

Comparison of Muscle Activity Between Handwriting and Touchscreen Use in Younger Adults and the Elderly

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Abstract: We sought to compare upper extremity muscle activity between handwriting on paper and touchscreen with dominant and non-dominant hands in younger adults (age 23.90 ± 1.12) and the elderly (age 75.55 ± 5.76). Muscle activity (percent of maximum voluntary contraction) in the biceps brachii muscle, triceps brachii muscle, flexor carpi ulnaris muscle, and extensor carpi ulnaris muscle was measured using an electromyography device. As a result, our data indicate that muscle activity is lower in younger adults than the elderly. Besides, muscle activity is lower in the dominant versus non-dominant hand, and lower when writing using a touchscreen than on paper. These results can be used to support recommending touchscreens in the elderly. Also, they can be used as baseline data for comparing the performance of non-paretic side and paretic side in patients relative to the central nervous system.

Keywords: Touchscreen; Handwriting; Muscle activity; Electromyography; The elderly

1. Introduction

The muscle strength of older adults decreases by about 15 percent as aging from 50 to 70 [1]. The decreased muscle strength reduces the motor function of the joint and comes into activities of daily living as negative influence. Especially, dyskinetic deterioration of hand affects one's agility, such as strapping, buttoning, and writing [2]. Writing is considered an essential skill for ordinary living, not only a means of communication but a functional activity, which accomplishes psychological satisfaction, creativity, and academic achievement [3, 4]. In the area of occupational therapy, writing has also been used as a tool for estimating one's developmental disability, such as Parkinson's disease, and stroke [5, 6]. Therefore, a quantitative measurement for the writing ability is a significant prospect in terms of clinical application.

With the rapid development of smart devices in recent decades, touchscreen toggle and writing have become more common input mode than conventional keyboard input and practical hand-writing. Also, the development of wireless networks has contributed to the establishment of various communication environments among members of society [7]. The tablet PC is a personal computer that uses a finger-based touchscreen input mode, and it has a merit that it is suitable for a person with movement disorder because of its' simple input mode [8]. Touchscreen input is the preferred method of all ages, but older people over their age of 60 tend to prefer practical hand-writing. Besides, there is a study that notes hand coordination of elderly people decreases as aging, but that the reduction of coordination function does not significantly reduce the clarity of writing [9]. In the study using magnetic resonance imaging, it had revealed that elderly people are more likely to compensate for decreased coordination by using more brain regions than younger adults to perform practical hand-writing [10]. Therefore, to encourage the elderly to practice the touchscreen instead of practical hand-writing, the psychological aspect and bio-mechanical validity must be proved.

In terms of biomechanics, handwriting is the manipulative activity that mainly uses isotonic contraction of distal muscles with isometric contraction of the body muscle [11]. Isometric contraction of the shoulder and upper arm muscles during hand-writing provides stability for lower arm, wrist, and finger movements [12].

Decreased muscle activity at body muscle and distal muscle means it is biomechanically efficient [5, 13, 14]. To verify these biomechanical efficiencies, Electro-myographic measurements (EMG) are needed. Especially, the surface electro-myography is widely used to measure specific muscle activities non-invasively during functional activities [15]. Therefore, it is necessary to measure muscle activity through surface electromyography to compare the touchscreen input mode with practical handwriting performance.

Reference [5] demonstrated that inactivity was inversely proportional to muscle activity. Both an increase in clarity and the decrease in muscle activity apply the efficiency of performance. To describe the efficiency and inefficiency of task performance, the performance of the dominant hand and non-dominant have been compared in this study. When the dominant hand task is performed, the muscle activity of the body is relatively lower than the muscle activity of the non-dominant hand in task performance. And the muscle activity of the body muscle is more increased than muscle activity of the dominant hand when performing the non-dominant hand task [16]. This means that the dominant hand is biomechanically more efficient than non-dominant hand in terms of task performance. Therefore, when using the touchscreen to write the same words, it could be considered that the use of the touchscreen is more efficient. Also, the relationship between age and muscle use patterns can be estimated by comparing younger adults with the elderly.

