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ORIGINAL RESEARCH

Forearm Posture Affects the Corticospinal Excitability of Intrinsic and Extrinsic Hand Muscles in Dominant and Nondominant Sides

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Different forearm postures can modulate corticospinal excitability. However, there is no consensus on whether handedness plays a role in such a mechanism. This study investigated the effects of 3 forearm postures (pronation, neutral, and supination) on the corticospinal excitability of muscles from the dominant and nondominant upper limbs. Surface electromyography was recorded from the *abductor digiti minimi*, *flexor pollicis brevis*, and *flexor carpi radialis* from both sides of 12 right-handed volunteers. Transcranial magnetic stimulation pulses were applied to each muscle's hotspot in both cerebral hemispheres. Motor-evoked potential peak-to-peak amplitude and latency and resting motor threshold were measured. The data were evaluated by analysis of variance. The level of significance was set at 5%. The resting motor threshold was similar for the 3 muscles and both sides. Motor-evoked potential peak-to-peak amplitude from *flexor pollicis brevis* was lower during supination, and the dominant upper limb latency was longer. The *flexor carpi radialis* presented lower motor-evoked potential peak-to-peak amplitudes for neutral and shorter latencies during supination. *Abductor digiti minimi* seemed not to be affected by posture or side. Different muscles from dominant and nondominant sides may undergo corticospinal modulation, even distally localized from a particular joint and under rest.

***Keywords*:** handedness, transcranial magnetic stimulation, motor-evoked potential

Postural adjustments are associated with an adequate orientation strategy for body segments while performing a given motor task.[1] For example, one may show a greater handgrip strength when the forearm is supinated than in pronation or neutral.[2] Such differences in motor performance depend on a complex integration of the sensorimotor system that considers proprioceptive and biomechanical features related to the task.[3] Better comprehension of the underlying mechanisms of functional performance in daily activities from different upper limb postures might improve sports performance and rehabilitation outcomes.[4–7]

Transcranial magnetic stimulation (TMS) has been extensively used to assess the neural substrates of motor control and, therefore, understand further how the central nervous system (CNS) can manage the mechanisms of muscle force gradation under different forearm postures.[4,6,8] Previous studies reported different motor-evoked potential (MEP) responses from proximal and distal upper limb muscles while the forearm assumed pronated or supinated positions.[4,8] These findings suggest that the excitability pattern, that is, attributed to latency and amplitude of MEP, of the corticospinal pathway to the muscles comprising a potential synergistic network may also dictate the biomechanical efficiency in the execution of a specific motor task. It is imperative to emphasize that although muscle length can influence corticospinal excitability[9] and, therefore, its capacity to generate torque, some proximal and intrinsic hand muscles, such as *triceps brachii*, *abductor digiti minimi* (ADM), and *abductor pollicis brevis*, which do not vary their lengths at these specific forearm postures, seem to be driven differently by the CNS, which, in turn, would affect their capacity to contribute to a motor task. Thus, the descending neural drives at each specific posture might lead to distinct motor unit recruitment patterns even from muscles not strictly related to a moving joint.[10,11]

In addition, previous studies suggested that the right cerebral hemisphere in right-handed individuals is particularly efficient in controlling the upper limb in space and may represent a proprioceptive advantage compared with the left (dominant) hemisphere.[12,13] For instance, it is possible to observe how dominant and nondominant hands contribute differently to a bimanual task, such as holding a soda can (nondominant hand, stabilizing function) and opening it (dominant hand, greater fine control and trajectory). Consequently, we may conjecture that handedness could contribute further to limb posture on corticospinal excitability. It would corroborate some neurobiomechanical mechanisms that differentiate motor performance between the dominant and nondominant sides. Even so, there is still no evidence of whether lateral preference or handedness contributes to the modulation of the motor responses of proximal and distal muscles in controlling upper limb joints and different postures, which is likely to be determinant in clinical and sports performance.

Thus, the present study aimed to investigate the effects of handedness and 3 forearm postures (pronation, neutral, and supination) on the corticospinal excitability of 2 intrinsic hand muscles and 1 forearm muscle in dominant and nondominant upper limbs. We hypothesized that the forearm posture affects the corticospinal excitability pattern of the muscles under investigation. This effect

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could be supported by comparatively lower MEPs obtained from the dominant side at the same TMS intensity, suggesting a potential enhancement in CNS efficiency on recruiting muscles of the dominant side as opposed to the nondominant side,[12,13] which has not yet been investigated. Consequently, there would be evidence of a proprioceptive afferent effect on the efferent motor pathways depending on forearm posture and manual dominance, leading to differences in motor performance.

