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Impact of handedness on electromyographic activity of hand muscles and nerve conduction velocity during mobile phone use in adolescents

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ABSTRACT

This study investigated the impact of handedness on electromyographic (EMG) activity of hand muscles and nerve conduction velocity during smartphone use and compared the effects of left- and right-handedness on hand muscle activation and nerve conduction velocities. This interventional parallel study included 70 participants (35 left-handed, 35 right-handed) aged 12 to 14 years. EMG activity and nerve conduction velocities (radial, median, and ulnar nerves) were measured before and after 10 minutes of smartphone use. Muscle activation was assessed for the abductor pollicis longus (APL), extensor carpi radialis (ECR), flexor carpi ulnaris (FCU), and first dorsal interosseous muscles. Statistical analysis was performed using SPSS software, version 27. Left-handed participants exhibited significantly greater activation in all assessed muscles during smartphone use ($p < 0.05$). Specifically, the activation of the APL, ECR, FCU, and first dorsal interosseous muscles was higher in left-handed individuals. Sensory ulnar and median nerve conduction velocities were significantly higher in right-handed subjects during smartphone use ($p < 0.05$), while no significant differences were observed in motor nerve conduction velocities. The study demonstrates that handedness influences neuromuscular activity during smartphone use, with left-handed individuals showing greater muscle activation and right-handed individuals exhibiting higher sensory nerve conduction velocities.

KEYWORDS

Handedness; Electromyographic Activity; Nerve Conduction Velocity; Smartphone Use; Muscle Activation

1. INTRODUCTION

Handedness is a well-recognized behavioral phenomenon, characterized by a preference for using one hand consistently when performing certain tasks over the other (Corey et al., 2001). Approximately 85 to 90% of individuals are right-handed, while 10 to 15% are left-handed (Frayer et al., 2012). Asymmetries in both physiology and anatomy at different levels of the central nervous system, which controls the upper extremities, are well-established. These asymmetries, related to handedness, are evident in the motor cortex and corticospinal tract (Seizeur et al., 2014). Moreover, variances have been identified in peripheral nervous pathways, including elevated sensory detection thresholds and increased conduction velocities in the motor nerve of the dominant arm (Wright, 1934; Giovagnoli & Parisi, 2024).

Apart from disparities in the nervous system, differences also arise in the muscles. Prolonged preferential utilization of muscles on the dominant side of the body may lead to alterations in muscle fiber composition, characterized by a higher predominance of slow-twitch type I fibers. The transition towards slow-twitch fibers is linked to alterations in motor unit control properties, leading to decreased firing rates of motor units on the dominant side (Adam et al., 1998; Diederichsen et al., 2007).

In particular, concerning muscle activity, researchers examined electromyography (EMG) signals from 4 and 8 muscles responsible for shoulder and elbow joint control during different upper limb movements. Their analysis indicated that muscle activity levels were lower on the dominant side compared to the non-dominant side, suggesting the potential for task-specific variations in muscle activity patterns (Diederichsen et al., 2007).

The impact of handedness on muscle organization and coordination (muscle synergies) during the execution of complex tasks was explored. Results indicated that right-handed and left-handed individuals exhibited distinct muscle organization when performing circular trajectories. Furthermore, a task-specific asymmetry in muscle synergies was observed (Duthilleul et al., 2015). It appears that left-handed and right-handed individuals execute movements with distinct muscle activity arrangements: varying levels of complexity in muscle organization, indicated by differences in the number of muscle synergies, were noted during broad movements, while fine movements displayed a different arrangement of motor modules (Duthilleul et al., 2015; Liang et al., 2021).

From a clinical standpoint, comprehending potential differences in muscle synergies related to handedness among healthy subjects could offer insights into motor patterns in individuals with neurological conditions characterized by motor and muscular imbalances, like stroke. Indeed, handedness may complicate result interpretation or serve as a criterion for patient classification.

