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# Comparison of Muscle Activation Using Various Hand Positions During the Push-Up Exercise

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**Abstract.** Cogley, R.M., T.A. Archambault, J.F. Fibeger, M.M. Koverman, J.W. Youdas, and J.H. Hollman. Comparison of muscle activation using various hand positions during the push-up exercise. *J. Strength Cond. Res. 19(3):628–633. 2005.*—Popular fitness literature suggests that varied hand placements during push-ups may isolate different muscles. Scientific literature, however, offers scant evidence that varied hand placements elicit different muscle responses. This study examined whether different levels of electromyographic (EMG) activity in the pectoralis major and triceps brachii muscles are required to perform push-ups from each of 3 different hand positions: shoulder width base, wide base, and narrow base hand placements. Forty subjects, 11 men and 29 women, performed 1 repetition of each push-up. The EMG activity for subjects' dominant arm pectoralis major and triceps brachii was recorded using surface electrodes. The EMG activity was greater in both muscle groups during push-ups performed from the narrow base hand position compared with the wide base position ($p < 0.05$). This study suggests that, if a goal is to induce greater muscle activation during exercise, then push-ups should be performed with hands in a narrow base position compared with a wide base position.

Key Words. electromyography, pectoralis major, triceps brachii

## Introduction

The standard push-up can be used either in the assessment of muscle performance or as an exercise to increase chest, shoulder, and arm strength. The push-up maneuver requires a combined movement of horizontal adduction across the shoulder and extension at the elbow. As a form of exercise, therefore, its primary purpose is to develop increased strength in the pectoralis major and triceps brachii muscles. As a tool for assessing muscle performance, the push-up is incorporated in a battery of tests designed to assess individuals' fitness levels, such as in the Army Physical Fitness Test (12). Performance on the push-up therefore measures strength and endurance of several upper-extremity and trunk muscles. Whether used as an assessment tool or a strengthening exercise, it is important to understand activation patterns of the muscles that perform the movement so that maximal benefits can be realized.

Popular fitness literature has asserted that performing push-ups from different hand positions may better isolate either the pectoralis major or the triceps brachii. For example, Weede and Kraemer (22) and others (11, 17, 21) suggest that performing push-ups from a narrow base (NB) hand position will better isolate the triceps brachii. Geiger (5) suggests that widening one's grip during a bench press, a movement similar to that required of a push-up, will reduce triceps involvement and therefore produce more isolated work of the pectoralis major. Other sources advocate the wide base (WB) push-up for isolating the pectoralis major as well (7, 11). Little scientific evidence, however, can support these claims. Nevertheless, the validity of these sources may have implications regarding the performance of exercises aimed at recruiting specific muscle groups.

Many studies have examined muscle activation responses in a variety of shoulder strengthening programs (1, 13, 16, 18–20). For example, Signorile et al. (18) compared muscle activation patterns during the lateral pull-down exercise performed from varying hand placement positions. They reported that changes in handgrip position affect electromyographic (EMG) activation levels in certain muscle groups. Most notably, more EMG activity occurs in the latissimus dorsi muscle when the lateral pull-down is performed from a wide grip position. Anderson et al. (1) examined muscle activation patterns during seated push-ups but did not examine the muscle recruitment response of the standard push-up exercise. Donkers et al. (4) examined mechanical demands at the elbow during standard push-ups performed from the shoulder width (SW), WB, and NB hand positions. They found that the flexion torque at the elbow during push-ups is greatest when the exercise is performed from a NB, hands-together position. The study did not examine force requirements at the shoulder or muscle activation patterns. Nevertheless, the study points out that biomechanical and kinesiologic differences may occur during push-ups performed from the SW, WB, and NB hand positions. Few controlled studies have used kinesiologic methods to examine the demands of the standard push-up exercise. No study, to our knowledge, has examined the effect of hand position on muscle recruitment during the exercise, specifically recruitment in the pectoralis major and triceps brachii muscles. Therefore, the claims in popular literature (5, 7, 11, 17, 22) that hand position changes may elicit different muscular recruitment responses appear to be unsubstantiated empirically.

The purpose of this study was to examine muscle activation of the pectoralis major and triceps brachii muscle groups during push-ups performed from each of 3 selected hand positions: SW base, WB, and NB. Based on the suggestions of Weede and Kraemer (22) and Geiger (5) and the empiric evidence of Donkers et al. (4), we hypothesize that greater muscle activation will be elicited in the triceps brachii from the NB hand position and in the pectoralis major from the WB hand position.

