

Bench press and pushup repetitions to failure with equated load

Taran L Eckel, Casey M Watkins, David C Archer,
Megan A Wong, Jose A Arevalo, Anne Lin,
Jared W Coburn, Andrew J Galpin and Lee E Brown

Abstract

The bench press and pushup are commonly used for training upper body muscular strength and endurance. Although they are often used interchangeably, differences between the two relative to body mass load are unknown. Furthermore, sex differences may exist due to anthropometric body mass specificity. The purpose of this study was to evaluate the relationship between the pushup and bench press when performing repetitions to failure with an equated load. On day 1, 25 recreationally trained subjects (16 men, age = 23.00 ± 2.36 years, height = 178.19 ± 9.61 cm, mass = 74.80 ± 13.44 kg; 9 women, age = 23.11 ± 2.71 years, height = 160.78 ± 5.95 cm, mass = 53.63 ± 5.60 kg), performed a one repetition maximum bench press and an isometric pushup on a force plate to determine bodyweight load supported in both the up and down positions. Grip width on the bench press was measured as the distance between middle fingers and was used for hand placement during pushups. For the down position, a safety squat device was placed on the right triceps to signal that the upper arms were parallel to the ground, while for the up position, triceps were perpendicular to the floor. Days 2 and 3 consisted of performing repetitions to failure for either the bench press or pushup exercise with a load that was equal to the average relative bodyweight force of the up and down pushup positions. For the pushup, subjects followed a 60 beats per minute tempo and the test was terminated if they failed to complete a full repetition; they could not maintain cadence or there were three faults in form. For the bench press, they followed the same 60 s tempo and the test was terminated if they failed to complete a full repetition or could not maintain cadence. A 2 (exercise: bench press, pushup) \times 2 (sex: men, women) mixed factor ANOVA demonstrated no interaction, but there were significant ($P < 0.05$) main effects for exercise and sex where more repetitions were performed in the pushup (19.36 ± 11.68 reps) than the bench press (11.40 ± 8.38 reps) exercise. Also, men performed significantly more repetitions to failure (men = 20.22 ± 8.20 reps, women = 6.78 ± 5.69 reps). For combined sexes, there was a significant ($P < 0.05$), strong relationship ($r = 0.82$) between bench press and pushup repetitions to failure. For men, there was a significant ($P < 0.05$), strong relationship ($r = 0.81$), while for women, there was a moderate relationship ($r = 0.76$). Men had significantly ($P < 0.05$) greater bench press one repetition maximum (men = 99.29 ± 23.98 kg, women = 42.17 ± 8.88 kg), percentage of body mass supported as an average of the up and down positions (men = $74.33 \pm 2.57\%$, women = $69.70 \pm 2.63\%$) and bench press one repetition maximum relative to their body mass (men = $1.32 \pm 0.22\%$, women = $0.79 \pm 0.13\%$). The bench press and pushup are two distinct upper body exercises for repetitions to failure due to upper body musculature and body position sex differences. Choice of the pushup or bench press exercise should be based on training goal and sex.

Keywords

Gender, muscular endurance, sex differences, strength, upper-body exercise

Introduction

The bench press and pushup are commonly used to develop upper body strength and power. Although both exercises share similarities in movement patterns and benefits in the development of the upper body, the bench press requires expensive equipment. Additionally, the bench press provides a training stimulus at low, moderate, and high intensities, while the load of a traditional pushup is determined by

Reviewers: Margaret Jones (George Mason University, USA)
Chad Kerkisick (Lindenwood University, USA)

Department of Kinesiology, California State University, Fullerton, USA

Corresponding author:

Lee E Brown, Department of Kinesiology, California State University, 800 N. State College Blvd., Fullerton, CA 92831, USA.
Email: Leeebrown@fullerton.edu

bodyweight.^{1,2} With an increase in intensity approaching maximal load, the bench press has been shown to increase muscle activation with greater pectoral activation in the eccentric phase, and triceps activation in the concentric phase.³ Although the relationship between the bench press and pushup has been examined, variability in upper body strength between sexes produces different relationships.⁴ Even relative to bodyweight, women may be at a physiological disadvantage when performing upper body movements, such as the pushup.⁵ Previous studies have shown that women have lower force output but have faster recovery ability after performing high intensity exercise.⁶ Men have been shown to produce both more absolute and relative force in upper body exercises and produce different movement patterns in the pushup.⁷

