Evaluating hand performance and strength in children with high rates of smartphone usage: an observational study

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Abstract. [Purpose] This study investigated the interaction effects between the levels of smartphone use and hand dominance on handgrip, pinch strengths, and functional hand performance in children. [Participants and Methods] A total of 60 children aged between 9 and 15 were assigned into two groups: Group A (high-frequency smartphone users) and Group B (low-frequency smartphone users). Use levels were determined according to the smartphone addiction scale-short version. A hand dynamometer and pinch gauge were used to measure handgrip and pinch strength respectively. Functions of the upper extremity and hand were scored using the Quick Disabilities of the Arm, Shoulder, and Hand questionnaire. [Results] Group A participants had reduced measurements in handgrip and pinch strength, especially in the dominant hand. However, Quick Disabilities of the Arm, Shoulder, and Hand questionnaire. [Conclusion] Results indicated that high levels of smartphone use diminished handgrip and pinch-grip strengths as well as hand function. That is, hand and pinch-grip strengths were reduced in the dominant hands of high-frequency smartphone users. However, hand functions were affected in the dominant hands among both high and low-level smartphone users.

Key words: Smartphone overuse, Hand function, Hand-grip strength

INTRODUCTION

Modern technology plays a key role in daily human life. This involves keeping pace with rapid changes in the field of communication technology. In this context, smartphones have become an essential part of life, not only in matters related to communication, but also as essential social accessories1–3). As a result of this social involvement in communication technology, young children have become avid smartphones users2). Laptops are now being developed for children as young as five, while smartphones are now commonly used by children as young as 104, 5). The authors conducted a survey on media use and found that children aged between 8–18 spent an average of 10 hours in media exposure each day6).

Children are attracted to smartphones because they devices can be used anywhere and contain games that are specifically matched to their ages1, 8). It is not longer strange to see children walking along the street while carrying smart devices as their fingers move along touch screens9). Youths are specifically at a higher risk for smartphone addiction due to this strong attraction. Many also consider the smartphone “second self.” A large of smartphones users have also stated that they would...
not be able to live without a smartphone\textsuperscript{10}).

Frequent smartphone use without taking regular rest periods may result in cumulative trauma disorders to the neck, shoulders, hands and wrists. These disorders may occur because smartphone use typically requires thumb and finger interactions with the screen\textsuperscript{9}). Reports have shown that extended smartphone use accompanied by awkward wrist posture can lead to collective trauma disorders of the wrist joints, particularly when the wrist, hands, and fingers are overused\textsuperscript{11–18}). Repetitive static motion of the hands may also decrease blood supply and prevent nutrients from being delivered to muscles, thus leading to pain and muscle fatigue\textsuperscript{9–21}).

Research on the association between mobile-phones use and musculoskeletal disorders has only emerged over the past few years. However, many of these studies have implied that grasping, repeated pushing movements, and repeated motions of the thumb were risk factors that could lead to upper limb dysfunction\textsuperscript{22, 23}).

A previous study by Ming et al.\textsuperscript{1}) reported that adults who used smartphones for a period exceeding three years were found to have upper limb musculoskeletal disorders. Repetitive wrist movements during smartphone overuse are involved in etiopathology of carpal tunnel syndrome due to narrowing of the carpal tunnel. It was also suggested that there is a relationship between stroke counts and hand disorders, such as degeneration of the first carpometacarpal and De Quervain disease. Cervical joints are becoming under more stress due to sustained bending over smartphones. Sustained pressure on the cervical joints is disturbing signals to the brain that might cause problems of balance and disturbed cervical proprioception\textsuperscript{24}). Moreover, Gold et al.\textsuperscript{25}) observed the postures and typing styles of over 800 university students who use mobile phones and confirmed that the majority (over 90\%) had assumed neck flexion, shoulder protraction and faulty wrist posture on the texting hand. Further, Gustafsson et al.\textsuperscript{26}) compared muscle activities in the neck, shoulder and forearm regions as well as neck and thumb kinematics among users of keypad phones. Results indicated that the symptomatic group more frequently exhibited adverse posture and higher muscle activation when texting on mobile phones. Kim and Kim\textsuperscript{23}) stated that repetitive upper limb work would not only cause minimal damage to the muscles, nerves, joints, and blood vessels, but would also produce chronic pain and paresthesia in the neck, shoulders, arms, wrists, and fingers.