## METHODS

### Experimental Approach to the Problem

Performing push-ups with the hands in a SW base position is the typical position from which the exercise is performed. Two variations of the common push-up include performing the exercise from a WB hand position and performing the exercise from a NB hand position (6, 7, 11, 17, 21). In this study we examined which hand position elicited the greatest EMG response from the pectoralis major and triceps brachii muscles. The EMG signals were collected with surface electrodes, processed with the root mean square algorithm, and normalized to a maximal voluntary isometric contraction. We used a within-subjects, repeated-measures design to test the null hypothesis that EMG activation in the pectoralis major and triceps brachii muscles is equivalent when push-ups are performed from each of the 3 hand placement positions. Testing order was randomized to reduce potential order threats to the study's internal validity. These procedures were designed to assess the muscle activation required of the pectoralis major and triceps brachii to perform push-ups from each of 3 hand positions. Specifically, the study design attempts to answer the following research question: "Does the magnitude of pectoralis major and triceps brachii EMG activation required to perform a push-up differ within individuals across SW, WB, and NB hand positions?"

### Subjects

Forty healthy volunteers between the ages of 22 and 39 years, 11 men (mean ± *SD* age, 24.3 ± 6.4 years; mean ± *SD* height, 180.3 ± 7.9 cm; and mean ± *SD* body mass, 88.0 ± 16.6 kg) and 29 women (mean ± *SD* age, 24.3 ± 15.8 years; mean ± *SD* height, 166.6 ± 7.7 cm; and mean ± *SD* body mass, 61.4 ± 7.1 kg), participated in this study. Subjects were recruited from the faculty and student populations through postings at the Mayo School of Health Sciences in Rochester, MN. Subjects reported an average of 1–5 hours of recreational activity per week, and greater than half were involved in strength training programs, which included triceps brachii and pectoralis major exercises. Subjects who had a history of shoulder, elbow, or wrist injury were excluded from this study. The study procedures were approved by the Mayo Institutional Review Board, Mayo Clinic, Rochester, MN. All subjects read and signed an approved informed consent form before their participation in the study.

### Instrumentation

Raw EMG signals were collected with D-100 bipolar surface electrodes (Therapeutics Unlimited, Inc., Iowa City, IA). The active Ag-AgCl electrodes had an interelectrode distance of 22 mm and were cased within preamplifier assemblies that measured 35 × 17 × 10 mm. The preamplifiers had a gain of 35. Electrode leads from the preamplifiers were connected to a main amplifier system GCS 67 (Therapeutics Unlimited, Inc.). The combined preamplifier and main amplifier permitted a gain of 100–10,000 with a bandwidth of 40 Hz to 6 kHz. The common mode rejection ratio was 87 dB at 60 Hz, and input impedance was greater than 15 MΩ at 100 Hz. Data were collected at a sampling frequency of 1,000 Hz. Raw EMG signals were processed with WinDaq data acquisition software (DATAQ Instruments, Inc., Akron, OH).

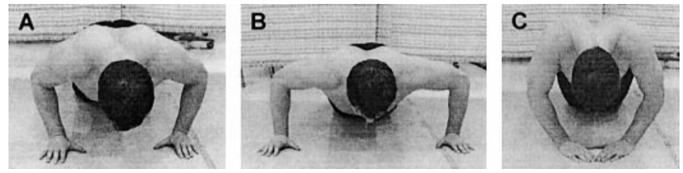


**FIGURE 1.** Electromyographic activity from the pectoralis major and triceps brachii was examined during push-ups performed from each of 3 hand positions: shoulder width (SW) base (A), wide base (WB) (B), and narrow base (NB) (C) hand positions. In the SW hand position, subjects positioned their middle finger at the end point of a plumb line hung from the edge of their deltoid. In the WB hand position, subjects positioned their hands 20 cm laterally from the SW position. In the NB hand position, subjects placed their hands together under the center of their sternum, forming a diamond shape between their thumbs and index fingers.

