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Texting with touchscreen and keypad phones - A comparison of thumb kinematics, upper limb muscle activity, exertion, discomfort, and performance

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ABSTRACT

This study aimed to compare thumb kinematics and upper limb muscle activity, and the influence of hand size, when texting on a keypad smartphone and a touchscreen smartphone. Furthermore, the study compared exertion, discomfort, and performance when texting on the two phones. The thumb kinematics were tracked using a 3D motion analysis system and muscle activity was registered in six upper limb muscles using surface electromyography in 19 participants. When texting on the touchscreen phone compared to the keypad phone thumb flexion ($p = 0.008$) and flexion/extension range of motion were smaller ($p = 0.02$), the thumb was on average less internally rotated ($p = 0.02$), and activity (50th and 90th percentile) of the thumb and forearm muscles was lower ($p \leq 0.05$). The differences in thumb flexion were found only in the group with shorter hands and the differences in muscle activity was found only in the group with longer hands. These findings suggest there are differences in risks for developing musculoskeletal disorders during smartphone use with different key activation mechanisms and different hand sizes.

1. Introduction

Over the last 20 years, mobile phone use has become ingrained in daily life for many people all over the world, in particular since the introduction of the smartphone about ten years ago. The smartphone, with its multi-functionality, has quickly become the most common type of mobile phone. For example, in Sweden 97% of the population (aged 9–79 years) had a mobile phone and 80% had a smartphone in 2016 (Nordicom). In Australia, as many as 89% of the population (aged 18–75 years) had a smartphone in 2014 (Mackay, 2014).

Accompanying the considerable use of mobile phones there have been concerns raised about possible musculoskeletal problems. Indeed, excessive texting with mobile phones has been associated with musculoskeletal disorders in the thumb and upper limb in case reports, and in experimental and epidemiological studies (Eapen et al., 2014; Gustafsson et al., 2017; Johnson et al., 2016; Ming et al., 2006; Storr EF and Stringer, 2007; Williams and Kennedy, 2011) suggesting that these concerns may be justified.

Highly repetitive thumb movements have been identified as a potential musculoskeletal disorder risk factor related to mobile phone use (Gold et al., 2012; Gold et al., 2009; Gustafsson et al., 2010, 2011). Much of the interaction with the smartphone is through tapping with the thumb as the most used digit for the interaction (Gold et al., 2012). The movements of the thumb are complex, and include flexion/extension, adduction/abduction, and opposition (Greene and Heckman, 1994) with involvement of muscles in the hand and forearm. Furthermore, during single-handed mobile phone texting when tapping with the thumb muscles on the dorsal and the palmar side of the forearm are involved in stabilizing the wrist.

Considering the immense and widespread use of smartphones for texting in almost all age groups, understanding the underlying causes of musculoskeletal disorders related to smartphone use is important.

There are two basic designs of smartphones. I. Phones with a physical keypad keyboard in the bottom half and with the screen occupying the top half of the phone (Fig. 1, phone A). II. Phones with a touchscreen occupying most of the phone front, with a virtual touchscreen keyboard available as needed, usually in the bottom half of the screen (Fig. 1, phone B). Today touchscreen phones are by far more popular and there is a trend that smartphones are becoming touchscreen only. But phones with physical keypads are still commercially available, showing there are still populations that use keypad phones. For example, the ability for keypad phones to be operated in a wider variety

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Fig. 1. Keypad phone, Nokia model E5 to the left (phone A), and touchscreen phone, iPhone model 3 GS to the right (phone B).

of situations (such as rain and with normal gloves) makes these designs attractive for military use (J. Coleman, personal communication, August 2015).

Considering the higher popularity of the touchscreen phone compared with the keypad phone, it is important to investigate if there is a difference in risk for developing musculoskeletal disorders in order to provide the users with appropriate guidance in selection and use of phones.

The two basic designs of smartphones have different key activation mechanisms and tactile feedback. Our hypothesis is that these differences, when using the different phones for texting, may pose different physical stresses on the upper extremities, e.g. differences in thumb postures and muscle activity, and thus influence the usability and musculoskeletal risk of phone use.

