

Influence of the “Slingshot” bench press training aid on bench press kinematics and neuromuscular activity in competitive powerlifters.

Running head: Impact of the Slingshot on bench press performance

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Abstract:

This study examined the acute effects of the 'Slingshot' on bench-press performance, prime-mover surface electromyographic (sEMG) amplitude, and barbell velocity during maximal and submaximal bench-pressing in competitive male powerlifters. Fifteen male powerlifters (mean \pm SD age: 27.05 \pm 5.94 years; mass: 94.15kg; 1RM bench-press: 139.7 \pm 16.79kg) participated in the study. Bench-press strength, average barbell velocity, and sEMG amplitude of the prime mover muscles (triceps brachii, pectoralis major and anterior deltoid) were measured during two conditions; 'Raw' (without use of any assistance) and 'Slingshot' [using the 'Slingshot' to perform both the weight achieved during 'Raw' 1RM testing (Raw max/SS), and absolute 1RM using the 'Slingshot' (SS)]. The results showed that the 'Slingshot' significantly increased bench press 1RM performance by a mean \pm SD of 20.67kg \pm 3.4kg. Barbell velocity and stick point analysis indicate that this improvement is likely driven by an increase in peak and pre-stick barbell velocity as triceps RMS was lower throughout all rep max phases with the 'Slingshot'. The 'Slingshot' also caused reductions in RMS, specifically of the triceps at all rep ranges but barbell velocity was better maintained in the last reps of all sets. These data indicate that the 'Slingshot' specifically de-loaded the triceps muscle throughout all rep ranges and provide assistance to maintaining barbell velocity under fatigue during later repetitions of multiple-repetition sets. The 'Slingshot' training aid could therefore be used in de-load phases of bench press training or as an over-reaching and velocity training aid.

Key words: Stick point, stick period, powerlifting, bench-press, slingshot

1 **Introduction:**

2 The bench press is one of the most utilised exercises within strength and
3 conditioning practice and programming (5). Similar to other free-weight
4 resistance exercises, the bench press is utilised for developing maximal strength,
5 power, and hypertrophy (30). The bench press is also one of the three
6 competition lifts within the sport of powerlifting (IPF, 2015). However, the
7 popularity of the bench press is due to its ability to develop the strength, power,
8 and hypertrophy of the prime movers: the pectoralis major, anterior deltoid, and
9 triceps brachii (14, 21, 23, 25). Several studies demonstrate the transfer of bench
10 press strength to improvements in motor unit recruitment through various
11 planes of the shoulder (14, 15), and more importantly for athletic performance,
12 strength in the bench press is an indicator of performance in strength and power
13 sports (11, 12, 22). Therefore developing strategies to improve bench press
14 performance has the potential to improve performance across a range of sports
15 including but not limited to powerlifting, discus throwing (11), swimming (12),
16 and kayaking (22).

17 When training for an increase in strength, several training methods and
18 strategies can be adopted. With regards to specificity and technical practice it is
19 important to perform the full movement itself, however there is a growing trend
20 to utilize supplementary or assistance training to develop the muscles,
21 movement patterns, or weak points within a given exercise (28, 29, 34). A recent
22 survey of competitive powerlifters demonstrated that over 50% are utilizing

23 resistance bands in their bench press training, more so than alternative
24 supplementary training methods such as the use of chains (29).

25 Elastic resistance training primarily involves the use of elastic bands of varied
26 thicknesses to challenge a movement pattern and align with the force capability
27 of the musculature throughout the range of motion of many movement tasks (28,
28 34). Several studies demonstrate that the use of combined elastic resistance
29 training in the bench press improves the development of upper body strength (1,
30 9, 13, 18), and in addition, a recent meta-analysis supports the efficacy of
31 variable resistance training methods (use of bands and chains) to improve
32 measures of maximal strength (27). Despite the increased popularity and
33 evidence for the use of elastic resistance training, far less attention has been
34 focused on elastic assistance training.

35 Elastic assistance training utilises an assistance or an over-speed approach
36 during the performance of athletic and strength training movements, allowing an
37 athlete to run faster, jump higher, or lift more weight than they could do without
38 the assistance (8, 31). Several studies demonstrate that elastic assistance acutely
39 improves jump height (31) and sprinting performance (8), whilst chronic jump
40 training with elastic assistance for 4-weeks significantly improved jump
41 performance compared to training without assistance (3). Relative to research
42 on elastic resistance devices, much less attention has been given to the
43 implementation of elastic assistance devices for upper-body strength
44 performance.

45 A recent study examined the acute effects of implementing a supportive
46 assistance device called the 'Slingshot', on 1RM bench press performance in 19

47 resistance-trained male participants (35). The study observed the effect of the
48 'Slingshot' in comparison to traditional 'Raw' bench press performance, and
49 report significant increases to 1RM and barbell velocity associated with trends
50 for decreased EMG amplitude for both the pectoralis major and triceps brachii.
51 They report that all participants showed an increase in absolute 1RM
52 performance by an average of ~16Kg whilst wearing the 'Slingshot', and that
53 participants were able to execute their 'Raw' 1RM weight at significantly higher
54 barbell velocity and power output when using the 'Slingshot'. However, when the
55 relative intensity was matched between the absolute 'Raw' vs. 'Slingshot' 1RM
56 average barbell velocity and average power output were not statistically
57 different and there was a trend for the prime mover normalised EMG amplitude
58 to be lower whilst wearing the 'Slingshot' despite the heavier load. These data
59 indicate that the 'Slingshot' was assisting participants to lift either heavier loads
60 or equal loads at a greater velocity, whilst the trends for decreased EMG
61 amplitude suggest potential de-loading in the prime movers.

62 We therefore assessed bench press kinematics and neuromuscular activation
63 during maximal and submaximal bench-pressing with or without the 'Slingshot'
64 in trained powerlifters. Our aim was to use stick point analysis (10, 32) in
65 conjunction with EMG assessments to try to understand the mechanism by
66 which the 'Slingshot' improves 1RM, and the influence it may have on matched
67 intensity submaximal sets. We hypothesized that the improvement in 1RM with
68 the 'Slingshot' would be due to either A) an increased normalised sEMG
69 amplitude of the prime movers during or after the stick-period of the bench-
70 press or B) that the improvement would be due to a greater peak and average

velocity in the early phases of the bench press as a result of the elastic assistance provided by the 'Slingshot'. As a secondary hypothesis we also theorized that the 'Slingshot' would maintain barbell velocity during sets with multiple repetitions.

Methods:

Experimental Approach to the problem

This study utilised a within-subjects design to examine the effects of Mark Bell's original 'Slingshot' on maximal and sub-maximal bench press kinematics and neuromuscular activity. The study was designed to assess how using the elastic assistance device, the 'Slingshot', altered neuromuscular recruitment patterns of the prime movers and the kinematics of the bench press during maximal and submaximal efforts. These measurements will allow us to determine the mechanism by which the 'Slingshot' may be working and illustrate what affect it may have on muscle recruitment.

Subjects

The methods and procedures implemented within this study were approved by the University of Stirling, School of Sport Research Ethics Committee and all participants provided informed consent upon recruitment selection. All testing took place at the Gannochy Sports Centre - Athlete Performance Laboratory, at the University of Stirling, Scotland, UK. Fifteen male competitive powerlifters (mean \pm SD: age = 27.05 \pm 5.94yrs; body mass = 94.15 \pm 13.43kg; height = 177.38 \pm 4.33cm; 1RM = 139.7 \pm 4.34kg) voluntarily participated in this study. Participants were contacted through word of mouth, social media, and through

study advertisement from 2 drug-tested powerlifting federations within the UK. Participants were selected based upon having ≥ 2 years powerlifting-based strength training. All participants were considered healthy and injury-free based upon their responses to a Physical Activity Readiness Questionnaire (PAR-Q) and understood no reason as to why their ability to exert maximal bench press force would be limited in any way.

