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The Effect of Different Weight Plate Widths (Bumper vs. Standard) on the Biomechanics of the Bench Press

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Abstract

Fiedler, MJ, Triplett, NT, Hamilton, KC, Needle, AR, and van Werkhoven, H. The effect of different weight plate widths (bumper vs. standard) on the biomechanics of the bench press. *J Strength Cond Res* 38(4): e143–e149, 2024—Anecdotal evidence suggests that bumper plates impact lifts in powerlifting and weightlifting differently than standard cast iron plates, but whether biomechanical differences exist between lifts using bumper versus standard plates has not been investigated. Eleven resistance-trained subjects performed the bench press at 70, 80, and 90% of their 1 repetition maximum (1RM) while being blinded to whether they were lifting with bumper or standard plates. Motion data were captured by an 8-camera motion capture system, and electromyography (EMG) data were recorded for the anterior deltoid, pectoralis major, and triceps brachii. Repeated-measures analysis of variances showed a significant main weight effect for time under tension ($p < 0.001$), total work ($p < 0.001$), and muscle activity through EMG (across all muscles; $p < 0.001$) and a significant weight × joint interaction effect for average joint moment ($p < 0.001$) and peak joint moment ($p < 0.001$). However, there were no significant differences observed between the different weight plates for any of the measures. The main finding of the study suggests that there are no biomechanical differences between using bumper plates compared with standard plates during the bench press lift.

Key Words: motion capture, EMG, weight lifting, barbell

Introduction

The flat barbell bench press is one of the most popular forms of free weight resistance exercise because the movement is easily learned and can be done with limited equipment. The bench press is regularly integrated into workout programs to improve strength, power, hypertrophy, muscle endurance, and injury prevention (1). It is a multijoint exercise, which primarily trains the pectoralis major, triceps brachii, and anterior deltoid along with other stabilizing muscles (3,18,23,28,42). Strength and conditioning coaches use the bench press as a primary method prior, during, and after a training program to evaluate an athlete's upper-body strength through a 1-repetition maximum (1RM) protocol (3,32).

The mechanical properties of the barbell used during a bench press can differ from manufacturer to manufacturer and are affected by the steel alloy used, distance between sleeves, diameter of the barbell, and length of the sleeves (4,26). Furthermore, a lifter can choose to use different types of weight plates during their lift, such as standard plates or bumper plates. Standard plates are traditionally made of cast iron and are best suited for powerlifting tasks, such as bench press and squat, whereas bumper plates are commonly made of rubber and are designed for Olympic lifts, such as cleans and snatches. Although the mass of these plates is clearly defined and should be identical for the same weighted plate, bumper plates can be up to 3 times wider than standard plates. When using the same barbell, the thicker width of the bumper plates increases the distance of the load center of mass from the bar center when compared with standard plates (13,21,26). This increased center of mass distance can enlarge the amount of deformation of the barbell. Anecdotal evidence suggests that this increased bar deformation could alter an athlete's performance during the lift (13,21). For example, when lifting 84 kg with identical barbells, bumper plates could augment a lifter's deadlift by increasing bar deformation up to 68% (13). This deformation causes a decrease in the total work needed to complete the lift because of the decreased distance that the center of the bar needs to travel (13). However, there have been no peer-reviewed studies to date examining the effects of bar deformation on powerlifting activities, and only a handful of studies have examined bar deformation and its effects on Olympic lifts (4,5,40).

A second factor to consider is the effect that wider bumper plates have on the moment of inertia of the barbell. A mass further distributed from the center point, or axis of rotation, increases the object's moment of inertia. Therefore, a bar loaded with bumper plates would have an increased moment of inertia over a standard plate-loaded bar. Because the moment of inertia equates to the resistance to angular rotation, the greater the moment of inertia, the harder it is to move a weight around a rotation point (22,26). Furthermore, a change in the moment of inertia of an object can affect the sensation of how an object feels in a person's hands. Previous work on handheld objects has shown that people are more sensitive to a change in an object's moment of inertia than a change in its mass (15,16). It is not clear what effects inertia would have on the ability of a lifter to perform and control the trajectory of the bar during heavy lifts. Although the bench press is a fairly simple lift, the path that the bar takes is not a straight line upward. If there are

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slight differences in force production between the 2 arms of the lifter, the bar will deviate from this bilateral symmetric path—the bar could be slight lower/higher on one side or slightly more anterior/posterior on one side. If this happens, with a system with higher moment of inertia, it would be more difficult to correct this path error. However, the opposite is also true. If the lifter can lift with very little asymmetry between the arms, then the fact that the moment of inertia is large, actually helps to keep the bar on the symmetrical path it is going. Previous work has shown that some movement asymmetry does exist during a bench press lift (11). Therefore, it suggests that the higher moment of inertia could make it more difficult to correct movement errors once they occur.

