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Gender Differences in Performance of Equivalently Loaded Push-Up and Bench-Press Exercises

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Abstract

Push-up and the bench- press are common exercises to develop upper-body strength and muscle endurance. The purpose of this study was to compare muscle endurance performance of matched load push-up and bench-press between men and women, where women perform modified push-up and men standard push-up. Thirty-two young healthy men and women (16 men and 16 women) participated in the study. Participants completed three tests, push-ups to failure, one repetition maximum (1RM) bench-press, and a bench-press test to failure performed with a load equivalent to percent body mass during the push-up. On average men performed 17.5 more repetitions than women in the bench-press test (men 25.3 (5.7), women 5.9 (4.2), $p < 0.001$). No difference ($p = 0.25$) was found between women and men in the number of push-ups performed (men 32.8 (8.3), women 29.6 (7.1)). However, within subjects differences were observed between bench-press and push-up exercises, $p < 0.001$. 1RM bench-press load was greater in men, in absolute values, men lifted 77.7 kg more than women ($p < 0.001$), and relative to body mass, men lifted 2.4 times more mass than women ($p < 0.001$). These results suggest that bench-press and push-up muscle endurance exercises differ greatly in women but not in men, likely due to gender differences in upper-body strength. This is an important consideration for upper-body strength training prescriptions.

Keywords: Biomechanics, fatigue, upper-body muscle endurance, upper-body muscle strength, close kinetic chain, open kinetic chain

Abbreviations:

1RM - One Repetition Maximum

6RM – Six Repetition Maximum

ABS - Absolute

ACSM - American College of Sports Medicine

AMTI - Advanced Medical Technologies Inc

EMG – Electromyography

RBM – Relative to percent Body Mass

SD – Standard Deviation

YRS - Years

Introduction

In the past several years, there has been a positive shift in women participation in sport and exercise. More women and young girls are taking part in a variety of sports and physical activities. The National Collegiate Athletic Association (NCAA) reported in 2014 that the number of female varsity athletes increased from 74,000 in 1981 to 208,000 in 2014, by almost three folds (Irick, 2014). In the 2013-2014 Annual Report of the National Federation of State High School Associations they have reported that the number of girls participating in sport increase by 11 folds from 294,015 in the 1971-72 academic year to 3,267,664 in 2013-14 academic year (National Federation of State High School Associations, 2014). In a recent fitness trends survey executed by the American College of Sports Medicine (ACSM) it was found that two of the top fitness trends for 2016 will be body weight (i.e. push-ups) training and strength training (i.e. bench-press) (Thompson, 2015). These fitness trends were in the top 10 for the past several years. This trend in increased participation of girls and women in sport activity is an aspect that needs to be further investigated to identify similarities and differences between genders performing or participating in these types of physical activities.

The push-up and bench-press are common upper-body muscle endurance and strength exercises that target the pectoralis major and triceps brachii muscles. Muscular endurance is measured as the ability of a muscle to perform repeated contractions against a submaximal load. Whereas, muscular strength is measured as the force a muscle can exert in a maximal effort (Baechle, Earle, & National Strength & Conditioning Association (U.S.), 2008). The push-up is a closed-kinetic chain exercise that is limited by body weight as a source of resistance, and is difficult to quantify load or training intensity. This is in contrast to bench-press, an open-kinetic chain upper-body exercise that applies measurable resistance loads. Despite the differences between the push-up and bench-press, electromyography (EMG) data indicate that the push-up and bench-press exercises are biomechanically comparable and evoke similar muscle activity (Blackard, Jensen, & Ebben, 1999; Dillman, Murray, & Hintermeister, 1994). Blackard et al. (1999) tested the mean integrated EMG values for the pectoralis major and long head of the triceps during push-up and bench-press with a load equivalent to the push-up, on average 66% of body weight, and bench-press with no load. Similar EMG values in the pectoralis major and long head of the triceps were demonstrated for equivalently loaded push-up and bench-press. However, significant differences were observed between the loaded bench-press and the unloaded bench-press, and the push-up and unloaded bench-press. The authors concluded that comparable external load for each exercise is most important when classifying an activity rather than open or closed kinetic conditions (Blackard, et al., 1999).