### Procedure

Each subject's skin was prepared by vigorously rubbing the electrode attachment site area with an alcohol wipe. After preparing the subject's skin, the electrode preamplifier assemblies were attached with double-sided, padded adhesive tape. The tape had wells that were aligned with the electrodes, in which conductive gel (Signa Crème electrode cream; Parker Laboratories, Fairfield, NJ) was used to conduct the myoelectric signal to the electrode. The electrodes were placed parallel to the line of action of the triceps brachii and pectoralis major muscles on each subject's dominant arm. The triceps brachii electrode was placed at the midpoint between the posterior aspect of the acromion and the olecranon process. The pectoralis major electrode was placed at a point one third of the distance between the anterior aspect of the acromion and the xiphoid process. The ground electrode was placed over the wrist flexor muscle group of the subject's forearm.

Once the electrodes were applied, maximal voluntary isometric contractions (MVIC) were obtained using traditional manual muscle test techniques described by Hislop and Montgomery (8). Subjects performed one 5-second isometric contraction against manual resistance provided by a researcher. The subject was asked to perform each manual muscle test with maximal effort.

Each subject randomly drew the order of push-up performance to reduce threats to the study's internal validity. All push-ups were performed with the subject's forearms pronated, wrists and fingers extended, and palms on the floor. The SW hand position was determined by hanging a plumb line along the edge of the deltoid muscle with the subject in a prone position. The subject's third digit was placed where the weight of the plumb line was positioned (Figure 1A). The WB push-up was performed with the hands placed 20 cm laterally from the SW position (Figure 1B). In the NB hand position, subjects were instructed to place their hands together in the shape of a diamond directly under the center of the sternum (Figure 1C). Subjects were instructed to perform the designated push-up starting from the floor and rising in a 3-second cadence. The standard cadence minimized influence of varying velocities of contraction on muscle performance (6). Subjects were each given a single practice trial to become familiar with the mechanical demands of the desired movement. Subjects were allowed a 2- to 3-minute

**TABLE 1.** Normalized electromyographic activity (mean ± *SE*) during push-ups.*

| | Pectoralis major (% MVIC) | | Triceps brachii (% MVIC) | |
|---|---|---|---|---|
| | Men | Women | Men | Women |
| Shoulder width base | 63.8 ± 6.9 | 106.0 ± 10.6 | 69.2 ± 6.9 | 113.4 ± 18.0 |
| Wide base | 66.3 ± 9.5 | 89.4 ± 8.6 | 62.3 ± 7.1 | 112.5 ± 20.6 |
| Narrow base | 85.8 ± 10.8 | 106.4 ± 9.9 | 82.6 ± 8.6 | 119.1 ± 19.0 |

* MVIC = maximal voluntary contractions.

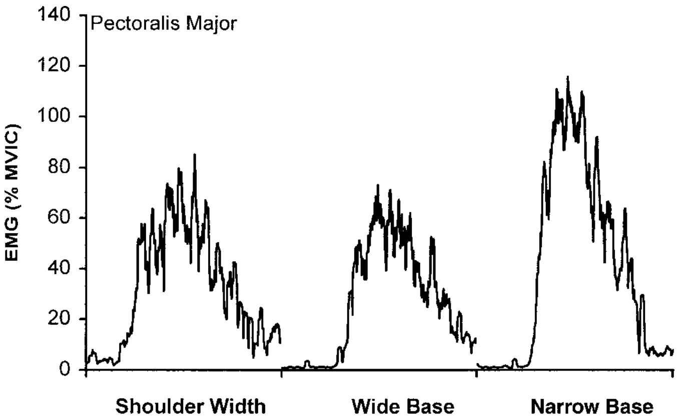


**FIGURE 2.** Normalized electromyographic (EMG) activity of the pectoralis major from a representative subject. Peak EMG activity occurs during the push-up performed from the narrow base hand position.

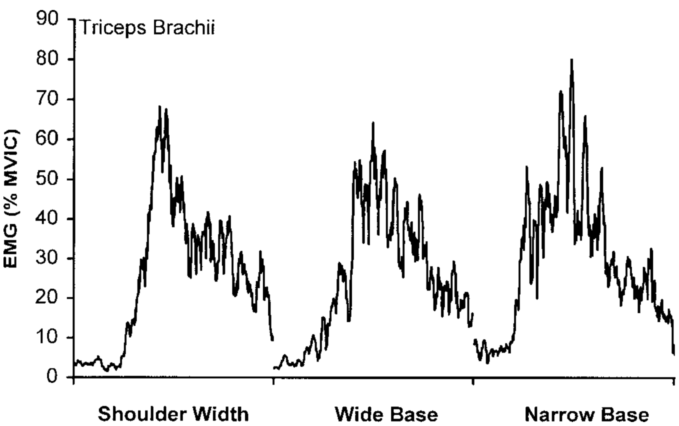


**FIGURE 3.** Normalized electromyographic (EMG) activity of the triceps brachii from a representative subject. Peak EMG activity occurs during the push-up performed from the narrow base hand position.