*** Table 1 about here ***

Procedures

The study consisted of two laboratory based trials of ~ 1.5 hours each. Trials were scheduled between 7-14 days apart and were completed at the same time of day to account for circadian variation (4). During each trial, participants' 1RM bench press was measured, followed by a predicted 3RM (3Rep) at 87.5% of achieved 1RM and 3 sub-maximal sets of 8 repetitions (8Rep) at 70% of achieved 1RM (2). All participants completed the 'Raw' trial first (without the use of the Slingshot), followed by the 'Slingshot' (SS) trial.

All bench press attempts were completed on a solid leather competition height bench secured in position inside a FT700 Power Cage (Fitness Technology, Australia), and using an IPF specification Eleiko PL competition barbell (Eleiko, Sweden), Eleiko WL coloured training discs (Eleiko, Sweden), and Eleiko Olympic WL competition collars (Eleiko, Sweden).

Prior to commencing the initial trial, participants were provided with a 3-day training and food diary, and asked to complete both diaries in the 2 days leading up to, and day of testing. Participants were advised to maintain their normal diet

117 and training habits and to avoid completing the bench press exercise 48 hours
118 prior to testing. Prior to the second trial participants were provided with their
119 original diaries and advised to replicate their activities to the upmost of their
120 ability.

121 Upon arrival to the laboratory, participants provided anthropometric
122 measurements comprised of their age (years), body mass (kg), and height (cm),
123 along with a competition-style bench press 1RM (kg) predicted to the best of
124 their ability. Participants were also allowed to select their preferred rack height,
125 and demonstrated their bench press grip width, which was measured and
126 recorded (cm) and marked for reference on the barbell using masking tape.

127 Prior to commencing any warm-up activities, participants were familiarised with
128 the testing protocol and requirements, and allowed to ask any questions or for
129 any further information if required. During the initial phase of the warm-up, all
130 participants were required to familiarise themselves with the sEMG
131 normalisation procedure by completing controlled and consistent bench press
132 repetitions using the empty barbell to a metronome set at 30bpm, prior to
133 loading. During this familiarisation, a clearly audible metronome was played
134 through a pair of speakers, and participants were required to complete a full
135 competition style set up, un-rack the barbell, and perform as many repetitions as
136 they deemed necessary until they felt confident executing the bench press
137 movement to the rhythm of the metronome. Each time the metronome sounded
138 indicated a change of phase (eccentric: concentric), requiring a controlled time
139 period of 2s per phase.

140 Following the metronome familiarisation, the barbell was loaded for participants
141 and they performed repetitions at various increments of their choosing. Number
142 of sets, repetitions, and loadings were recorded on a data collection sheet for
143 replication in the subsequent trial and rest intervals of 2-minutes were provided
144 throughout the warm up. For normalisation purposes, participants were
145 recorded performing one set of five repetitions at 70% of predicted 1RM to the
146 30bpm metronome, following the criteria highlighted above (7). Following the
147 single normalisation set, participants continued with their own self-selected
148 warm up.

149 Once participants exceeded 90% predicted 1RM, all attempts were considered
150 '1RM attempts' and were completed between 5-minute rest intervals and to
151 correct referee commands and competition rules (IPF, 2015). Participants
152 proceeded with 1RM attempts in increments of their choosing and in agreement
153 with the primary investigator until they reached muscular or technical failure. In
154 all instances, 1RM was achieved between 3-5 attempts. Attempts were
155 disqualified if the participant failed to successfully perform the repetition or if
156 they failed to meet all competition requirements for successful bench press
157 performance (IPF, 2015). Once participants had established a 1RM, they
158 performed three consecutive paused repetitions at 87.5% 1RM to demonstrate
159 execution of a predicted three-repetition-maximum (3Rep) with consideration to
160 fatigue accumulated following the 1RM protocol (2). Participants finally
161 completed three sets of eight continuous and dynamic repetitions (8Rep) using
162 70%1RM (2). Multiple repetition sets were also separated by a 5-minute rest

interval and assistance racking and un-racking the barbell was provided at the participants' choosing.

*** Figure 1 about here ***

Following the 7-14 day interval, participants returned to the laboratory and completed the SS trial. Participants were provided with an introduction to the Slingshot, and, identical to trial 1, participants' anthropometric characteristics were taken and a re-familiarisation to the procedures was provided prior to commencing the warm-up. Several different size selections were provided for the 'Slingshot' device, and were fitted to each participant according to the manufacturer's instructions. The same warm-up protocol was followed, and an identical rack height and grip width was implemented. All warm-up prior to, and including normalisation repetitions were taken without the use of the 'Slingshot', and all repetitions performed following the 70% normalisation were completed using the 'Slingshot'. The 'Slingshot' was worn across the elbow joint as recommended by the product manufacturers, and to avoid disruption to EMG signals on the triceps and pec placements (See Figure 2). The achieved Raw 1RM weight was performed as one of the 'SS' 1RM attempts (Raw max/SS), participants then proceeded to add weight and follow the same protocol as the 'Raw' trial until a separate 'SS' 1RM was achieved. Participants' 3Rep and 8Rep weight were established using 87.5% and 70% of the achieved 'SS' 1RM respectively, and were performed in the same manner described for the 'Raw' trial. All attempts throughout both trials were performed to the nearest 1kg.

*** Figure 2 about here ***

sEMG amplitude was collected via skin surface electrodes (SilveRest, Vermed, VT) from the pectoralis major, anterior deltoid, and triceps brachii of the participants' dominant side during all repetitions using a BioPac MP100 (BioPac Systems Inc., CA). Reference signals were provided via skin surface electrodes placed on the clavicularis and patella. Prior to applying the electrodes, the skin surface was prepared for collection by shaving, slightly abrading using sandpaper, and wiped with alcohol swabs (PDI Healthcare, NJ), in line with SENIAM guidelines (17). A small amount of SignaGel electrode gel (Parker Laboratories, NJ) was used on the centre of each electrode to aid signal quality. Electrodes were applied to the skin surface ~2cm apart and secured to the skin surface with masking tape if necessary. Due to the nature and placement of the 'Slingshot', electrodes for the pectoralis major were placed using medial and central clavicularis placements as suggested by Krol et al, (19) (See Figure 1). Electrode placement for both the anterior deltoid and triceps brachii were in line with recommendation by Perotto and colleagues (24). As participants performed bench press repetitions, the EMG amplitude of the pectoralis major, anterior deltoid, and triceps brachii (RMS) was collected using the Acqknowledge software for Windows (BioPac Systems Inc., CA) and saved for offline analysis.

A Celesco PT5A-125-S47-UP-10K-M6 linear transducer (Celesco, CA), connected to a BioPac MP100 data capture unit (BioPac Systems Inc., CA), was secured to the top of the power rack to measure participants' average barbell velocity (m/s) and bar displacement (cm) during all bench press attempts. During both 'Raw' and 'SS' trials, a Velcro strap attached to the transducer cable was secured in a consistent, slightly off centre placement on the barbell. The position of the

transducer was adjusted appropriately for each participant so that the cable ran vertically during bench press execution. As participants performed bench press repetitions, the velocity and displacement of the barbell was recorded using the Acqknowledge software for Windows (BioPac Systems Inc., CA) and saved for offline analysis.

