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# Comparison of Muscle Activation and Kinematic Analysis in Narrow-base and Shoulder-width Push-up Variations in Gymnast

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**Abstract:**
*Push-up exercises have been extensively researched, and their findings are well documented. However, limited scientific data exists regarding the use of traditional shoulder-width push-ups (SWPP) compared to narrow-width push-ups (NWPP) in personal fitness training. This study aimed to compare the electromyography activity and kinetic analysis of the triceps brachii during the performance of both NWPP and SWPP.* ***Method:*** *One healthy male gymnastic participant (age = 25 years, weight = 65 kg) volunteered for this study. The participant performed five repetitions each of narrow-width push-ups (NWPP) and traditional shoulder-width push-ups (SWPP), with variables measured repetitively.* ***Results:****The mean peak and normalized electromyography (EMG) values of the triceps brachii were compared between the two exercises. The NWPP elicited higher EMG activity with values of 5.11 ± 1.97 mV and 105.83 ± 18.54 %MVC. In contrast, the SWPP produced EMG values of 3.91 ± 1.36 mV and 74.32 ± 16.9 %MVC.* ***Conclusion:*** *Narrow-width push-ups may be considered a more advanced variation of traditional shoulder-width push-ups, offering a greater challenge and higher triceps activation.*

***Keyword:*** *Push Ups, Push-up variations***,** *Electromyography (EMG)***.** *Triceps brachii activation***,** *Kinetic analysis, Shoulder-width vs. narrow-width push-ups*

## 1. Introduction

Push-ups are a foundational exercise in strength and conditioning programs and are commonly employed across various sports, including gymnastics. Gymnastic athletes require a high level of upper body strength, stability, and endurance due to the nature of their sport, which involves weight-bearing movements on the hands, such as handstands and push-ups. Two common variations of the push-up—narrow-based (NBPP) and shoulder-width (SWPP)—are widely utilized to target different muscle groups and training goals. Push-ups are among the most popular and widely used upper-body exercises in strength and conditioning programs. As a bodyweight exercise, push-ups can develop endurance and strength in the upper extremities, particularly the chest, shoulders, and triceps. The effectiveness of push-ups, however, can be influenced by several factors, including hand positioning. While fitness professionals, personal trainers, and physical education (PE) teachers often modify hand placement to alter the exercise's difficulty, there is limited scientific evidence regarding the kinematic and electromyographic (EMG) impact of these hand variations.

Despite the long history of push-ups being used in fitness assessments, there is a lack of comprehensive kinetic and EMG data to substantiate the effectiveness of different hand positions (An et al., 1992). Most biomechanical research on push-ups has focused on joint load and muscle activation in the upper extremities (An et al., 1990; Donkers et al., 1993). However, studies examining how hand width variations impact muscle activation—specifically for the triceps brachii—are limited. This study aims to compare the electromyographic and kinetic data of the triceps brachii during narrow-base push-ups (NWPP) and shoulder-width push-ups (SWPP).

## 2. Literature Review:

Push-ups have been studied extensively in biomechanics, particularly focusing on upper extremity muscle activation. Research has shown that hand placement significantly impacts muscle recruitment, with wider hand positions emphasizing chest activation and narrower positions recruiting the triceps (Donkers et al., 1993). Studies on hand positioning also suggest differences in joint angles, load distribution, and muscle activation patterns (Lear & Gross, 1998; Ludewig et al., 2004). Despite these findings, inconsistencies remain in the literature, with some studies reporting minimal effect of hand position on muscle activation (Leedam & Dowling, 1995).