rest period between tests to minimize potential effects of fatigue. Following completion of the testing, the electrodes were removed and skin wiped clean.

### Data Processing

The EMG signals were processed with the root mean square algorithm at a time constant of 55 milliseconds. The EMG signals recorded during the test conditions were normalized to the muscles' respective peak activity levels in the MVIC trials and therefore were expressed as a percentage of MVIC. We analyzed specifically the half-second mean surrounding the peak normalized EMG activity level during the concentric phase of the push-up.

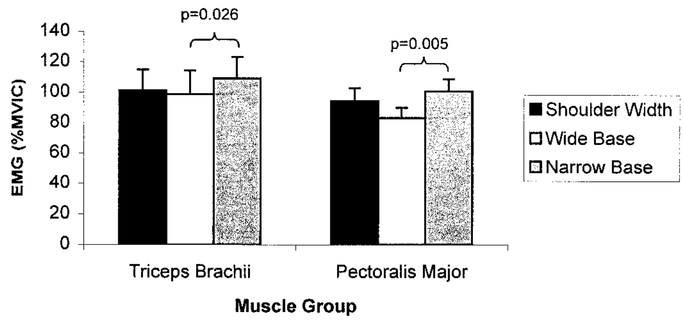


**FIGURE 4.** Mean normalized electromyographic (EMG) activity in the pectoralis major and triceps brachii muscles obtained during push-ups performed from the shoulder width, wide base, and narrow base hand positions. The EMG activity is significantly greater in the narrow base hand position than the wide base hand position in both the pectoralis major ($p$ = 0.005) and triceps brachii ($p$ = 0.026) muscles.

### Statistical Analyses

Data were analyzed with mixed-model analyses of variance (ANOVA), having 1 between-subjects factor (sex) and 1 repeated measure (hand position) to examine differences in normalized EMG activity between men and women and among the 3 hand positions. Two mixed-model ANOVAs were conducted, one test for each muscle. Keppel's (10) modified Bonferroni-adjusted post hoc comparisons were used to determine which hand positions differed. Statistical significance was established at $p \leq 0.05$ for all tests. Statistical procedures were performed with the SPSS 10.0 for Windows (SPSS Inc., Chicago, IL) statistical package.

## RESULTS

Although the women tended to perform the push-ups with greater magnitudes of EMG activation than the men (Table 1), greater variability occurred among the women, particularly in the triceps brachii, and the apparent differences in activation between men and women were not statistically significant (pectoralis major $F_{1,38} = 3.536$, $p = 0.068$, and triceps brachii $F_{1,38} = 1.942$, $p = 0.172$). In light of the nonsignificant differences between men and women, the remaining results are presented across sexes.

Sample EMG plots from a representative subject are presented in Figures 2 and 3 for the pectoralis major and triceps brachii, respectively. In the triceps brachii, mean ± *SE* normalized EMG activity was 101.3 ± 13.5% MVIC in the SW hand position, 98.7 ± 15.4% MVIC in the WB hand position, and 109.1 ± 14.1% MVIC in the NB position (Figure 4). The effect of hand position was significant ($F_{2,78} = 3.417$, $p = 0.038$). The EMG activity was significantly greater in the NB hand position than in the WB hand position (mean difference = 10.4% MVIC, $p$ =

0.026). Differences between the SW and WB hand positions and the SW and NB hand positions were not statistically significant ($p = 0.490$ and $p = 0.072$, respectively).

Similar results were noted in the pectoralis major muscle. Mean normalized EMG activity was 94.4 ± 8.4% MVIC in the SW hand position, 83.1 ± 6.9% MVIC in the WB hand position, and 100.8 ± 7.8% MVIC in the NB hand position (Figure 4). The effect of hand position was statistically significant ($F_{2,78} = 4.990$, $p = 0.009$). Pectoralis major EMG activity was significantly greater in the NB hand position than in the WB hand position (mean difference = 17.7% MVIC, $p = 0.005$). Differences between the SW and WB hand positions and the SW and NB hand positions were not statistically significant ($p = 0.077$ and $p = 0.195$, respectively).