It also appears that push-up training is just as effective as bench-press exercises for increasing 1RM bench-press among athletes and non-athletes when volume and intensity are comparable (Calatayud et al., 2015; Dannelly et al., 2011; Prokopy et al., 2008). In recent study, training load was set at six repetitions maximum (6RM) for the push-up and bench-press groups. This means that the participants were able to performed maximum of six repetitions for each of the exercises. Elastic bands were used to adjust the load during the push-up exercise so the resistance will be equivalent to 6RM. EMG data indicated that activation of the pectoralis major and deltoid muscles were similar between the two exercises. After five weeks of training similar strength gains were observed for the 1RM and 6RM bench-press test (Calatayud, et al., 2015). Thus, when the external load and number of repetitions performed to fatigue are matched, push-ups are just as effective as bench-press to improve maximal upper-body strength. Given this, the push-up and its variations are often viewed as viable alternative exercises to the bench-press and are commonly included in training regimens for sports that require upper-body performance (Contreras et al., 2012; Dannelly, et al., 2011; Prokopy, et al., 2008).

Recently, a study by Mier et al. (2014) determined that under static conditions, men and women support approximately 70% of their body weight in a standard push-up position and 55% of body weight in a modified push-up position with men's values being slightly higher than women's values (Mier, Amasay, Capehart, & Garner, 2014). Previous studies have identified that women’s upper body strength is 50% to 60% lower than men’s upper body strength (Bishop, Cureton, & Collins, 1987; Janssen, Heymsfield, Wang, & Ross, 2000; Miller, MacDougall, Tarnopolsky, & Sale, 1993). Thus, for women, the standard push-up elicits intensities that are more appropriate for muscle strength stimulation while the modified push-ups is better suited to stimulate muscle endurance and power because of the reduced total mass carried by the arms. Muscle power is the ability of muscle to exert high force while contracting at a high speed (Baechle, et al., 2008). Given the biomechanical (shoulder horizontal adduction and elbow flexion) and muscle activation similarities between the push-up and bench-press, a reasonable assumption is that when a load equivalent to the push-up is assigned to the bench-press, the number of repetitions performed would be similar. This may very well be among young healthy men that can lift over 100% of their body weight during a 1RM bench-press test.

However, it seems unlikely in women given their lower upper-body strength (Bishop, et al., 1987; Miller, et al., 1993). Even women with excellent upper-body strength lift only 80% to 90% of body weight, according to the American College of Sports Medicine's fitness categories (American College of Sports Medicine., 2014). Indeed, among several studies that tested both push-up performance and 1RM bench-press in young men and women (Enemark-Miller, Seegmiller, & Rana, 2009; Kraemer et al., 2001; Michaelides, Parpa, Henry, Thompson, & Brown, 2011; Mirzaei, Curby, Rahmani-Nia, & Moghadasi, 2009; Thomas, Lumpp, Schreiber, & Keith, 2004; Thomas, Seegmiller, Cook, & Young, 2004), men lifted 109% to 140% of body weight while women lifted only 56% to 71% of body weight. Push-ups performed by men ranged from 40 to 67 repetitions. Only one study measured push-up performance in women using the modified version with 47 repetitions reported (Enemark-Miller, et al., 2009). Two other studies tested push-up performance in women using the standard version; repetitions performed were 24 and 33. Thus, despite the relatively high external load during the push-up, women were capable of performing a great number of repetitions. These studies indicate a large discrepancy between push-up and bench-press performances in women, but not so much in men (Thomas, Lumpp, et al., 2004; Thomas, Seegmiller, et al., 2004).

