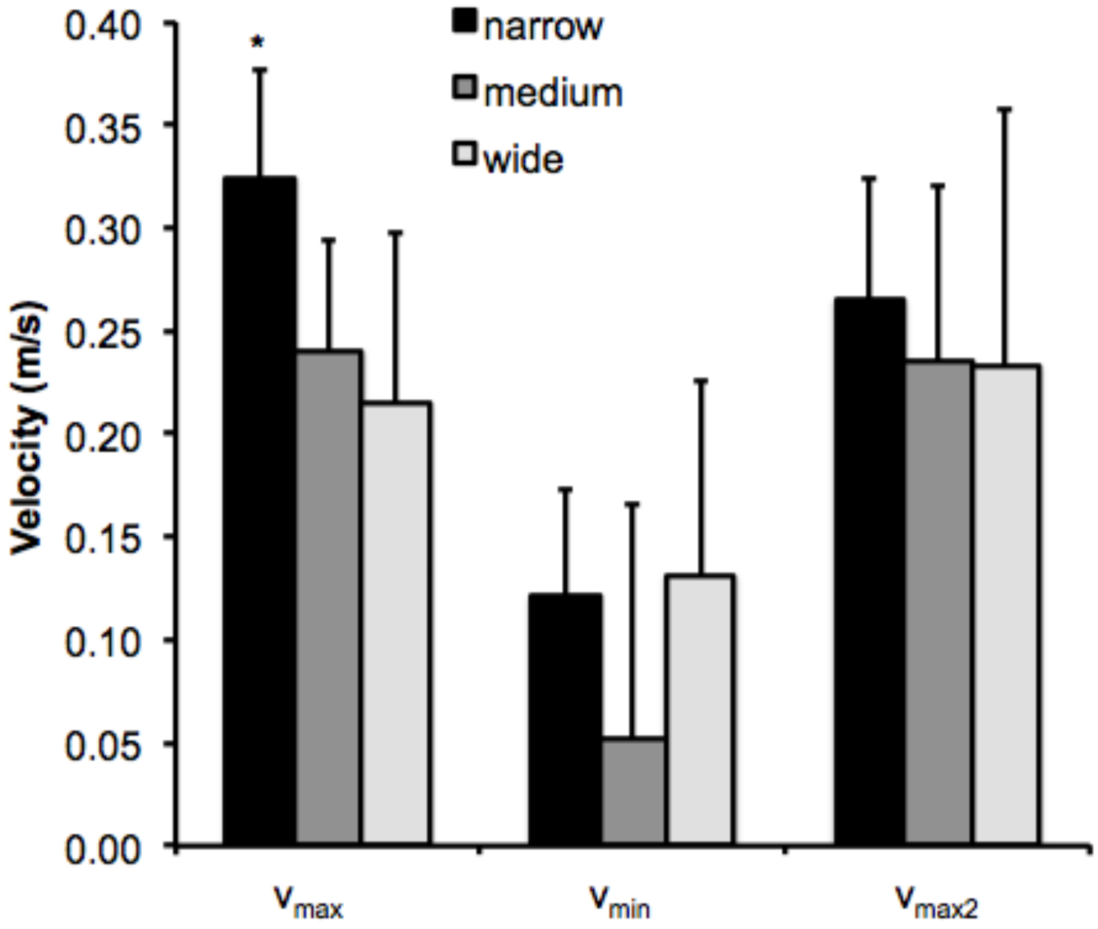

Figure 4: Velocity at v_{max}, v_{min} and v_{max2} with the three different grip widths.

* Indicates a significant difference compared to both the other two grip widths

† Indicates a significant difference between these two grip widths

Also significant differences were found in the position of the barbell from the sternum at all points (v_{max}, v_{min} and v_{max2}) between the three grip widths ($F_{2,22} \geq 14.558$, $p \leq 0.0001$, $\eta^2 \geq 0.570$) Post hoc comparisons showed that the position of the barbell with the narrow grip was significantly higher at v_{max} and v_{min} than with the other two grip widths ($p \leq 0.002$, fig. 5)and a significant higher position at v_{max2} with the narrow grip compared with the wide grip ($p<0.001$, fig. 5).