Although studies have shown correlations between the two exercises, there is a lack of research on sex effects in regards to the correlation between pushup and bench press performance relative to bodyweight.⁸ Anthropometry allows expression of intensity relative to bodyweight.⁹ Performing repetitions with lighter loads has been shown to be a relative endurance performance attribute that indicates strength relative to bodyweight,¹⁰ while heavier loads indicate absolute strength, or the maximum capability of force production. Two popular tests of assessing muscular endurance include the YMCA bench press and pushup tests; however, both quantify intensity relative to bodyweight leading to an uncertainty of the relationship between exercises.¹¹ The purpose of this study was to evaluate the relationship between pushups and bench press when performing repetitions to failure with an equated load. We hypothesized that due to sex differences in upper body strength, there would be a higher correlation between the pushup and bench press in men and that they would perform more repetitions when compared to women, even with an equated load.

Methods

Participants

Twenty-five healthy, recreationally resistance trained subjects (16 men and 9 women) who had prior experience in the bench press exercise (performing the bench press exercise for at least six months, twice a week) volunteered to participate. No subject had an orthopedic or musculoskeletal injury within the past six months.

Design

The study was observational research comparing the sexes on pushup and bench press exercise repetitions to failure with an equated load.

Methodology

Day 1: Baseline. There were three sessions separated by at least 48 h. Upon arrival, subjects read and signed an informed consent document approved by the University institutional review board. Then, height and body mass were measured using a stadiometer (PRODOC Detecto Seca, Ontario, CA, USA) and electronic scale (ES200L; Ohaus Corporation, Pinebrook, NJ, USA). Body composition was measured using a three-site skinfold with a caliper (Beta Technology, Santa Cruz, CA, USA).^{12–15} For men, the three-sites were the chest, abdomen, and thigh on the right side.¹⁵ For women, the three-sites were the triceps, suprailium, and thigh on the right side.¹⁴ A total of two trials for each site were taken and the Jackson and Pollock three-site skinfold equation was used to analyze body fat percentages.^{13–15} Then the subject assumed the set up position for bench press in a squat rack (Rogue Fitness, Columbus, OH) by lying on the bench and placing their hands on a 20-kg barbell in a position that felt comfortable. Using a tape measure, their grip width was measured as the distance between their middle fingers. After this, subjects performed a warm up of three consecutive pushups, then rested for 2 min. For isometric pushup testing, subjects first stood on an AMTI force plate (Advanced Mechanical Technology, Inc., Watertown, MA, USA) with legs shoulder-width apart and hands on their hips for 3 s to measure mass. Then in random order, they performed an isometric pushup in the up or down positions on the force plate for 3 s each. In relation to the floor, the triceps were parallel in the down position and perpendicular in the up position. To ensure they were parallel to the floor in the down position, a safety squat device (BFS, Salt Lake City, UT) was placed around their right triceps brachii. The subject laid down on the force plate and had their hand placement set to match the grip width measurement of their bench press. For the up position, elbows were fully extended, triceps remained perpendicular to the ground, and they held a straight torso from their heels to the back of their head (Figure 1). For the down position, triceps remained parallel to the ground with a straight torso from the heels to the back of the head (Figure 2).

After isometric pushup force was measured, subjects performed a bench press one repetition maximum (1RM) test. Prior to the test, they warmed up with 10 repetitions at 50% of their estimated 1RM, 5 repetitions at 70%, 3 repetitions of 80%, and 1 repetition at 90%. Each set was separated by 3-min rest. Subjects were given three attempts to achieve their 1RM. At the end of day 1, subjects were given a familiarization of the next two sessions by performing pushups at a tempo of 60 beats per minute (30 pushups per minute) using a metronome (EM-900; Franz Mfg Co,



Figure 1. Pushup: Up position.



Figure 2. Pushup: Down position.

