

Changes in Body Position during a 2-Minute Push-Up Test

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Abstract

Push-ups are a common exercise for individuals of all ages and abilities. Ensuring that the body maintains optimal positioning is crucial throughout any activity. This brief study investigates the changes in hand height and torso angle throughout a 2-minute push-up test. A total of 26 males (23.3±6.9 years old) participated in this study. Video was collected of the entire 2-minute push-up bout. Of interest to the researchers was the distance the hand was in relation to the shoulder and the angle of the torso to the horizontal (both measure from participants' sagittal view). Three consecutive repetitions at the start and end of the bout were used for comparative analysis. Both hand placement in relation to the shoulder and torso angle decreased significantly ($p=0.00$) from the start of the bout to the end. These results indicate that as participants became tired, they assumed a body position that likely allowed for a greater portion of their body weight to be supported by their lower body. While this adjustment allowed them to continue the exercise, compensational patterns like this should be identified and addressed in training in order to strengthen the primary muscles targeted by the exercise.

Keywords: Hand height; Torso angle; Form; Technique; Assessment; Muscular endurance; Body angles; Hand position

Abbreviations: Hand Ht: Hand Height in relation to the shoulder; Torso: Torso angle to the horizontal

Introduction

The push-up exercise is a common fundamental exercise used to train and assess the muscular endurance of the entire body [1-4]. Due to the emphasis on body control and ease of administration, this exercise has been performed regularly for decades by a wide variety of athletes, military personnel, and recreational fitness enthusiasts alike. The standardized 2-minute push-up test has been performed by all active duty U.S. Army Soldiers and reservists as part of the Army Physical Fitness Test (APFT) every 6 months for almost 40 consecutive years [5], with the total number of repetitions completed to standard recorded for each participant. While technique is anticipated to deteriorate over the course of the bout, being able to maintain proper body positioning for as long as possible is desirable as it will likely increase the number of repetitions recorded.

While extensive research has investigated differences in initial hand placement, joint stresses and optimizing training effectiveness [6-18], little attention has been given to the changes in body position over the course of an extended push-up bout when compensational movement patterns are likely to be adopted. Therefore, the purpose of this article was to compare the natural push-up body positioning from the beginning to the end of a continuous 2-minute standardized push-up assessment. To the knowledge of the authors of this study, there is currently no research published that investigates body

positioning changes adopted throughout the course of a push-up test. As technical standards for push-ups vary considerably among researchers and sports professionals, the APFT push-up guidelines were used as the standardized push-up protocol for this movement analysis [19].

Materials and Methods

Subjects

A total of 26 males (height: 1.76±8.6 m, weight: 84.2±11.3 kg; age: 23.3±6.9 years) from the United States Military volunteered to participate in this study. All participants were free of injury at the time of testing. Prior to participation, informed written consent was obtained from each participant. All procedures were approved by the Human Research Protection Program before commencing the study.

Testing protocol

Following a self-selected warm-up, each participant assumed the front leaning rest position (i.e. plank position) when ready. On the researcher's command, participants performed as many push-ups as they were able to within the allotted 2-minute time period. At no time were participants allowed to drop their knees to the ground. However, resting in pike position (i.e. downward dog) or

the front leaning rest position was allowed as needed. The hands were allowed to be repositioned as needed by sliding them across the testing surface. Additionally, push-ups were only counted if

- 1) The upper arm reached parallel (or lower) to the ground during the downward phase of the movement,
- 2) The elbow reached full extension in the front leaning rest position after each repetition, and
- 3) The body moved as one unit, forming a straight line from head to ankles throughout the movement.

Upon completion of the 2-minute exercise bout, participants were asked to perform a self-selected cool-down on their own before leaving the lab.

One camera recorded the entire 2-minute bout for each participant. The camera was placed on the right side of the body, in line with the participants' shoulder. Two measurements from this camera were of interest to the researchers for this analysis:

- 1) The distance from the heel of the hand to the shoulder (Hand Ht), and
- 2) The torso angle to the horizontal at the start of each repetition (Torso) (Figure 1).

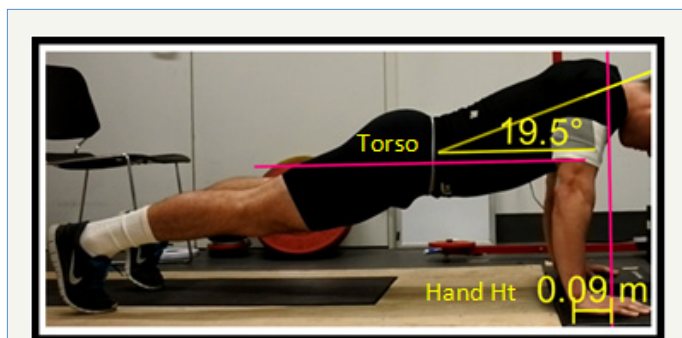


Figure 1: Measurements of interest: hand height in relation to the shoulder (Hand ht) and Torso angle to the horizontal (Torso).

