

Differences between Men and Women in Percentage of Body Weight Supported during Push-up Exercise

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ABSTRACT

International Journal of Exercise Science 7(2) : 161-168, 2014. The purpose of this study was to investigate the effects of push-up method (standard vs modified) and gender on percentage of body weight supported. Thirty seven men and women completed five push-ups in the standard (SPU) and modified (MPU) positions, and 5-sec hold (static) in the up (elbow extension) and down (elbow flexion) positions. Vertical ground reaction forces (expressed as load relative to body weight) were measured using force platforms. From a video-captured image, a computer software distance tool measured vertical range of motion (ROM) achieved in the down position expressed as a percentage of full vertical ROM. Maximal relative load was greater in men than women (SPU: $97.7 \pm 8.1\%$ vs $80.0 \pm 3.9\%$; MPU: $79.7 \pm 7.4\%$ vs $68.2 \pm 3.0\%$, $p < .0001$) with a greater effect during SPU ($p < .0001$). In the static up position, relative load did not differ between men and women (SPU: $67.0 \pm 3.8\%$ vs $65.1 \pm 3.1\%$; MPU: $52.5 \pm 3.7\%$ vs $51.5 \pm 3.1\%$); however, relative load was greater in men during the static down position (SPU: 74.6 ± 3.6 vs $70.3 \pm 3.1\%$; MPU: 60.1 ± 4.5 vs $56.6 \pm 2.7\%$, $p < .0001$). Percentage of full vertical ROM was greater in men than women (SPU: $67.7 \pm 6.1\%$ vs $50.1 \pm 11.4\%$; MPU: $66.6 \pm 6.9\%$ vs $60.1 \pm 8.9\%$, $p = .001$). These data indicate that women perform the push-up with less relative load and ROM, likely due to gender differences in movement patterns which can be altered by fatigue.

KEY WORDS: health-related fitness; upper-body muscular endurance; muscle fitness; muscle strengthening exercises

INTRODUCTION

The push-up test is a common field method to assess upper body muscular endurance (2, 4, 9, 20). To evaluate performance, the maximum number of push-ups completed without rest is recorded. For health-related fitness assessment, the push-up protocol differs by gender (2, 9). For males, the standard position with the toes as the pivot point is used, whereas females perform the test in the modified position, with the knees serving as the pivot point. However, certain

physical fitness readiness tests, such as those used by the United States Army, include the standard push-up for both men and women (20). Likewise, the Cooper Institute Fitnessgram® incorporates the standard push-up test for boys and girls between ages 5 and 17 (4).

The gravitational resistance or load experienced during the push-up is largely determined by body weight and how it is supported on the ground. Because load relates directly to body weight, the vertical

ground reaction force brought on by gravitational resistance during a push-up can be expressed as a percentage of body weight (relative load). Gouvali et al. (8) determined that the relative load in a static position when elbows are extended was 66% of body weight during the standard push-up, but only 53% during the modified push-up. Similarly, Suprak et al. (19) observed 69% and 54% body weight in the elbow extended position during the standard and modified push-ups, respectively. Suprak et al. also reported relative load of 75% and 62% experienced in the elbow flexion position during the standard and modified push-ups, respectively. These studies suggest that the difference between standard and modified push-ups can be related to differences in moment arm and the relative supported body weight. Overall, as much as three quarters of body weight could be supported during a standard push-up and over half the body weight is supported during the modified push-up performed by men.

According to the push-up standards set forth by the United States Army (20), women perform 40% to 60% fewer standard push-ups than men. For health-related assessments, women complete about 20% to 24% fewer modified push-ups than men that perform standard push-ups to achieve the same percentile rank (9). Upper body strength in women is about 50% to 60% that of men which may account for differences in push-up performance (3, 12, 14, 18, 21). However push-up performance in men and women correlates weakly ($r = 0.26$ to 0.56) to upper body strength measured by one repetition maximum during a bench press test (11, 16, 17). Thus, gender differences in push-up performance may be the result of

other factors that can affect relative load, including a change in the moment arm which is determined largely by body mass distribution and its effect on whole body center of mass (5, 8, 15, 19). Variations in movement patterns and muscle activation, including hand position relative to the shoulders (8, 22), forearm rotation (5) and speed of movement (7, 13) can also alter the relative load. Generally, women have shorter stature and arm length, and hold a lower proportion of body mass in the upper body compared to men (1, 12). Because of these differences, it is possible that load expressed relative to body weight during the push-up would also differ between men and women.