Inc., New Haven, CT, USA). A full repetition consisted of starting in the up position and descending to the down position and returning to the up position. After the pushup repetitions were completed, they performed five bench press repetitions at a tempo at 60 beats per minute using the same metronome with a weight that equaled 50% of their 1RM. A full repetition consisted of bringing the bar down to chest level, lightly touching the sternum then returning to the up position until the elbows were fully extended and locked. Reliability via intraclass correlation coefficient (ICC), for the 1RM bench press has been previously shown to be very high ($ICC = .98$).¹⁶

Days 2–3: Pushups to failure (48-h apart). Subjects started by performing a warm up consisting of three pushups then rested for 2 min. The safety squat device was placed around the right triceps brachii and they were instructed to perform repetitions to failure. Their hand placement was measured to match their bench press grip width. The test began in the up position then repetitions were performed at 60 beats per minute with the



Figure 3. Bench press: Top position.

metronome. A full repetition was counted once the up position was reached while two faults in form were allowed. If a third fault was detected, the test was terminated and the two other faults were subtracted from the final number of repetitions. Faults included not performing a full repetition, failing to complete a repetition following the tempo, not performing a full repetition, or the body arching and not remaining straight. A repetition was counted every time they reached the up position. Reliability for the push up test and number of bench press repetitions with a percentage of bodyweight has been shown to be high for both men ($ICC = .87$) and women ($ICC = .80$).⁴

Days 2–3: Bench press to failure (48-h apart). Subjects started by performing a warm up consisting of three repetitions of the bench press at 50% of their 1RM then rested for 2 min. The load of the bench press matched their average relative load of the isometric up and down positions of the pushup exercise measured on day 1. They laid supine on the bench and their grip width was measured to match their grip on day 1. Repetitions were performed to failure, or when they could no longer maintain 60 beats per minute with the metronome. A full repetition consisted of lowering the bar from full elbow extension (Figure 3) down to the sternum (Figure 4) and raising it back up till the elbows were again fully extended and locked. Faults included failing to complete a full repetition, not keeping pace with the metronome, or not keeping the five points of contact, including feet on the ground, hips on the bench, posterior deltoids on the bench, and back of the head on the bench. A repetition was counted every time they raised the bar up to full elbow extension. Reliability for the bench press test with relative load has been previously shown to very high ($ICC = 0.98$).¹⁶

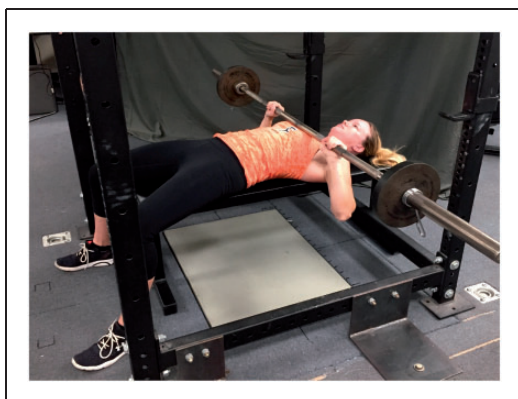


Figure 4. Bench press: Bottom position.

Statistical analyses

All data were analyzed with SPSS version 24.0 software (SPSS Inc., Chicago, IL). An alpha level of 0.05 was used to determine significance. A 2×2 (exercise \times sex) mixed factor ANOVA analyzed repetitions to failure between the bench press and pushup exercises. Pearson product moment correlations determined relationships between variables. Interpretation of the size of correlation coefficients was classified as very strong correlation (.90–1.00), strong (.70–.90), moderate (.50–.70), weak (.30–.50), and negligible (00–.30)¹⁷. Independent-samples t-tests analyzed sex differences between body fat percentages, bench press 1RM, bench press repetitions to failure, pushup repetitions to failure, percentage of body mass used in the pushup for the up, down and average of the up and down positions, average relative bodyweight pushup force, and bench press 1RM relative to body mass.