Because different plates and barbells are generally used for different lifting activities, one needs to consider these mechanical differences when purchasing equipment. With financial constraints, small schools, home gyms, and/or fitness centers may decide to purchase one type of weight plate, for example, bumper plates only, to reduce costs (10,14,25). Therefore, it is important to know whether biomechanical differences exist when using different weight plates during a lift, such as the bench press, to reach desired training program outcomes and help prevent injuries.

The purpose of this study was to examine the biomechanical and neuromuscular differences, specifically kinetics and muscle activation, during the bench press when using either bumper plates or standard plates. Because previous research and anecdotal evidence suggests that bar deformation affects total work, it was hypothesized that bumper plates would show increases in total work, which will also cause an increase in time under load. It was further hypothesized that the increased moment of inertia of the bumper could reduce the lifter's ability to make small adjustments to force production during the lift and would therefore cause an increase in muscle activation and an increase in the joint moments at the shoulder, elbow, and wrist.

Methods

Experimental Approach to the Problem

A within-subjects cross-sectional design was used to assess and compare joint kinetics and muscle activity of the upper body during the performance of the bench press while using either standard or bumper plates. After subjects' 1RM was determined at the first session, joint kinetic and electromyography (EMG) data were collected for 3 sets of bench press (70, 80, 90% of 1RM) at sessions 2 and 3. The amount of intensity and volume (Procedures section below) were chosen to mimic similar intensities and volume used in the field for hypertrophy and strength training (3,32). During each session (2 or 3), all subjects performed the bench press using 1 type of plate. In the next session, the other plate type was used. This was a crossover trial design—all subjects completed the activity with both types of plates. In both sessions 2 and 3, the subjects were blinded to the type of plate by placing boxes over the weights (Figure 1).

Subjects

Fourteen subjects, 12 men and 2 women, were recruited from Appalachian State University (Table 1). Subjects between the ages of 18 and 35 years, possessing at least 1 year of bench press experience, and exhibiting a 1RM of at least 100 lb (45.36 kg) on the bench press were included. The exclusion criteria were a history of upper-extremity injury in the past 6 months that changed their activity level for more than 24 hours, a history of an upper-arm traumatic fracture, pregnancy, and had a pacemaker or automated defibrillator. Before participating in the study, the subjects were informed of all potential risks involved and signed a written consent approved by the Appalachian State University's Institutional Review Board.

Figure 1. Setup of bench press showing bench, rack and bar, as well as the blinding boxes attached to prohibit subjects from seeing the type of weight plates (bumper or cast iron) used.

Procedures

The testing was divided into 3 sessions with each session separated by at least 1 week. The subjects were asked not to perform any upper-body exercises 72 hours before each session. All the testing sessions occurred at the university's biomechanics laboratory. For all 3 sessions, grip width was standardized to 150% of the subject's biacromial distance. In the first session, the subject's maximal bench press strength was assessed through a 1RM testing protocol using standard plates and a standard barbell. The 1RM testing followed the 1RM guidelines set by the National Strength and Conditioning Association (NSCA) (3). During session 2, all subjects performed the bench press with 1 type of plate, and during session 3, all subjects performed the bench press with the other type of plate (Table 2 for plate details). The plate order was not the same for all subjects. Some subjects (n = 7) used standard plates during session 2 and bumper plates during session 3, and other subjects (n = 7) did the opposite. The subjects were blinded to whether they were lifting bumper or standard plates by a large cardboard box attached to the barbell (Figure 1), but subjects were informed of the exact load they were lifting during each lift. The subjects performed 3 warm-up sets of the bench press: one set of 5 repetitions at 60%, one set of 5 repetitions at 65%, and one set of 5 repetitions at 70%. After the warm-up sets, the subjects performed 3 sets of bench press during which data were collected: 1 set of 8 repetitions at 70%, 1 set of 4 repetitions at 80%, and 1 set of 2 repetitions at 90% of their 1RM rounded to the nearest 5-lb (2.72 kg) increment with a 5-minute rest period between the lifts. The loads were created using the least total number of plates possible. Because the study did not have access to 5 lb (2.72 kg) and 2.5 lb (1.13 kg) bumper plates, standard plates were used for both bumper and standard plate protocols for these specific weight increments. Because of only having 1 set of 10 lb (4.54 kg) bumper plates, a thicker 10-lb standard plate