This study investigates the impact of handedness on electromyographic (EMG) activity of hand muscles and nerve conduction velocity during smartphone use and compares the effects of left- and right-handedness on hand muscle activation and nerve conduction velocities.

2. METHODS

2.1. Study Design and Participants

This was an interventional parallel study conducted in the Department of Physiology. A sample size of 70 was deemed sufficient to detect differences in muscle activation between left- and right-handed subjects, with a power of 80%, an alpha error of 5%, and an attrition rate of 20%. Seventy adolescents (35 left-handed, 35 right-handed), aged 12 to 14 years, with a normal BMI (16.5-24 kg/m^2) and no regular athletic activity, participated. All participants shared the same socioeconomic level and used the same smartphone model (6.7-inch touchscreen). Exclusion criteria included peripheral nerve injury, upper extremity movement limitations, a history of upper extremity fractures or deformities, and neurological disorders such as peripheral neuropathy due to type I diabetes mellitus.

This study was approved by the Ethical Review Committee at the Modern University for Technology and Information (MTI) University, Faculty of Physical Therapy (REC/211/MTI.PT/2406251). The study protocol was registered at ClinicalTrials.gov (NCT06497179). Informed consent was obtained from the legal representatives of the adolescents after explaining the potential risks and benefits of the study interventions.

2.2. Evaluation Procedures

EMG was used to measure motor and sensory nerve conduction velocity and muscle activation in the dominant hand while using a smartphone. EMG data was collected at a sampling frequency of 1,000 Hz through six channels. Maximal Voluntary Isometric Contraction (MVIC) was measured for each muscle.

2.2.1. Nerve Conduction Velocity Assessment

Nerves Assessed: Ulnar, median, and radial

Phases:

- *Phase 1:* Pre-test without smartphone use.
- *Phase 2*: After 10 minutes of smartphone use.

Consistency: Testing and laboratory environments were kept constant. The same physiotherapist and neurophysiologist administered all tests. Measurements were taken while participants used their dominant hand to operate the smartphone.

2.2.2. Muscle Activation Assessment

Muscles Assessed: Flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), abductor pollicis longus (APL), and first dorsal interosseous muscle.

Positioning: Participants sat on a chair with feet on the ground. Coupling gel was applied to electrodes, straps were used to prevent movement and wires were kept loose. EMG machine functionality was checked prior to use. MVIC measures and evaluates muscle strength and normalizes EMG data.

Procedure: Explained to parents beforehand, with measurements taken on the same day. Peak force and target muscle force were analyzed for MVIC. Average Rectified EMG (ARV) was used to measure muscle activity, as it is less variable compared to peak EMG variables. Changes in EMG signal indicating muscle fatigue included increased mean absolute value, amplitude, duration of muscle action potential, and a shift to lower frequencies.

2.3. Statistical analysis

Data are presented as mean ± standard deviation (SD) and were analyzed using independent samples t-tests. Statistical analysis was performed using SPSS software, version 27, with two-tailed tests applied at a significance level of 0.05.

3. RESULTS

The study included 70 participants, with 35 in the left-handed group and 35 in the right-handed group. The mean age of participants was 12.91 years with a standard deviation of 0.80 years. There was no statistically significant age difference between the left-handed and right-handed groups (p = 0.766), as detailed in Table 1.