All data were analysed using the Acqknowledge software for Windows (BioPac Systems Inc., CA). Repetition phases were defined in accordance with (10, 33). sEMG signals for the pectoralis major, anterior deltoid, and triceps brachii were digitised individually at a sampling rate of 2,000 Hz and recorded in Volts. sEMG signals were root mean square (RMS) processed based on previous recommendations for research investigating neuromuscular activation levels (16).. Average RMS was calculated for a moving window 100ms time period across the entire waveform for each activity. sEMG signals were then normalised against corresponding repetitions extracted from the set of 5 reps performed to a metronome at 70%1RM (7) as part of the participants' warm-up.

*** Figure 3 about here ***

Analysis of the transducer data was performed by highlighting only the concentric phase of the repetitions. Phases were defined in accordance with Van den Tillaar et al, (33). For both maximal and sub-maximal repetitions, the start of the concentric phase was identified as the first point at which velocity reached 0m/s, indicating a change of direction. For maximal attempts, the phases of the concentric portion of the bench press were defined as per Van Den Tillaar et al, (33) (See Figure 3 for representative trace). This involved defining the beginning of the pre-stick period (phase 1) by identifying the point at which velocity was 0

m/s at the end of the eccentric phase, identifying the stick point and beginning of the stick period (phase 2) as the point of peak velocity during the concentric phase, and identifying the post-stick period (phase 3) as the point at which acceleration again crossed 0 m/s². The lift ended when velocity reached 0 m/s at the end of the concentric phase. Each phase and/or repetition was analysed individually for total time (s), average bar speed (m/s), and the stick point was identified (m) comparative to the total displacement.

Statistical Analysis

All statistical analyses were carried out in GraphPad, Prism (GraphPad Software, CA). Where 2 groups were compared, a 2 tailed t-test was performed. Where more than two groups were compared, a 1 way ANOVA was utilized with a Tukey's HSD test. Where multiple comparisons were made across groups, a 2 way ANOVA was performed with a Bonforoni's multiple comparisons test. Normality of data was tested using D'Agostinio-Pearson omnibus normality test. Where data were not normally distributed then the non-parametric two tailed t-tests were performed. When multiple comparisons were made on non-normal data then a Friedman test was utilized with a Dunn's multiple comparisons test. All data were reported as mean \pm SEM and significance was set as a p value of $p \leq 0.05$. Correlations were determined via a simple linear regression.

Results:

*** Figure 4 about here ***

All participants displayed an increase in absolute bench press performance whilst using the “Slingshot” from $139.7 \pm 4.34\text{kg}$ ‘Raw’ to $160.4 \pm 4.43\text{kg}$ “SS” for an average increase of $\sim 20\text{Kg}$ (Figure 4A). The absolute gain from the ‘Slingshot’ was not related to the amount lifted (Figure 4B) but instead was highly correlated to the individuals bodyweight ($R^2 = 0.334$), indicating that despite all participants wearing an appropriately sized device, the larger participants were able to gain more from the ‘Slingshot’ (Figure 4C). The ‘Raw’ 1RM corresponded closely to the calculated ‘SS’ 3Rep (Figure 4D). These data were plotted and correlated revealing that there was a highly significant correlation between participant’s ‘Raw’ 1RM and ‘SS’ 3Rep ($R^2 = 0.9538$) (Figure 4E).

*** Figure 5 about here ***

During maximal 1RM bench press attempts, ‘Raw’ normalised triceps RMS ($169.64 \pm 15.26\%$) was significantly higher than both ‘Raw max/SS’ and ‘SS’ conditions ($87.28 \pm 5.84\%$ & $115.84 \pm 10.64\%$) (Figure 5A). Normalised RMS for the pectoralis was significantly lower in the ‘Raw max/SS’ condition compared to the ‘SS’ condition ($90.83 \pm 6.97\%$ vs. $117.8 \pm 11.27\%$) during 1RM attempts (Figure 5A). Normalised RMS for all muscles (grouped) was significantly reduced during 1RM performance for ‘Raw max/SS’ ($95.58 \pm 5.47\%$) than during the ‘Raw’ condition ($138.82 \pm 9.42\%$) (Figure 5A). Normalised triceps RMS was also observed to be significantly higher during the ‘Raw’ condition ($126.02 \pm 9.19\%$) than the ‘SS’ condition ($83.12 \pm 9.97\%$) during a set

of 3 repetitions (Figure 5B), and during both set 1 (108.15 ± 6.25 % vs. 75.96 ± 7.36 %) and set 3 (115.35 ± 7.48 % vs. 84.37 ± 8.45 %) of the multiple sets of 8 repetitions (Figure 5C).

*** Figure 6 about here ***

Average barbell velocity was significantly greater across the whole concentric phase by ~3fold for the 'Raw max/SS' condition (0.29 ± 0.02 m/s) when compared to the 'Raw' & 'SS' conditions (0.11 ± 0.01 m/s & 0.10 ± 0.01 m/s) (Figure 6A). The peak velocity during the maximal attempts was significantly higher in the 'SS' condition compared to the 'Raw' condition (0.31 ± 0.02 m/s vs. 0.27 ± 0.02 m/s), as was the average velocity of phase 1 (Figure 6A). There is a trend for phase 3 to have a lower velocity in the 'SS' condition compared to 'Raw'. There is a high degree of variability between the 'SS' and 'Raw' conditions when plotting these data as individual responses, whilst during phase 1 there is a consistent increase in phase 1 velocity (9 subjects increase) when wearing the 'Slingshot' (Figure 6B).

The displacement data demonstrates that there was no effect of wearing the 'Slingshot' on total displacement indicating that hand position was replicated accurately between trials and that the 'Slingshot' did not affect the range of motion (Figure 6C). However, the 'Slingshot' significantly altered the displacement at which the stick point occurred (Figure 6C). The effect was small, ~1cm higher in the concentric phase, but very consistent with 12 out of 15 subjects demonstrating an upward shift in the start of the stick point (Figure 6C and 6D). The sticking period tended to occupy a greater proportion of the concentric phase whilst wearing the 'Slingshot' however this did not reach

significance. Whilst not significant, when the individual data were plotted as % of the total displacement there was a similar trend but a high degree of inter-subject variability, with 7 subjects demonstrating an increase and 8 subjects demonstrated a decrease in the stick period length whilst wearing the 'Slingshot' (Figure 6D).

No significant differences were found for average barbell velocity (m/s) during reps 1 and 2 of the 3Rep, however average barbell velocity was significantly faster for the 'SS' condition than the 'Raw' condition (0.21 ± 0.02 m/s vs. 0.18 ± 0.02 m/s) during rep 3 of the 3Rep (Figure 6E). Similarly, the change in barbell velocity (%) between reps 1 and 3 of the 3Rep were significantly lower in the 'SS' than the 'Raw' condition ($-15.72 \pm 5.36\%$ vs. $-25.57 \pm 9.4\%$) (Figure 6F). Average barbell velocity was significantly faster during the 'SS' than the 'Raw' condition for both set 1 rep 8 (0.35 ± 0.04 m/s vs. 0.30 ± 0.04 m/s) and set 3 rep 8 (0.34 ± 0.07 m/s vs. 0.26 ± 0.03 m/s) during the multiple sets of 8 repetitions (Figure 6G). Similarly, the change in barbell velocity (m/s) between reps 1 and 8 of the multiple sets of 8 were significantly lower in the 'SS' than the 'Raw' condition ($-19.38 \pm 4.4\%$ vs. $-31.18 \pm 4.82\%$) (Figure 6H).