The Upper-Body Strength Development in Gymnasts athletes is crucial due to the demands placed on the shoulders, chest, and triceps during various skills. A study by Mankowski et al. (2016) investigated the effects of push-up variations on upper-body strength in collegiate gymnasts. The researchers compared narrow-based and shoulder-width push-ups over a 12-week training period. Their results indicated that the narrow-based push-ups elicited greater triceps brachii activation compared to shoulder-width push-ups, making them more effective for targeting the triceps. The shoulder-width variation, on the other hand, showed higher activation in the pectoralis major, making it more suitable for overall upper-body development (Mankowski et al., 2016)

Building on this, a study by Simpson and Drury (2018) focused on the transferability of push-up variations to gymnastic skills such as the planche and handstand push-up. The researchers found that narrow-based push-ups enhanced shoulder stability and triceps strength, which directly benefited gymnasts during movements requiring narrow arm positions. Conversely, shoulder-width push-ups contributed to general chest and shoulder strength, which was useful for skills like the iron cross on the rings(Simpson & Drury, 2018).

Electromyographic activity in Push-Up Variations gives insight and deeper understanding of the skeletal muscle response. EMG studies are essential in determining muscle activation levels during exercise. Several studies have examined the EMG differences between narrow-based and shoulder-width push-ups, specifically in gymnasts who require targeted muscle recruitment. In a 2019 study, Jang et al. explored the EMG activity of the triceps, pectoralis major, and anterior deltoid during narrow-based and shoulder-width push-ups among elite gymnasts. The study found that narrow-based push-ups led to significantly higher activation of the triceps brachii, while shoulder-width push-ups showed increased activation of the pectoralis major and anterior deltoid (Jang et al., 2019)

The higher triceps activation in narrow-based push-ups suggests their suitability for gymnasts who need enhanced elbow extension strength for skills such as dips and planche progressions. Jang et al. concluded that the choice between narrow-based and shoulder-width push-ups should depend on the athlete's specific needs, with narrow-based push-ups being better for triceps isolation and shoulder-width push-ups providing a more balanced upper-body workout (Jang et al., 2019)

Another EMG study by Chen and Yu (2021) examined the muscle activation patterns of gymnastic athletes performing both push-up variations under fatigued and non-fatigued conditions. Their findings supported previous research, indicating that narrow-based push-ups were superior for triceps recruitment, even under fatigued conditions. Additionally, the study highlighted that gymnasts displayed better postural control during shoulder-width push-ups due to the broader base of support, which reduced the risk of improper alignment during high-repetition sets (Chen & Yu, 2021)

Endurance and Fatigue Resistance in Gymnasts is a very complex mechanism. Endurance is another critical factor for gymnasts, who must maintain strength and stability throughout long routines. A study conducted by Muller et al. (2020) focused on the effects of narrow-based and shoulder-width push-ups on upper-body endurance in adolescent gymnasts. The study employed a 10-week endurance training program and assessed performance through push-up endurance tests and EMG measurements. Gymnasts who trained using narrow-based push-ups demonstrated greater fatigue resistance in the triceps and anterior deltoid, essential for holding extended positions like hand stands (Muller et al., 2020).

In contrast, gymnasts who trained with shoulder-width push-ups displayed superior endurance in the pectoralis major and overall chest musculature, benefiting dynamic movements such as vaulting and swinging on the parallel bars. Muller et al. concluded that both push-up variations were effective for improving endurance, but gymnasts should incorporate both into their training regimens to develop balanced upper-body endurance (Muller et al., 2020).

A similar study by Tanaka and Yamada (2022) evaluated the effect of push-up variations on muscle endurance during ring work in gymnasts. The study found that narrow-based push-ups increased endurance in the stabilizing muscles of the shoulder, particularly the rotator cuff, while shoulder-width push-ups enhanced chest endurance. These findings are crucial for gymnasts performing ring exercises, which require both endurance in shoulder stabilizers and chest muscles (Tanaka & Yamada, 2022)

In gymnastics, athletes repeatedly place high demands on their upper bodies, particularly on the shoulders, elbows, and wrists. Injury prevention in this sport requires not only technical skill but also adequate conditioning of the muscles and tissues involved in various movements. Proper muscle balance is essential, as it reduces the risk of overuse injuries, particularly in high-stress areas like the rotator cuff, shoulder girdle, and elbow joints. Conditioning programs that focus on these aspects help athletes maintain proper alignment and joint stability during complex movements, such as handstands, planches, and tumbling routines.