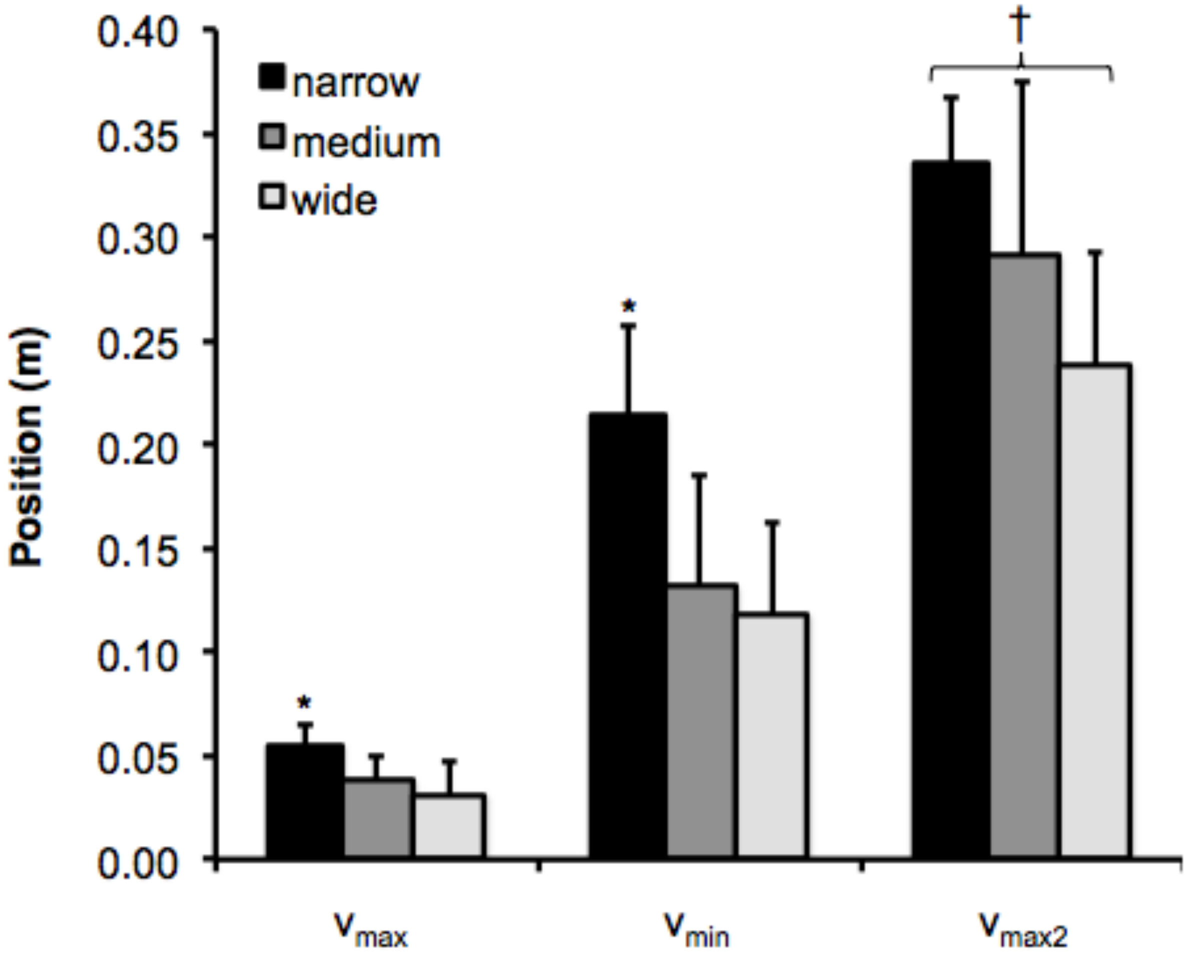

Figure 5: Bar position at v_{max}, v_{min} and v_{max2} with the three different grip widths.