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Table 1
Subject information, mean (*SD*).*

Age (y)	21.21 ± 1.97
Height (m)	1.77 ± 0.09
Mass (kg)	84.61 ± 14.91
Bench press experience (y)	4.14 ± 1.51
1RM (kg)	99.51 ± 32.90
70% 1RM (kg)	71.68 ± 23.28
80% 1RM (kg)	81.29 ± 26.23
90% 1RM (kg)	91.61 ± 30.10

*1RM = 1 repetition maximum.

was used for any load that required a second 10-lb plate. A certified Strength and Conditioning Specialist (NSCA-CSCS) supervised all sessions.

Kinematic and Kinetic Data Recording. To measure arm kinematic and kinetic data, subjects were fitted with retroreflective markers on selected anatomical bony landmarks based on previous studies (6,12,20,24,33). The reflective landmarks were placed bilaterally on the acromion process, the midpoint between the acromion process and the medial epicondyle of the elbow on the anterior surface of the upper arm, the lateral epicondyle of the elbow, the medial epicondyle of the elbow, the midpoint between the lateral epicondyle and radial styloid process on the dorsal surface of the forearm, the radial styloid process, the ulnar styloid process, and third metacarpal bone. A final reflective marker was placed 2 finger widths inferiorly from the jugular notch on the sternum. Barbell kinematic and kinetic data were measured by placing 2 retroreflective markers directly opposite to each other next to the edge of each sleeve on the inside shaft of the barbell, and a reflective marker placed in the outside center of each sleeve of the barbell. Three-dimensional data recording and analysis were performed using an 8-camera Vicon Vantage motion analysis system (Oxford Metric, Oxford, United Kingdom). The analysis focused on the transverse plane and the 2-dimensional planar motion associated with this plane during the bench press activity because visual inspection of the task and previous work suggests this to be a major plane of interest during the bench press (20,24). From the data collected, 2-dimensional kinematic and kinetic variables (associated with the transverse plane) were calculated using projections of 3-dimensional data in the transverse plane. Calculations were performed using custom code written in MATLAB (MathWorks, Natick, MA). The joint moments of interest were horizontal adduction/abduction at the shoulder, flexion/extension at the elbow, and ulnar/radial deviation at the wrist. Joint kinematics at the wrist, elbow, and shoulder were calculated from marker data that were low-pass filtered up to a frequency of 6 Hz using a modified technique of Fink et al. (9). For the kinetic analysis, the effect of load was included by estimating the external force associated at each hand because of half of each lifted weight. Once joint kinematics and the external force because of the load was calculated, inverse dynamics were used to estimate joint moments associated with each lift. The external load applied to the hand segment and acceleration of the hand (linear and angular), along with inertial properties of the hand (mass, moment of inertia, and center of mass location) were then used to calculate wrist joint reaction forces and the wrist joint moment (ulnar or radial deviation) using the Newton-Euler equations of motion. This process was continued up the chain of the upper extremities to the forearm, to calculate elbow joint flexion or extension moments, and finally the upper arm, to calculate shoulder joint horizontal abduction or adduction moments. Segment accelerations were calculated using the central difference equation, and inertial properties of the hand, forearm, and upper arm were taken from Ramachandran et al. (29). Average and peak moments were calculated over each repetition. These results were then averaged across the repetitions for each load to give 1 average moment and 1 peak moment result for each subject using each plate type (standard or bumper) at each load (70, 80, 90% 1RM). Variables that were used to test the hypothesis specifically were average time under load per repetition, average total work per repetition, and average peak or average moments (wrist or elbow or shoulder) per repetition.

Table 2
Plate characteristics.*

Type of plate	Weight (lb)	Mass (kg)	Diameter (m)	Thickness (m)
Bumper	45.0	20.41	0.451	0.095
Bumper	35.0	15.88	0.451	0.079
Bumper	25.0	11.33	0.451	0.057
Bumper	10.0	4.54	0.451	0.035
Standard	45.0	20.41	0.442	0.030
Standard	35.0	15.88	0.360	0.031
Standard	25.0	11.33	0.271	0.033
Standard	10.0	4.54	0.228	0.017
Standard	5.0	2.27	0.200	0.011
Standard	2.5	1.13	0.161	0.008
Thick standard	10.0	4.54	0.204	0.021

*A standard Olympic barbell was used for all sessions.