If it is assumed that the percentage of body weight lifted by women during a modified push-up approximately 55% of body weight, and 70% of body weight lifted by men during the standard push-up (Mier, et al., 2014), it can be expected that women would not have the upper-body strength to perform the same number of repetitions on the bench-press with an equivalent load as men, as a result of their lower upper body maximal strength. In contrast, given their relative upper body strength on the bench press, men should exhibit a similar number of repetitions during bench press and push-up when the exercises are matched for external load. Therefore, the purpose of this study was to compare endurance performance of matched external load push-up and bench-press between active men and women, where women perform modified push-up and men standard push-up. The researchers hypothesized that the number of push-ups performed to fatigue would be similar between physically active men and women, whereas repetitions during the match load bench-press would be significantly lower in women than in men.

Methods

Participants

Thirty-two young healthy men and women (16 men and 16 women) participated in the study (Table 1). Inclusion criteria for the study were physically active for the past year at least three times a week, having experience in correctly performing push-up and bench-press exercises (self reported). Participants were asked to refrain from vigorous activity at least 24 hours prior to the tests. All experimental procedures were approved by the university's review board and each participant read and signed the consent form prior to participation.

Table 1. Participants' anthropometric data *Mean* ± (*SD)*

	Age (yrs)	Height (cm)	Body Mass (kg)
Men	24.0 (3.1)	177.6 (7.3)	81.4 (7.4)
Women	22.3 (2.4)	163.0 (6.0)	62.2 (8.3)

Procedures

Participants completed three tests, push-ups (women performed modified, men performed standard) to failure, one maximum repetition (1RM) bench-press, and a bench-press test performed with a load equivalent to percent body weight during the push-up. The participants completed the study in two sessions. In the first session, body weight was measured using two AMTI (Advanced Medical Technologies Inc., Watertown, MA) force plates. The participant was instructed to stand on the force plate without moving for three seconds. The data from the two force plates were added and the data from the middle second were averaged to get the estimated body weight (Mier, et al., 2014). Each participant performed one trial of static push-up using the two force plates (each hand on a different force plate) to measure the average relative body weight carried during the push-up test. The participant perform static push-up in two positions, the up position (elbows extended) followed by the down position (elbow flexed). Each position was held for three seconds. The data of the middle second of each position were averaged. These values were averaged to get the relative weight carried during the push-up. The value obtained was later used to estimate the resistance in kilograms the participant required to use during bench-press to fatigue test.

Following the data collection of the body weight and the relative weight carried in the static push-up, the participant performed five practice trials of the dynamic push-ups to assist in performing the push-ups correctly. Feedback on technique and form was provided. In both the modified and standard push-ups, the participant positioned the hands below the shoulders with the fingers pointing forward. For the modified position, knees and feet were in contact with the floor with the ankles plantarflexed; whereas, the pivot point in the standard position was the toes. The back remained straight through the whole range of motion for both positions (American College of Sports Medicine., 2014). Participants were instructed to lower themselves into the down position making contact with a foam block (10 cm height), using their chin or forehead. The purpose of the block was to insure that all participants achieved at least a 90° angle at the elbow, so that the upper arms were parallel to the ground. Full extension of the arms was required in the up position.

Following the practice session and a rest period of at least 2 minutes, the dynamic push-up was performed to failure. Each participant was instructed to perform as many repetitions as possible. To control the pace of the push-up the pace was set to one second down and one second up, regulated by a metronome. Failure was established when the participant could no longer keep pace, extend elbows, touch the block with their chin or forehead, or maintain a straight back. Maximum number of push-ups was recorded for each participant.