To determine the mechanism behind the improved 1RM performance whilst wearing the 'Slingshot' we split the analysis of the prime mover RMS over the 3 phases of the bench press; pre-stick period [1], stick period [2], and post-stick period [3]. These data revealed that there was no effect of the 'Slingshot' on pectoralis (Figure 7B) or deltoid (Figure 7C) RMS activation. However, the triceps RMS was significantly lower during the stick [2] and post-stick [3] periods (Figure 7A).

*** Figure 7 about here ***

Discussion:

This is the first study to assess the impact of the “Slingshot” bench press training aid on bench press kinematics and neuromuscular activity in trained powerlifters across a range of intensities. The ‘Slingshot’ was found to be an effective elastic assistance device for enhancing 1RM bench press performance in all participants, on average producing a fixed absolute increase of ~20kg. This elastic assistance allowed the ‘Raw’ 1RM to be lifted with an average velocity ~3x faster than the ‘Raw’ 1RM performed unassisted. The increased velocity whilst wearing the ‘Slingshot’ occurred in spite of significantly reduced RMS in the triceps brachii. Furthermore, when intensity was matched (same relative %1RM with or without the ‘Slingshot’) the RMS of the triceps was reduced at all intensities. During both of the multiple repetition conditions (3Rep/8Rep), the last rep was performed with a higher velocity than the corresponding ‘Raw’ condition. This preservation of barbell velocity throughout a set may be indicative of reduced fatigue (26) suggesting that despite matching for relative intensity, the ‘Slingshot’ may effectively reduce fatigue.

Components of the velocity data from our study are somewhat reminiscent of the velocity data obtained from performing the bench press with chain weight (6). At the beginning of the concentric phase, the assistance from the device will likely be greatest, and like with chains, the force required to move the bar off the chest will be lower with the weight experienced increasing into lockout. Therefore, increased velocity is an attractive theory for the mechanism of how the ‘Slingshot’ may work. Despite the greater load, the average barbell velocity of the

maximal lift was the same between conditions, with peak barbell velocity significantly faster during a maximal attempt with the 'Slingshot'. Assessing barbell velocity during the different pressing phases revealed that during the pre-stick period [1], barbell velocity was significantly faster whilst wearing the 'Slingshot'. The velocity data yields some insight into the mechanism by which the 'Slingshot' may allow an individual to complete a full lift with significantly more weight than their 'Raw' 1RM. We initially theorized that as the concentric phase progressed, the activation of the prime movers would increase to compensate for the reducing assistance supplied by the elastic device. To our surprise the RMS of the pectoralis and the deltoids was the same between the 'Raw' and 'SS' conditions, whilst the RMS of the triceps was significantly reduced in the 'SS' trial. These data indicate that despite ~20kg extra on the bar, the triceps are having to activate to a lesser extent to complete the lift, even during the post-stick [3] phase of the lift where the assistance from the device would be assumed to be minimal. We hypothesize that the ability to complete the repetition with a significantly greater load during the 'SS' trial is driven by both the increased peak velocity, and increased velocity throughout the pre-stick [1] period imparting more momentum to the barbell. However, it is unlikely that increased velocity is the mechanism responsible for every individual, as several individuals display a reduced velocity during the pre-stick period [1]. As a result, we must explore additional theories as to how the 'Slingshot' allows individuals to lift significantly higher loads, despite similar, and in some cases reduced, prime mover sEMG.

One possibility is that the 'Slingshot' may alter the mechanics of the bench press by pulling the elbows into a more mechanically advantageous position. Van den Tillaar et al, (33), suggest that the stick period during the bench press is partly due to the arm position transitioning into a less mechanically advantageous position. It is possible that due to the nature and placement of the 'Slingshot', that it may be maintaining the elbows in a position which may allow for a stronger press. Another possibility for how the 'Slingshot' alters the bench press performance is that the 'Slingshot' shifts the displacement at which the stick period begins. Whilst the shift in where the stick period begins was small, ~1cm higher during 'SS' vs 'Raw', we cannot rule out the possibility that this small shift may have had a significant effect on the ability to complete the lift.

The study by Ye et al, (35), similar to ours, found a fixed increase in 1RM performance from wearing the 'Slingshot'. They observed an increase in absolute 1RM performance from 114.6kg to 132.1kg and a fixed mean increase of 17.6kg whilst wearing the 'Slingshot'. Our findings however, showed that the 'Slingshot' improved mean 1RM bench press performance from 139.7kg to 160.4kg with a mean fixed increase of 20.67kg. Although largely similar, the slight differences in findings between our study and those of Ye et al, (35) are possibly due to the training status and technical competency of the different sample groups. As in our study, they also found no correlation between the 1RM and the gain from wearing the 'Slingshot'. These data indicate that the weight lifted whilst wearing the 'Slingshot' is not related to the amount of weight on the bar. We find however, that the mass of the individual is significantly correlated to the gain from wearing the 'Slingshot'. The range in gain from wearing the 'Slingshot' in

our study was 15-27kg with the greatest gain achieved by the largest (by body mass) individual in the study (124.1kg). We theorize that this effect may be driven by chest girth i.e. greater chest girth creating a greater stretch producing more elastic assistance. Future studies should correlate more comprehensive anthropometric measures to the gain from wearing the 'Slingshot' thus allowing for an individual to estimate the gain they will get from the device by making a simple anthropometric measure.

Practical applications:

Aside from suggesting how the 'Slingshot' works, our data also suggest some potential uses for the device in training. Some researchers have theorized that the benefit of elastic training is that it allows for similar forces to be produced but at faster velocities (20). The 'Slingshot' could be used as a speed training device, as our data clearly demonstrate that velocity is substantially improved whilst wearing the 'Slingshot'. Therefore, it may have some utility in velocity training for sports such as the shot-put. However, the sEMG data shows that the triceps are very likely de-loaded at all intensities with the 'Slingshot'. These findings combined with the velocity data from the multiple repetition sets suggest that the 'Slingshot' likely reduces fatigue and could also be used as a de-loading tool. One advantage of the 'Slingshot' over other de-loading or speed training tools, such as using bands and chains, is its ease of use. Furthermore, unlike other commonly used de-loading tools, the 'Slingshot' allows for a full range of motion to be performed as demonstrated by total barbell displacement during both 'Raw' and 'SS' trials. It should be noted that if the 'Slingshot' was employed for a bulk of training, that the potential de-loading of the triceps would

very likely lead to a reduced performance on the bench press therefore it should be used strategically and as a supplement to traditional bench press training.

In summary, the acute increases observed in bench press performance resultant of using the 'Slingshot' suggest that it may be an effective training device for speed training and de-loading the bench press exercise during a variety of intensities whilst maintaining the full range of motion of the traditional format of the bench press.

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Figure Legends:

Figure1. **‘Slingshot’ placement during a representative repetition.** Subjects were instructed to perform the ‘Slingshot’ repetitions to the same IPF standards as in the previous ‘Raw’ trials.

Figure2. **Electrode placement and positioning of the ‘Slingshot.’** Participants were instructed to wear the ‘Slingshot’ with the crease centred at the elbow. Electrodes were placed as described in the methods to ensure that the ‘Slingshot’ did not disrupt the electrodes during bench pressing.

Figure3. **Defining the phases of maximal bench press attempts.** Figure 3 illustrates a representative trace of acceleration, velocity and displacement during a 1RM attempt. The beginning of the pre-stick period (phase 1) was identified as the point at which velocity was 0 m/s at the end of the eccentric phase. The stick point, and the beginning of the stick period (phase 2) was identified as the point of peak velocity during the concentric phase. The post-stick period (phase 3) began when acceleration again crossed 0 m/s². The post-stick period ended when velocity reached 0 m/s at the end of the concentric phase.