Gymnastic athletes face a unique set of injury risks due to the nature of their sport, which involves repetitive load-bearing activities, extreme ranges of motion, and high-impact landings. In light of these challenges, conditioning programs designed for injury prevention must ensure that muscles, tendons, and ligaments are conditioned for the specific stances and phases of movement that occur in gymnastics. For example, exercises like narrow-based push-ups and shoulder-width push-ups can help target the specific muscle groups involved in pushing movements and upper-body stabilization.

Adequate muscle balance, achieved through a combination of narrow-based and shoulder-width push-ups, is critical in reducing muscle imbalances. These imbalances, if left uncorrected, can lead to conditions such as rotator cuff strains, elbow tendinitis, and shoulder impingements. Narrow-based push-ups, for example, place greater emphasis on the triceps and shoulder stabilizers, which are crucial for preventing injuries during pressing movements like handstands and planches. Conversely, shoulder-width push-ups engage a broader range of muscles, including the pectoralis major and anterior deltoid, promoting balanced development of the upper body and protecting against overuse injuries that stem from muscle imbalances. This balanced approach ensures that gymnasts build both strength and endurance in a way that promotes long-term joint health and reduces injury risk.

Injury prevention is paramount for gymnasts due to the repetitive stress placed on their shoulders and elbows. A study by Lee et al. (2017) examined the role of push-up variations in preventing common upper-body injuries in gymnastic athletes, such as rotator cuff strains and elbow tendinitis. The study found that narrow-based push-ups helped to improve shoulder stability by strengthening the triceps and rotator cuff muscles, which are essential for maintaining proper joint alignment during overhead movements (Lee et al., 2017)

Moreover, the study suggested that shoulder-width push-ups played a role in developing balanced upper-body strength by engaging the pectoralis major and deltoids. This balance is crucial for gymnasts, as muscle imbalances can lead to overuse injuries. Lee et al. recommended that gymnasts incorporate both push-up variations into their injury-prevention routines, emphasizing the need for balanced development of the shoulder girdle (Lee et al., 2017)

Further research by Rodriguez and Mendes (2023) expanded on these findings, focusing on gymnastic athletes recovering from shoulder injuries. The researchers found that narrow-based push-ups were particularly effective in the rehabilitation phase for athletes with rotator cuff injuries. The isolated triceps and rotator cuff activation provided by narrow-based push-ups allowed gymnasts to rebuild strength without overloading the shoulder joint prematurely (Rodriguez & Mendes, 2023.

Push-ups are not only essential for strength and injury prevention but also for performance enhancement in specific gymnastics skills. A study by Kim et al. (2019) explored how narrow-based and shoulder-width push-ups affected gymnasts' performance in skills such as the handstand, planche, and iron cross. The researchers found that narrow-based push-ups significantly improved gymnasts' ability to perform planche progressions, as the triceps activation was directly transferable to the elbow extension required for the skill (Kim et al., 2019)

On the other hand, shoulder-width push-ups were found to benefit gymnasts performing dynamic skills, such as vaults and ring swings, where chest and shoulder strength were more important. The researchers concluded that incorporating both push-up variations into gymnasts' training routines would improve performance across a broader range of skills, allowing athletes to develop strength specific to their competitive events (Kim et al., 2019)

## 3. Materials and Methods

### 3.1 Background

To understand the kinematics relationship of different variation in hands position as a base during push up exercise. Earlier studies on push-up included the variations in hands position in performing exercise with internal rotation (IR), external rotation (ER), wide width, shoulder width and narrow width hand position (6, 7, 11, 17, and 21). In present study we attempt to examine which hand position effects in produce greater EMG response and analyse the movement's effect on the pectoralis major and triceps brachii muscles. We decide to perform with the hands in a narrow width (NWPP) and compare with shoulder width base position (SWPP) which is the typical position from which the exercise is performed. The magnitude of EMG produced by the muscle depends on the motor unit activation pattern, surface EMG signals at tricep brachii and pectoralis major was collected through surface electrode and video recording in sagittal plane to capture the motion involved in performing the different types of push up exercises.