The purpose of this study was to compare the muscle activity of proximal muscle and the distal muscle of hand in using touchscreen, and then estimates the potential of touch-screen as an alternate of practical handwriting.

2. Materials and Methods

2.1 Participants

This study was conducted from September to November in 2017, with 20 students enrolled in the Department of Occupational Therapy at D-University in Busan and 20 elderly people living in Busan. The mean age of the enrolled students (younger adult group) male adults was 23.90 ± 1.12 years, mean height was 171.50 ± 16.26 cm and mean body weight was 67 ± 21.21 kg. The elderly group was 10 males and 10 females, mean age was 75.55 ± 5.76 years, mean height was 160.7 ± 7.63 cm and mean weight was 61.15 ± 7.31 kg. After explaining the purpose of the study to all subjects, subjects approved participation in the study.

2.2 Experimental Tasks: Handwriting and Touchscreen

Subjects were asked to write a sentence from the writing category of Jebsen-Taylor Hand Function Test [18]. With start instruction from a researcher, subjects wrote a Korean sentence “붕어는 아가미로 숨쉰다”(Crucifixes breathe with gills) for both hands 3 times. Between each writing, subjects took a rest time for 1 minute.

Tap-book DUO (10T550-B530K, LG Electronics Inc., 2015) was used for this study. With start instruction from the researcher, subjects wrote a Korean sentence “붕어는 아가미로 숨쉰다”(Crucifixes breathe with gills) to the touchscreen device for both hands 3 times, only using their index fingers. Between each writings, subjects took a rest time for 1 minute.

2.3 Experimental Apparatus

In this study, an electromyogram device (2EM 4D-MT, Relive, Gimhae, Korea) was used to measure the muscle activity of Biceps Brachii, Triceps Brachii, Flexor Carpi Ulnaris, and Extensor Carpi Ulnaris in both practical handwriting and touchscreen use. 2EM can be applied to Bluetooth and Smart devices based on Android. So, its' data which is acquired from actual human muscles are more simply analyzed than common electromyogram device.

2.4 Muscle Selection and Measurement

The main muscles of the upper limb, which is used for practical hand-writing were selected based on reviewing previous researches [17]. The muscles measured in this study were Biceps Brachii, Triceps Brachii, Flexor Carpi Ulnaris, and Extensor Carpi Ulnaris. The skin resistance was minimized by removing hair of

region of interests and washing the skin with an alcohol solution, and then it was kept the distance between skin and electrode as 2 cm. Electrodes used in this study were attached to skins in parallel.

To measure Percent of Maximal Voluntary Contraction (%MVC), the maximum contraction of the left and right Biceps Brachii, Triceps Brachii, Flexor Carpi Ulnaris, and Extensor Carpi Ulnaris had been measured for 3 times in 5 seconds as Isometric contraction posture and then calculated as an average value. After measurement of MVC for each muscle, subjects took a rest time for 5 min to minimize fatigue of muscle, and then muscle activity was measured.

The handwriting measurement is performed while holding the pen at hand, and when the researcher gives the start signal, writing of the short Korean sentence was repeated 3 times. The touch screen measurement is performed while holding the hand on the table. When the researcher gives the start signal, only the index finger is used, and short Korean sentence writing is repeated three times with the touch screen input type keyboard as same as in the case of hand-writing.

2.5 Data Analysis

Measured data were processed by IBM SPSS Version 18.0. The significant level (α) was set to 0.5. As a statistical analysis, t-test in comparison of hand-writing and touch screen in younger adults, t-test in comparison of hand-writing and touch screen in elderly people, and independent t-test in comparison of younger adults and elderly people was performed.