Electromyography. Average integrated EMG per repetition was used to compare muscle activity between standard and bumper plates. Electromyography data, time synchronized with kinematic and kinetic data, were collected on the pectoralis major, anterior deltoids, and triceps brachii. Wireless EMG electrodes (Delsys Trigno, Natick, MA, 27 × 37 × 15 mm dimension with 4, 5 × 1 mm contact points; gain = 909, bandwidth frequency = 20–450 Hz, common mode rejection ratio = 85 dB; sampling = $1{,}000 \cdot s^{-1}$) for the anterior deltoids and triceps brachii were placed based on standardized protocols as prescribed from SENIAM (SENIAM.org). Electromyography electrodes for the pectoralis major were placed according to protocols from Cram (7). Electromyography data were analyzed using custom MATLAB code. To normalize surface EMG values, all subjects performed two 5-second maximal isometric bench repetitions at 200% of 1RM (which prevented bar displacement). During the maximal isometric test, the subject's elbows were at 90 degrees of flexion and shoulders at 90° of abduction with the upper arms parallel to the ground. The maximal voluntary contraction (MVC) EMG data were band-pass filtered (20–400 Hz), full wave rectified, and low-pass filtered at 10 Hz creating a linear envelope. The average peak EMG of each muscle over the 2 maximal repetitions was used as MVC for analysis (23,24). For each trial, the collected EMG data also underwent the complete linear envelope analysis, similar to MVCs. The results were integrated between the intervals (duration of each repetition) and divided by maximum MVC results to get a normalized EMG value based on the effort throughout each repetition. Average integrated EMG values per repetition at each load were compared across different conditions.

Session Rating of Perceived Exertion. After sessions 2 and 3, subjects filled out a survey rating of their perceived effort on a scale of 1–10.

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Table 3
Mean (±*SD*) values for standard plate lifts.*

Plate type	Standard plates								
	70% 1RM			80% 1RM			90% 1RM		
TUT (s)		1.97 ± 0.43			2.39 ± 0.42			3.34 ± 0.80	
TW (J)		532.35 ± 112.34			604.06 ± 126.13			676.36 ± 145.39	
Joint	**Wrist**	**Elbow**	**Shoulder**	**Wrist**	**Elbow**	**Shoulder**	**Wrist**	**Elbow**	**Shoulder**
AJM (N·m)	−9.69 ± 3.88	−5.19 ± 10.39	82.09 ± 32.45	−11.03 ± 4.24	−5.91 ± 12.19	93.06 ± 37.57	−12.70 ± 4.83	−5.01 ± 12.65	105.69 ± 41.60
PJM (N·m)	−13.24 ± 5.56	−16.64 ± 9.60	101.65 ± 43.10	−14.5 ± 5.89	−19.59 ± 11.63	114.87 ± 49.65	−16.16 ± 12.90	−23.43 ± 10.56	127.47 ± 56.16
Muscle	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**
EMG (V·s)	0.85 ± 0.52	0.99 ± 0.47	0.95 ± 0.27	1.11 ± 0.30	1.33 ± 0.74	1.17 ± 0.88	1.60 ± 1.25	1.95 ± 1.03	1.66 ± 0.54

*TUT = time-under-tension; TW = total work; AJM = average joint moment; PJM = peak joint moment; EMG = electromyography; 1RM = 1 repetition maximum.
Negative wrist moment = ulnar deviation, negative elbow moment = extension, positive shoulder moment = horizontal adduction.

Statistical Analyses

All statistical analysis was performed in SSPS software version 27.0 (SPSS Inc., Chicago, IL). Factorial analyses of variance comparing the effect of weight (3 levels: 70, 80, 90 %1RM) and plate type (2 levels: standard, bumper) were used to assess differences in time under tension and total work. Joint kinetics (average moment, peak moment) were assessed with factors of weight, plate type, and joint (3 levels: wrist, elbow, shoulder). Electromyography activation was assessed with the factors of weight, plate type, and muscle (3 levels: triceps brachii, pectoralis major, anterior deltoid). If sphericity was violated (sphericity ≤0.001), a Greenhouse-Geisser correction was used. An a priori level of significance was set at 0.05. Fisher's least significant difference pairwise comparisons were used post hoc. Final analysis used a reduced data set as one subject dropped out of the study before the second session because of a shoulder injury outside this study. Because of errors in data collection, further kinetic analysis could not be performed on 2 subjects' data, whereas errors during EMG collection removed muscle activation data for another 3 subjects. Therefore, final kinetic analysis was performed on the data of 11 subjects, whereas muscle activation analysis was performed on the data of 8 subjects.