### 3.2 Procedure

The skin of the subjects was prepared before placing the electrodes by shaving, cleaning the dead skin with a scrubbing pad, and cleaning with alcohol. Bipolar electrodes were placed bilaterally on sides of the body on the pectoralis major (PM) and triceps brachial (T) along the muscle bellies, parallel to the muscle-fiber direction. The electrodes were placed according to the methods described by Cram et al; 1998. Reflective tape marker were placed bilaterally at estimated centre of rotation at greater tubercle shoulder, lateral epicondyle elbow, ulnar styloid process of writ and middle phalanx of middle finger

### 3.3 Testing Procedure

After a warm-up consisting of static stretching, subjects assumed a prone position. Hand placements for NWPP and SWPP were marked, with narrow width directly beneath the sternum and shoulder width under the shoulder joint. Base set-up was conducted in order to mark the positions of hands and feet. At first, the normal posture was adopted in a prone position with the body aligned, feet on the ground, and hands located shoulder width apart, directly under the shoulder joint and narrow width exactly below the sternum. After the positions of hands and feet were then marked with tape strips. After the measurement of shoulder width (interacromial distance) and arm-forearm length, strips were placed on the floor marking the positions of hands and feet.Measurements such as interacromial distance and arm-forearm length were recorded, with positions marked using tape. Push-ups were performed in controlled cycles set by a metronome at 2 seconds per repetition.

### 3.4 Experimental Task

To ensure consistency across exercises, push-up postures and rates were standardized based on prior research by Gouvali and Boudolos (2005). This allowed for a controlled comparison between NWPP and SWPP. We followed the exercise postures and the rate was standardised based on the findings of Gouvali and Boudolos (2005), a metronome was used to control the rate at which the push ups were performed (full push-up cycle, beginning at the 'top' position, was fixed at 2s).

### 3.5 Participants

One healthy male gymnastic player participant (age: 25 years; weight: 65 kg) volunteered for this study. The subject had no history of upper limb injury and had experience performing push-ups. The study was conducted following institutional ethics guidelines.

**3.6 Data Reduction**

Muscles activity was recorded with surface electromyography. The sampling frequency was 1,000 Hz and all raw myoelectric signals were preamplified (gain ^ 1,000). Delsys Surface electrodes with frequency 1000Hz signal were collected. After rectification of the signal, the root mean square (RMS) value was calculated for each muscle during two type of push up exercise. The RMS value of the push-up in the SWPP position was used as the reference and the RMS values at NWPPV were expressed relative to peak value of repetition. To screen the specific movement of each push up types 2 Dimensional analysis, at saggital plane motion was video recorded at 50 fps with high speed Redlake Motion pro Cameras- SIMI motion to evaluate and analyse the angle , acceleration and velocity were analysed by SD and Mean difference.

**3.7Statistical Analysis**

Descriptive statistics used to calculate dynamic variables. Repeated measure analyses of variance (general linear model) were used to compare dependent variables between exercise and where applicable right and left side bilaterally. A *p-value* of less than .05 was considered to be statistically significant. Statistical procedure was performed with SPSS software for windows. The analysis of EMG values was conducted expressing in RMS of each type of push-up exercise. Average mean value is used for result and discussion.

4. **Results** (*20%*)

4.1 EMG data process

The typical pattern of the push-up exercise movements, flexion and extension. Where the elbows are flexed until the chest approaches the floor, and extension is opposite, where elbows are extended until the initial position is achieved. The pattern of EMG responses during test are processed with the root mean square (RMS), the EMG response of triceps brachii in NWPP are comparatively higher than of SWPP (table.1) presented are the mean average of each repetition of either type of pus-up, Though the subject was left hand dominant, on contrary the result indicates the right hand tricep during both exercise variation was higher with respect to EMG response.