3. Results

3.1 Comparing handwriting with the touchscreen in younger adults

- Dominant hand

In the case of dominant hand in young adults, touchscreen use results in decreased muscle activity of Triceps Brachii and Flexor Carpi Ulnaris significantly than the case of handwriting ($p=.00$; $p=.00$). Biceps Brachii, Extensor Carpi Ulnaris have not shown a statistically meaningful difference ($p=.14$; $p=.69$) (Table 1).

Table 1. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	13.75±11.84	24.80±12.47	14.90±6.90	31.20±10.88
Touchscreen	18.90±9.85	6.25±4.85	9.00±5.27	29.60±14.07
<i>t</i>	-1.50	6.20**	3.04**	.40

* $p<.05$; ** $p<.01$

- Non-dominant hand

In the case of younger adult's non-dominant hand, touchscreen use results in decreased muscle activity of Biceps Brachii, Triceps Brachii and Flexor Carpi Ulnaris significantly than the case of handwriting ($p=.00$; $p=.00$, $p=.04$). Extensor Carpi Ulnaris has not shown a statistically meaningful difference ($p=.14$; $p=.88$) (Table 2).

Table 2. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the non-dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Hand Writing	12.75±1.98	10.70±1.65	13.10±1.75	33.60±2.86
Touchscreen	19.25±2.43	5.55±0.83	8.90±0.81	34.25±3.20
<i>t</i>	-2.07**	2.78**	2.17*	-.15

* $p<.05$; ** $p<.01$

3.2 Comparing handwriting with the touchscreen in elderly people

- Dominant hand

In the case of dominant hand in elderly people, touchscreen use results in decreased muscle activity of Extensor Carpi Ulnaris, Triceps Brachii and Flexor Carpi Ulnaris significantly than that of the handwriting ($p=.00$; $p=.00$, $p=.00$). Biceps Brachii has not shown a statistically meaningful difference ($p=.26$) (Table 3).

Table 3. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	22.44±12.93	43.32±14.98	32.67±18.91	66.26±18.05
Touchscreen	29.24±23.53	9.81±5.47	14.55±8.87	35.02±19.25
<i>t</i>	-1.13	9.40**	3.88**	5.30**

* $p<.05$; ** $p<.01$

- Non-dominant hand

In the case of younger adult's non-dominant hand, touchscreen use results in decreased muscle activity of Extensor Carpi Ulnaris, Triceps Brachii and significantly than the case of handwriting ($p=.00$; $p=.00$). Biceps Brachii, Flexor Carpi Ulnaris have not shown a statistically meaningful difference ($p=.21$; $p=.38$) (Table 4).

Table 4. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the non-dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	24.45±18.02	13.93±8.16	19.4±11.79	55.09±16.02
Touchscreen	32.35±20.68	6.98±4.24	16.12±11.71	34.88±18.28
<i>t</i>	-1.29	3.38**	.88	3.72**

* $p<.05$; ** $p<.01$

3.3 Comparing younger adult with elderly people as for the hand-writing

- Dominant hand

In the case of handwriting in younger adult and elderly people's dominant hand, Biceps Brachii, Triceps Brachii, Flexor Carpi Ulnaris, Extensor Carpi Ulnaris have shown a significant difference ($p=.03$; $p=.00$; $p=.00$; $p=.00$) (Table 5).

Table 5. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	13.75±11.84	24.80±12.47	14.90±6.90	31.20±10.88
Touchscreen	22.44±12.93	43.32±14.98	32.67±18.91	66.26±18.05
<i>t</i>	2.22*	4.25**	3.95**	7.44**

* $p<.05$; ** $p<.01$

- Non-dominant hand

In the case of handwriting in younger adult and elderly people's non-dominant hand, Biceps Brachii, Extensor Carpi Ulnaris have shown significant difference ($p=.01$; $p=.00$). Triceps Brachii, Flexor Carpi Ulnaris have not shown a statistically meaningful difference ($p=.20$; $p=.05$) (Table 6).