Thus far, gender differences in the relative load of body weight supported during the push-up have not been thoroughly investigated. It remains of interest to study these differences to provide a more meaningful analysis of push-up performance in men and women. Because the push-up is a common exercise to improve upper body endurance and strength in men and women, knowledge of gender differences in the relative load of body weight supported can be directed toward more effective and safe exercise programs. Thus, the purpose of this study was to investigate the effects of push-up method (standard vs modified) and gender on the percentage of body weight supported (relative load) as measured by the vertical ground reaction forces. We hypothesized that women would experience a lower relative load while performing standard and modified push-ups during both dynamic and static conditions and that relative load would be lower in both men and women during the modified push-up vs the standard push-up.

METHODS

Participants

Nineteen men and 18 women of similar age (mean \pm SD; 25 \pm 7 yr and 22 \pm 3 yr, respectively) completed the protocol. Body mass (78.6 \pm 10.7 kg vs 64.1 \pm 6.8 kg) and body height (176.9 \pm 8.0 cm vs 165.5 \pm 6.3 cm) were ($p < 0.05$) greater in men. Participants were selected only if they engaged in recreational or competitive physical activities that included upper body resistance exercise at least once a week and were capable of correctly completing five continuous repetitions of the standard push-up. Participants were asked to refrain from vigorous upper body activity at least 24 hours prior to the test. All experimental procedures were approved by the university's Institutional Review Board, and each participant read and signed an informed consent form prior to participation.

Protocol

Each participant performed a total of eight push-up tests, four dynamic and four static tests. The dynamic tests consisted of two sets of five repetitions in the standard position (SPU) and two sets of five repetitions in the modified push-up position (MPU). The static tests consisted of two sets of push-ups held for five seconds in the up position and five seconds in the down position for both SPU and MPU. The eight tests were counterbalanced with all possible orders and included a 5-min rest period between them. Kinetic data were collected using two AMTI force plates (Advanced Mechanical Technology, Inc., Watertown, MA, USA) sampled at 960 Hz, interfacing with Vicon Nexus 1.7.1 software (Vicon, Centennial, CO, USA). Low pass fourth order Butterworth filter with a cut-

off frequency of 300 Hz was used to filter all data. Prior to the push-up tests, the participant removed his or her shoes and was then weighed while standing erect with each foot centered on a force plate. Data were collected for one second while the participant remained still and the recordings between 0.25 and 0.75 seconds were averaged for each force plate. Body weight was then calculated as the sum of the two force plate average recordings.

To perform the push-up, the participant was instructed to position each hand at the center of a force plate with fingers pointing forward and hands positioned below the shoulders. In the standard position, legs were fully extended and the toes supported the body. In the modified position, lower legs were in contact with the floor with ankles plantar-flexed and back straight. Participants were instructed to lower themselves into the down position to at least the point where the upper arms become parallel to the floor, to keep the body generally straight and to fully extend the arms in the up position (20). Prior to data collection, the participant practice the different push-ups. During the practice trial, if repetitions appeared to not be performed correctly, the participant was verbally instructed to correct his or her position for the next repetition. Consequently, all repetitions were performed correctly during the actual test. An exception made to the standard protocol was the use of a metronome that paced the participant to perform one push-up (elbow flexion followed by extension) in two seconds. Maximal vertical ground reaction force was identified during the 2nd, 3rd and 4th repetition and the average recorded as the maximal relative load. During the static positions, vertical ground reaction forces

between the 2nd and 4th seconds were measured and the average recorded as the relative load.