Methods

Twelve healthy male volunteers (age: 25.7 [3.3] y; height: 1.78 [0.10] m; body mass: 86.0 [13.4] kg) participated in this study. Participants were all right handed and free of neurological and motor disorders. Handedness was assessed with the modified version of the Edinburgh Handedness Inventory (https://www.brainmapping.org/shared/Edinburgh.php), and only participants with a laterality index greater than +50 were considered as right handed (handedness-modified Oldfield score: +70.6 [11.8]).[14] The sample characteristics are shown in Table 1. The local ethical committee approved the experimental protocol (CAAE: 56028316.9.0000.5257), and informed consent was obtained from all participants before the session.

Surface electromyography signals of the *abductor digit minimi* (ADM), *flexor pollicis brevis* (FPB), and *flexor carpi radialis* (FCR) muscles were recorded from dominant and nondominant sides (right and left, respectively). These muscles were chosen because they play active and distinguishable roles in the handgrip and wrist stabilization tasks, with high coactivation and overlapping cortical motor representations.[15] Furthermore, given that the median nerve innervates the FCR and FPB muscles, and the ADM and FCR exhibit a significant degree of cortical motor representation overlap, our findings may help elucidate whether the potential impact of posture and laterality on the corticospinal excitability of the muscles under investigation primarily derives from an anatomical perspective related explicitly to innervation and/or the extent of cortical overlap.

Surface electrodes (silver/silver chloride [Ag–AgCl]; 1-cm diameter; 2223 BRQ-3M) were placed in a pseudomonopolar montage with one electrode over the muscle's innervation zone, using an atlas with anatomical landmarks,[16] and the other over the nearest bony prominences (radial and ulnar styloid processes).[17,18] The surface electromyography signals were amplified with the device EMG System do Brasil (São José dos Campos–Brazil; model: EMG 410C; 4 channels; gain: 2000; sampling frequency: 3.5 kHz per channel; band-pass Butterworth filter (fourth order): 20–500 Hz; A/D converter: 12 bits; CMMR: ≥100 dB). The reference electrode was placed over the cervical prominence C7. The skin was shaved and cleaned with alcohol and neutral soap before placing the electrodes.

During the experimental session, the participants were instructed to stay seated with arms and hands resting on a pillow over their lap. In addition, shoulder and elbow joints were kept abducted (~30^{o}) and flexed (~90^{o}), respectively. Three forearm postures were assessed: supination, neutral, and pronation. The pronated and supinated postures were characterized by the palm's gentle support and the hand's back on the pillow surface. Similarly, the neutral posture was defined by the support of the ulnar side of the forearm and also on the pillow surface. The maintenance of the 3 forearm postures was visually monitored during the entire session. In addition, the surface electromyography signals were constantly monitored to ensure the desired posture control under resting conditions. Moreover, during the experimental session, participants were vision deprived to eliminate visual feedback from the posture maintenance process.

The corticospinal excitability was assessed using single-pulse TMS delivered with a figure-of-eight coil (model FEC-01-100, 75 mm in diameter) connected to a Neuro-MS stimulator (Neurosoft-Voronin). Coil positioning was guided using the neuronavigation software *InVesalius*[19] connected to the MicronTracker SX60 system (ClaroNav Inc). Neuronavigation was performed with magnetic resonance imaging (Achieva 3T; Philips Healthcare) with a T1-weighted gradient-echo sequence (acquisition matrix

Table 1 Participants' Characteristics (Age, Height, Body Mass, Oldfield's Modified Score Version, rMT for FPB, ADM, and FCR Muscles From Dominant [Right] and Nondominant [Left] Sides)