Prior studies on the effect of different types of information and communication technology input devices have demonstrated that design differences can have significant impacts on posture, muscle activity and discomfort in neck and upper extremities (Briggs et al., 2004; Chany et al., 2007; Gustafsson and Hagberg, 2003; Oude Hengel et al., 2008; Rempel et al., 2007; Straker et al., 2008b; Xiong and Muraki, 2014). However, there is very limited knowledge about differences in thumb postures, muscle activity, and discomfort during the use of these two basic types of phones. A recently published study reported higher muscle activity in one thumb muscle and two muscles in the forearm when entering text on a keypad phone compared to a touchscreen phone (Kietrys et al., 2015), but no details on kinematics of these activities were provided. Given prior evidence on the importance of a variety of thumb and forearm muscles for thumb movement and wrist stabilization (van Oudenaarde et al., 1997) a better understanding of both kinematics and muscle activity during use of the two types of phones is required. There is also a lack of knowledge about how thumb kinematics and muscle activity are influenced by hand size when entering text on a touchscreen phone and a keypad phone. The perceived exertion and discomfort during phone use may also be important early indicators of musculoskeletal risk and should be further explored. Finally, differences in performance using the different types of phones are likely to be important for guiding appropriate selection and use of phones.

Therefore, the aim of this study was to compare thumb kinematics and upper limb muscle activity, and the influence of hand size when texting on a touchscreen smartphone and a keypad smartphone. Furthermore, the user ratings of perceived exertion and discomfort, and their performance when texting on the two phones were compared.

Table 1
The study population's age, anthropometric data and their current used phone (own phone). For age, hand and thumb size mean and range are given.

	All	Women	Men
	(n = 19)	(n = 12)	(n = 7)
Age (yr)	30.1 (21; 51)	30.9 (21; 51)	28.7 (21; 43)
Hand (cm)			
Length	18.3 (16.5; 20)	17.8 (16.5; 19)	19.1 (18; 20)
Width	8.6 (7.5; 9.5)	8.3 (7.5; 9)	9.2 (8.5; 9.5)
Thumb (cm)			
Length	6.4 (5.5; 8)	6.3 (5.5; 8)	6.6 (6; 7.5)
Width	6.3 (5.5; 7)	6.0 (5.5; 6.5)	6.7 (6; 7)
Hand length (n)			
Short (≥18.5 cm)	8	7	1
Long (≤18 cm)	11	5	6
Current phone (n)			
Keypad	5	3	2
Touchscreen	14	9	5

n = number; yr = year.

2. Method

2.1. Study participants

Nineteen participants (aged 21–51 years, 7 men, 12 women) without ongoing musculoskeletal symptoms in the thumb and upper extremities were recruited from the local university community (Curtin University, Perth, Australia). All participants had daily use of either a keypad phone in portrait mode for typing or a touchscreen phone with a keyboard in portrait mode (Table 1). Fourteen participants were currently using a touchscreen phone, and had owned and used a keypad phone within the last 12 months. Five participants were currently using a keypad phone and all five had the experience of using a touchpad phone. One woman and one man were left handed, the other seventeen participants were right handed.

2.2. Experimental protocol

The study was a laboratory study with a cross-over design in which all participants performed a texting task for 3 min with a keypad phone and a touchscreen phone. The order of the phones being used (keypad and touchscreen) was randomized. For each phone, a text was randomly assigned from three different paragraphs of texts from an athlete's autobiography. All paragraphs of text had a similar number of words, characters, syllables, and spaces.

The keypad phone used was a Nokia model E5 (Eshoo, Finland, size 115 × 58.9 × 12.8 mm; 126 g; key size 6 × 4 mm; distance from bottom of the phone to lowest key row 15 mm; mechanical key force 1.6 N; key travel 0.7 mm) with full qwerty keyboard and the touchscreen phone used was an iPhone model 3 GS, Apple Inc., (Cupertino, CA, USA,115.5 × 62.1 × 12.3 mm; 135 g; key size 6 × 4 mm; distance from bottom of the phone to lowest key row 22 mm). These phones were chosen to represent the two basic designs of smartphones studied in this study and these particular phones were chosen to be as similar in size, weight, key size, and key position as possible (Fig. 1).

The texting tasks were performed with participants in a sitting position on a chair with backrest and without armrests. The phone was held in one (preferred) hand while the thumb on this hand was used to activate the keys. The participants were instructed to sit upright with their back against the backrest, their elbow against their body, and without any forearm support. The participants read the text from a paper copy on a document holder placed at eye level in front of them. The participants were instructed to copy the text as correctly as possible using their normal typing speed and to type as they normally would do but without punctuations or capital letters. Similar display text sizes were used on both phones.