* Indicates a significant difference compared to both the other two grip widths

† Indicates a significant difference between these two grip widths

Significant differences in elbow extension angle were found at v_0, v_{max} and v_{min} ($F_{2,22} \geq 6.16$, $p \leq 0.007$, $\eta^2 \geq 0.36$), but not at v_{max2} ($F_{2,22} = 1.92$, $p = 0.17$, $\eta^2 = 0.15$). Post hoc comparisons showed that at v_0 and v_{max} the extension angle significantly differed across grip widths, narrow grip having the smallest extension angle followed by medium and then wide ($p < 0.01$, fig. 6). It was also found that at v_{min} the extension angle with medium grip was significantly lower than the other two grip widths ($p < 0.033$, fig. 6).

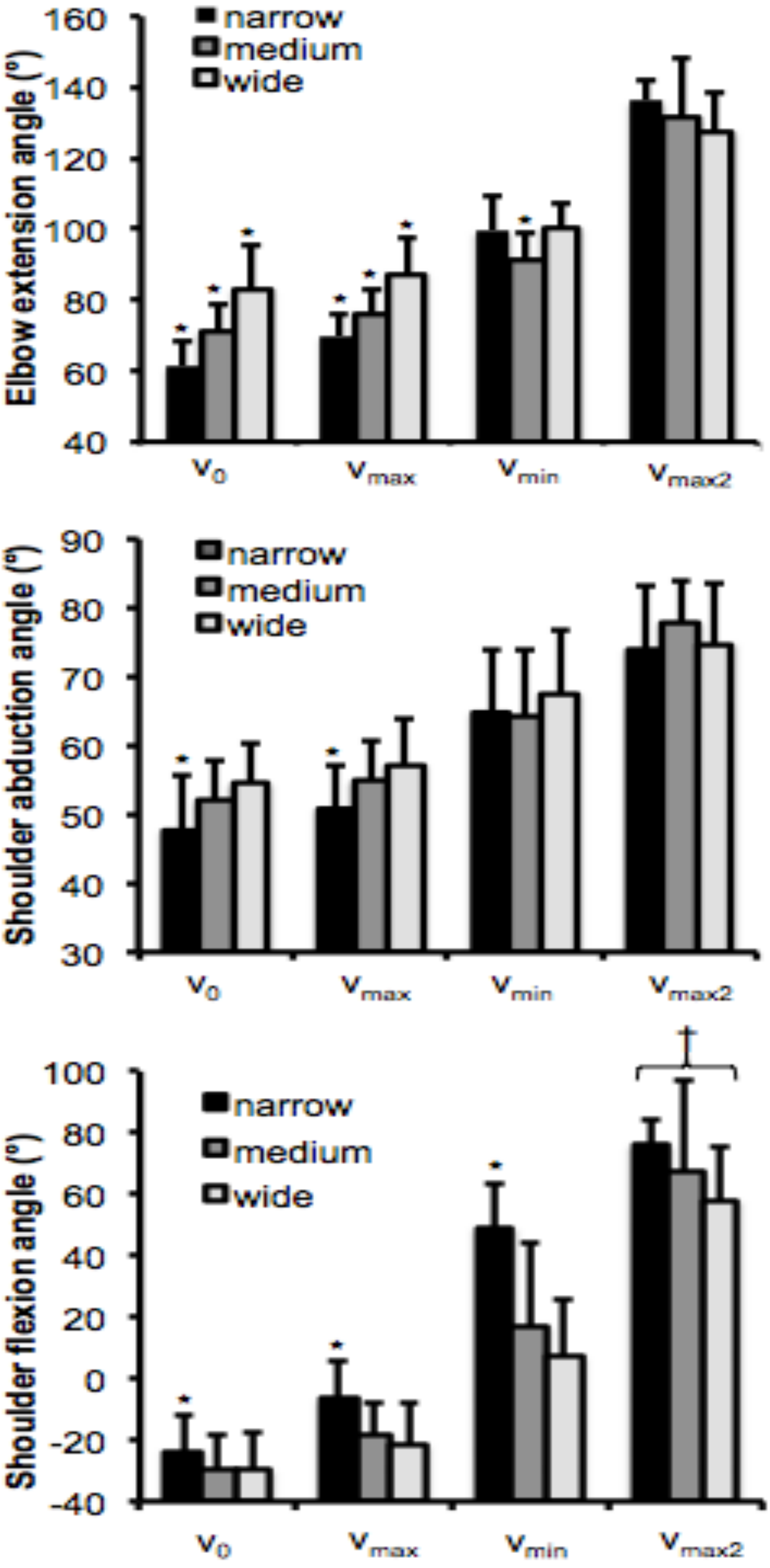

Figure 6: Joint angles at v_0, v_{max}, v_{min} and v_{max2} with the three different grip widths.

* Indicates a significant difference compared to both the other two grip widths

† Indicates a significant difference between these two grip widths

Furthermore, significant differences in shoulder abduction angles were found between the three grip widths at v_0 and v_{max} ($F_{1.2,14.1} \geq 6.554$, $p \leq 0.017$, $\eta^2 \geq 0.375$), but not at v_{min} and v_{max2} ($F_{2,22} \leq 1.89$, $p \geq 0.174$, $\eta^2 \geq 0.147$). Post hoc comparisons showed that the abduction angle with narrow grip was significantly lower at v_0 and v_{max} compared to the two other grip widths ($p \leq 0.046$, fig. 6).

Shoulder flexion angle at v_0 ,v_{max} and v_{min} were significantly different ($F_{2,22} \geq 7.831$, $p \leq 0.035$, $\eta^2 \geq 0.654$) between the three grip widths (fig. 6), with no significant difference at v_{max2} ($F_{2,22}=3.0$, $p=0.07$, $\eta^2=0.215$). Post hoc comparisons showed that the flexion angle at the first three points was significantly higher with the narrow grip compared to the other two grip widths (fig. 6) and at v_{max2} narrow was significantly higher than the wide grip ($p=0.009$, fig. 6), but not the medium grip.

