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Study of Thumb Muscles to Determine Optimum Screen Size for One Hand Mobile Phone Use

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Abstract: **The study was focussed on thumb movements and the associated muscles while operating mobile phones of three different sizes. The three targeted muscles were FDI (First Dorsal Interrosei), APB (Abductor Pollicis Brevis) and Extensor Digitorum muscles. An EMG was used for monitoring the muscle activities which was connected to the software installed in the computer. A total of eight subjects, four male and four female were selected for the experiment within the age range of 19 to 33 years. Subjects were given tasks like scrolling, tapping and typing which ensured maximum extension and maximum flexion of the thumb. The sequence of mobile use and tasks was randomized using Minitab statistical software. After sufficient data collection, analysis was done which concluded the project on the optimum screen size of 5.7 inches for most of the subjects.**

Keywords: **FDI (First Dorsal Interrosei), APB (Abductor Pollicis Brevis) and Extensor Digitorum muscles.**

1. INTRODUCTION

In today's world, use of mobile phones has crossed all the horizons. Mobile phones are used not only for call or texting people, but today, you could email, video call, pay your bills, play games, and do conference meeting over the mobile device. It has almost replaced the laptop for general use. Mobile phones are available in various sizes by different manufacturers. Considering the increase in the use of mobile phones, various studies have been conducted to study the effects on human health, musculoskeletal disorders, effect on eyes due to prolonged use and effect on neck due to neck flexion and extension occurring during the use of mobile phone. Along with this, many studies have been conducted to analyze the psychological effects of mobile phones in social life. Comparatively, there is not much analysis and study conducted to study the thumb muscles involved in the use of mobile phone using one hand to conclude that there is one optimum screen size which suits the use by using one hand causing less stresses and strains in the thumb muscles.

In this study, the objective was to study the thumb muscles and the related flexion and extension happening during the use of mobile phone using one hand. The analysis would give us the optimum screen size of the mobile phone which will cause less stress and strains on the associated thumb muscles i.e., FDI (First Dorsal Interrosei), APB (Abductor Pollicis Brevis) and Extensor Digitorum.

2. METHODOLOGY

2.1 Subjects: A total of eight subjects have participated in this study (4 Males and 4 Females), all of them were right handed and fall in the age range of 19 years old to 33 years old. All of the subjects were free from any musculoskeletal disorders. At the start of the experiment, the subjects were given a briefing about the project, motive behind conducting the experiment, the procedure and the instruments which will be used.

2.2 Targeted Thumb Muscles: A total of three muscles of thumb and forearm were targeted in this study, FDI (First Dorsal Interrosei), APB (Abductor Pollicis Brevis) and Extensor Digitorum muscles. All of the muscles have been accurately marked and then the EMG electrodes were placed on them.

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Figure 1. Placement of electrodes on selected muscle

2.3 Types of smart phones and screen sizes : The smart phones used in this experiment were:

- Samsung Galaxy Core 2 – 4.5 inches screen size.
- Asus Zenfone 5 – 5 inches screen size.
- Samsung Galaxy Note 4 – 5.7 inches screen size.

3. DATA COLLECTION

3.1 Maximum Voluntary Contraction:

Maximum voluntary contraction is the maximum force the subject can produce in a specific exercise. As there were three muscles in the experiment, the MVC for each muscle was calculated as follows:

- FDI (First Dorsal Interrosei): The MVC data for this muscle was collected by using hand dynamometer and asking the subject to use it in transverse plane with midpronated position of the wrist.
- APB (Abductor Pollicis Brevis): The MVC data for this muscle was collected by using pinch gauge and asking the subject to use it in transverse plane and by applying key pinch.
- Extensor Digitorum: The MVC data for this muscle was collected by using hand dynamometer and asking the subject to use it in transverse plane with midpronated position of the wrist.

3.2 EMG:

After the collection of data for MVC, EMG electrodes were placed on the selected muscles. The act was simulated in the lab room. EMG electrodes were placed on the selected muscles and the tasks were given to the subjects according to the randomized run order. The simulation was of 15 minutes duration constituting tapping game, scrolling and typing as described earlier.

4. DESIGN OF EXPERIMENT

The mobile phones of 4.5 inches, 5 inches & 5.7 inches were the three dependent factors. The independent factors were the tasks assigned, i.e., tapping game and scrolling/typing on Facebook application as they were same on all mobile phones.

4.1 Tasks:

The tasks selected for the experiment were such, which would make the thumb movements in all the directions, planes and positions. The intension behind task selection was that the thumb should go to maximum flexion as well as maximum extension. So, the tasks were as follows:

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4.1.1 Facebook application over mobile phone: We conducted a small survey in the university campus about which application do the students use most of the time. We asked the students as well as with their consent, we checked the battery monitor of the mobile phone. We found that Facebook was the application which consumed the maximum energy from the battery. So Facebook application was decided as one of the task as it involved scrolling (horizontal and vertical), typing, tapping, etc.

