

Comparative Analysis of Ground-Based and Elevated Pushup Exercises for Pectoralis Major Muscle Activation

Análisis comparativo de ejercicios de flexiones elevadas y en el suelo para la activación del músculo pectoral mayor

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Abstract. This study aimed to measure muscle activation by comparing electromyography (EMG) of two types of pushups i.e., ground-based and elevated. 20 male active sportspersons (age 20.12 ± 3.57 years, weight 65.38 ± 9.32 kg, height 175.5 ± 10.5 cm) were recruited in the study. The upper body muscle pectoralis major (PM) was chosen as target muscle for the study. Root mean square (RMS) of EMG activities were analysed for the PM muscle to determine maximum muscle involvement. In the elevated pushups, the samples performed the pushups on an elevated pushup bar of 18-centimeter height, in which they gripped the bar as per their shoulder width. Also, their feet were ground-based on a similar height platform. The paired t-test was used as the statistical tool to compare the EMG activation of PM between both variations of pushups. Further, mean and standard deviation values were considered for descriptive statistics. The level of significance was set at 0.05. The result of the study showed that there was no statistically significant difference in EMG activities of PM muscle between the two pushup variations with a *t*-value of -0.89. However, the descriptive statistics showed that the mean value of elevated pushups (RMS, 350.63) was higher than the grounded pushups (RMS, 311.44). These findings suggest elevated pushups may induce greater PM muscle activation, potentially due to increased instability due to the influence of elevated exercise variations on muscle engagement.

Key words: pushups, muscle activation, electromyography, pectoralis major, exercise variations, root mean square

Resumen. Este estudio tuvo como objetivo medir la activación muscular comparando la electromiografía (EMG) de dos tipos de flexiones, es decir, en el suelo y elevadas. En el estudio se reclutaron 20 deportistas activos masculinos (edad $20,12 \pm 3,57$ años, peso $65,38 \pm 9,32$ kg, altura $175,5 \pm 10,5$ cm). El músculo pectoral mayor (PM) de la parte superior del cuerpo fue elegido como músculo objetivo para el estudio. Se analizó la raíz cuadrática media (RMS) de las actividades EMG para el músculo PM para determinar la participación muscular máxima. En las flexiones elevadas, los samplees realizaron las flexiones en una barra elevada de 18 centímetros de altura, en la que agarraron la barra según el ancho de sus hombros. Además, sus pies estaban apoyados en el suelo sobre una plataforma de altura similar. La prueba *t* pareada se utilizó como herramienta estadística para comparar la activación EMG del PM entre ambas variaciones de flexiones. Además, se consideraron los valores de media y desviación estándar para la estadística descriptiva. El nivel de significancia se fijó en 0,05. El resultado del estudio mostró que no hubo diferencias estadísticamente significativas en las actividades EMG del músculo PM entre las dos variaciones de flexiones con un valor *t* de -0,89. Sin embargo, la estadística descriptiva mostró que el valor medio de las flexiones elevadas (RMS, 350,63) fue mayor que el de las flexiones en el suelo (RMS, 311,44). Estos hallazgos sugieren que las flexiones elevadas pueden inducir una mayor activación de los músculos PM, potencialmente debido a una mayor inestabilidad debido a la influencia de variaciones elevadas del ejercicio en el compromiso muscular.

Palabras clave: flexiones, activación muscular, electromiografía, pectoral mayor, variaciones de ejercicio, raíz cuadrática media

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Introduction

Pushups are a widely used exercise for strengthening the upper body, often employed to assess muscle functionality and promote arm, shoulder, and chest strength. This exercise involves coordinated horizontal shoulder adduction and elbow extension movements, primarily targeting the pectoralis major (PM) and triceps brachii muscles. This exercise is frequently included in fitness assessments to evaluate an individual's level of physical fitness (Blackard et al., 1999; Knapik et al., 2001). It is popular due to its simplicity, equipment-free nature, and adaptability to various fitness levels. Additionally, it can be performed in different variations, making it versatile for target improvement of different upper body muscle groups. However, despite recommendations for hand and foot movement variations, lim-