Results

Time Under Tension and Total Work

There were no significant interaction effects for time under tension ($F_{[2, 20]} = 0.216$, $p = 0.808$, $\eta^2 = 0.021$) or total work ($F_{[2, 20]} = 2.659$, $p = 0.095$, $\eta^2 = 0.210$). Similarly, there was no significant main effect of plate type for time under tension ($F_{[1, 10]} = 0.144$, $p = 0.712$, $\eta^2 = 0.014$) or total work ($F_{[1, 10]} = 1.372$, $p = 0.269$, $\eta^2 = 0.121$). However, there was a significant main effect of weight for both time under tension ($F_{[1.076, 10.756]} = 51.033$, $p < 0.001$, $\eta^2 = 0.836$) and total work ($F_{[1.050, 10.503]} = 55.451$, $p < 0.001$ $\eta^2 = 0.847$; Tables 3 and 4). For both, post hoc tests yielded greater time under tension and total work from 70 to 80% (time under tension: 0.46 seconds [95% CI: 0.34–0.57], $p < 0.001$; total work: 71.69 J [95% CI: 51.41–91.97], $p < 0.001$) and 80–90% (time under tension: 0.90 seconds [95% CI: 0.57–1.22, $p < 0.001$; total work: 77.89 J [95% CI: 52.46–103.51], $p < 0.001$) of 1RM.

Joint Kinetics

Average joint moment demonstrated that there was no significant 3-way interaction effect ($F_{[4, 40]} = 2.401$, $p = 0.066$, $\eta^2 = 0.194$) and also no significant interaction effect for plate type by joint ($F_{[2, 20]} = 0.323$, $p = 0.728$, $\eta^2 = 0.031$). However, there was a significant weight by joint interaction effect ($F_{[4, 40]} = 60.744$, $p < 0.001$, $\eta^2 = 0.859$; Figure 2, Tables 3 and 4). *Post hoc* analysis showed that the average ulnar deviation moment increased significantly as weight increased from 70 to 80% (1.56 N·m [95% CI: 1.16–1.96], $p < 0.001$) and 80–90% (1.70 N·m [95% CI: 1.10–2.30], $p < 0.001$). However, there were no significant differences in average joint moment from 70 to 80% ($p = 0.678$) and 80–90% ($p < 0.719$) at the elbow joint. At the shoulder joint, the average horizontal adduction moment significantly increased as weight increased from 70 to 80% (10.95 N·m [95% CI: 7.54–14.35], $p < 0.001$) and 80–90% (11.49 N·m [95% CI: 7.99–14.98], $p < 0.001$). *Post hoc* analysis additionally indicated that the average joint moment was significantly larger at the shoulder compared with the average joint

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Table 4
Mean (±*SD*) values for bumper plate lifts.*

Plate type	Bumper plates											
	70% 1RM			80% 1RM			90% 1RM					
TUT (s)			1.92 ± 0.47			2.43 ± 0.49			3.26 ± 0.63			
TW (J)			521.47 ± 128.29			593.14 ± 128.29			676.80 ± 153.38			
Joint	**Wrist**	**Elbow**	**Shoulder**	**Wrist**	**Elbow**	**Shoulder**	**Wrist**	**Elbow**	**Shoulder**			
AJM (N·m)	−10.06 ± 5.18	−4.16 ± 11.50	81.70 ± 33.69	−11.83 ± 5.75	−4.82 ± 11.41	92.62 ± 37.49	−13.57 ± 6.57	−6.67 ± 14.00	102.97 ± 42.16			
PJM (N·m)	−13.41 ± 6.33	−16.07 ± 12.90	99.44 ± 44.51	−15.57 ± 7.35	−19.54 ± 13.71	113.49 ± 49.48	−17.29 ± 7.62	−24.90 ± 14.46	130.10 ± 57.94			
Muscle	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**	**Pectoralis major**	**Anterior deltoid**	**Triceps brachii**			
EMG (V·s)	1.03 ± 0.43	1.02 ± 0.31	0.95 ± 0.22	1.37 ± 0.63	1.33 ± 0.35	1.27 ± 0.24	1.85 ± 0.81	2.22 ± 0.99	1.83 ± 0.34			