On a separate day, each participant performed the 1RM bench-press followed by the bench-press test to fatigue. The American College of Sports Medicine (ACSM) protocol for 1RM bench-press was followed. Before performing the 1RM test, the participant warmed up with two sets of 5-10 repetitions bench-press at a low resistance. Followed a 2-min break, the estimated 75% of 1RM resistance load was set for the first trial. 1RM max was established within four sets (American College of Sports Medicine., 2014). Maximum resistance lifted was registered in pounds and converted to kilograms. Following a 15-min rest period, the participant performed the bench-press to fatigue using a barbell load that approximated his or her percent of body mass supported during the push-up. Participants were instructed to perform as many repetitions as possible. Participant chose his or her own pace to lift and lower the bar. Test was stopped if participants could not extend their arms fully. Maximum number of repetitions was recorded.

Data analysis

A two-way ANOVA was used to measure interaction between gender (male and female) and muscle endurance tests (push-up and bench-press). An independent t-test was use to compare mean values between genders in the 1RM bench-press. For all statistical tests alpha level was set to 0.05. Equality of variance was determined using Levene's Test. Data are presented as *mean* ± *standard deviation*.

Results

Equal variances between groups were met for the number of push-ups (F = 0.001, p = 0.98) and bench-press repetitions (F = 3.45, p = 0.07) performed, but not for the 1RM bench-press (F = 8.08, p = 0.008). During the static push-up test, men's *mean* and *standard deviation* force was 71.5 ± 2.1% of body weight and women's mean force was 51.8 ± 6.5%. To match the load of the push-up test during the bench-press, men lifted 58.2 ± 5.5 kg and women lifted 31.4 ± 5.0 kg. The two-way ANOVA test identified interaction between gender and test, p < 0,001. With these loads, men bench-pressed 17.5 more repetitions than women (p < 0.001) (figure 1). The mass lifted when expressed as a percentage of 1RM was 51.7 ± 7.4% for men and 86.1 ± 11.7% for women (p < 0.001). No difference (p = 0.25) was found between women and men in the number of push-ups performed (figure 1). Looking at the within difference, significant differences were observed for bench-press and push-up in both male and female, whereas the difference in the male was lower, p < 0,001. On average, Men bench-press to fatigue 25 repetitions while women did on average six repetitions. However, both men and women performed, on average, more push-ups. Men performed 33 repetitions whereas women performed 30 push-ups on average.