ited scientific evidence is available to characterise the difference in muscle coordination and dynamics associated with these exercise variants (Gouvali & Boudolos, 2005). Studies by An et al. (1992) and Donkers et al. (1993) investigated the impact of hand positions on elbow-joint load during pushup exercises. Their findings revealed significant differences in static and maximum joint force based on hand placement. Chou et al. (2002) and Lou et al. (2001) further examined joint loads during pushups with two hands or one hand, respectively, highlighting extensive force magnitude and direction variations. These studies emphasise the importance of careful instruction during pushup exercises, particularly for injured or recreational athletes, and their connection to falling patterns on one or two hands. However, the lack of scientific evidence limits practical applications, such as developing training programs, despite earlier research (An et al., 1992; Donkers et al., 1993) examining

the effects of hand positions on elbow-joint loading.

According to Cogley et al. (2005), pushups are commonly performed exercises to strengthen the PM muscle. Thus, in this study, the electromyography (EMG) analysis of the PM muscle was conducted by having the samples perform pushups at different variations, i.e.; ground-based and elevated. This study aimed to record the EMG activity of the PM muscle during pushup exercises and explore how it varies across different pushups variations. It was hypothesised that elevated pushups position will affect the EMG activity of the PM muscle.

Materials and methods

Study participants

A total of twenty (n=20) male active sportspersons (age 20.12 ± 3.57 years, weight 65.38 ± 9.32 kg, height 175.5 ± 10.5 cm). were recruited for the study. They were included in the study if found actively involved in systematic training for any of the following sports, i.e.; track and field, volleyball, basketball, football, and hockey for last five (5) years or more. It was also made sure that none of the sample was suffering from any injury during the time of data collection. All samples were well aware of pushups exercise and they had given verbal confirmation of it. The study was approved in advance by Institute Ethical Committee of Lakshmbai National Institute of Physical Education, Gwalior (IEC/LNIPE/128/22). Furthermore, all the samples voluntarily provided written informed consent before participating in the study.

Instrumentation

Muscle activation data was recorded using a wireless BTS FREE EMG Analyzer (version 2.9.40.0). The utilisation of the root mean square (RMS) value as the measurement for assessing PM muscle activation during pushups performance in different variations. Numerous researchers have employed the RMS as a measurement to evaluate EMG activities in their respective studies (Babault et al., 2022; De Luca & Merletti, 1988; Dias et al., 2020; Guo et al., 2021; Gupta et al., 2017; Kumar et al., 2022; Papagiannis et al., 2019), further emphasising its significance and applicability in this context. The RMS EMG signals were subjected to band-pass filtering using the Butterworth smoothing technique, with a lower cut-off frequency of 20 Hz and an upper cut-off frequency of 400 Hz, as suggested by Halaki & Gi (2012).

Procedure

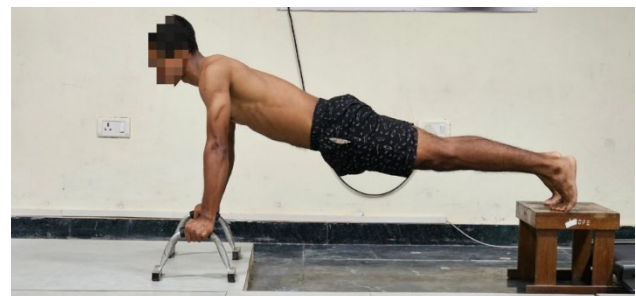
The data was collected in indoor condition and the recorded temperature was 27-28 degree celsius at the time of data collection. The wireless surface EMG probe was placed on right side of the sample's PM muscle. We identified the 2nd and 5th intercostal spaces, midclavicular line following Glass & Armstrong (1997) to place the EMG probe over the PM muscle. A 10-second surface EMG protocol was set to record the activities of PM muscle. All pushups variations

were performed thrice and the best reading out of the three was selected for final analysis. The samples were provided time for self warm-up and there were one hour rest between performance of the other variation of pushups to ensure no carryover effect.



Figure 1 Ground-Based Pushups

Ground-based pushups: The samples assumed a prone position on ground (figure 1), with their legs fully extended and toes of the feet firmly secured on the ground. The samples executed ground pushups with the shoulders abducted at a 90-degree angle and the elbows flexed at 90 degrees. The instructions were followed in consideration of the guidelines provided by Maeo et al. (2014).