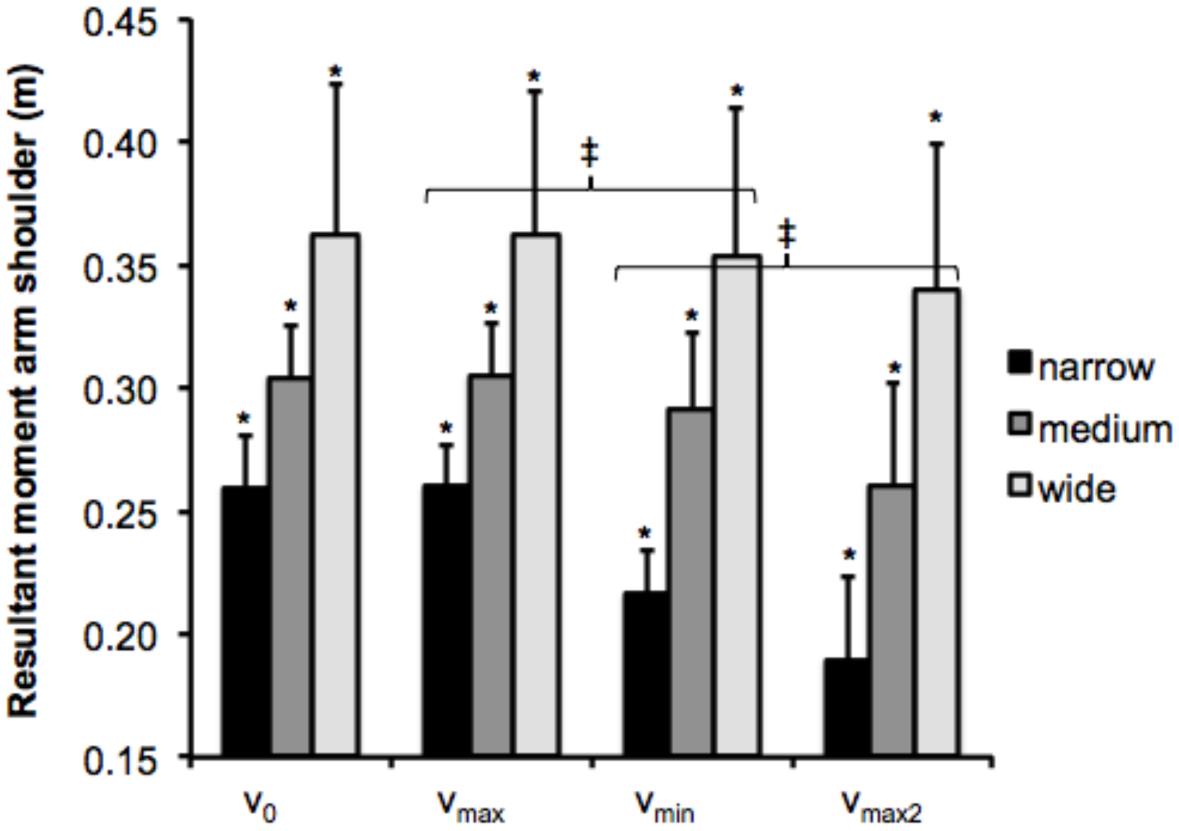

Figure 7: Resultant moment arm of the barbell about the shoulder joint at v_{max}, v_{min} and v_{max2} with the three different grip widths.

* Indicates a significant difference compared to both the other two grip widths

† Indicates a significant difference between these two grip widths

‡ Indicates a significant difference between these two points of the lift for all grip widths

Resultant moment arm of the barbell about the shoulder joint showed in a two-way ANOVA 3*4 repeated measures design that there was a significant change in moment arm over the four points ($F_{1.19,13.1}=23.774$, $p<0.001$, $\eta^2=0.684$), together with an effect of grip width ($F_{1.237,13.608}=53.735$, $p<0.001$, $\eta^2=0.830$) and an interaction ($F_{3.260,13.608}=18.602$, $p<0.001$,$\eta^2=0.628$). Post hos comparison showed that the moment arm differed significantly ($p<0.001$, fig. 7) between the three grip widths in all four points, narrow being the smallest, followed by medium and wide. The moment arm decreased significantly from v_{max} to v_{min} and to v_{max2}in all grip widths ($p<0.02$, fig. 7).The interaction which was found showed that the differences in moments arms between the three grip widths changed significantly different over the four points i.e. with the narrow grip the moments arm decreased more than the medium and the medium decreased more than the wide grip over the four points.