Subject	Age, y	Height, m	Body mass, kg	Handedness (Modified Oldfield score)	rMT FPB Right, %	rMT FPB Left, %	rMT ADM Right, %	rLM ADM Left, %	rLM FCR Right, %	rLM FCR Left, %
1	24	1.60	82.0	63.33	44	54	48	60	44	52
2	26	1.68	105.0	83.33	54	59	55	60	53	72
3	19	1.72	70.0	63.33	52	52	51	53	47	53
4	27	1.79	76.0	53.33	56	57	55	58	58	61
5	23	1.68	67.0	83.33	53	55	51	56	52	53
6	22	1.80	77.5	73.33	49	46	57	54	55	51
7	27	1.76	94.0	66.70	65	75	70	76	71	70
8	25	1.79	105.0	56.70	44	41	42	38	50	42
9	30	1.78	77.0	80.00	54	53	51	51	53	47
10	28	1.88	83.0	60.00	41	48	41	51	43	45
11	27	1.90	96.0	73.33	47	48	48	50	51	49
12	30	1.94	100.0	90.00	44	45	43	45	43	46
Mean	25.7	1.78	86.0	70.6	50.3	52.8	51.0	54.3	51.7	53.4
SD	3.3	0.10	13.4	11.8	6.8	8.8	7.9	9.3	7.8	9.6

Abbreviations: ADM, abductor digit minimi; FCR, flexor carpi radialis; FPB, flexor pollicis brevis; rMT, resting motor threshold. Note: The mean values and *SD* for all characteristics are also shown (bottom).

240 × 240 × 240, voxel size 1 × 1 × 1 mm^3, 3.1 ms echo time, and 6.7 ms repetition time). In addition, a cloth cap was used to mark the cranial references on each cerebral hemisphere according to the 10 to 20 EEG system (vertex, C3, and C3 and C4 over the left and right primary motor cortex, respectively). The TMS coil was positioned tangentially to the scalp and approximately perpendicular to the central sulcus, with current induced in the posterior–anterior direction.[20–22] Each muscle's hotspot was determined on both cerebral hemispheres as the scalp location, resulting in maximal MEP peak-to-peak amplitude for a fixed suprathreshold TMS intensity. Then, the resting motor threshold (rMT) of each muscle was defined as the lowest intensity of the maximum TMS output capable of evoking at least 3 out of 6 MEPs with peak-to-peak amplitudes equal to or greater than 100 µV.[23,24] We selected this threshold to obtain a slightly higher stimulus intensity for more reliable and less variable MEPs from the 3 investigated muscles.[15,25,26] During the rMT and hotspot search, the forearm was kept in a neutral position (control condition), which is usually adopted when using different handheld tools and minimizes muscle and ligament stress by reducing the stretching of joint-spanning tissues.[27] Hotspots were marked on the cap and digitized with the neuronavigation system. Then, 10 to 15 MEPs were collected in pseudorandomized interpulse intervals of 5 to 10 seconds, with a stimulation intensity at 120% of rMT from each muscle.

MEPs were obtained from 18 different conditions, that is, 3 forearm postures (pronation, neutral, and supination); 2 upper limb sides (dominant × nondominant); and 3 hotspots (FPB, ADM, and FCR). The sequence of stimulation was pseudorandomized to avoid habituation.

In the next step, EMG signals were digitally filtered with a second-order band-pass Butterworth filter (10–500 Hz). The peak-to-peak amplitude and latency were automatically computed from a 15- to 60-ms window after the TMS pulse using the *SignalHunter* software,[28] written in MATLAB R2015a. The implementation details on how the amplitude and latency were computed are described in Milardovich et al.[29] Amplitude and latency annotations were visually inspected and corrected using a user interface implemented in *SignalHunter*.

We evaluated the effect of the stimulation side (dominant cerebral hemisphere × nondominant cerebral hemisphere) and forearm posture (pronation × neutral × supination) on the MEP peak-to-peak amplitude ($\text{MEP}_{\text{P-P}}$) and latency in each muscle separately with a 2-way analysis of variance. Pairwise effect sizes of the forearm posture are presented as Cohen *d*. $\text{MEP}_{\text{P-P}}$ and latency were normalized within subjects, that is, the raw values were divided by the average across all arm positions and sides. Multiple comparisons were performed using a post hoc Tukey HSD test when necessary. The probability plot of residuals did not reveal any apparent deviations from the normal distribution, and the data's homoscedasticity was verified before using analysis of variance. Statistical analyses were performed in R version 3.4.0 (R Core Team), and the level of significance (α) was set at 5%.