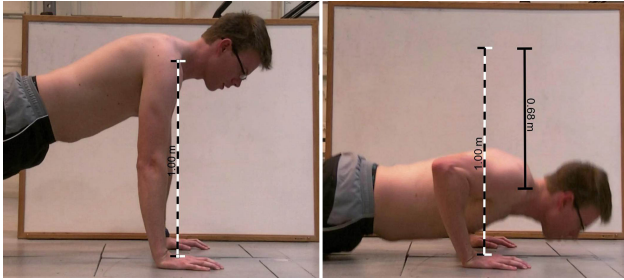


Figure 1. The calculation of vertical distance achieved in the down position relative to full ROM, presenting the vertical full ROM (left) and the vertical ROM achieved (right).

To assess vertical distance achieved in the down position relative to full ROM, a digital video camera captured each push-up test in the sagittal plane. Vertical full ROM was considered the distance between the acromion process and the styloid process of the ulna while the participant was in the up position and arms fully extended. The camera was positioned approximately 25 cm above the ground with the lens leveled parallel to the floor and the participant's shoulder centered on the LCD screen. A visible marker was placed on the acromion process as a reference point for the shoulder and the styloid process of the ulna was recognized at the point of wrist extension. In the video-captured image, the frame was frozen with the participant in the up position. Using Dartfish ProSuite software v4.0 (Dartfish, Atlanta, GA, USA), a vertical reference line was drawn from the acromion marker to the point level with the styloid process of the ulna (Figure 1). Next, the video was forwarded to the point where the participant reached the lowest position. Another vertical line was drawn from the top of the reference line to the point level with the acromion process. The length of

the second line was displayed relative to the reference line and was considered to be the vertical ROM achieved in the down position expressed as a percentage of full vertical ROM.

Statistical Analysis

Analyses were performed using PASW Statistics v19.0 (SPSS Inc, Chicago, IL). Analysis of variance with repeated measures was used to test mean differences between genders and push-up tests (SPU vs MPU) and to determine interaction effects of gender and push-up test. The dependent variables were the maximal positive vertical ground reaction force averaged from the 2nd to 4th repetition (dynamic), the average positive vertical ground reaction force measured in the held (static) up (elbow extension) and down (elbow flexion) positions and the vertical range of motion (ROM). The forces were expressed as a percentage of body weight (relative load) and the vertical ROM was expressed as percent of full vertical ROM achieved in the down position. Each of the dependent variables was measured during the SPU and MPU. Significance was set at an alpha ≤ 0.05 . The 95% confidence interval (CI) for a mean difference is reported when significance was achieved.

Internal consistency between push-up repetitions was tested using an intraclass correlation (ICC) 2-way mixed effects model for single measures (ICC (3,1)). The maximal vertical ground reaction force between repetitions was highly reliable for both SPU ($r=0.96$, 95% CI: .94-.98) and MPU ($r = 0.94$, 95% CI: -.90-.97). Likewise, test-retest reliability was determined using a 2-way mixed effects model for average measures (ICC (3,k)) between two sets of SPU ($r = .098$, 95% CI: .96-.99) and MPU ($r =$

0.87, 95% CI: .75-.94). Consequently, the average of three repetitions was recorded for each set and the average of two sets was recorded for final analyses.

RESULTS

Maximal load expressed relative to body weight during the dynamic SPU and MPU was lower ($p < .0001$, 95% CI [13.4, 16.2]) in women than men (Table 1). There was an interactive effect ($p < .0001$) such that the difference between men and women was greater during SPU. Likewise, relative load was lower in women ($p = .001$, 95% CI [1.8, 6.1]) in the static down position, but no difference was observed in the static up position. Overall, relative load was lower during the modified push-up with respect to standard push-up in both the up ($p < .0001$, 95% CI [12.8, 15.2]) and down ($p < .0001$, 95% CI [13.1, 15.1]) static positions.