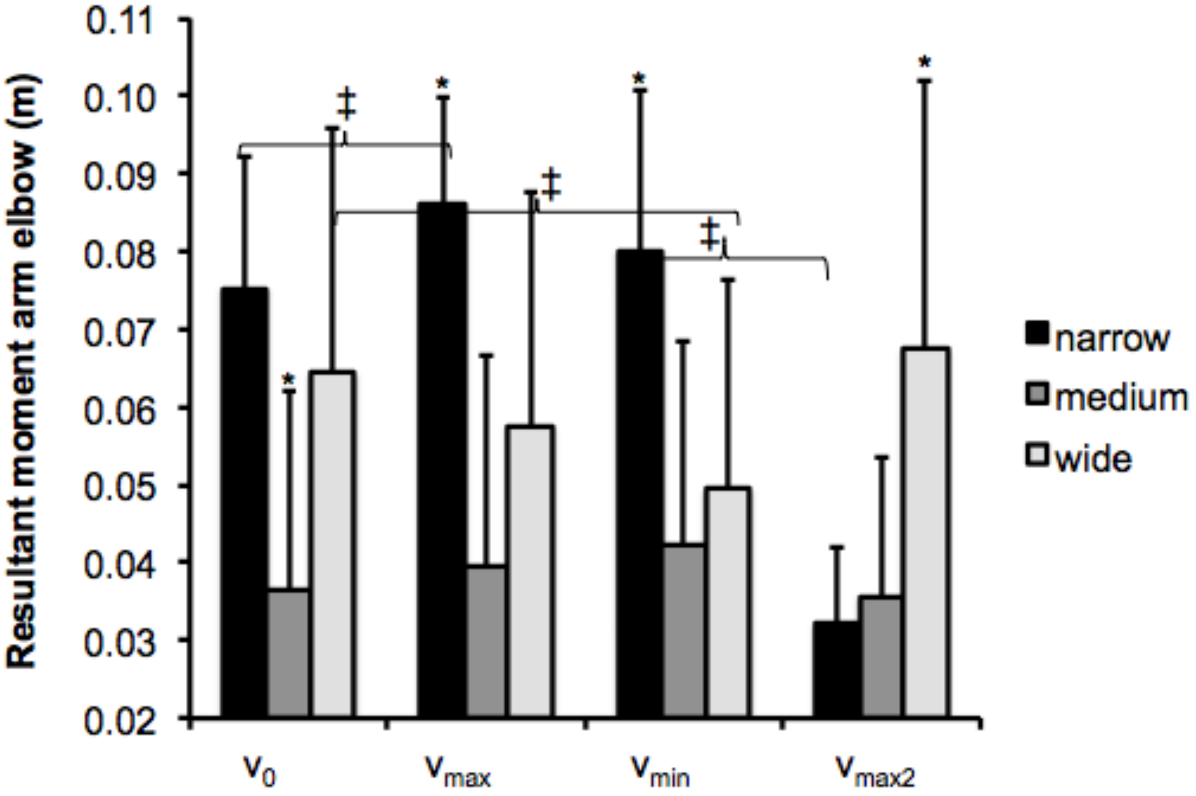

Figure 8: Resultant moment arm of the barbell about the elbow joint at v_{max}, v_{min} and v_{max2} with the three different grip widths.

* Indicates a significant difference compared to both the other two grip widths

† Indicates a significant difference between these two grip widths

‡ Indicates a significant difference between these two points of the lift with this grip width

Resultant moment arm of the barbell about the elbow showed in a two-way ANOVA 3*4 repeated measures design that there was a significant change in moment arm over the four points ($F_{1.741,19.148}$=6..032, p<0.012, η^2=0.354), together with an effect of grip width ($F_{2,22}$=5.707, p<0.001, η^2=0.342) and interaction ($F_{3.262,35.880}$=22.193, p<0.001,η^2=0.669). Since an interaction was found a one-way ANOVA was performed with each grip width, this showed that there was a significant change of moment arm in the narrow ($F_{1.404,15.448}$=36.155, p<0.001, η^2=0.767) and wide grip ($F_{1.317,14.486}$=8.716, p<0.001, η^2=0.442) width during the four points, while no differences what found with the medium grip ($F_{1.401,15.410}$=14.286, p=0.001, η^2=0.565). Post hoc comparisons showed that with the narrow grip the moment arm first increases from v_0 to v_{max} (p=0.011) and then decreases significantly from v_{min} to v_{max2} (p<0.0001). While the moment arm with the wide grip only decreased significantly from v_0 to v_{min} (p=0.016, fig. 8).

4 Discussion

The aim of this study was to examine the occurrence of the sticking region by examining how three different grip widths affect the sticking region in powerlifters bench press performance. It was hypothesized that the sticking region would occur at the same joint angle of the elbow and shoulder independent of grip width, indicating a poor mechanical region for vertical force production at these joint angles.

A prominent sticking region was found in all participants 1-RM lifts with all three grip widths, which was in accordance with the literature (Lander et al. 1985; Elliot et al. 1989; Hamilton, 1995; Newton et al. 1997; van den Tillaar and Ettema 2009; 2010; van den Tillaar et al. 2012). The main findings of this study were that the results did not concur with the hypothesis that the sticking region was angle specific. The narrow grip width had significantly smaller shoulder abduction angle and greater flexion angle than the two other grip widths at the start of the sticking region, and a greater shoulder flexion angle at the end of the sticking region. Elbow extension differed significantly between all grip widths at the start of the sticking region, but at the end only medium grip differed from the two others. The joint angles, for the wide grip, found in this study were similar to those found by van den Tillaar and Ettema (2010). For the medium and narrow grip no earlier studies reported the joint angles during the sticking region and therefore it was not possible to compare.