Results

The average and participant-specific rMT of the 3 studied muscles are shown in Table 1. The rMTs were similar for all 3 muscles ($F_{2,66} = 0.18$; $P = .830$) and for the dominant and nondominant sides ($F_{1,66} = 1.24$; $P = .268$). The forearm posture ($F_{2,71} = 0.70$; $P = .500$) and cerebral hemisphere ($F_{1,71} = 1.41$; $P = .240$) did not affect the $\text{MEP}_{\text{P-P}}$ for the ADM muscle, as illustrated in Figure 1a. In addition, there was no interaction between the forearm posture and the cerebral hemisphere ($F_{2,71} = 0.008$; $P = .921$). In contrast, $\text{MEP}_{\text{P-P}}$ from the FPB significantly varied among the forearm postures ($F_{2,71} = 7.44$; $P = .001$; Figure 1b). In supination, $\text{MEP}_{\text{P-P}}$ was lower than in pronation ($P = .001$; $d_{(\text{pronation-supination})} = 0.70$; 95% CI, 0.11 to 1.28) and neutral ($P = .001$; $d_{(\text{neutral-supination})} = 0.65$; 95% CI, 0.06 to 1.22) positions. MEPP-P was similar for the dominant and nondominant cerebral hemispheres ($F_{1,71} = 0.31$; $P = .581$), and there was no interaction between these factors (*forearm posture* × *cerebral hemisphere*: $F_{2,71} = 0.33$; $P = .721$). The forearm posture significantly affected the $\text{MEP}_{\text{P-P}}$ from the FCR ($F_{2,71} = 4.48$; $P = .015$), being higher in pronation than in neutral posture ($P = .001$; $d_{(\text{pronation-neutral})} = 0.42$; 95% CI, −0.15 to 0.99), as shown in Figure 1c. The dominant side presented higher $\text{MEP}_{\text{P-P}}$ than the nondominant ($F_{1,71} = 7.77$; $P = .007$), as illustrated in Figure 1c. There was no interaction between the forearm posture and cerebral hemisphere ($F_{2,71} = 0.68$; $P = .509$) on the FCR $\text{MEP}_{\text{P-P}}$.

The MEP latencies in ADM were similar for all forearm postures ($F_{2,71} = 2.44$; $P = .095$) and between both cerebral hemispheres ($F_{1,71} = 3.59$; $P = .062$) (Figure 2a). Also, no significant interaction was observed between the forearm postures and cerebral hemispheres ($F_{2,71} = 1.06$; $P = .352$). Interestingly, MEP latency from FPB was longer for the dominant compared with the nondominant side ($F_{1,71} = 5.98$; $P = .017$; Figure 2b). However,