(a) Elevated push-ups; up position



(b) Elevated push-ups; down position

Figure 2 Elevated Pushups

Elevated pushups: The samples performed the pushups on a set of elevated pushup bars of 18-centimeter height, in which they gripped the bars as per their shoulder width (figure 2). Also, their feet were grounded on a similar height platform. The directions were followed while taking into account the recommendations made by Maeo et al. (2014)). In figure 2b, it is evident that the sample's upper torso surpasses the point where the hands make contact while descending in pushups. This would not have been possible if

the pushups were performed on the ground instead of using pushup bars.

Statistical analysis

The paired *t*-test was used as the statistical tool for the study. Mean and standard deviation values were considered for descriptive statistics. All the statistical calculations were conducted using IBM SPSS 25 software (Armonk, 2017). The data were entered manually, and all the necessary procedures were followed, taking Logan (2013) into consideration. For all the statistical calculations, the level of significance was set at $p \leq 0.05$.

Results

Since the paired *t*-test was employed because one group performed pushups of two different types, it was important to demonstrate the normality of the data distribution before using statistics (Hahs-Vaughn & Lomax, 2020). Hence, q-q plots were constructed to demonstrate the normal distribution of the EMG activities of both data sets, i.e., ground-based pushups and elevated pushups (figure 3 and figure 4).

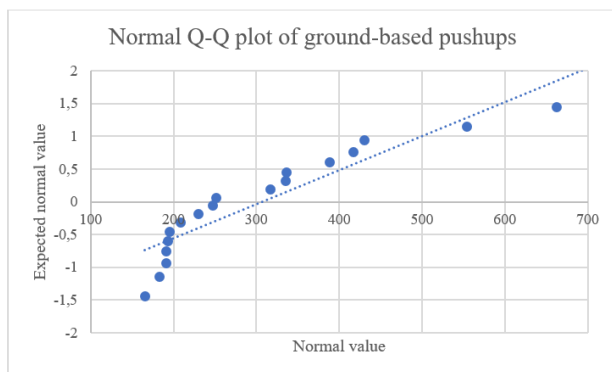


Figure 3. Normal Q-Q plot demonstrating the normalcy of ground-based pushups RMS recordings

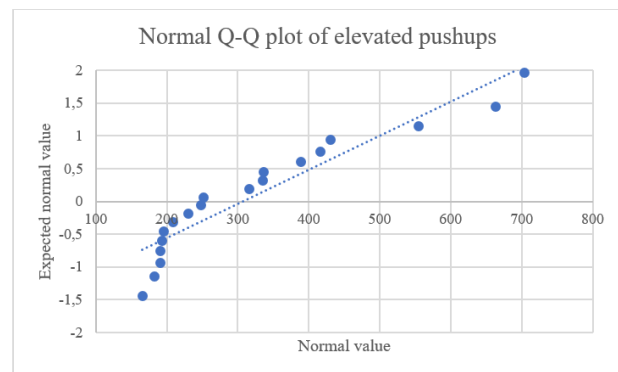


Figure 4. Normal Q-Q plot demonstrating the normalcy of elevated pushups RMS recordings

Regarding the data's normality, the assumptions in the aforementioned figures (figure 3 and figure 4) seem to be reasonably secure. The blue dotted line indicates that the points appear to fall around a straight line. After establishing the data's normality, a paired *t*-test was carried out to compare how the PM muscle responded, in terms of muscle activation, to ground-based and elevated pushups, respectively.

Table 1
Descriptive Statistics of RMS of EMG of PM Muscle while Performing Ground-based and Elevated Pushups

		Mean	N	SD	SEM
Pair 1	Grounded Push Ups	311.44	20	172.16	38.49
	Elevated Push Ups	350.63	20	192.59	43.06

Note. N: Number of samples; SD: Standard Deviation; SEM: Standard Error of Means.

Table 1 presents the descriptive statistics for electromyographical recordings of the PM muscle during ground-based and elevated pushups. The mean RMS for ground-based pushups was 311.44, while the mean RMS for elevated pushups was 350.63. It is evident that the electromyographical recordings of samples' PM during elevated pushups exceeded those during ground-based pushups. However, it was crucial to compare the obtained 't' value with the tabulated 't' value to reach a conclusion.