Reflective markers were placed at the acromion process and iliac crest for measurement purposes.

Statistical analyses

Measurements (Torso and Hand Height) were recorded and averaged over the 2nd, 3rd and 4th repetition and the 4th, 3rd and 2nd to last repetition. Paired t-tests were used to determine if there was significant difference in these measures from the beginning to the end of the bout. Statistical significance was set at $p \leq 0.05$.

Results and Discussion

At the beginning of the assessment, participants began with their hands (Hand Ht) positioned significantly lower (66%) in relation to the shoulder than at the end of the bout ($t(25)=3.0, p=0.00, d=0.73$), (Table 1). This initially indicated that the hands were repositioned to a higher placement during the exercise, likely in an attempt to lessen the strain and fatigue being experienced by the muscles (e.g. pectorals and triceps) [4,20]. However, when

viewing the video footage participants' hands were not actually repositioned at all throughout the bout, indicating that some other adjustment must have been made during the course of the exercise.

Table 1: Hand height (Hand Ht) and torso angle to the horizontal (Torso) at the start and end of a 2-minute continuous push-up bout.

Measurement	Start Mean±SD	End Mean±SD	p-value
Hand Ht (cm)	10.8±5.4	6.8±5.6	0.00*
Torso (degrees)	24.7±6.5	17.8±8.8	0.00*

*Indicates significance at the $p \leq 0.05$ level

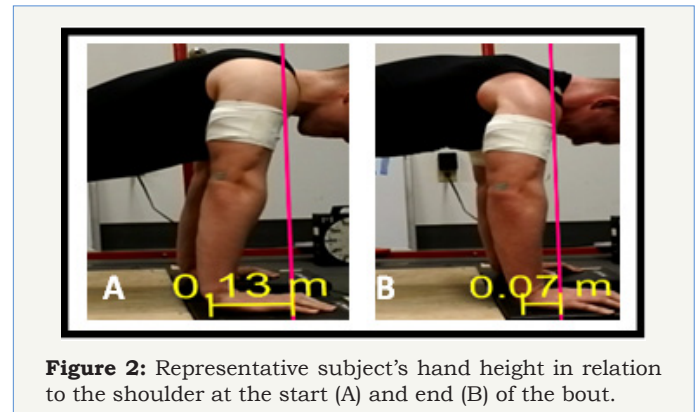


Figure 2: Representative subject's hand height in relation to the shoulder at the start (A) and end (B) of the bout.

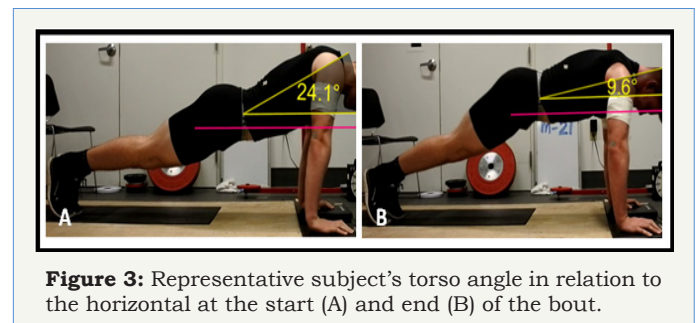


Figure 3: Representative subject's torso angle in relation to the horizontal at the start (A) and end (B) of the bout.

Similarly, the angle of the torso (Torso) to the horizontal was also found to decrease significantly (72%) throughout the bout ($t(25)=5.1, p=0.00, d=0.89$). As participants began to experience fatigue, they adopted a more horizontal torso position through increased hip flexion. This combined with the hands positioned closer to the shoulder at the end of the bout indicated that as participants began tire, they did not fully return to the front leaning rest position. At the beginning of the exercise, a greater percent of body weight is likely supported by the upper body as the hands were positioned more in line with the chest as opposed to the shoulders (Figure 2). The altered body position at the end of the bout (Figure 3) likely allowed for a greater percent of the body weight to be supported by the lower body (similar to the modified push-up position), thereby relieving some of the strain to the muscles of interest (i.e. pectorals and triceps) [1,3,4].

Conclusion

Attention to technical characteristics of push-up performance is often focused on the optimal starting execution position (e.g.



hand position, upper arm angle, etc.). However, over the course of an assessment that is meant to challenge the muscular endurance of an athlete, it is reasonable to assume that compensational movement patterns (e.g. piking at the hips, hand placement higher than shoulder height, etc.) will likely be adopted once the primary muscles (i.e. pectorals and triceps, and core musculature) begin to fatigue in order to continue the exercise. It is important to identify these compensational strategies so that training can target the areas of deficiency. If an athlete begins to display such assistive movement patterns, it is advised that the exercise be stopped and additional muscular endurance training be implemented. Athletes should be aware of their body positioning throughout any exercise. In addition to verbal feedback, coaching tools such as mirrors and video cameras (e.g. cell phones and tablets) are recommended as a means of immediate visual feedback during training sessions to promote proper body alignment and spatial awareness.

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