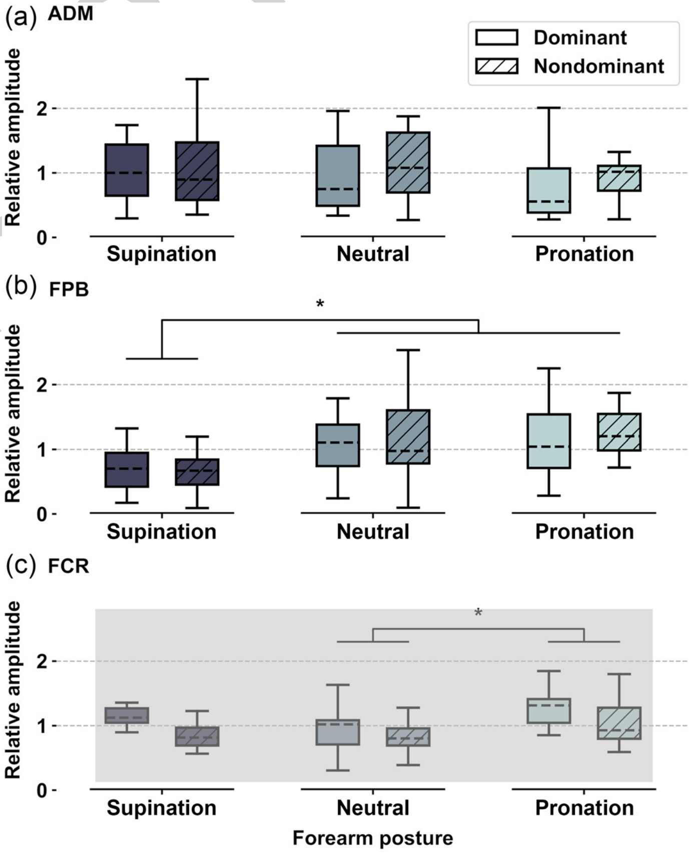

Figure 1 — (a) ADM, (b) FPB (*$P = .001$), and (c) FCR (*$P = .007$) relative MEP peak-to-peak amplitudes in the 3 different postures and dominant (solid) and nondominant (diagonal line) sides. The dominant side presented higher $\text{MEP}_{\text{P-P}}$ than the nondominant ($P = .007$) for FCR, as highlighted in gray (1c). ADM indicates *abductor digiti minimi*; FCR, *flexor carpi radialis*; FPB, *flexor pollicis brevis*; MEP, motor-evoked potential.

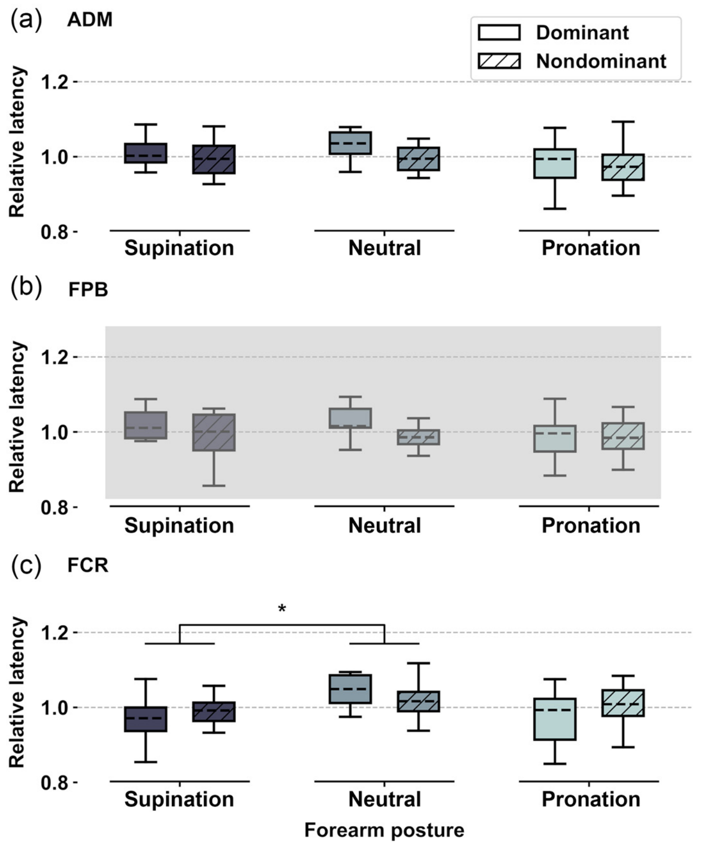

Figure 2 — (a) ADM, (b) FPB, and (c) FCR relative MEP latencies recorded with the different forearm postures and on dominant (solid) and nondominant (diagonal line) sides (*$P = .008$). The dominant side presented longer MEP latencies than the nondominant ($F_{1,71} = 5.98$; $P = .017$) for FCR, as highlighted in gray (2b). ADM indicates *abductor digiti minimi*; FCR, *flexor carpi radialis*; FPB, *flexor pollicis brevis*; MEP, motor-evoked potential.

this parameter was not affected by the different forearm postures ($F_{2,71} = 0.68$; $P = .508$). There was no interaction between both factors (*forearm postures × cerebral hemispheres*: $F_{2,66} = 1.30$; $P = .278$). MEP latency from FCR muscle changed depending on the forearm posture ($F_{2,71} = 5.25$; $P = .008$) but not for the stimulation side ($F_{1,71} = 0.51$; $P = .476$) (Figure 2c). Neutral posture presented longer latencies than supine ($P = .008$; $d_{(\text{neutral-supination})} = 0.63$; 95% CI, 0.04 to 1.20). No difference between MEP latencies in pronation was observed compared with supine and neutral postures.

Discussion

Different forearm postures influence the motor performance of the hand in various functional activities, such as when using handheld tools.[4,6] However, it is still unclear how postural adjustments can contribute to the execution of a motor task and how dominance can lead to distinct profiles of muscular recruitment. Our findings reveal that forearm posture affects the corticospinal excitability of intrinsic and extrinsic hand muscles differently. This difference can be decisive for the CNS in defining muscle recruitment strategies and, consequently, joint torque generation.