Despite such widespread smartphones use (especially among children), the possible effects on hand function have not been defined. Few studies have investigated the effects of extensive smartphone use on hand function among children. This study therefore assessed the influence of high smartphone use on hand performance and strength while examining the possibility of an interaction effect between the level of smartphone use and hand dominance usage on the handgrip and pinch strength in children.

**PARTICIPANTS AND METHODS**

An observational study was conducted at the Physiotherapy Clinic, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Saudi Arabia.

Participants were subjected to evaluation after their parents signed consent forms, which were approved by the Research Ethics Committee affiliated with the Department of Physical Therapy and Health Rehabilitation, Prince Sattam bin Abdulaziz University. All procedures followed guidelines outlined by the (Declaration of Helsinki, 1967).

A total of 60 mentally and physically healthy children were selected to participate in this study. They were then assigned to one of two groups of equal number according to their level of smartphone use (i.e., Group A was for high-frequency smartphone users, while Group B was for low-frequency smartphone users). Use levels were determined based on smartphone addiction scale-short version (SAS-SV). Normative data showed the following cut-off points based on gender: 31 and 33 (out of 60) to distinguish “high smartphone male and female users,” respectively\textsuperscript{27}). Basic participant characteristics are shown in Table 1. There were 26 boys and 34 girls (age: 13.1 ± 1.7 years, height: 156.3 ± 3.6 cm, bodyweight: 44.7 ± 4.1 kg). All participants had used smartphones for at least two years prior to study. Smartphone screen sizes were not greater than 4.5 inches. Individuals were excluded from the study if they had auditory, visual, or perceptual deficiencies or a history of orthopedic or neurological problems in their upper extremities within four months prior.

The smartphone addiction scale short version (SAS-SV) is a validated questionnaire designed to detect the level of smartphone addiction in children\textsuperscript{14, 28}). It has both content and concurrent validity and internal consistency (Cronbach's alpha:

| Table 1. Participants’ demographic data |
|---------------------------------------|
|                                      |
| **High-frequency smartphone users**   |
| (Group A, n=30)                       |
| **Low-frequency smartphone users**    |
| (Group B, n=30)                       |
| Age (years)                           | 13.3 ± 1.6 | 12.9 ± 1.7 |
| Height (cm)                           | 155.9 ± 3.6 | 156.7 ± 3.6 |
| Weight (kg)                           | 45.1 ± 3.8 | 44.2 ± 4.4 |
| Girls (%)                             | 16 (53.3) | 18 (60) |
| Boys (%)                              | 14 (46.7) | 12 (40) |
| Right hand (%)                        | 22 (73.3) | 21 (70) |
| Left hand (%)                         | 8 (26.7) | 9 (30) |
The questionnaire consisted of 10 questions about daily activities (e.g., interruption, positive anticipation, departure, worldwide web-oriented relationship, overdose, and patience). Each question was graded on a dimensional scale from 1 to 6. That is, participants were asked to answer the questions according to their level of agreement (6=strongly agree, 5=agree, 4=slightly agree, 3=slightly disagree, 2=disagree and 1=strongly disagree)27. The overall scores thus varied from 10 to 60. Highest values indicate high smartphone addiction30–32. Specifically, males are addicted when scores are greater than 31, while females are addicted when scores greater than 33.14, 33, 34.

Upper extremity functional assessments were conducted using the Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) questionnaire. The qDASH is a shortened version of the DASH. Rather than the 30 questions of the DASH, the qDASH contains only 11 questions designed to measure physical function and symptoms in participants with any multiple musculoskeletal problems in their upper extremities35. The qDASH was given to all participants. Out of the 11 items, at least 10 require answers in order to determine a qDASH score. There are 5 answer choices for each question. One point is provided for the mildest symptom or functional status, for the most severe symptoms and disabilities 5 points were given.