Table 6. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the non-dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	12.75±1.98	10.70±1.65	13.10±1.75	33.60±2.86
Touchscreen	24.45±18.02	13.93±8.16	19.4±11.79	55.09±16.02
<i>t</i>	2.61*	1.31	1.99	4.69**

* $p < .05$; ** $p < .01$

3.4 Comparing younger adult with elderly people as for the touchscreen

- Dominant hand

In the case of handwriting in younger adult and elderly people's dominant hand, Triceps Brachii, Flexor Carpi Ulnaris have shown a significant difference ($p=.04$; $p=.02$). Biceps Brachii, Extensor Carpi Ulnaris have not shown a statistically meaningful difference ($p=.08$; $p=.32$) (Table 7).

Table 7. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	18.90±9.85	6.25±4.85	9.00±5.27	29.60±14.07
Touchscreen	29.24±23.53	9.81±5.47	14.55±8.87	35.02±19.25
<i>t</i>	1.81	2.17*	2.40*	1.02

* $p < .05$; ** $p < .01$

- Non-dominant hand

In the case of handwriting in younger adult and elderly people's non-dominant hand, Biceps Brachii, Flexor Carpi Ulnaris have shown significant difference ($p=.02$; $p=.01$). Triceps Brachii, Extensor Carpi Ulnaris have not shown a statistically meaningful difference ($p=.27$; $p=.90$) (Table 8).

Table 8. Comparing the percent of maximal voluntary contraction of younger adult's handwriting and touchscreen use in the non-dominant hand (%MVC)

	Biceps Brachii	Triceps Brachii	Flexor Carpi Ulnaris	Extensor Carpi Ulnaris
Handwriting	19.25±2.43	5.55±0.83	8.90±0.81	34.25±3.20
Touchscreen	32.35±20.68	6.98±4.24	16.12±11.71	34.88±18.28
<i>t</i>	2.51*	1.13	2.63*	0.12

* $p < .05$; ** $p < .01$

4. Discussion

In this study, we compared the muscle activity of the upper limb muscles with handwriting and touch screen of younger adults and the elderly. As a result, study showed the touch screen was relatively less active than handwriting. In the case of dominant hand, both younger adult and elderly had lower muscle activity in Triceps Brachii and Flexor Carpi Ulnaris than using touch screen. This means Triceps Brachii, which provides mobility of proximal muscle and Flexor Carpi Ulnaris, which provides mobility of distal muscle perform with less effort [5]. During the writing process, isotropic contraction of proximal muscle provides stability for the movement of the distal muscle. However, long-term isotonic contraction causes musculoskeletal disorders, so the elderly have a higher prevalence rate of musculoskeletal disorders such as neck pain, shoulder pain, and back pain than younger adults [19].

In the case of comparing non-dominant hand, the muscle activity was lower when using the touch screen for Triceps Brachii and Flexor Carpi Ulnaris in younger adults, and in Triceps Brachii and Extensor Carpi Ulnaris in the elderly. Following the result of the non-dominant hand case, the efficiency of the proximal muscle and distal muscle are higher when the touch screen is used. Therefore, if the touch screen training has limited with the right hand, performing the touch screen training with the left hand would have a similar efficiency [20]. This can be assumed that touch screen training with a non-dominant hand can replace handwriting for a hemiplegic patient whose dominant hand function has deteriorated in clinical practice.

The result of the comparing of the muscle activity of the dominant hand of younger adults and the elderly showed that the younger adult had lower muscle activity than the elderly. As for the non-dominant hand, younger adult had lower muscle activity in Triceps Brachii, Flexor Carpi Ulnaris than the elderly. This means that younger adults use distal muscle and proximal muscles more efficiently than the elderly. An isometric contraction occurs in the proximal during movement of the distal muscle, which is a pattern that uses more isometric contraction in the elderly than in younger adults. Regarding upper motor neuron injury patients, it would show a more tensional contraction pattern [21]. Therefore, the touch screen to reduce the isometric contraction of the distal muscle can be considered as a more efficient method than the handwriting in terms of Motility efficiency. Follow research will also be needed to demonstrate the effectiveness of touch screen use in patients with nervous system impairment.