Asymmetries were observed between the dominant and nondominant hemispheres only in the FCR muscle, in agreement with certain studies[30,31] and differing from others.[32–34] Notably, the ADM muscle showed no effect from handedness and forearm postures. Hence, differences in observed results compared with other studies suggest that task-specific factors, such as posture of engaged segments and lateral preference, can significantly influence the CNS strategies in muscle recruitment. For example, Schieppati et al[35] and Teo et al[36] proposed that asymmetries in corticospinal pathway excitability between the dominant and nondominant sides are more apparent during motor tasks than resting conditions. Moreover, the nature of the task can modulate the corticospinal excitability of both distal and proximal muscles, especially in precision tasks, that is, those involving muscle contractions below ~10% of maximal voluntary contraction.[37] We should note that the type of TMS coil may play a significant role in interpreting our findings. For instance, differences in rMT between the dominant and nondominant upper limbs have been observed with circular TMS coils[30,31] but not with focal figure-of-eight coils.[38] The absence of differences for a nonfocal model is mainly supported by the larger cortical area, which results in lower anatomical selectivity and higher stimulation intensities than focal TMS coils. Gordon et al[39] reinforced the hypothesis of a greater connectivity between body parts compared with the classical model proposed by Penfield. Hence, we may speculate that stimulating a larger cortical area might recruit synergic muscular networks.

The present study observed differences in the $\text{MEP}_{\text{P-P}}$ of FCR between sides and forearm postures during rest. This difference is possibly due to the reciprocal, continuous interaction and spatial and temporal coherent interplay performed by the primary motor cortex and somatosensory cortex from each adopted forearm posture.[40,41] These findings corroborate, at least for the FCR muscle—an extrinsic hand muscle, the hypothesis posited in this study that motor performance between the dominant and nondominant sides relies on the level of corticospinal excitability, ensuring specific muscle recruitment strategies that maximize the motor performance.

$\text{MEP}_{\text{P-P}}$ from the FCR increased as the forearm position changed from neutral to pronation, possibly related to decreased FCR muscle length. Based on the muscle length–tension relationship,[42] we hypothesized that shorter or longer muscle lengths, out of the maximal tension capacity, will require an increase in CNS drive to compensate for a mechanical deficit, as reported by Moraes et al.[43] However, the pronated position does not seem to support this statement. Besides, the FPB also appeared to be affected by changes in forearm postures, with the supination leading to lower $\text{MEP}_{\text{P-P}}$, in contrast to neutral and pronation positions. This result may suggest a distinct sensorimotor contribution according to the variation of forearm postures to the corticospinal excitability of the FPB muscle (in this case, a muscle agonist in a grasping task).

In turn, as the FPB does not alter its length while the forearm posture changes (ie, its muscle spindles provide invariable afferent information), it should present similar $\text{MEP}_{\text{P-P}}$ among forearm postures. It showed lower corticospinal excitability during supination, possibly because FPB is innervated by the median nerve that supplies other forearm muscles, such as FCR and *pronator teres* muscle. Both are elongated during supination, and previous work suggested that $\text{MEP}_{\text{P-P}}$ of some muscles of the upper limbs is greater when they are shortened.[11,44] Therefore, other muscles, such as the FCR, with the same innervation, may send afferent signals, resulting in different motor commands to the FPB, as highlighted previously. Such a mechanism may have caused an inhibitory effect of FPB muscle during supination, reinforcing the influence of posture even on those muscles distally localized and not influenced by length changes. Sasaki et al[45] reported similar results for upper limb muscles by modifying trunk posture and claimed this mechanism might be mentioned as a "remote effect." Therefore, proprioceptive feedback may influence the corticospinal excitability of an intrinsic hand muscle. In summary, these findings support the hypothesis that various muscles undergo modulation in corticospinal excitability, whether increased or decreased, contingent on their functional postural role within a specific motor task and emphasize the influence of joint adjustments on muscle performance, which is still inadequately understood, highlighting the importance of considering posture in the assessment of motor performance.[46]