The following formula calculates a score:

\[
\text{qDASH score} = \left( \frac{\text{sum of } n \text{ responses}}{n} \right) - 1 \times 25, \text{ where } n \text{ is the total number of questions.}
\]

The qDASH score cannot be available if more than one questions are not answered. The score ranges from 0 to 10036, 37.

Grip and pinch strengths in the dominant and non-dominant hands were evaluated for all participants by the same physiotherapist, who was not aware of their SAS-SV scores. A JAMAR hand dynamometer (Sammons Preston Inc, Bolingbrook, IL, USA) was used to measure Kilogram grip strength in both hands. This method had high test-retest and both inter and intra-rater reliability38–40. According to handgrip measuring recommendations provided by the American Society of Hand Therapists, participants were seated with their shoulders adducted and neutrally rotated; for the measured hand, the elbow was flexed at 90° while the forearm and wrist were in neutral positions. Participants were then asked to squeeze the dynamometer handle as much as he/she can while maintaining maximal grip strength. Three trials were performed with 30-second rest-periods in between. An average score was recorded for each participant based on all three trials38–40. Tip, key, and palmer pinches were evaluated using a B&L pinch gauge (B&L Engineering, Tustin, CA, USA). Pinch-strength evaluations are most often used to measure thumb weakness. Reports have indicated that pinch-gauge method has high test-retest and both inter and intra-rater reliability in measuring pinch-strength23. Such evaluations were conducted in the same trunk and arm positions as during the grip-strength measurement; the pinch gauge was held in a lateral position (forearm in neutral) for the key pinch, while the forearm was pronated with the pinch gauge held in an upright position for the tip and palmer pinch40.

The sample size estimate was based on the effect size (d=0.15) reported by previous studies41, 42. Here, the G*power 3.0.10 software (University of Dusseldorf, Dusseldorf, Germany) was used with power set at 80% and a probability of 0.05 among a sample size of 49 children. However, this study recruited 60 children to increase the power of analysis and assumed a maximum withdrawal of 20%

Statistical analyses were conducted using IBM SPSS (Statistical Package for Social Sciences (SPSS), Version 23, Chicago, IL, USA). All data were expressed as mean ± SD, normally distributed, and checked according to the Shapiro-Wilk test. A χ² test was used to analyze the categorical variables in terms of gender and hand-dominance differences between the groups. An Independent samples t-test was conducted to determine changes in continuous baseline data between the groups. A Two-way MANOVA (2 × 2, level of smartphone use × dominant hand) was carried out for each of the research-dependent variables except for upper-arm and hand disabilities. A Two-way ANOVA (2 × 2, level of smartphone use × dominant hand) was performed to explore any changes in upper-arm and hand disabilities as expressed through qDASH scores. Effect size was measured according to a partial eta squared (η²). A priori α significant level was set at p<0.05.

**RESULTS**

There were no significant differences in term of age, height, weight, gender, and hand dominance between groups (Table 1). The Two-way MANOVA revealed a significant impact for the level of smartphone use across grip strength, tip pinch, key pinch and palmar pinch measurements (F(4, 53)=157.4, p<0.05; Wilks’ Λ=0.08, partial η²=0.92). A separate analysis of variance for the four strength measurements revealed significant smartphone use differences on grip, tip pinch, key pinch, and palmar pinch strengths. All values for grip and hand-pinch strengths were weaker on the dominant sides when compared to the non-dominant sides in Group A (Table 2). To the contrary, the dominant sides in Group B showed higher values for grip and hand strengths when compared to the non-dominant sides. Regarding the effect of hand-dominance alone on grip, tip pinch, key pinch, and palmar pinch strengths, however, the same MANOVA revealed a non-significant difference (F(4, 53)=0.882, p=0.481; Wilks’ Λ=0.93, partial η²=0.06).