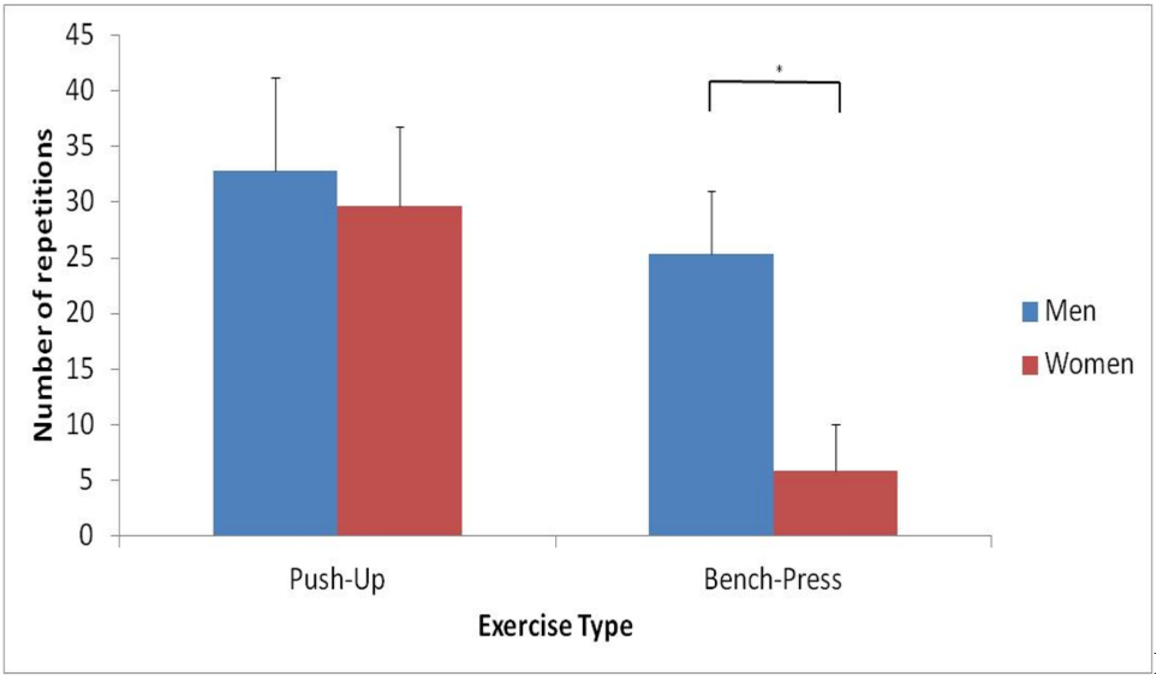

Figure 1.

The m*ean*s and *standard deviations* of the maximum number of repetitions performed by men and women during bench-press and push-up tests performed to fatigue with equal loads. *$p < 0.001$.

1RM bench-press load was greater in men (Table 2). In absolute values, men lifted 77.7 kg more than women ($p < 0.001$). When mass lifted was related to body mass, men lifted 2.4 times more mass than women ($p < 0.001$).

Table II. Men and women 1RM bench-press results as absolute (1RM ABS) and relative to percent body mass lifted (1RM RBM) values *Mean* ± (*SD)*. *$p < 0.001$.

	1RM ABS (kg)	1RM RBM (%)
Men	114.8 (18.9)*	141 (20.7)*
Women	37.1 (7.8)	59.5 (8.7)

Discussion

Similar to previous work (Gouvali & Boudolos, 2005; Mier, et al., 2014; Suprak, Dawes, & Stephenson, 2011) our current study determined that women supported approximately 52% of body weight during the modified push-up compared to men that supported approximately 71% of body weight during the standard push-up. Under these conditions, men and women performed a similar number of repetitions (33 and 30, respectively) which placed both groups in the "Excellent" fitness category according to the American College of Sports Medicine (American College of Sports Medicine., 2014). In contrast, when a load equivalent to that of the push-up was applied to the bench-press, the number of repetitions performed by men was significantly greater than that observed in women (25 vs. 6). Thus, while the push-up and bench-press exercises at equivalent loads give comparable performance results in men, although significantly different (33 vs. 25), women's performance on the bench-press is markedly reduced compared to the push-up (30 vs. 6). These findings support the researchers' hypothesis that men will performed better than women do on the bench-press to fatigue test while having a closer number of repetitions as the push-up to fatigue test.

One of the reasons for the discrepancy in bench-press performance in men and women is upper-body maximal strength differences. It is well known that women's upper-body maximal strength, typically measured on the bench-press is about 50% to 60% that of men's (Bishop, et al., 1987; Miller, et al., 1993). Our data indicated that in absolute values, women's strength was only 32% that of men. When strength ratio (weight lifted/body weight) was compared, men achieved 1.41, which placed them in the "Excellent" category, while women achieved 0.60, placing them in the "Good" category (American College of Sports Medicine., 2014). The larger than normal gap between men and women in terms of strength may have to do with quality or type of training performed by the men in our study.

Although all participants were physically active with some resistance training included in their routine, it is possible that men's training placed greater emphasis on upper-body strength using the bench-press as the main exercise. Indeed, when the bench-press load was equivalent to 72% of body weight, the load was 52% of bench-press 1RM in men; in contrast, 52% of women's body weight translated to 86% of 1RM on the bench-press.