## DISCUSSION

In this study, we examined the EMG activity in the pectoralis major and triceps brachii required to perform a push-up. The pectoralis major is generally acknowledged to be a horizontal adductor of the humerus, although it also assists in adducting the humerus from an abducted position and medially rotating the humerus (15). Acting alone, the clavicular head of the pectoralis major can flex the humerus and the sternocostal head can extend the humerus from a flexed position. The triceps brachii is generally acknowledged to be an extensor of the forearm across the elbow joint (15), although the long head of the triceps brachii also extends the humerus across the glenohumeral joint. Since the push-up maneuver requires a combined movement of horizontal adduction across the shoulder and extension at the elbow, its primary purpose is to develop increased strength in the pectoralis major and triceps brachii muscles. It is generally thought that the specific movement that elicits the greatest activity from a muscle during an exercise will most efficiently produce a strengthening effect. Various sources in popular fitness literature (6, 7, 11, 17, 21, 22) suggest that different hand positions during performance of the push-up can better isolate either the pectoralis major or the triceps brachii, although the claims are unsubstantiated in scientific literature. We therefore set out to examine the claims with EMG analysis.

Interpreting the results of this study requires that the reader comprehend an elementary knowledge of muscle mechanics and the relationship to EMG activity. Briefly, surface EMG monitors the motor unit recruitment of muscle. Myoelectric activity from a "window" of muscle fibers under the active electrodes is measured as the muscle fibers contract. As tension demand increases within a muscle, more motor units are recruited and therefore EMG levels increase. Since EMG provides insight into muscle activity, it can be a good tool for determining the movements or positions that place higher demand on a muscle's performance capability. The EMG activity levels, however, can be influenced by numerous factors, and therefore one's interpretation of EMG studies can be difficult. For example, for any given external loading condition on a muscle, EMG amplitudes will be greater for a concentric contraction than an eccentric contraction (2). To control for the contraction-related influence on EMG activity, we therefore analyzed only the concentric phase of the push-up in this study. Similarly, contraction velocity during concentric contractions also affects the tension that is developed within a muscle, such that less tension is developed at higher contraction velocities and greater tension is developed at lower contraction velocities. The EMG changes reflect those differences inversely. For a given external loading condition, EMG amplitude will be greater for a high-velocity contraction than a low-velocity contraction, reflecting the motor unit requirements for completing a movement at the various velocities (2). Therefore, we attempted to minimize this effect by standardizing the cadence over which the subjects in this study performed their push-up movements. Numerous other factors can influence EMG amplitude but are beyond the scope of this article.

Results of the study reveal that push-ups performed from the NB hand position elicit the greatest EMG activity in both the pectoralis major and triceps brachii muscles. The difference between the NB and WB hand positions was statistically significant in both muscles. These data suggest that push-ups performed from the NB hand position recruit more motor units and therefore require more contractile demand from the pectoralis major and triceps brachii muscles than push-ups performed from the WB hand position. Push-ups performed from the NB hand position may therefore be more efficient as a strengthening exercise for both muscle groups than are push-ups performed from the WB position.

The results, particularly for the triceps brachii, seem to be consistent with other literature. In popular fitness literature, Weede and Kraemer (22) suggest that push-ups performed from the NB position better isolate the triceps brachii. Our results support that claim. Additionally, in an empirical study of push-up mechanics, Donkers et al. (4) report that the peak external flexion torque across the elbow is greatest when push-ups are performed from the NB hand position. The flexion torques across the elbow are 71% of the maximal isometric torque in the NB hand position, 56% of the maximal torque in the SW hand position, and 29% of the maximal torque in the WB position. Most of the internal moment required during a push-up to overcome the external flexion torque is generated by the triceps brachii contraction. The EMG results from our study, indicating that triceps brachii muscle activity is highest in the NB hand position, are consistent with the results of Donkers et al. (4).