Table 1. Vertical ground reaction force during a push-up expressed as a percentage of body weight.

	Men		Women	
	SPU	MPU	SPU	MPU
Dynamic Max	97.7 ± 8.1	79.7 ± 7.4	80.0 ± 3.9*	68.2 ± 3.0*
Static Down	74.6 ± 3.6	60.1 ± 4.5	70.3 ± 3.1*	56.6 ± 2.7*
Static Up	67.0 ± 3.8	52.5 ± 3.7	65.1 ± 3.1	51.5 ± 3.1

Data are mean ± SD. * $p < .001$ vs men. MPU = modified push-up; dynamic max = maximal force during movement, static down = force during the down position held for 5 sec, static up = force during the up position held for 5 sec.

Percentage of full vertical ROM achieved in the down position and measured during the dynamic push-up was greater in men ($p = .001$, 95% CI [6.9 - 17.2]) (Figure 2). There was an interactive effect ($p < .0001$) such that the difference between men and

women was greater during SPU. Similar results were observed when the distance between the static up and down held positions was measured ($p = .001$, 95% CI [9.8 - 20.0]) during both SPU (men: 68.6 ± 6.4% vs women: 49.3 ± 13.3%) and MPU (men: 68.9 ± 5.2% vs women: 58.4 ± 8.9%). There was an interactive effect ($p = .005$) such that the difference between men and women was greater during SPU.

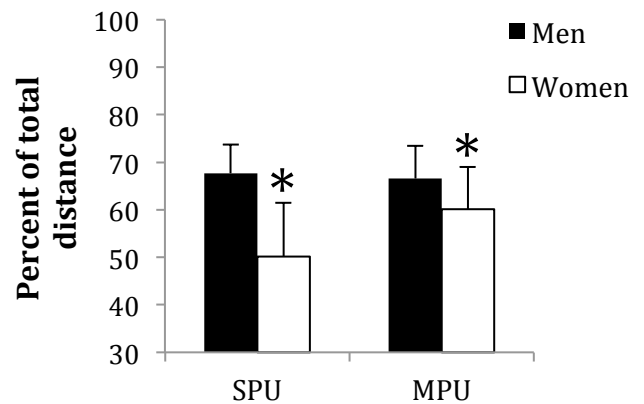


Figure 2. Percentage of full vertical ROM achieved in the down position during the dynamic push-up. SPU = standard push-up, MPU = modified push-up. Data are presented as mean ± SD. * $p < 0.05$ vs men.

DISCUSSION

Our data demonstrate gender differences in the relative loads experienced during the push-up and confirm previous studies that measured relative load experienced during the static push-up performed by men (8, 19). We determined that approximately 75% of body weight is supported while holding the down position (elbow flexion) compared to 67% in the up (elbow extension) position during the standard push-up. In comparison, the relative load experienced during the modified push-up is approximately 15% less in both the up and down positions, similar to the results from previous studies (8, 19). In this study, the differences among the up and down

positions in the standard and modified push-ups are likely attributed to the distance between point of contact with the floor and whole-body center of mass (moment arm). An increase in moment arm when flexing the elbow is possible as the body becomes parallel to the ground in the down position. The differences between the standard and modified push-ups are likely attributed to differences in body weight supported and change in moment arm.

Women demonstrated similar patterns when comparing standard and modified push-up in the static up and down positions held for 5 sec. There was no gender difference in relative load in the static up position; however, relative load was lower in women in the static down position. Women hold a slightly lower proportion of their skeletal muscle mass in the upper body (1, 12), and generally have narrower chest and shoulder girth compared to men. This could contribute to a shorter moment arm in women, most evident in the down position when the body is more parallel to the ground. A more likely contributor is that men reached a lower position, evident from their greater vertical ROM, most prominent during the standard push-up. This would also contribute to differences in moment arm between men and women as men would more likely achieve a parallel position to the ground.