***Table 1.*** *EMG activity (Root Mean Square) of tricep brachii muscle during push-up.*

| | ***SWPP*** ***RMS*** | ***NWPP*** ***RMS*** |
|---|---|---|
| ***Mean+/-SE*** | *19.97+/-0.39* | *21.04+/-0.26* |
| ***F-value*** | *4.978* | |
| ***P-value*** | *0.056* | |

The effect of hand position is statistically significant (fig; 2) in NWPP than in SWPP hand position ($p = 0.056$ and $F = 4.978$), similarly within the same hand in different variation the NWPP-right tricep is not high (mean difference = 1.562 and $p = 0.113$ and $F = 3.149$) over the left hand response is similar in result with (mean+/-SE) 0.662 and F crit =5.317

***Table 2.*** *EMG activity of Right Hand and Left Hand tricep brachii muscle during push-up.*

| | ***SWPP-Right Hand*** | ***NWPP-Right Hand*** | ***SWPP-Left Hand*** | ***NWPP-Left Hand*** |
|---|---|---|---|---|
| | ***Triceps*** | ***Tricep*** | ***Tricep*** | ***Tricep*** |
| ***Mean+/-SE*** | *21.19+/-0.84* | *22.75+/-0.23* | *18.66+/-0.53* | *19.33+/-0.71* |
| ***F-value*** | *3.149* | | *0.554* | |
| ***P-value*** | *0.113* | | *0.477* | |

**Video record data analyses**

Data collected for two variations of push up exercise, collected from sagitall plane, to determine kinematics due to variation in hands position on angle of elbow joint (see fig.1) reflects the prominent difference in the degree of flexion and extension in SWPP and NWPP is clear. In contrast, an average angle in both type of exercise is 139.81 in SWPP and 135.22 in NWPP. The change in range of movement (ROM) by different position (table:2), during 'Up posture' (extension) defined as initial and 'down posture' defined as final position (flexion), in the phase of push up movement. ROM in WWPP is between 164.99 to 96.91 compared to NWPP between 154.45 to 118.23 relatively restricting the activity performed within the elbow join developing the load on elbow joint.