Figure4. **The ‘Slingshot’ increases the bench press 1 repetition maximum in a manner correlated to body mass.** Fifteen trained power-lifters underwent rep max testing on two occasions separated by 7-14 days. The ‘Raw’ repetition maximum (1RM) was determined without any assistance and the SS repetition maximum was determined whilst wearing the ‘Slingshot.’ After the 1RM testing, 3 repetitions (3Rep) were

performed at 87.5% of the achieved 1RM followed by 3 sets of 8 (8Rep) at 70% of the achieved 1RM. The mean weight lifted in each of these conditions is plotted in (A) with the individual 1RM data plotted on the inset graph in (A). The absolute gain from wearing the 'Slingshot' (the difference between Raw and SS trials) was plotted against the Raw 1RM achieved (B) and against the body mass of the individuals (C). The individual data for the Raw 1RM and the weight lifted on the 3Rep SS trial were plotted (D) with a linear regression of these variables plotted in (E). * indicates significantly different from corresponding 'Raw' condition (as assessed by paired t-test between respective 'Raw' and 'SS' conditions). Significance was determined as $p \leq 0.05$.

Figure5. The 'Slingshot' reduces sEMG amplitude of the triceps brachii at all intensities. The 'Raw max/SS' was performed during the warm up of the SS trial day and consisted of performing the previous session's raw 1RM whilst wearing the 'Slingshot'. Surface EMG (sEMG) amplitudes were recorded during all sets and reps as described in the methods. All data presented are root mean squared (RMS) processed and normalised to the 70% normalisation set. A) sEMG amplitudes recorded during repetition maximum testing, B) sEMG amplitudes recorded during the set of 3 repetitions at 87.5% and C) sEMG amplitudes recorded during the 3 sets of 8 repetitions at 70%. Φ indicates 'Raw' is significantly different from both 'Raw max/SS' and 'SS' (as assessed by multiple comparisons). α indicates significantly different from 'SS' (as assessed by multiple comparisons). \S indicates significantly different from 'Raw' (as assessed by multiple comparisons). * indicates significantly different from 'Raw' (assessed by paired t-test). Significance was determined as $p \leq 0.05$. Tricep – triceps brachii, pec – pectoralis clavicularis, delt – anterior deltoid, grouped – sEMG grouped for all 3 muscles assessed.

Figure6. The 'Slingshot' improves peak barbell velocity on maximal efforts and maintains mean barbell velocity in multiple repetition sets. Barbell velocity was tracked during all movements using a vertical transducer. The phases of the bench press were determined by assessing the acceleration curves with the stick period defined as the period between negative and positive barbell acceleration. A) Barbell velocity during rep max testing. B) Individual changes in barbell velocity between 'Raw' and 'SS' trials assessed by phases of the maximal effort. C) Barbell displacement during maximal efforts with the displacement at which the stick point occurs and also the displacement over which the stick period lasts also plotted. D) The % of the total displacement at which the stick period begins (stick point) and the % displacement over which the stick period lasts plotted as individual responses from the 'Raw' to the 'SS' trials. E) Average barbell velocity for each repetition of the set of 3 reps at 87.5%. F) The % decrement in barbell velocity from repetition 1 to repetition 3 on the 'Raw' and 'SS' trials. G) Average barbell velocity for the first and last rep of the first and last set of the 3 sets of 8 repetitions at 70%. H) The % decrement in barbell velocity from repetition 1 to repetition 8 on the third set of the 'Raw' and 'SS' trials. Φ indicates 'Raw' is significantly different from both 'Raw max/SS' and 'SS'. α indicates significantly different from 'SS' (assessed by multiple comparisons). ϵ indicates significant difference between two bars (assessed by multiple comparisons). * indicates significantly different from 'Raw' (assessed by paired t-test). Significance was determined as $p \leq 0.05$.

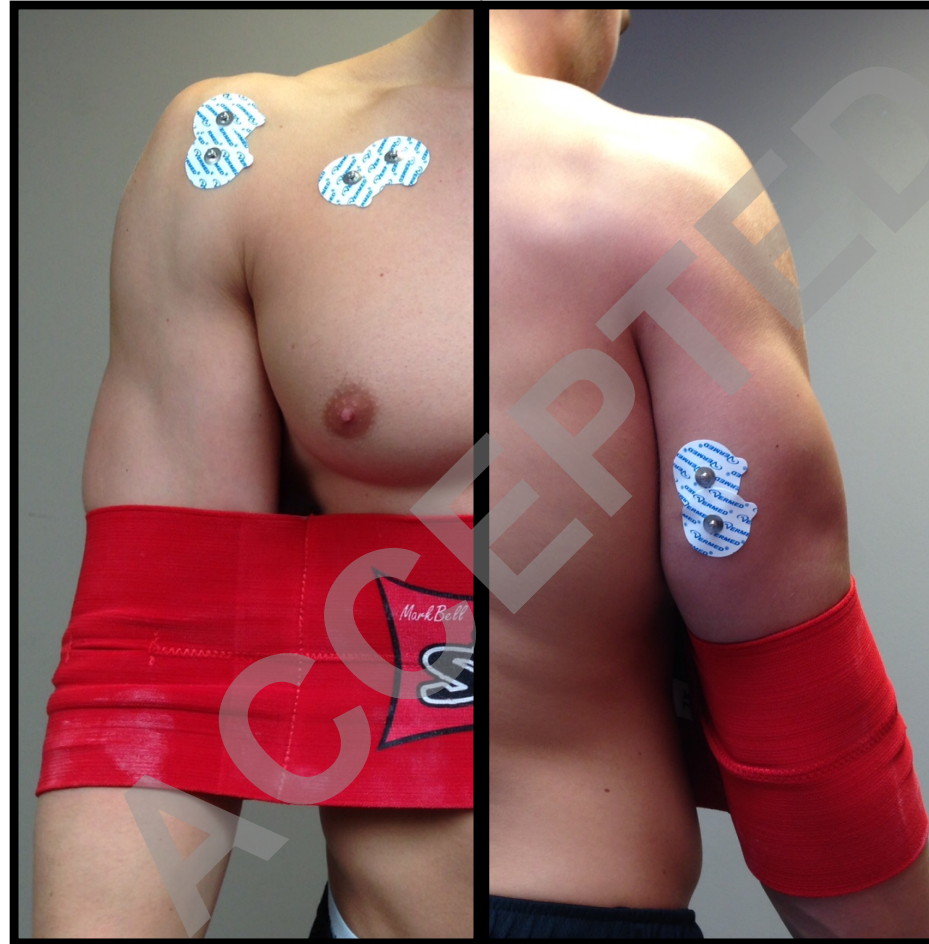
Figure7. **The 'Slingshot' reduces sEMG amplitude of the triceps brachii during a maximal effort.** Surface EMG (sEMG) amplitudes were recorded during repetition maximum testing as described in the methods. All data presented are root mean squared (RMS) processed and normalised to the 70% normalisation set. A) sEMG amplitudes of the triceps brachii, B) sEMG amplitudes of the pectoralis clavicularus and C) sEMG amplitudes of the anterior deltoids. α indicates significantly different from 'SS' (as assessed by multiple comparisons $p \leq 0.05$).