*TUT = time-under-tension; TW = total work; AJM = average joint moment; PJM = peak joint moment; EMG = electromyography; 1RM = 1 repetition maximum.
Negative wrist moment = ulnar deviation, negative elbow moment = extension, positive shoulder moment = horizontal adduction.

moment at both the elbow and wrist at 70% (wrist: 91.77 N·m [95% CI: 67.44–116.10], $p < 0.001$; elbow: 86.80 N·m [95% CI: 67.20–106.40], $p < 0.001$), 80% (wrist: 104.27 N·m [95% CI: 76.74–131.81], $p < 0.001$; elbow: 98.20 N·m [95% CI: 76.48–119.93], $p < 0.001$), and 90% (wrist: 117.46 N·m [95% CI: 86.67–148.26], $p < 0.001$; elbow: 110.17 N·m [95% CI: 85.79–134.54], $p < 0.001$). There was no significant difference between the average joint moment between the elbow and wrist at 70% ($p = 0.166$), 80% ($p = 0.138$), and 90% ($p = 0.108$). Furthermore, average joint moment had a significant plate by weight interaction effect ($F_{[2,\ 20]} = 5.358$, $p = 0.014$ $\eta^2 = 0.349$). However, *post hoc* analysis did not show a significant difference between bumper and standard plates at 70% ($p = 0.949$), 80% ($p = 0.960$), and 90% ($p = 0.101$). Average joint moment did significantly increase for both bumper and standard plates as weight increased from 70 to 80% (bumper: 2.98 N·m [95% CI: 1.47–4.49], $p = 0.001$, standard: 2.97 N·m [95% CI: 0.94–5.01], $p = 0.009$) and 80–90% (bumper: 2.25 N·m [95% CI: 0.21–4.29], $p = 0.034$, standard: 3.96 N·m [95% CI: 2.35–5.56], $p < 0.001$).

Peak joint moment demonstrated parallel results to average joint moment because analysis showed there was a significant weight by joint interaction effect ($F_{[1.628,\ 16.280]} = 33.474$, $p < 0.001$, $\eta^2 = 0.770$; Tables 3 and 4). *Post hoc* analysis displayed that the peak joint moment for ulnar deviation significantly increased as weight increased from 70 to 80% (1.78 N·m [95% CI: 1.25–2.31], $p < 0.001$) and 80–90% (1.62 N·m [95% CI: 1.14–2.10], $p < 0.001$). Peak elbow extension moment also significantly increased at the elbow joint as weight increased from 70 to 80% (3.21 N·m [95% CI: 0.92–5.49], $p = 0.011$) and 80–90% (4.61 N·m [95% CI: 0.92–8.30], $p = 0.019$). The peak horizontal adduction moment significantly increased as weight increased from 70 to 80% (13.63 N·m [95% CI: 8.05–19.22], $p < 0.001$) and 80–90% (14.61 N·m [95% CI: 6.12–23.10], $p = 0.003$). *Post hoc* analysis additionally indicated that the peak shoulder joint moment was significantly larger than the peak moment at both the elbow and wrist at 70% (wrist: 113.87 N·m [95% CI: 82.01–145.74], $p < 0.001$; elbow: 116.90 N·m [95% CI: 89.91–143.90], $p < 0.001$), 80% (wrist: 129.29 N·m [95% CI: 93.17–165.41], $p < 0.001$; elbow: 133.74 N·m [95% CI: 102.71–164.78], $p < 0.001$), and 90% (wrist: 145.52 N·m [95% CI: 104.62–186.41], $p < 0.001$; elbow: 152.96 N·m [95% CI: 115.92–189.99], $p < 0.001$). There was no significant difference between the peak joint moment between the elbow and wrist at 70% ($p = 0.352$) and 80% ($p = 0.235$), but there was a significant difference at 90% (7.44 N·m [95% CI: 0.60–14.28], $p = 0.036$).