On the other hand, our results contrast with the apparent recommendation of Geiger (5) that if one wishes to better isolate the pectoralis major demand during push-ups, the WB hand position should be used. The results also contradict our hypothesis that EMG activity would have its greatest amplitude in the pectoralis major during push-ups performed from the WB hand position. Pectoralis major EMG activity was significantly greater in the NB hand position than in the WB hand position. This finding may be a function of the range of motion through which humeral adduction occurs during the push-up maneuver. Although we did not examine the range of joint motion required to perform the push-ups from the various hand positions in this study, it is apparent that the push-ups are performed in different ranges of shoulder horizontal abduction and adduction range of motion. In the WB hand position, the arms are in a relatively horizontally abducted position, even at the termination of the push-up movement. In contrast, in the NB hand position, the arms are in a neutral to slightly horizontally adducted position at the termination of the movement, meaning the pectoralis major is in a shorter position throughout the push-up. The length-tension relationship of muscle mechanics suggests that muscles generate less tension at shorter muscle lengths than at longer muscle lengths. Therefore, for a given loading condition, a muscle in a shortened position must recruit a greater number of motor units to develop the tension necessary to meet the loading condition. We believe the EMG results of our study reflect this issue of muscle mechanics. The relatively shortened muscle length of the pectoralis major in the NB hand position requires greater motor unit activation.

The primary limitation of this study is the assumption that greater EMG activation is desired to improve the efficiency of muscle strengthening during exercise. The reader must understand that EMG, however, is not a direct reflection of the force produced by a muscle. It merely provides insight into the motor unit activity necessary to perform the movement and the number of motor units represented beneath the active electrodes. Nevertheless, the results provide empirical evidence that push-ups performed from different hand positions elicit different amplitudes of EMG activation. Additionally, other than hand position and cadence, we did little to standardize the performance of the push-ups among individual subjects. For example, we did not test subjects' maximum performance capability. The load used to measure muscle activation responses in other studies, such as that of Signorile et al. (18), was normalized to a percentage of each subject's 10-repetition maximum. One advantage of using a normalized loading condition is that it allows an investigator to compare EMG activity levels among individuals from equivalent loading conditions. The fact that we neither tested subjects' maximum performance capability nor used a normalized loading condition likely had an influence on the sex comparison in the present study. Nevertheless, the primary purpose of the present study was to examine EMG activation responses within individuals. The within-subjects analysis would not have benefited from either a normalized loading condition or knowing subjects' maximum performance capability. Another potential limitation of the study is that each subject was only instructed to perform the push-up to the best of his or her ability regardless of change in posture. While most subjects were able to perform each push-up with a rigid spinal posture, some were unable to maintain the correct posture throughout the push-up. We are unsure whether a subject's change in posture during push-up performance affected muscle recruitment.

As long as push-ups continue to be advocated as a strengthening exercise for the pectoralis major and triceps brachii, we believe that several remaining questions should be addressed empirically. For example, our hypothesis that the pectoralis major would be activated at a higher amplitude in the WB hand position came from suggestions in popular literature that a wide hand position be used during the bench press to better isolate the muscle (5). It is not clear, however, whether the bench press and push-up are equivalent exercises from a biomechanical standpoint. Studies by Mayhew et al. (14) and Invergo et al. (9), in fact, show that push-up performance is only moderately predictive of performance in the bench press. In contrast, Blackard et al. (3) analyzed EMG activation in the pectoralis major and triceps brachii during equivalently loaded push-ups and bench presses and reported that EMG activity did not significantly differ between the exercises. Nevertheless, they did not examine EMG responses from different hand placements, and one would have to be careful about extrapolating the results we obtained with push-ups to the bench press exercise. An additional question is whether hand placement position may affect performance on the push-up. An interpretation of our results is that the increased EMG activation observed in push-ups performed from the NB hand position is a response to greater contractile demands on the muscle. One might extrapolate this to mean that performance, e.g., maximal number of repetitions, would be reduced in the NB hand position compared with the WB hand position. We did not examine whether performance differs, but the question merits investigation.

## Practical Applications

The primary purpose of the push-up as a strengthening exercise is to develop increased strength in the pectoralis major and triceps brachii muscle groups. Therefore, it is important to understand which hand position elicits greatest activity from these muscles during the exercise. Results of our study indicate that most EMG activity is elicited when push-ups are performed from a NB hand position. If an individual uses the push-up as a form of upper-extremity exercise to strengthen the pectoralis major and triceps brachii, we recommend using the NB hand position.

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