ACCEPTED

	Age (yrs)	Mass (kg)	Height (cm)	Bench Press 1RM (kg)	Training Age (yrs)	Training Sessions/ wk (days)
N=15	27.05 ± 5.94	94.15 ± 13.43	177.38 ± 4.33	139.73 ± 16.79	5.93 ± 5.67	4.2 ± 0.53

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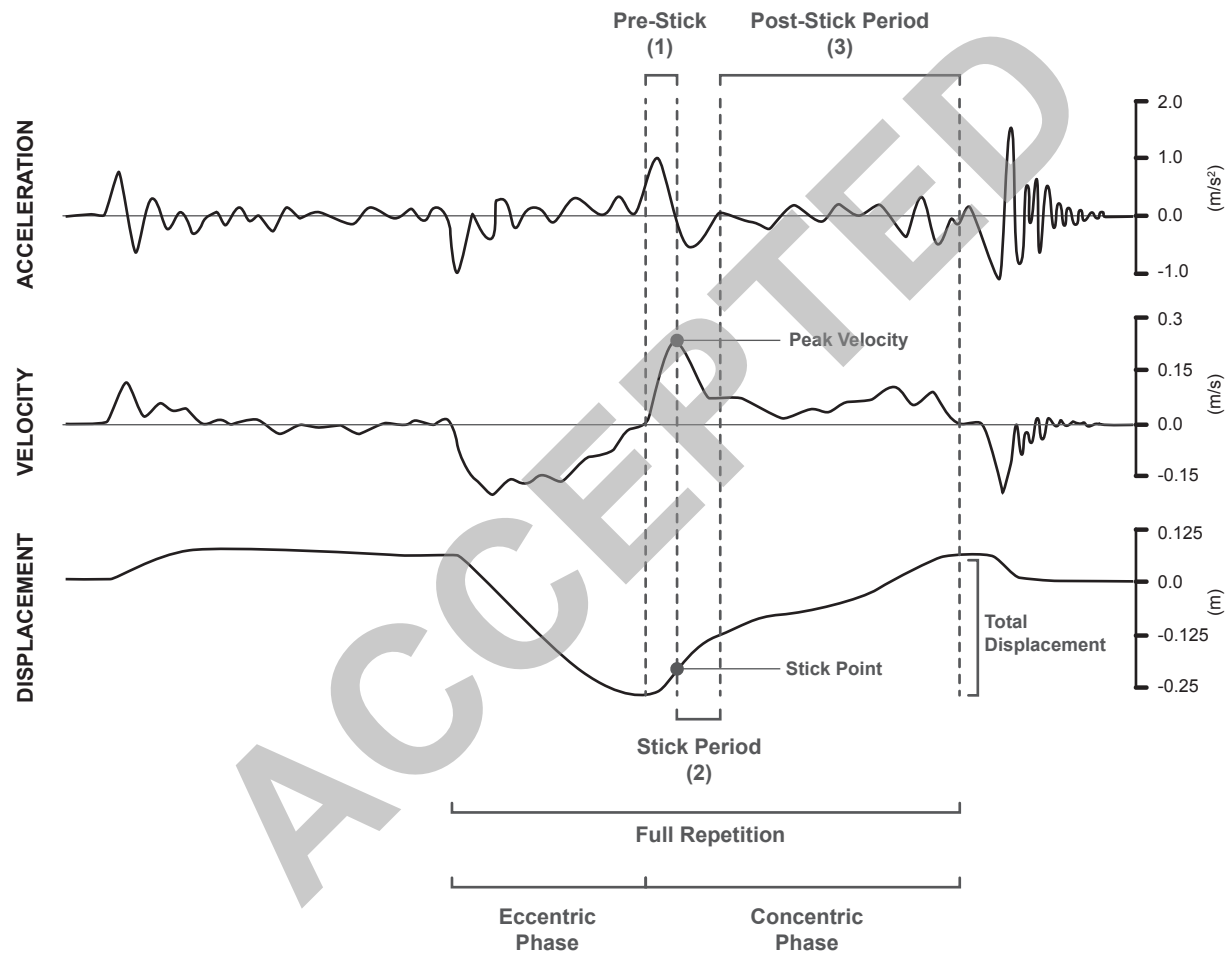
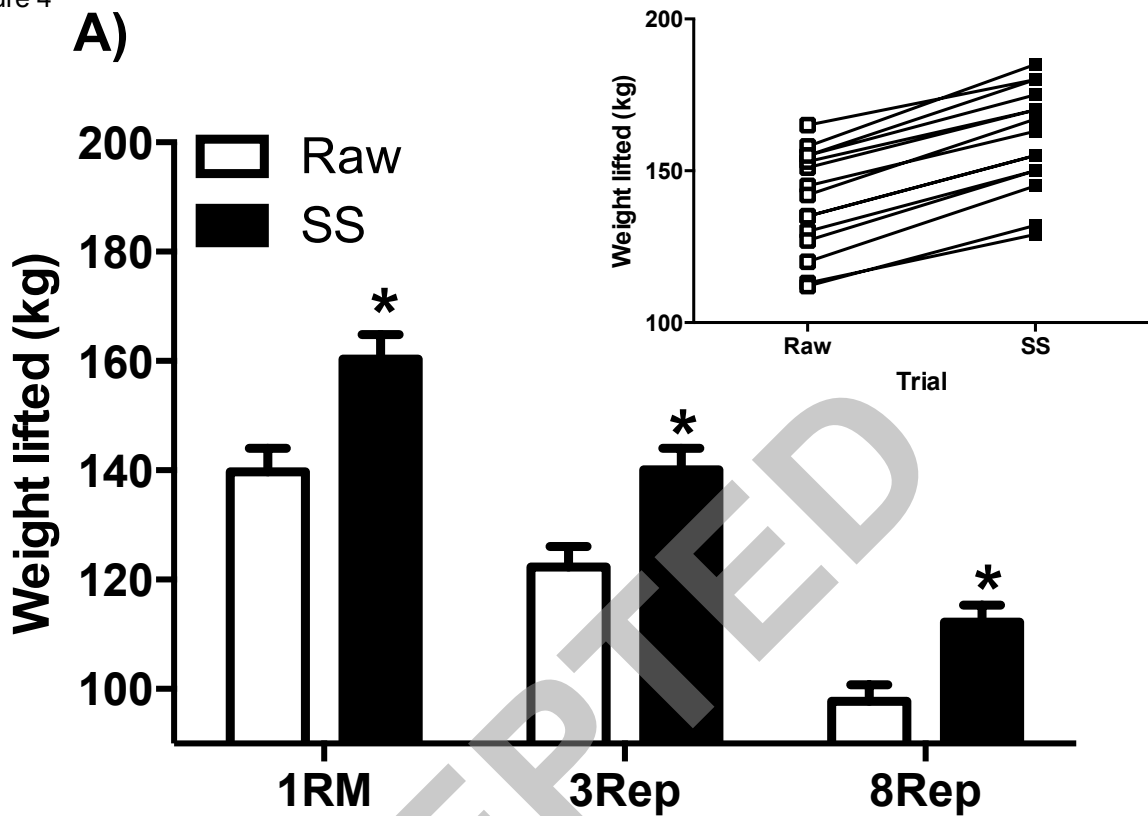
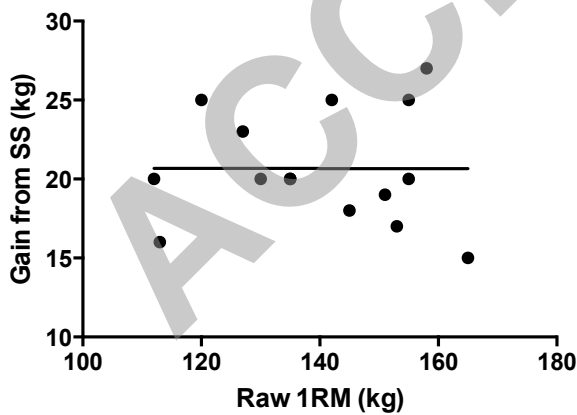