Another possibility may be related to the characteristics of an open-kinetic chain bench-press exercise vs. closed-kinetic chain push-up exercise. To perform the bench-press exercise the participant needs to control the movement of the bar from the chest vertically up, from flexed elbows to extended elbows. However, the barbell movement is controlled only by the upper extremities muscles. Changes in the barbell position towards any direction, beside the vertical, will create a torque towards this direction. To compensate for this new torque the participant will have to activate other muscles, such as the rotator cuff muscles, to control the movement. This will increase the energy demand on the upper extremities musculature, which may lead to reduction in force output for the different bench-press tests as a result of early onset of fatigue. On the other hand, when performing push-up the participant is pushing on a stable surface, the ground. In a push-up position, the participant has a wide base of support created by the hands and legs. This reduces the demand to stabilize the body when moving.

Discrepancy in muscle force production between the right and left sides of the upper-body may contribute also to the differences in performance of the bench-press and push-up exercises. When performing the bench-press exercise the participant has to keep the barbell almost parallel to the ground. If the participant upper-body strength production is not similar between the right and left side, the participant will not be able to keep the barbell parallel to the ground while pushing it up. This creates a larger torque towards the weaker side of the body and the participant may not be able to overcome this torque to lift the bar further, which will lead to an incomplete repetition. On the other hand, during the push-up exercise, the ground is not moving and the center of mass of the body is distributed evenly between the sides. If one side is weaker, the participant can shift their body distribution to the stronger side so they can compensate for the weaker side. This may explain why women, in the modified position, can perform similar numbers of push-ups as men in the standard position. However, they cannot bench-press the same relative body weight.

Nevertheless, we determined that despite the large difference in bench-press performance, women performed as well as men during the push-up. Data from previous studies of young men that performed the standard push-up test and a 1RM bench-press test indicate that push-up performance was moderately correlated to upper-body maximal strength ($r = 0.47$ to 0.61) (Invergo, Ball, & Looney, 1991; Mayhew, Ball, & Arnold, 1991; Vaara et al., 2012). On the other hand, among college-aged women that performed the modified push-up, a weak relationship ($r = 0.26$) to bench-press maximal strength was observed. (Mayhew, Ball, Bowen, & Arnold, 1990) Thus, while the push-up and bench-press have biomechanical similarities, push-up performance is a weak predictor of bench-press maximal strength in women. It is likely that muscle co-activation is more prominent during the push-up exercise by nature of its closed-kinetic chain characteristics. Previous studies have provided evidence that abdominal and psoas major muscles are recruited during the push-up, most likely for trunk stabilization (Calatayud, Borreani, Colado, Martin, & Rogers, 2014; Freeman, Karpowicz, Gray, & McGill, 2006; Juker, McGill, Kropf, & Steffen, 1998). It is possible that co-activation of synergistic and stabilizing muscles play a significant role in push-up performance and their contribution may be greater in women as a means of overcoming strength limitations.

In this study, both men and women participants were physically active individuals with experience in performing push-up and bench-press exercises correctly. However, the actual participant training protocols were not recorded. If the men's training protocols consisted of more bench-press exercises than the women, or greater training loads for upper body musculature this could have influenced our results. Calatayud et al. (2015) measure the differences in maximal strength gain in 1RM bench-press between push-up and bench-press training and determined that load affects muscle adaptations more than the type of exercise. Thus, it is possible that the men who participated in our study trained at higher intensities than women did.

In summary, it appears that in regards to upper body endurance performance, women perform better during the push-up than the bench press when external load is approximately 52% of body mass. In contrast, due to their relatively high upper body strength, men perform about as many push-ups as bench press repetitions at an external resistance approximately 72% of body mass. For the athlete or strength and conditioning coach, push-up exercises for females should be considered at a higher intensity where loads may exceed bench press strength. Furthermore, the athlete or strength and conditioning coach should emphasize and add the bench-press exercise as an integral part of the resistance training protocol. Further research is needed to measure the influence of other upper body and lower body exercises such as pull-ups and squats. Moreover, the influence of free weight training and its application to relative strength and endurance in women should be measured.

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