The estimation with touchscreens can also be analyzed in the "activity and occupational demand" of occupational therapy implementation systems. The system is categorized into two parts, the "required body structure" aspect and the "social demand" aspect [22]. Considering the "required body structure", the elderly have a higher prevalence of musculoskeletal disorders than younger adults. As of 2017, the number of the elderly aged 65 or older in Korea is about 14% of the population, which is expected to reach 24.3% in 2030 and 40% in 2060. 53.9% of the elderly have musculoskeletal diseases such as arthritis, back pain, shoulder pain, and osteoporosis, which show a higher prevalence rate than other diseases. Also, structural changes in musculoskeletal and muscle atrophy occur exhaustion easily [23]. Musculoskeletal disorders have a negative influence on the ordinary living and social participation of the elderly [19]. Therefore, it is necessary to increase the biomechanical efficiency of performing activities of daily living. The use of a smart device such as a touch screen could be suitable. Recently, musculoskeletal disorders caused from the use of smart devices have been generally reported, however this is the result of long-term use due to convenience and immersion, and it is more efficient to use smart devices than practical work such as hand-writing.

As elderly people become accustomed to using touchscreens, their familiarity with and use of smart devices could be higher. In terms of "social demand", smart devices could be a mediator for social networks. The social network, which based on the Internet helps to resolve the loss of old age and feelings of alienation and to increase self-esteem with participation in social [24]. As the degeneration of the musculoskeletal system in the elderly's the efficiency of movement is reduced. The use of smart devices can compensate for this degeneration of the musculoskeletal system and contribute to the improvement of quality of life through participation in online society [25]. To do so, applications and social network services, which are easy to use for the elderly should expand its scale. Also, it is necessary to provide repetition education based on utilization so that elderly people become more familiar with smart devices.

The limitation of this study is that the quality of handwritten text and the screen size for touchscreen test is not considered as the variable for performing estimation [26]. In following studies, it would be possible to add an evaluation method that can take into account the qualitative aspects of handwriting, or use a touch pen instead of a hand-writing to measure more objective hand-writing. In this study, we used 10.1-inch screen. As the screen size increases, it is expected to increase the quality of performance. The age of the younger adult was limited to the 20s, and the age of the elderly ranged from 60s to 80s. In further studies, the same number of people may be assigned to each age group from age 20 to age 80. And other performance changes may be observed as increasing age.

Summarizing our study, First of all, we found that the use of touchscreen use is more efficient than that of handwriting, and therefore we suggest that complementary devices such as a touchscreen can be helpful to improve the efficiency of daily tasks for the elderly people. Second, the comparison between dominant hand and non-dominant hand can be used as a fundamental data to compare the performance of the paralysis region and the non-paralysis region in patients with central nervous system injury. Because the movement patterns of the dominant hand differ from those of the non-dominant hand, and also the movement patterns of the healthy

hand from those of paralyzed hand. When performing the task with the paralyzed side, the quality of performance is lower than the non-paralyzed side.

5. Conclusions

In our study, we compared touchscreen use with handwriting and younger adults with elderly people. The result showed as following.

- The muscle activity during touchscreen use (dominant hand: Triceps Brachii and Flexor Carpi Ulnaris; non-dominant hand: Triceps Brachii and Flexor or Extensor Carpi Ulnaris) was lower than during handwriting.
- The muscle activity of younger adults (dominant hand: Triceps Brachii and Flexor Carpi Ulnaris; non-dominant hand: Biceps Brachii, Flexor Carpi Ulnaris, Extensor Carpi Ulnaris) was lower than elderly people.

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