The effect of medullar circuitries on $\text{MEP}_{\text{P-P}}$ should be considered when dealing with corticospinal excitability.[47] For instance, Perez and Rothwell[48] suggested that postural changes lead to corticospinal modulation of intrinsic hand muscles from cortical circuitry. In contrast, others support a spinal origin due to changes in the FCR Hoffmann reflex (H-reflex) while subjects were advised to keep their forearms in the same postures we studied.[8,49] For the FPB muscle, our results are possibly explained by a supramedullary effect due to different neural drivers between the Q9 supination and other forearm postures to offer specific conditions for the hand function as the $\text{MEP}_{\text{P-P}}$ remained unaffected by changes in the muscle's length. However, our interpretations are limited by not observing the H-reflex, which precludes us from refuting the hypothesis of not being modulated at the spinal cord level. Thus, future studies could consider additional methods that contribute to understanding further sensorimotor processing at the spinal level.

Two possible different mechanisms seem to explain the changes in MEP latencies. First, the "Size Principle" suggests that motor units with smaller diameter axons would have a lower conduction velocity and higher latency than larger ones.[50] Second, at the central level, TMS results in descending volleys composed of indirect (I) and direct (D) waves, and other possible summation and stimulation parameters would partially explain the changes in latency.[51,52] We observed longer latencies for the FPB muscle compared with the others. For this specific muscle, it is possible that TMS preferentially activated smaller motor units and/or later I-waves in the dominant hemisphere. However, our interpretation remains speculative without the appropriate experimental approach to disentangle such mechanisms. Interestingly, the FCR's MEP latency was higher with the forearm in neutral than in supination. Mitsuhashi et al[4] suggested that differences in MEP latency may provide evidence for the influence of a specific muscle as an antagonist on a motor task, even though the underlying mechanisms must be better elucidated.

Therefore, in conclusion, the latency and amplitude of the MEP can, together, provide insights about the corticospinal excitability Q10 profile and help us understand the CNS strategies that will guide how muscles comprising a synergistic network will generate joint torques. In addition, they may help to elucidate how CNS leads with different muscle recruitment strategies depending on the joint adjustments and, consequently, can maximize motor performance.

Nevertheless, our findings suggest caution when planning and reporting TMS experiments. Some studies have investigated the reliability of MEPs induced by TMS to assess corticospinal excitability, revealing insights into MEP interpretation. For instance, Spampinato et al[53] underscored the importance of considering that MEPs, originating from the primary motor cortex, are influenced by contributions from cortical and spinal circuits, resulting in MEP amplitude variability. They also emphasized the involvement of both excitatory and inhibitory pathways in MEP composition, particularly in neurological patient monitoring. Thus, concurrently recording the H-reflex as a measure of Q11 monosynaptic Ia—α motoneuron excitability alongside MEP measurements appears appropriate to discriminate spinal- and supraspinal-level contributions to MEP properties. However, as previously detached, we did not record H-reflex from the investi- Q12 gated muscles, a study limitation discussed in this manuscript. Even so, enhancing measurement reliability in healthy subjects can involve considering $\text{MEP}_{\text{P-P}}$ values as parameters, employing techniques like neuronavigation[19,25] and adopting stimulus intensities at or above 120% of the rMT.[25] Moreover, ensuring continuous posture control during MEP recording is crucial as even joints distal to the regions of interest can impact corticospinal excitability modulation.[54]

In summary, despite the limitations, the present study utilized all available instrumental and methodological resources according to those cited earlier to ensure the robustness of the MEP obtained via TMS. Furthermore, it is noteworthy that studies conducted by our research group have been dedicated to understanding how different electrode configurations can affect MEP properties.[17,18,55] In this regard, the current study employed an electrode arrangement designed to maximize MEP recording at low TMS stimulation intensities, which, in conjunction with other methodological aspects, would further enhance the robustness of the obtained measurements.

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Queries

Q1. As per journal style, repeats in the article title are not allowed in keywords. Hence, the keywords "forearm posture, corticospinal excitability" have been deleted. Please check.

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Q6. Please provide expansion for "rLM."

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Q8. Please provide expansion for "EEG."

Q9. Please check the sentence "For the FPB muscle ..." for clarity and consider rephrasing.

Q10. Please check that changes made to the sentence "Therefore, in conclusion ..." preserve the intended meaning.

Q11. Please clarify "monosynaptic Ia—**α** motoneuron" in the sentence "Thus, concurrently recording ... ."

Q12. Please check use of "detached" in the sentence "However, as previously ..." and correct if necessary.