There was also a statistical interaction effect between the level of smartphone use and hand dominance on the combined dependent variables, (F(4, 53)=26.7, p<0.001; Wilks’ Λ=0.332, partial η²=0.668). The effects of smartphone use frequency on grip and hand-pinch strengths were not the same for the dominant and non-dominant hands; the dominant hand expressed low values for all four strength variables among high-frequency smartphone users (Group A). Nevertheless, the same
variables were measured at higher values for the non-dominant hand among low-frequency smartphone users (Group B). As for upper-extremity and hand functions as expressed by qDASH scores, the two-way ANOVA revealed that only the level of smartphone use significantly affected the result (F=22.03, p<0.05; partial η²=0.282), while hand dominance did not influence the state of upper-arm and hand disability (F=2.88, p=0.095; partial η²=0.049). Upper-arm and hand functions among low-frequency smartphone users were better than those among high-frequency smartphone users. Table 3 shows the effect of smartphone-use frequency and hand dominance on qDASH scores. There were otherwise no statistical interaction effects between the level of smartphone use and hand dominance on arm and hand disability scores (F=0.374, p=0.543; partial η²=0.007). Dominant-hand use had a more significant impact on arm and hand functions than the non-dominant hand for both groups.

**DISCUSSION**

It is now common for children to spend many hours each day playing smartphone games and thus assuming awkward postures. As such, these children may incur musculoskeletal complications. This study examined the effects of smartphone overuse on functional hand performance in children and assessed the interaction effects between the level of smartphone use and hand dominance on handgrip strength, pinch strength, and overall hand function.

Results indicated that the level of smartphone use alone significantly decreased grip, hand-pinch strength, and qDASH scores. Grip and hand-pinch strengths were weaker on the dominant side than the non-dominant side in the high-frequency smartphone-user group. This may be the result of modern smartphone designs, which require repeated finger motions such as clicking, scrolling, swiping, tapping, and pressing buttons. These requirements may affect fingertip forces, tendon excursion, and muscular effort.43 Furthermore, many studies have shown that longer durations of smartphone use may decrease blood flow, prevent oxygen and nutrients from being supplied to muscles, and lead to small amounts of pain and fatigue.44–47.

The human hand has unique features; functional impairment can affect quality of life.19 Studies on hand pain resulting from repetitive tasks have found that hand function and pinch strength were reduced through frequent smartphone use. This study’s results specifically supported research by both Kalra18, Kim et al.48 who found that frequent smartphone use resulted in decreased grip strength and hand function. Both reported that these conditions may have been due to physical factors, including a reduced number of contracting muscle fibers, decreased motor-unit firing rates, and changes in muscle fiber type.

Moreover, Samaan et al.42 reported that repetitive tasks (e.g., using smartphones) may be associated with repetitive microtrauma to the musculoskeletal structures. This condition is caused by an alteration of the length-tension relationship in the muscles. Aly et al.7 also reported that repetitive strain injuries may be caused by repeated finger motions that are performed for long periods of time at high velocity.

Smartphone users typically adapt their hand postures to the constraints of smartphone design layouts.38. In this context, faulty postures such as prolonged wrist flexion and repeated thumb use may affect median nerve.49 Ilik et al.41 reported that repeated wrist-flexion and extension movements may have resulted in the larger median nerves that were noticed among high-frequency smartphone users. Wrist-flexion or extension motions are also related to increased pressure in the carpal tunnel resulted in decreased space for the median nerve inside.60.

This study’s results also revealed that hand dominance had no significant effect on any of the measured variables by itself. However, hand dominance affected both grip and hand-pinch strengths depending on the level of smartphone use. These find-

### Table 2. Influence of smartphone use and hand dominance on hand strength

| Strengths          | High-frequency smartphone users | Low-frequency smartphone users | Significance |
|--------------------|---------------------------------|---------------------------------|--------------|
|                    | Dominant hand                   | Non-dominant hand               |              |
| Grip strength (kg) | 19.6 ± 2.22                    | 29.8 ± 1.6                     |              |
| Tip-pinch strength (kg) | 4.7 ± 1.9  | 6.3 ± 2.1                     | *            |
| Key-pinch strength (kg) | 5 ± 0.9  | 7.8 ± 0.5                     | *            |
| Palmar-pinch strength (kg) | 4.4 ± 0.8  | 6.2 ± 0.5                     | *            |

* p<0.05.