Figure 4

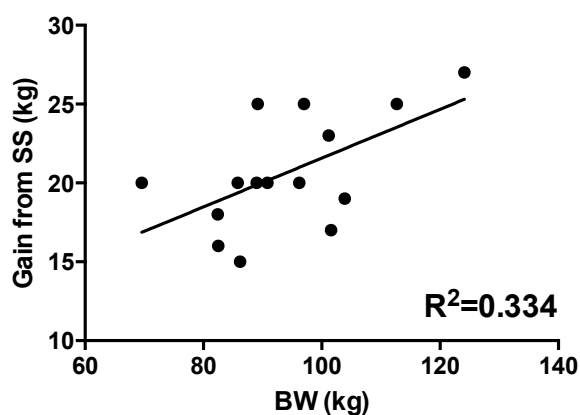
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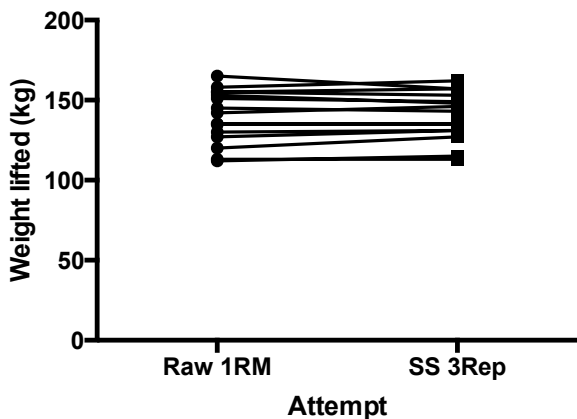
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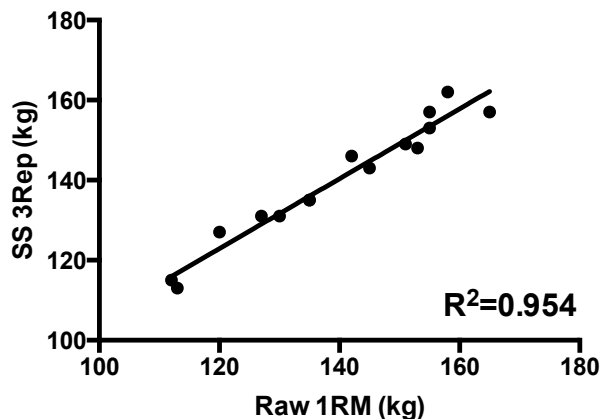
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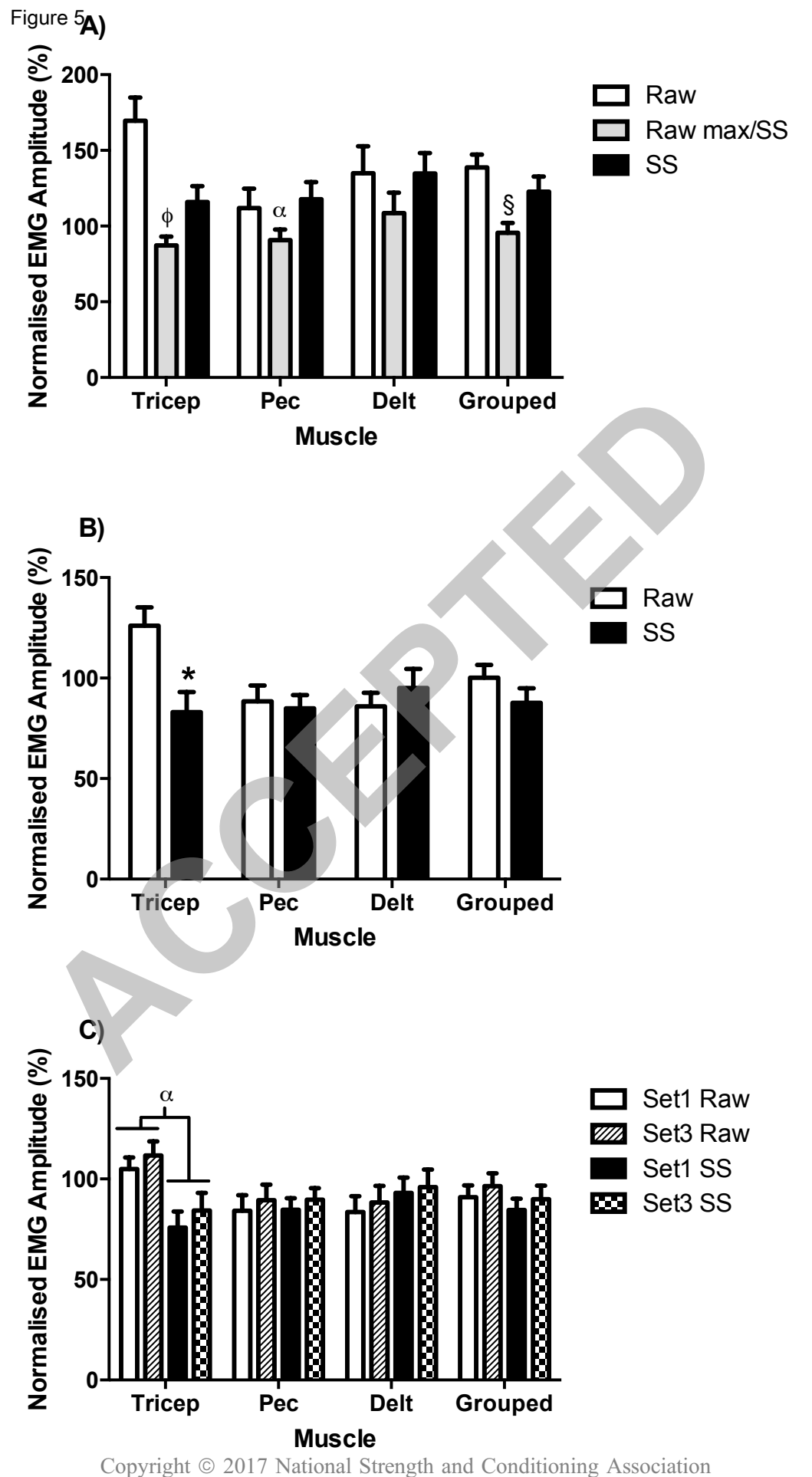