Table 1. Comparison of right-handed and left-handed subjects

Variables	Right-sided (n = 35)		Left-sided (n = 35)		Overall (n=70)	p-value
	Mean	SD	Mean	SD	Mean ± SD	
Age	12.94	0.80	12.89	0.80	12.91±0.80	0.766
APL muscle	22.27	7.40	28.98	5.96	25.63 ±7.48	<0.001*
ECR muscle	13.13	4.53	15.65	5.59	14.39 ± 5.2	0.042*
FCU muscle	15.51	3.09	17.43	4.17	16.47 ± 3.77	0.032*
First interosseus	16.18	2.36	17.56	1.65	16.87 ± 2.14	0.006*
Motor ulnar nerve (before smartphone use)	67.52	8.59	64.81	10.95	66.17 ± 9.86	0.254
Motor ulnar nerve (after 10 min of smartphone use)	67.52	8.59	64.81	10.95	66.17 ± 9.86	0.254
Sensory ulnar nerve (before smartphone use)	65.08	10.40	62.27	10.99	63.67 ± 10.71	0.276
Sensory ulnar nerve (after 10 min of smartphone use)	64.81	9.74	59.89	9.08		0.032*
Motor radial nerve (before smartphone use)	64.11	9.38	65.17	9.88	64.64 ± 9.58	0.644
Motor radial nerve (after 10 min of smartphone use)	63.48	9.14	65.17	9.88		0.459
Sensory radial nerve (before smartphone use)	62.27	10.99	61.36	11.45	61.81 ± 11.15	0.734
Sensory radial nerve (after 10 min of smartphone use)	61.81	11.00	60.40	9.88		0.575
Motor median nerve (before smartphone use)	68.42	11.18	67.54	9.38	67.98 ± 10.25	0.721
Motor median nerve (after 10 min of smartphone use)	67.59	11.16	65.81	8.79		0.46
Sensory median nerve (before smartphone use)	65.38	9.64	62.92	9.32	64.15 ± 9.49	0.281
Sensory median nerve (after 10 min of smartphone use)	64.97	9.68	56.84	6.21		<0.001*

*APL: Abductor pollicis longus, ECR: Extensor carpi radialis, FCU: Flexor carpi ulnaris. SD: Standard deviation. *: Significant p-value (p ≤ 0.05).*

The activation of the APL muscle among all subjects had a mean of 25.63 ± 7.48. Left-handed subjects demonstrated significantly greater activation compared to right-handed subjects (p < 0.001).

The activation of ECR muscle among all subjects had a mean of 14.39 ± 5.2. Left-handed subjects demonstrated significantly greater activation compared to right-handed subjects (p = 0.042).

The activation of FCU muscle among all subjects had a mean of 16.47 ± 3.77. Left-handed subjects demonstrated significantly greater activation compared to right-handed subjects ($p = 0.032$).

The activation of the first dorsal interosseous muscle had a mean of 16.87 ± 2.14 among all subjects. Left-handed subjects exhibited significantly greater activation than right-handed subjects ($p = 0.006$).

The conduction velocity of the motor ulnar nerve among all subjects had a mean of 66.17 ± 9.86, measured both before and after smartphone use. There was no significant difference in conduction velocity between right-handed and left-handed subjects during these periods ($p = 0.25$).

The conduction velocity of the sensory ulnar nerve among all subjects had a mean of 63.67 ± 10.71 before smartphone use, with no significant difference between right-handed and left-handed subjects ($p = 0.28$). However, after smartphone use, right-handed subjects exhibited a significantly higher conduction velocity compared to left-handed subjects ($p = 0.032$).

The motor radial nerve conduction velocity among all subjects had a mean of 64.64 ± 9.58 before smartphone use, with no significant difference between right- and left-handed subjects ($p = 0.64$). After smartphone use, this difference also remained insignificant ($p = 0.46$).

The sensory radial nerve conduction velocity among all subjects was 61.81 ± 11.15 before smartphone use, with no significant difference between right- and left-handed individuals ($p = 0.73$). This difference also remained insignificant after smartphone use ($p = 0.58$).

The motor median nerve conduction velocity among all subjects had a mean of 67.98 ± 10.25 before smartphone use, with no significant difference between right- and left-handed subjects ($p = 0.72$). This difference remained insignificant after smartphone use ($p = 0.46$).

The sensory median nerve conduction velocity among all subjects had a mean of 64.15 ± 9.49 before smartphone use, with no significant difference between right- and left-handed subjects ($p = 0.28$). However, after smartphone use, right-handed subjects showed a significantly higher conduction velocity than left-handed subjects ($p < 0.001$) (Table 1).