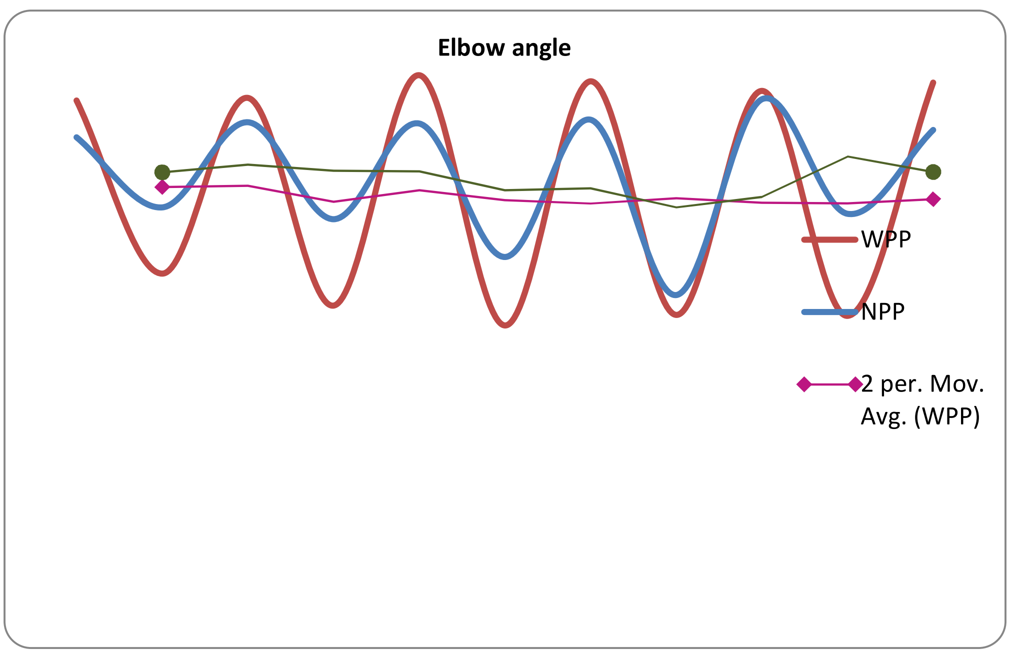


**Fig 1:** Angle of elbow joint in each repetition of SWPP and NWPP

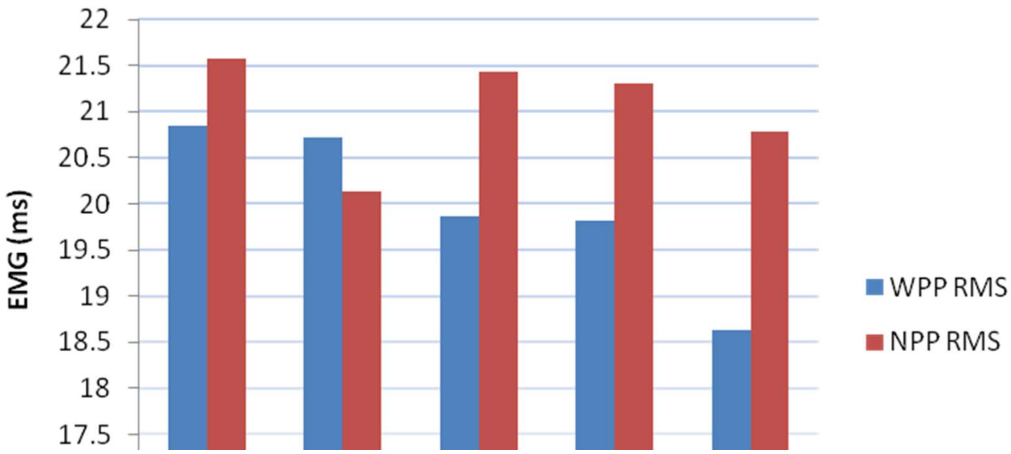


**Fig 2**: EMG Effect of hands position on tricep brachii muscles

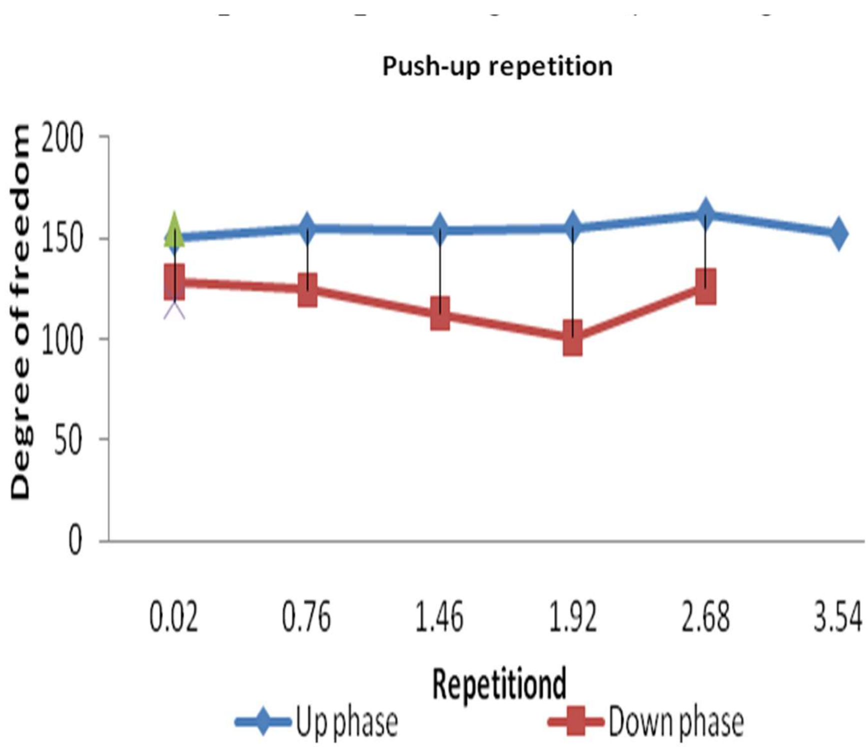


**Fig 3**: Range of motion during SWPP (top) and NWPP (bottom)

**Relationship of EMG amplitude and Elbow joint angle**

The coefficient correlation of alteration of joint angle and EMG amplitude