Results

For repetitions to failure, the ANOVA demonstrated no interaction, but there were main effects for exercise ($F = 30.79$) and sex ($F = 20.66$) where more repetitions were performed in the pushup than the bench press exercise ($P = 0.00$; effect size 0.78; Table 1) and men performed more repetitions than women ($P = 0.00$; effect size 1.90; Table 1). For combined sexes, there was a significant ($P < 0.05$) strong relationship ($r = 0.82$) between bench press and pushup repetitions to failure. For men, there was a significant ($P < 0.05$) strong relationship ($r = 0.81$), while for women, the relationship was still strong ($r = 0.76$), but weaker than males. Men demonstrated significantly ($P < 0.05$) greater bench press 1RM, percentage of body mass used in the pushup down and up positions, average of the up and down positions, average relative bodyweight pushup force and bench press 1RM relative to body mass (Table 2).

Table 1. Mean \pm SD for repetitions to failure by exercise ($n = 25$) and sex (16 men and 9 women).

Exercise		Sex	
Bench press	Push up	Men	Women
11.40 \pm 8.38	19.36 \pm 11.68*	20.22 \pm 8.20**	6.78 \pm 5.69

*Significantly greater than bench press ($P < 0.05$).

**Significantly greater than women ($P < 0.05$).

Table 2. Bench press variables by sex (mean \pm SD).

	Men	Women
Age	23.00 \pm 2.36 years	23.11 \pm 2.71 years
Height	178.19 \pm 9.61 cm*	160.78 \pm 5.95 cm
Mass	74.80 \pm 13.44 kg*	53.63 \pm 5.60 kg
% Body fat	15.41 \pm 5.29%*	26.64 \pm 8.68%
Bench press		
1RM	99.29 \pm 23.98 kg*	42.17 \pm 8.88 kg
RTF	16.38 \pm 6.05 reps*	2.56 \pm 2.13 reps
1RM REL. BM	1.32 \pm 0.22 kg*	0.79 \pm 0.13 kg
% Reps REL. PU	71.36 \pm 17.02%*	30.18 \pm 19.15%
Pushup		
RTF	24.06 \pm 10.35 reps*	11.00 \pm 9.25 reps
AVG % BM UP, DWN	74.33 \pm 2.57%*	69.70 \pm 2.63%
AVG. REL. BM	55.79 \pm 11.49 kg*	37.32 \pm 3.71 kg
% BM UP	71.95 \pm 3.09%*	66.26 \pm 2.63%
UP REL. BM	54.00 \pm 11.08 kg*	35.45 \pm 3.27 kg
% BM DWN	76.70 \pm 2.56%*	73.14 \pm 3.14%
DWN REL. BM	57.58 \pm 11.97 kg*	39.18 \pm 4.22 kg

1RM: one repetition maximum; RTF: repetitions to failure; 1RM REL. BM: one repetition maximum relative to body mass; % Reps REL. PU: percent of repetitions relative to pushup repetitions to failure. Pushup variables by sex (mean \pm SD). AVG % BM UP, DWN: average percent of body mass supported in the up and down position; AVG. REL. BM: average body mass supported in the up and down position relative to total body mass; % BM UP: percent of body mass supported in the up position; UP REL. BM: body mass supported in the up position relative to total body mass; % BM DWN: percent of body mass supported in the down position; DWN REL. BM: body mass supported in the down position relative to total body mass.

*Significantly different ($P \leq 0.05$).

Discussion

The purpose of this study was to evaluate the relationship between pushups and bench press repetitions to failure with an equated load. The major findings were a strong relationship between the two exercises and that more repetitions were performed in the pushup than the bench press. Also, men performed more repetitions than women overall and supported a higher percentage

of their bodyweight in the pushup than women. These results may be due to differences in sex specific upper-body musculature, body fat, body position, and trunk angle relative to the upper body limbs during the execution of both exercises.

The bench press and pushup are two well-known upper body exercises that are often used interchangeably for the development of muscular strength and endurance. Our findings of a strong relationship and differences in repetitions to failure is in support of previous research by Calatayud et al. who observed comparable EMG amplitude levels with an equated load between the bench press and pushup exercises.² However, in order to achieve an equated load, they used pushups with elastic bands, rather than the traditional pushup, and the load for each exercise was determined by a 6RM.² Invergo et al. concluded that pushup performance is a direct measure of muscular endurance relative to body mass compared to absolute maximal bench press.¹¹ Although the current study emphasized repetitions to failure, rather than 1RM or 6RM, an equated load was calculated relative to body mass, which may have contributed to differences in repetitions performed between the two exercises.