4. DISCUSSION

Handedness, a well-recognized behavioral phenomenon, indicates a preference for using one hand over the other in various tasks (Chapman & Chapman 1987; Papadatou-Pastou et al., 2020).

In this study, significant differences were found in the activation of various hand muscles between left-handed and right-handed individuals during smartphone use. Left-handed subjects demonstrated greater activation in several muscles, including the APL, ECR, FCU, and the first dorsal interosseous muscle ($p<0.05$). Moreover, differences in nerve conduction velocities were also observed, particularly in the sensory ulnar nerve and sensory median nerve during smartphone use, where right-handed subjects showed higher velocities compared to left-handed subjects ($p<0.05$). These findings highlight the influence of handedness on neuromuscular function during the specific task of smartphone use, suggesting that handedness should be considered in clinical assessments and ergonomic designs.

To the best of our knowledge, this is the first study to directly compare the effects of left- and right-handedness on hand muscles and nerves during tasks such as using a smartphone. However, direct comparisons between dominant and non-dominant sides have been reported in the literature. The averaged normalized EMG activity for 6 out of 8 shoulder muscles during abduction in the scapular plane showed significant differences between the dominant and non-dominant sides. The muscles were the supraspinatus, serratus anterior, anterior deltoid, middle deltoid, latissimus dorsi, and upper trapezius (Diederichsen et al., 2007).

Physiological and anatomical asymmetries in the central nervous system, including the motor cortex and corticospinal tract, are well-documented and are related to handedness. These asymmetries extend to peripheral nervous pathways, where dominant arms exhibit increased motor nerve conduction velocities. Additionally, prolonged use of dominant side muscles can lead to changes in muscle fiber composition, favoring slow-twitch type I fibers, and resulting in altered motor unit control properties and muscle activation patterns (Triggs et al., 1994; Gutwinski et al., 2011; Galamandjuk et al., 2019).

An earlier study comparing 93 right-handed and 53 left-handed adults reported that overall performance was generally normal for both groups, with no significant differences between them. However, there was a significant difference in preference: left-handed subjects were significantly less lateralized than right-handed subjects (Borod et al., 1984). These findings suggest that left-handed subjects exert more effort with their left hand, resulting in less lateralization and greater use of both sides.

Consistent with our findings, a prior investigation with 24 healthy participants, either right or left-hand dominant, aimed to understand the variation in hand usage between individuals with different dominant hands. Using a brief questionnaire, the study found that right-handed individuals tended to favor their dominant hand for all skilled tasks, whereas left-handed individuals exhibited some inclination towards using their non-dominant hand (Mcsp et al., 2003).

In contrast, a study involving 28 right-handed and 29 left-handed participants used a 96-image stimulus set, a response box, a PC, and specialized software. Right-handed participants were quicker at controlling right-handed tasks than left-handed participants, while left-handed participants were faster at controlling left-handed tasks than right-handed participants. However, when viewed from allocentric perspectives, neither right-handed nor left-handed participants showed a significant difference in response time (Ní Choisdealbha et al., 2011).

5. LIMITATIONS

This study is limited by its small sample size and focus on a specific age group, which may not be representative of the broader population. Additionally, the homogeneity of the participants' ages and the lack of variability in other demographic factors may affect the generalizability of the findings.

6. CONCLUSIONS

This study demonstrates that left-handed individuals exhibit significantly greater EMG activity in various hand muscles during smartphone use compared to right-handed individuals. Additionally, while sensory ulnar and median nerve conduction velocities were higher in right-handed subjects during smartphone use, there were no differences in motor nerve conduction velocities between the two groups. These findings suggest distinct neuromuscular adaptations in left-handed individuals, highlighting the importance of considering handedness in ergonomic assessments and the design of handheld devices.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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