### Table 3. qDASH-scores differences between groups

|                   | High-frequency smartphone users | Low-frequency smartphone users | Significant |
|--------------------|---------------------------------|---------------------------------|--------------|
|                    | Dominant hand                   | Non-dominant hand               |              |
| qDASH              | 19.5 ± 6.2                      | 18 ± 5.2                       | *            |
|                    | Dominant hand                   | Non-dominant hand               |              |

* p<0.05; (qDASH) Quick Disabilities of the Arm, Shoulder, and Hand.
ings indicate that smartphone overuse mainly affects the dominant hand because it is more engaged in both this activity and daily-routine activities, thus subjecting it to fatigue at higher rates than the non-dominant hand. This was supported by the Cinderella hypothesis, which states that the continuous activity of specific motor units during low-level muscle contraction results in a metabolic overload of motor units\(^4\). This hypothesis applies to muscles that are active for durations long enough to damage muscle fibers\(^7\).

Namwongsa et al.\(^5\) revealed the three main risk factors responsible for upper-limb musculoskeletal disorders (i.e., posture, muscle force, and muscle use). Smartphone users commonly assume three poor postures, including protracting and bending the shoulders more than 20 degrees, setting elbows at more than 100 degrees and bending wrists more than 15 degrees with ulnar deviations, and forward neck and trunk flexion of 20 degrees or more. As a golden rule, the more the posture deviates from neutral, the greater stress placed on joints, ligaments, muscles, discs, and nerves; this may directly, decrease upper-extremity function.

The two other risk factors are muscle force and muscle use. Continuous static contraction of the upper-limb muscles with no or little resting time in between and the weight of the smartphone device, results in fatigue and muscle weakness. The main affected muscles are the upper trapezius (UT), extensor pollicis longus (EPL), and abductor pollicis (AP). This is consistent with finding by El-Azab et al.\(^2\), who reported a positive correlation between daily smartphone-usage time and the severity of upper-limb symptoms such as pain, fatigue, and poor posture, the matter which impact upper-limb functions.

Both one and two-handed smartphone use places mechanical loads on the hand and shoulder-girdle muscles (although one-handed use results in higher loads). Supporting a smartphone while tapping its touch-screen with the same hand may be more difficult than operations using a two-handed grip. For instance, if the thumb is involved in maintaining device stability while being used to tap the screen, then these two functions may conflict. Thus, performance is decreased. Gustafsson et al.\(^2\) and Kietrys et al.\(^5\) both similarly indicated that holding the phone while typing with the same hand resulted in greater EPL, AP, and UT muscle activity when compared to the two-handed grip. These findings were attributed to the higher required stabilizing forces when typing and gripping the phone with the same hand. However, the UT was measured at higher muscle-activity values and lower pain-threshold values in subjects who bilaterally used smartphones for longer times than those with small-time usages; this is because the UT acts for both mobility and stability in the upper limb\(^2\). Essential issues to reduce the risks of using smartphones in adolescents should be mentioned. Two-handed use and decreasing the time of chatting and searching less than 4 hours per day are considered as important factors to reduce the mechanical loads on hand and shoulder-girdle. Moreover, enhancing working or studying environment by preventing wrong body alignment as a lying position ensure decreasing the overpressure on the cervical spine. Finally, using a larger display screen may reduce the complaint rate of musculoskeletal symptoms through diminishing the bending angle of the cervical spine while using smartphones.

Based on this study’s results, it can be concluded that high levels of smartphone use decrease hand and pinch-grip strengths and overall hand function. Specifically, hand and pinch-grip strengths were reduced on the dominant-hand side with high-frequency smartphone use. However, hand functions were affected in both the dominant and non-dominant hands with either high or low-level smartphone use.

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**Conflict of interest**

None.

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