Table 2.
Results of Paired T-Test

		Mean	SD	SEM	t	DF	Sig. (2-tailed)
Pair 1	Ground based push ups – Elevated push ups	-39.18	197.00	44.05	-0.89	19	0.38

Note. SD: Standard Deviation; SEM: Standard Error of Means; DF: Degree of Freedom.

The output (table 2) reveals that the *t*-test is not significant at 0.05 level of significance; therefore, the null hypothesis was failed to be rejected, and it may be concluded that there is no statistically significant difference in the EMG activities of PM muscle between the two pushup variations.

Discussion

The lack of statistically significant difference in the EMG activities of the PM muscle between elevated and ground-based push-up variations can be attributed to several factors. A study by Malik and Ramakrishnan (2021) found that muscle activation was generally higher in push-ups performed on a fitness structure compared to the ground, but

this was not specific to the pectoralis major alone. Similarly, AdavamPurath et al. (2020) observed that while different hand positions (wide, narrow, and shoulder-width) influenced muscle activation, the type of push-up bar used did not significantly alter the EMG activity of the PM. Mok et al. (2017) also reported no significant differences in pectoralis major activation across various hand positions during push-ups, suggesting that hand placement might be a more critical factor than the elevation of the push-up surface. Additionally, Lanza (2018) found that while the pushup device increased pectoralis major activation compared to conventional push-ups, the difference was not statistically significant, indicating that variations in push-up form might not drastically change muscle activation levels. Furthermore,

Park et al. (2014) highlighted that traditional push-up plus exercises showed higher EMG activity in the serratus anterior but did not significantly affect the pectoralis major compared to modified versions. These findings collectively suggest that the pectoralis major muscle's activation is relatively stable across different push-up variations, whether elevated or ground-based, due to the muscle's consistent role in the push-up movement, regardless of the specific conditions or equipment used.

However, one key outcome extracted from this investigation highlights the notable increase in EMG activity within the PM muscle during elevated pushup variation as compared to its ground-based counterpart even though it's not statistically significant. This study corresponds with previous research conducted by Maeo et al. (2014). Their study supported the concept that performing sling-based pushup exercises induces higher activation in the upper limb muscles when compared with traditional ground-based pushups. These findings are also supported by the works of Beach et al. (2008) and Freeman et al. (2006). Ground-based pushup exercise, characterised by rapid and explosive movements, have long been associated with improving one's proprioceptive awareness and kinesthetic sense, factors of vital importance in terms of stability and coordination (Reaper et al., 1996). This observation is applicable to athletes and individuals in post-injury recovery. Study by Reaper et al. (1996), although not exploring into precise muscle activity measurement, highlights the aptitude of experienced individuals in effectively coordinating their musculature during bodyweight exercises, pointing out the role of practice and experience.

The higher EMG activity observed in the PM muscle during elevated pushups may also be attributable to other factors. A prior investigation has indicated that exercises executed on unstable surfaces necessitate higher engagement of the trunk musculature compared to exercises performed on stable surfaces (Granata & Marras, 2000). This higher engagement is attributed to the amplified postural control demands and the inherent instability, posing an elevated risk of balance loss, characterising exercises on unstable surfaces. In a similar perspective, Vera-Garcia et al. (2000) noted increased muscle activation in the torso musculature when executing curl-up exercises on unstable surfaces as opposed to stable ones. In these variations involving unstable surfaces, samples had to use torso linkage to control hand pressures, potentially offering notable training benefits to specific individuals. These findings collectively emphasise the complex nature of EMG activity during distinct pushup exercises and the influence of exercise surface stability on muscle engagement.

Conclusion

This research investigated the electromyographical activity of pectoralis major muscle over different pushup variations, offering valuable insights into how stability impact

muscle activation. The findings contribute to our understanding of pushup biomechanics. Moreover, the study suggests potential progression paths from foundational pushup workouts to more challenging variants, such as those involving unstable surfaces and dynamic configurations. Moving forward, it is recommended to expand research efforts to encompass a broader demographic spectrum and explore variations in environmental conditions to gain a comprehensive understanding of exercise physiology and performance.

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Conflict of interest

The author declares that there is no conflict of interest.

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