During the performance of upper-body exercises, it has been shown that there are sex differences where women produce less force relative to their body mass than men.^{5,7,18} Our findings of differences in performance of the bench press and pushup repetitions to failure with an equated load is supported by the findings of Constance et al. and Eurich et al. who reported that men displayed greater force and power relative to bodyweight in comparison to women.^{5,7} The present study found that men performed more repetitions to failure using an equated load relative to body mass, supported more of their bodyweight in both positions of the pushup, and also produced a slightly greater positive relationship between the two exercises. Differences in pushup repetitions have also been seen in previous studies where men performed more repetitions in bodyweight exercises.^{4,19} Eurich et al. concluded that women may be at a disadvantage when compared to men when producing peak performance in upper body movements, which is most likely related to women's lack of upper body muscle mass.⁵ This mass disparity also probably explains differences in repetitions in the current study.

The current study demonstrated that repetitions to failure with an equated load relative to body mass resulted in a strong positive correlation between exercises, which is similar to Baumgartner et al. who also demonstrated a high correlation between number of repetitions performed relative to body mass.⁴ In comparison to the present study, Baumgartner et al. equated the load based on the up position of the

pushup; however, men performed at 70% of their bodyweight, while women performed at 40%.⁴ Also, their results demonstrated that men had a stronger positive correlation than women.⁴ McManis et al. observed that college women lacked upper-body strength to hold the down position of a pushup.¹⁹ Their subjects were asked to perform 90° pushups and women struggled to keep their hips off the ground.¹⁹ Similarly, in the present study, women had difficulty with proper performance of pushups at 90°, following tempo, and completing a full pushup repetition, possibly due to lack of upper-body strength, which may have contributed to the slightly weaker relationship between exercises for women.

The pushup is a closed-kinetic chain exercise while the bench press is open-kinetic chain, yet they have similar biomechanical characteristics.² Both sexes displayed a strong relationship; however, differences were seen in total number of repetitions performed for both exercises. These differences may be due to trunk position, core activation, upper body musculature, and kinematics of movement. Contreras et al. summarized the biomechanics of the pushup and concluded that maximal core muscle activation was primarily in the external oblique and rectus abdominis muscles.²⁰ In contrast, Norwood et al. observed the bench press and found the highest EMG muscular core activation in the erector spinae muscles.²¹ These results show that there are differences between the pushup and bench press exercises that are commonly seen as similar. Therefore, the pushup may have greater core muscular activation than the bench press, which might have led to differences in repetitions to failure in the current study, even with an equated load. Duffey et al. concluded that the kinematics of the bench press change during a set to failure.²² A difference in the bar path of the bench press may lead to a decrease in upward velocity, leading to an increase in time to lift the bar, which could lead to differences in number of repetitions performed.²²

Lastly, differences in body position exist between the bench press and pushup. The bench press involves the participant lying supine with the head and trunk supported by the bench, knees bent, feet flat on the floor with a flat back, and arms at 90° to the body.³ The up position of the pushup requires them to maintain a straight torso, but at an incline relative to the floor, which becomes more parallel in the down position. Due to changes in moment arm flexion, the percentage of body mass supported is ~75% body mass in the down position and ~69% in the up position.^{7,20} These differences may be due to whole-body center of mass being directed further from the point of contact (the feet) with the support surface (the floor) leading to greater force requirements at the pushup bottom

position.²³ Additionally, only the hands and toes touch and support the entire bodyweight during the pushup.⁴ Therefore, the pushup resembles a decline bench press leading to a shorter moment arm, and less range of motion to complete a full repetition, which may have contributed to greater repetitions to failure than the bench press.

Conclusions

The findings of the current study suggest that the bench press and pushup should be considered two distinct upper body exercises both within and between sexes. The exercises should be differentiated based on sex and goal as repetitions to failure are significantly greater in the pushup and for men even with an equated load. Although both exercises can be used for upper body muscular endurance goals, pushups may be used as an exercise for a weaker lifter with less upper body muscle mass while the bench press may be used for a stronger lifter with greater upper body muscle mass.

Declaration of Conflicting Interests

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