Electromyography

No significant 3-way or 2-way interaction effects related to EMG were detected. There was no significant plate effect, but there was a significant main effect of weight ($F_{[2,\ 14]} = 65.967$, $p < 0.001$, $\eta^2 = 0.904$), with *post hoc* analysis showing a significant increase in EMG across all muscles (pectoralis major, anterior deltoids, and triceps brachii) as weight increased from 70 to 80% (0.30 V·s [95% CI: 0.18–0.41], $p = 0.001$) and 80–90% (0.59 V·s [95% CI: 0.42–0.76], $p < 0.001$; Tables 3 and 4).

Session Rating of Perceived Exertion

There was no significant difference in session rating of perceived exertion (sRPE; bumper plate: 7.08 ± 1.32; standard plates: 7.31 ± 1.03) using a Chi-squared test ($X^2_{[4,N\ =\ 26]} = 2.311$, $p = 0.679$).

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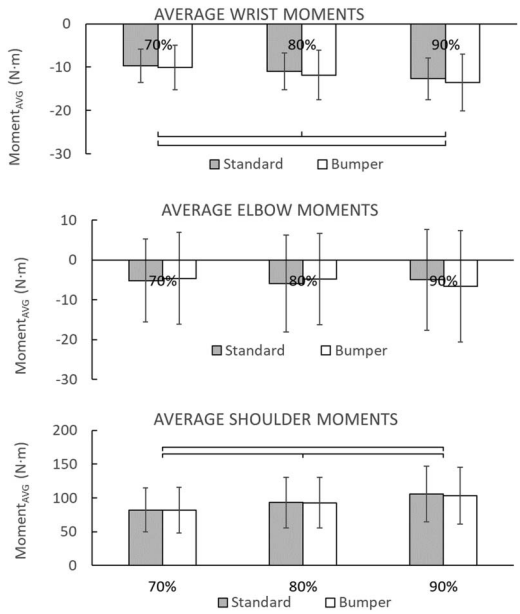

Figure 2. Average joint moments at the wrist, elbow, and shoulder. Significant differences ($p < 0.05$) between loads (70, 80, 90%) shown with line connecting loads below (⊔) or above (⊓). Negative wrist moment indicates ulnar deviation. Negative elbow moment indicates extension. Positive shoulder moment indicates horizontal adduction.

Discussion

The aim of this study was to identify any possible biomechanical and neuromuscular differences during the bench press when using either bumper plates or standard plates. The specific variables of interest were related to the kinetics of the movement (time under tension, total work, average joint moments, peak joint moments) and muscle activation. Although there were significant results, mainly that joint moments and muscle activation increased with higher loads, our main hypotheses were not supported—there were no significant kinetic differences or muscle activation differences between using bumper and using standard plates during the bench press.

The magnitude of measures in this study are comparable to previous studies that have measured other aspects of the bench press exercise. In this study, time under tension (Tables 3 and 4) had a mean time per repetition similar to the estimated per repetitoin time of 1.90 seconds for 70% and 2.04 seconds for 80% from a previous study comparing time under tension for the bench press under different weights and repetitions (8). The shoulder horizontal abduction and elbow extension peak moments measured in this study (Tables 3 and 4) were similar to shoulder horizontal abduction (123.0 ± 48.50 N) and elbow extension peak moments (22.15 ± 8.35 N·m) in a study by Mausehund et al. (23) at 80% of 1RM. Parallel to a previous study, peak moments for shoulder abduction, elbow extension, and ulnar deviation significantly increased with an increase in weight (31). Electromyography activity of the anterior deltoid, triceps brachii, and pectoralis major all increased as weight increased, which is similar to results found in a study on the effect of weight on the bench press by Król and Gołaś (17).

There are a few potential reasons why our main hypotheses, finding differences between the 2 different types of plates, were not supported. It is noteworthy, although not the main purpose of this study, that subjects filled out a survey asking their RPE on scale of 1–10 for each session (different weight plates). There was no significant difference in RPE ($p = 0.679$) between bumper and standard plates suggesting that subjects did not perceive a difference, at least in exertion, between lifting the different types of weight plates.