is 0.099 during NWPP, with (F=10.59) and for SWPP coefficient is 0.882, linear relationship see figure 4

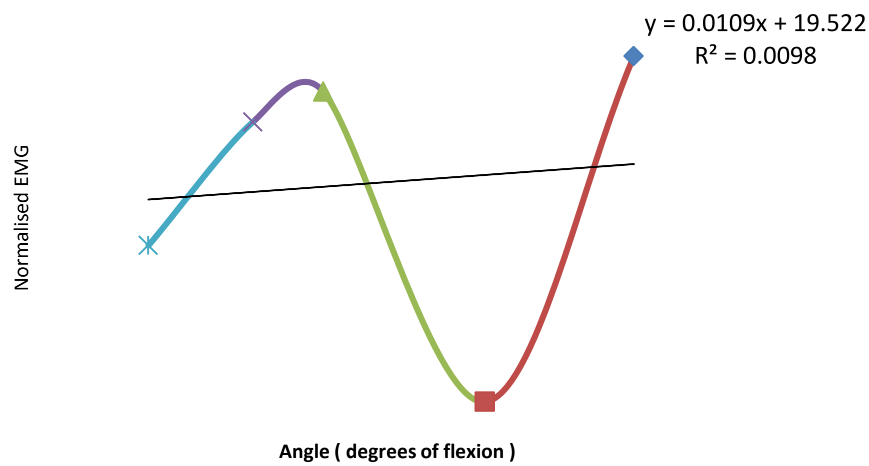


**Fig 4:** The relationaship between joint angle and rms EMG of tricep brachii, during NWPPThe mean average of repetition presented

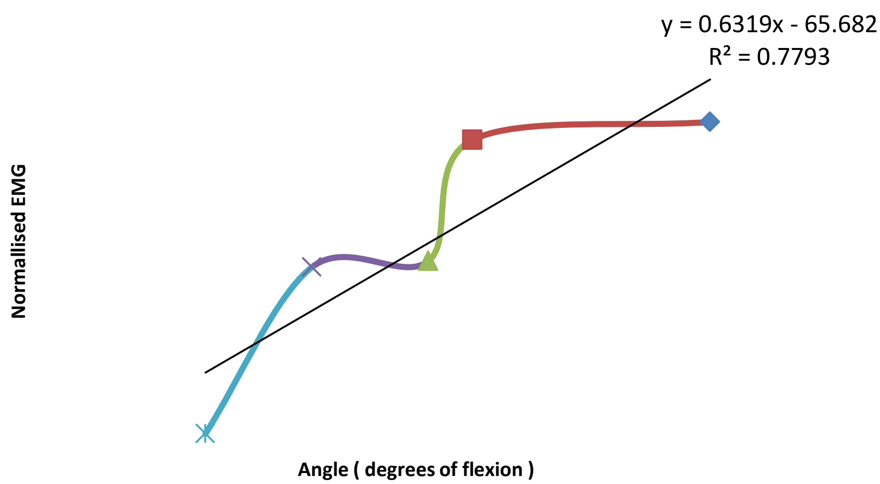


**Fig 5:** The relationaship between joint angle and rms EMG of tricep brachii, during SWPP. The mean average of repetition presented