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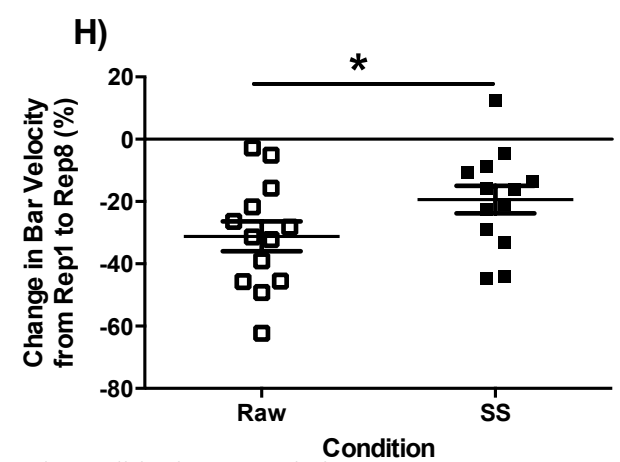
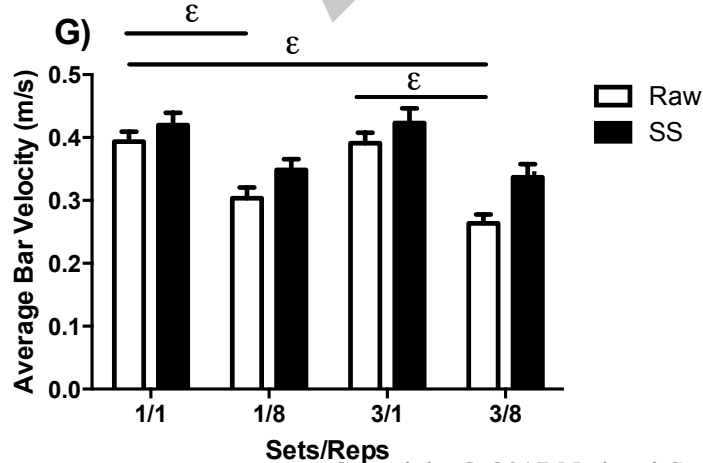
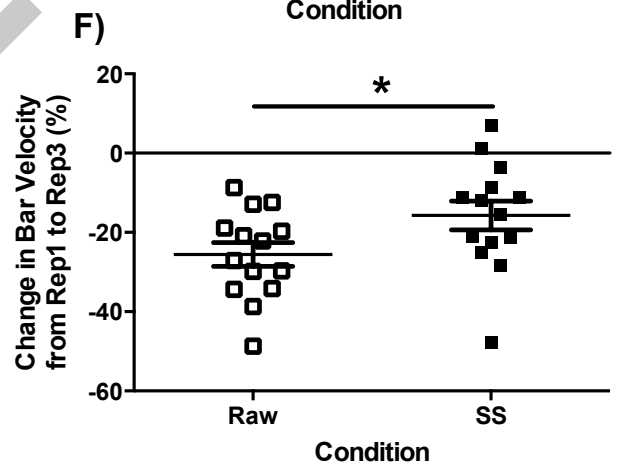
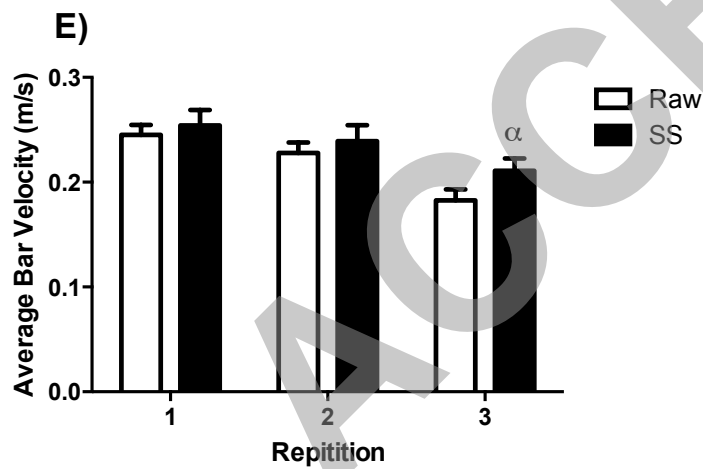
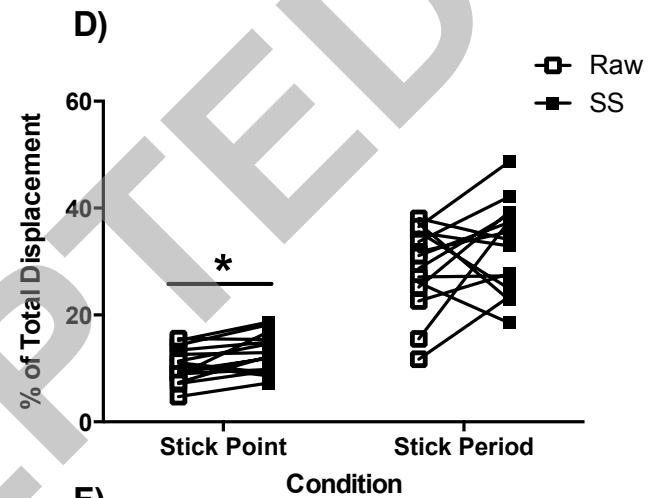
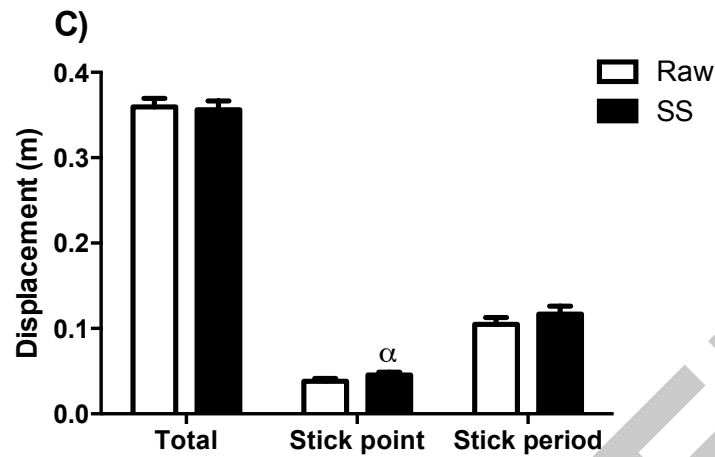
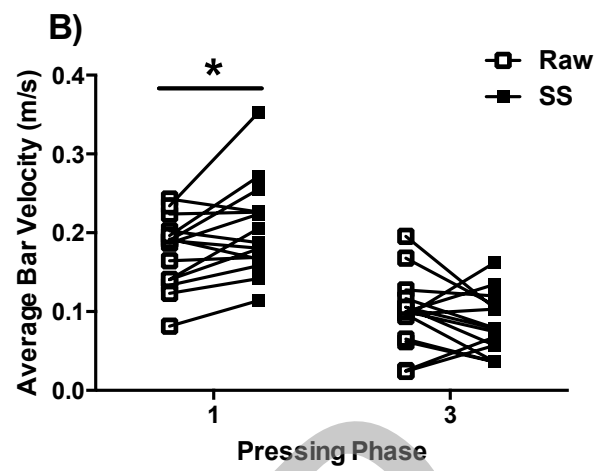
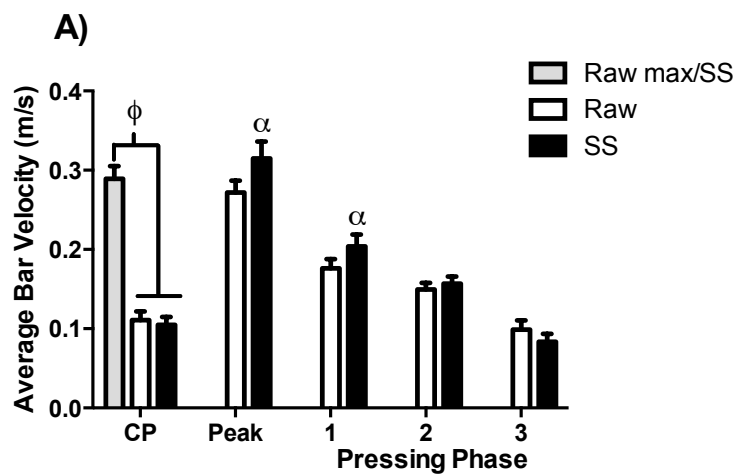


Figure 7