Based on previous studies on bar deformation and anecdotal evidence, it was hypothesized that the thicker width of the bumper plates would affect the amount of bar deformation and therefore increase the bar path of the bench press. For a bumper plate–loaded bar, the lifter's hands would need to be lower at the end of the eccentric phase compared with the hand position of the standard plates in order for the bar to contact the lifter's chest, which should affect both total work and time under tension. One study compared several different barbells and found that the amount of deformation from the end of the barbell to the center of the barbell was 1.37 ± 0.16 cm at 70 kg, 2.24 ± 0.19 cm at 120 kg, 3.18 ± 0.26 cm at 170 kg, and 4.01 ± 0.19 cm at 220 kg (4). Using the finding of this previous study, the bar deformation in this study would be estimated between 1.4 and 2.2 cm for 1RMs in this study (Table 1). This amount of deformation might not have been enough to elicit an increased distance, which would affect time under tension or total work. The exact amount of bar deformation to have a significant impact on time under tension and total work is unclear. During more dynamic lifts such as clean, this amount of deformation can increase to 4–6 cm (5). It has been shown that a cambered bar, with a depth of 9 cm, significantly increased the distance the bar traveled and therefore increased both time under tension and total work (19). Further investigations need to be conducted to examine the effect of various amounts of bar deformation on the biomechanics of bench press.

It was further hypothesized that the increased thickness of the bumper plates would affect moment of inertia of the barbell, which could alter the joint kinetics of the barbell during the bench press. Because the moment of inertia of the barbell system (barbell and weights) is a summation of the inertias of each component of the barbell and the plates, the thicker width of the bumper plates would increase the total moment of inertia and therefore increase the barbell resistance to change in angular velocity (22). It was believed that this increased resistance to angular velocity would potentially increase the moments at the joints as the subject controls the barbell throughout the bench press movement. Because the bench press is a symmetric and controlled movement, it is possible that the angular acceleration of the bar during the lift might not have been large enough to cause a discernable increase in joint moments.

Furthermore, our protocol might not have fatigued the muscles enough for the increased moment of inertia to overcome the muscles' ability to control the barbell. Other studies looking at upper-extremity stability used rapid movements, a large number of repetitions, working to a fatigued state, and working to muscle failure (1,2,6,12). One study found that as fatigue increased, the moment and force significantly increased on the elbow joint (12). Another study demonstrated that as fatigue increased, the stability of the upper extremity decreased and increased the yaw and pitch perturbations of the barbell (6).

One of the interesting findings of this studies was that there was no difference in average elbow joint moment as weight increased, but there was a difference in peak elbow joint moment as weight increased. It is not clear why this was the case. Schütz et al. (31) also found differences in peak joint moments across different bench press weight conditions, but these researchers did not measure average joint moments. However, others have also found inconsistency when comparing average and peak joint moments. For example, Mausehund et al. (24) found differences in peak but not average joint moment at the elbow during a bench press task across different sexes and training experiences, indicating that net joint moments at the elbow can be affected by sex and lifting technique. *Post hoc* analysis of our subject data showed that sometimes the elbow moment often varied

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considerably, with a flexion moment being produced at the end of the upward phase and start of the downward phase. The combined flexion and extension moment would of course affect average joint moment calculation but would not have the same effect on peak moment calculations because peak moment was always the highest extension joint moment. Future research should consider analyzing the time-varying signals with more suitable measures. Recent work in the use of statistical parameter mapping to specifically evaluate differences in continuous data, such as joint moments, could be explored (27).

Our study did have potential limitations. To our knowledge, there have not been any previous studies looking at the difference between bumper and standard plates in any powerlift. Therefore, the minimum bench press was set at 100 lb (45.45 kg) to cover a wide range of lifters, but future studies should consider more elite bench press athletes with a minimum 1RM of 350 lb (159.09 kg) to examine whether there is enough of an increase in both bar deformation and moment of inertia to significantly affect the kinetics of the bench press. Another limitation of the study was that few of the subjects reported that they could hear the sound of the cast iron plates rub against each other as they performed repetitions, although many steps were taken to help blind the subject from the plate type. Muscle activation in stabilizing muscles should be monitored to see if there is any increased muscle activation. To complete the inverse dynamic analysis, the external forces acting on the hands needed to be known. Actual measurement of forces between the hand and the bar was not possible, and the assumption was made that the weight from the bar was evenly distributed between the 2 hands—this is a limitation.

Practical Applications

The main finding of this study might be helpful for recreational lifters, personal trainers, gym owners, and strength and conditioning coaches. When bench pressing, a lifter can choose to lift with bumper or standard plates without affecting time under tension, total work, average joint moments, peak joint moments, and muscle activation. Therefore, equipment purchasing decisions can be made to achieve the broadest utilization of the equipment for the least financial investment.

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