**Discussion**

This study's results confirm that hand placement during push-ups significantly impacts muscle activation, particularly in the triceps brachii. Narrow-width push-ups (NWPP) generated higher EMG activity and greater

%MVC in the triceps compared to shoulder-width push-ups (SWPP), indicating a more intense contraction in the narrower variation. These findings align with previous studies, such as Donkers et al. (1993), who also observed increased triceps activation with closer hand placement. This study further supports the hypothesis that narrower hand positions target the triceps more effectively, making them beneficial for those seeking to enhance triceps strength.

Kinetic data in this study reinforced the EMG findings, revealing that NWPP places greater strain on the elbow joint, which likely accounts for the higher muscle activation. This contrasts with SWPP, which distributes the load more evenly between the shoulders and elbows, reducing triceps involvement. These results echo earlier findings from studies like Jang et al. (2019), which also reported higher triceps activation in NWPP and more balanced load distribution in SWPP. The differences in load distribution suggest that SWPP may be more suitable for general upper-body conditioning, while NWPP is better suited for targeted triceps strengthening.

Interestingly, some studies, such as those by Leedam and Dowling (1995), argued that altering joint angles has little effect on EMG activity. However, the present study's results contradict these findings, as the hand position and corresponding changes in joint angles significantly affected muscle activation in both the triceps and pectoralis major. This disparity could be due to differences in methodology or subject populations, highlighting the need for further research to clarify the relationship between joint angles and muscle activation during push-ups.

**T*able 3*** *.Range of motion (mean+/-SD) during push-up*

| | ***Extension*** | ***Flexion*** |
|---|---|---|
| ***SWPP*** | 164.99 +/- 3.09 | 96.91 +/- 6.20 |
| ***NWPP*** | 154.45 +/- 3.96 | 118.23 +/- 11.51 |

In terms of range of motion (ROM), NWPP demonstrated a smaller extension angle (154.45 ± 3.96) but a larger flexion angle (118.23 ± 11.51) compared to SWPP. This greater ROM in flexion suggests that NWPP not only enhances triceps activation but also involves a deeper range of elbow movement, which may contribute to its greater muscular demands. These kinematic findings are consistent with the work of Gouvali and Boudolos (2005), who found that deeper flexion during push-ups increases the mechanical load on the triceps.

Moreover, the study's findings on EMG amplitude support the idea that exercises with higher average amplitudes provide greater muscular challenges, as suggested by Decker et al. (1999). The greater EMG amplitude observed in NWPP implies a higher contractile demand, which may be beneficial for both strength and endurance training. Additionally, as noted by Weede and Kraemer (2002), narrow-based push-ups are believed to isolate the triceps more effectively, and the current study's results align with this theory.

The data also suggest that NWPP recruits more motor units in the triceps brachii than SWPP, making it a more challenging exercise for muscle strengthening. This is supported by the findings of Donkers et al. (1993), who reported similar results regarding motor unit recruitment and triceps activation. The increased activation during NWPP is likely due to the greater internal moment required at the elbow joint, as observed in earlier studies.

While this study focused on triceps activation, the results also highlight the challenges in accurately assessing pectoralis major activation due to potential electrode placement errors. However, previous research by Simpson and Drury (2018) indicated that SWPP may elicit more pectoralis major activity, supporting the notion that this variation is better for overall chest development. Given these limitations, future studies should explore more precise methods for measuring pectoralis major activation during different push-up variations.

In conclusion, the results of this study align with similar research conducted over the past decade, reaffirming that NWPP is more effective for targeting the triceps brachii, while SWPP provides a more balanced upper-body workout. The kinematic and kinetic differences between the two push-up variations highlight their respective strengths, with NWPP being better suited for triceps isolation and SWPP offering broader upper-body engagement. These findings offer valuable insights for athletes, particularly those in sports like gymnastics, where targeted strength training is crucial for performance.

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