The elbows were moved laterally during the sticking region, which was also found by Lander et al. (1985), Elliot et al (1989) and van den Tillaar and Ettema (2010). This caused a reduction of the resultant moment arm of the barbell about the shoulder joint, which is in agreement with the previous literature (Elliot et al. 1989; van den Tillaar and Ettema 2009; 2010). The moment arm of the barbell about the elbow was not reduced significantly during the sticking region, but varied across grip widths. This might be an explanation for why the results of this study did not concur with the hypothesis. The three different grip widths had different moment arms on the elbow in the sticking region, the greater moment arm on the elbow will logically create a higher degree of lateral forces and a lesser amount of the total forces produced put vertically on the barbell. If the total force production is the same in all three grip widths throughout the lift, the differences in moment arms will cause the vertical forces to be different. Thereby making the region of poor vertical force production to occur at different joint angles although the region of poor total force production might be joint angle specific. A closer look into the joint angles shows that there were some degrees of elbow extension, shoulder abduction and flexion that all the grip widths went through in the sticking region. For elbow extension this was 87.3° to 91.25°, for shoulder abduction it was 57.1° to 64.4° and for shoulder flexion it was -6.7° to 6.9°. At these degrees of extension, abduction and flexion, vertical force production was reduced in all three grip widths (sticking region). The reason why joint angles were not the same through out the entire sticking region might, as explained above, be the moment arms.

The other factors measured in this study; time and position at the different points, were all in accordance with earlier literature for wide grip (Wagner et al. 1992; van den Tillaar and Ettema 2009; 2010; van den Tillaar et al. 2012) and narrow grip (Wagner et al. 1992), no comparable data was found for the medium grip width. The only significant differences found between grip widths were that with the narrow grip the position at v_{min} and v_{max} were higher. This was different from the study of Wagner et al (1992) who found that there were no differences in vertical position of the barbell at the start and end of the sticking region between the narrow and wide grip width. The reason for the difference in narrow compared to the two other grips in the present study might be that because the narrow grip required greater elbow flexion at the start of the ascent, the lifters were afraid of getting injured, and thereby reported a 1-RM, when it was not a true 1-RM. This is plausible because the velocity at v_{max} was significantly higher with the narrow grip, and that may have caused the higher position of the barbell at v_{min} and v_{max}. Thereby different angles at sticking region may also have been measured due to this underestimation. If we look at only the medium and wide grip, significant differences were found only in the elbow extension in the sticking region (Fig. 6).

Another interesting finding was that the preferred grip width (wide grip) was the grip width with the biggest resultant moment arm about the shoulder joint, and the second biggest about the elbow joint in the sticking region. This was an interesting finding seen as one would believe that athletes on a national level would have found the technique and lifting style that was most efficient for their anthropometry. However, the findings of our study suggest that the subjects would profit from using the medium grip width when looking at moment arms around elbow and shoulder joint during the sticking region.

This study has uncovered some possibilities for methodical improvements. One was that the 1-RM lift was by some means self-reported. Some of the participants did not miss a lift, but reported a near miss lift, and this was taken as the 1-RM. However, this might not be true, the participants might have overestimated how heavy the lift was and thereby reporting a 1-RM lift, when it was not a 1-RM. This could perhaps be improved by increasing the weight until a missed lift, thereby reducing the risk of finding a false 1-RM. In the present study we did not continue until a lift was missed in each grip width because of the possibility that the fatigue caused by a missed lift could affect later lifts with the other grip widths. Furthermore in this study no EMG measurements were performed which perhaps could give more detailed information about the muscle behavior during the lifts. In addition lateral forces were not measured which is necessary for calculating the total force production. Further research should be done with a device measuring the lateral forces, thereby finding if there is a region of poor total force production. The study could be done with the same design as this study, thereby seeing if this hypothetical region of poor total force production is joint angle specific.

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