No previous studies have tested gender differences in relative load during the static up or down position. However, Ebben et al. (6) measured maximal relative load during both the standard and modified push-up and found no gender differences. In contrast, we observed maximal relative load to be lower in women by almost 18%

during the standard and over 11% during the modified push-up. Our results may have differed from Ebben et al. (6) because of the difference in cadence. In their study, participants performed the push-up with a 2-sec down and 2-sec up cadence. This is considerably slower than a self-paced push-up which would create greater acceleration and deceleration forces, and therefore, relative loads (13). Indeed, the values reported by Ebben et al. (relative loads of 64% and 49% for the SPU and MPU, respectively) are closer to the values we and others (8, 19) observed during a static held position. During the dynamic push-up, our participants performed the protocol in half the amount of time compared to Ebben et al. (6). Another possible difference between our study and Ebben et al. (6) is that only two push-ups were performed in their study, while our participants performed five and the 2nd to 4th push-ups were averaged and used to determine maximal ground reaction force. It is possible that the number of push-ups performed could affect movement patterns that contribute to the gender differences observed in our study, but were lacking in Ebben et al.'s study (6).

It appears that the movement pattern during a push-up not only affects the relative load experienced but can contribute to greater gender differences, especially during the standard push-up. Indeed, men experienced a load approximate to their body weight, whereas women experienced 80% of body weight during the standard push-up. The greater load observed in men may be due to their greater vertical ROM achieved in the down position. However, a greater vertical ROM in men was also observed in the held down position when gender difference in relative load was considerably less. Thus, a more likely

explanation for the gender difference in relative load during the dynamic push-up is that men exhibited a greater explosive pattern of movement, cover a longer distance in the same time frame, which would increase acceleration and deceleration forces and muscle activation patterns that result in increased vertical ground reaction forces (7, 10). In addition, because women on average perform fewer push-ups than men (9), an earlier onset of fatigue would likely be experienced by women during a 5-rep push-up test. Fatigue would be associated with reduced power output which could be manifested from reduced range of motion (vertical distance traveled) and/or reduced velocity of movement. Although we asked participants to perform the push-up at a 1/1 cadence (1 sec up and 1 sec down), the time to complete a range of motion may have been less in men.

In this study we wanted the push-ups to be performed as prescribed in the field. As a result, a limitation is that we did not visually detect differences in vertical range of motion between men and women during the test. It is possible that some women did not feel comfortable lowering themselves as far as needed because of their breasts. Further, it is also possible that some men lowered their bodies below parallel, which could be related to the speed of the push-ups. Consequently, we determined differences in vertical ROM between men and women from *post hoc* analyses. Another limitation is we did not match men and women for body weight or height, which might have provided greater insight into gender differences in push-up performance. Last, although we recruited physically active participants that were engaging in upper body resistance exercise, we did not

match men and women for training volume, which may contribute to some of the observed gender differences. However, all men and women in this study met the requirement of completing five push-ups.

In summary, our data demonstrate that men experience a greater relative load when performing the push-up, most evident during the standard push-up. This is likely due to men achieving a more vertical down position, using more explosive movements, or experiencing less fatigue during five repetitions. However, the push-up still requires at least 50% to 80% of women's body weight to be supported. As the push-up is often used in fitness programs, the relative load supported must be considered because it significantly contributes to the power output and work performed during the push-up exercise (13). Concerning exercise programming, the strength and conditioning coach should be attentive to the gender differences in upper body muscle mass and strength when prescribing exercise intensity that is dependent upon body weight. In general, men's upper body strength allows them to support a greater percentage of body weight during a standard push-up, which would likely fall within an appropriate range of intensity most beneficial for muscle endurance and power. Because of women's lower upper body strength in general, the standard push-up will likely require an intensity that is more appropriate for muscle strength. Hence, the modified push-up would be more suitable for muscle endurance and power improvements in women. As far as physical fitness testing is concerned, our data reinforce the necessity for objective criteria to be applied to the push-up procedure, including the means of

determining whether the required range of motion has been achieved.

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