Figure 2. Facebook mobile Application

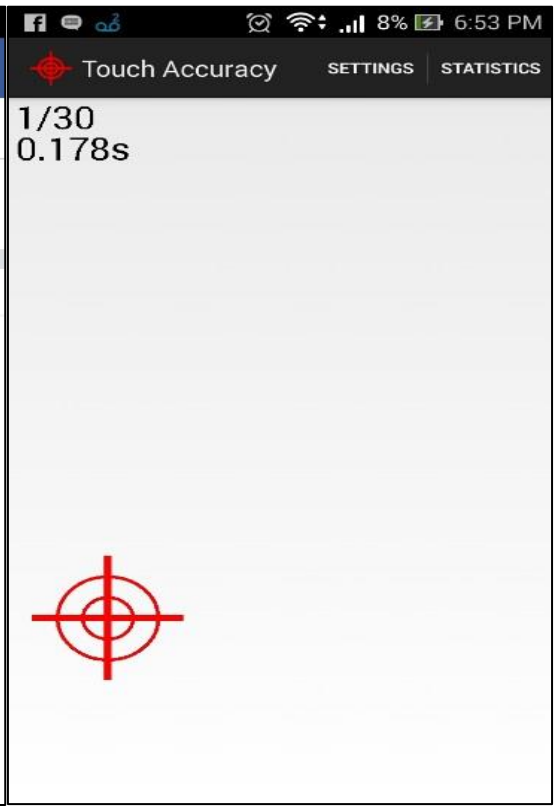

Figure 3. Tapping Game

4.1.2 Tapping game over mobile phone: The experiment required that the thumb should go to the extreme of the screen size to get the maximum flexion and maximum extension which would induce stresses and strains in the selected muscles. So, a tapping game was selected in which the user has to tap the screen as per the position of the circle on the screen.

Both the tasks were available on android platform.

4.1.3 Equipment's used for the experiment:

- Electromyography (EMG)
- Hand dynamometer
- Stop watch
- Vernier calliper
- Pinch gauge

5. STATISTICAL ANALYSIS

Data values collected from the Electromyography (EMG) electrode channels while performing the data collection (tapping task and scrolling task) and Maximum Voluntary Contraction (MVC) task were subjected to RMS value filter (Root Mean Square) using the Delsys EMG Works Analysis software (Delsys Inc., MA, USA). The data was then laid out in the Design of Experiment (DOE) format designed previously. Minitab 17 statistical analysis software (Minitab Inc., PA, USA) was used for analysing the data obtained from EMG. The factor (Mobile Device Screen Size) was given 3

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levels and the data was run using the General Linear Model or multivariate ANOVA (Analysis of Variance). The significance level of 5% was maintained throughout the entire experiment.

5.1 Muscle Responses for Male Subjects:

The ANOVA (Analysis of Variance) for all male subjects (except for one subject) differed according to hand anthropometry and adaptability. For 75% male subjects, the screen size was significantly different ($p<0.000$, ANOVA, Table 1). For the last subject, the Screen size was not significant ($p=0.986$, ANOVA, Table 1). That may be due to the fact that the experiment was conducted for the first time during that run and manual error could've played a major part. Also, the EMG electrodes might not have adhered properly to the subject's skin, which could've given us the faulty results. For all subjects, the neutral position was maintained.

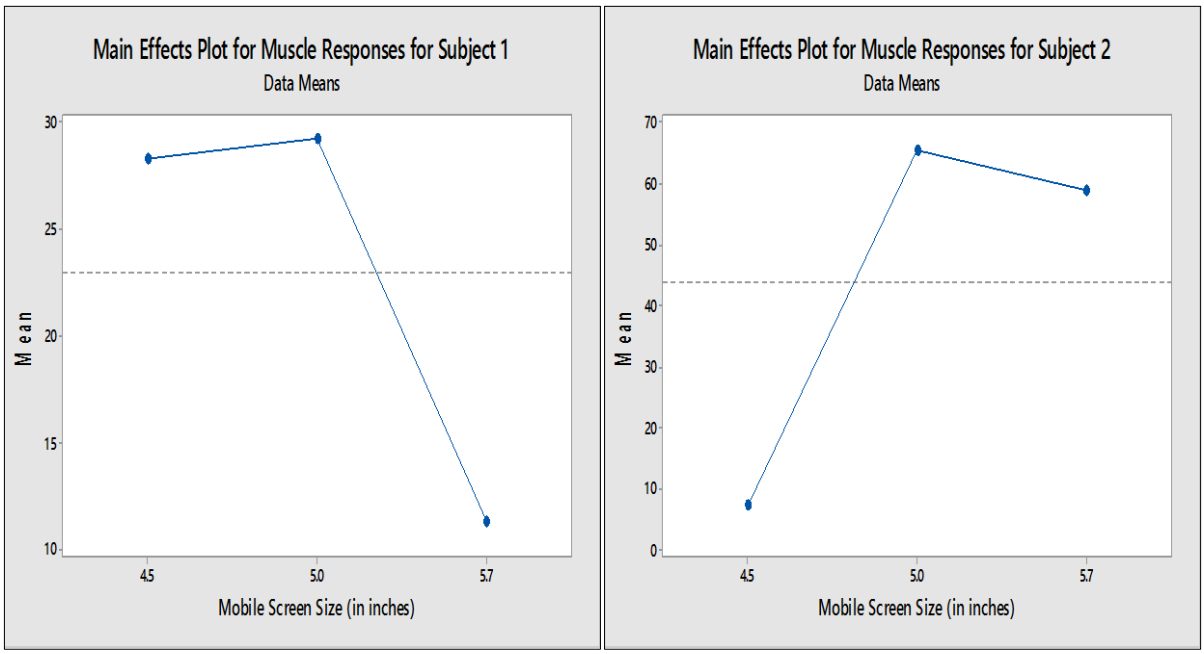
5.2 Muscle Responses for Female Subjects:

The ANOVA (Analysis of Variance) for all female subjects differed according to hand anthropometry and adaptability. For all subjects, the screen sizes significantly affected the targeted muscles ($p<0.000$, ANOVA, Table 1). For all subjects, the neutral position was maintained.

Table 1. Effect of Mobile Screen Sizes for all Test Subjects

No	Subject Name	Gender	F- Statistic	P - value	R - square value (adj.)	Recommended Screen Size
1	Subject 1	Male	81.67	0.00029	95.28%	5.7"
2	Subject 2	Male	261.6	0.000078	98.49%	4.5"
3	Subject 3	Male	374.88	0.0000053	98.94%	5"
4	Subject 4	Male	0.01	0.986	0.00%	5.7"
5	Subject 5	Female	293.1	0.000031	98.65%	5.7"
6	Subject 6	Female	92.27	0.00027	95.80%	5.7"
7	Subject 7	Female	131.7	0.00054	92.03%	5.7"
8	Subject 8	Female	1092.38	0.000089	99.63%	4.5"

The main effects plots for all the test subjects are given below. The graphs below indicate the most appropriate mobile screen sizes with respect to the test subject.



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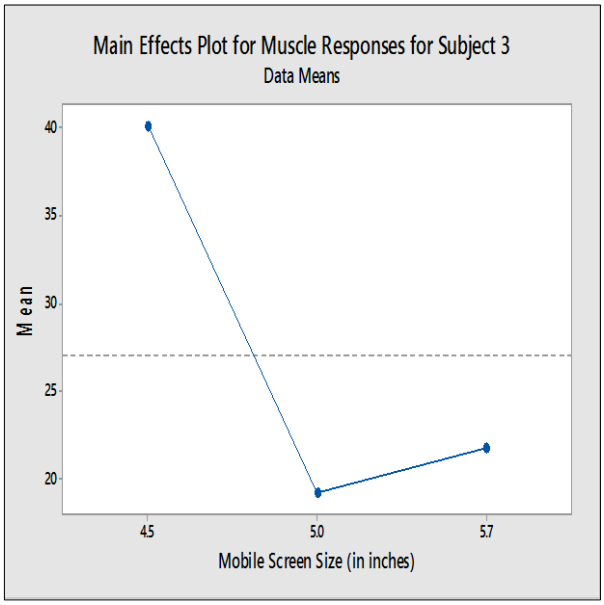

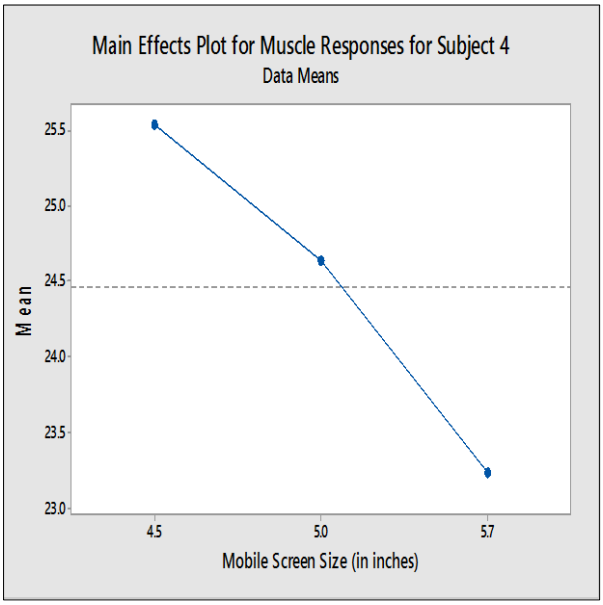

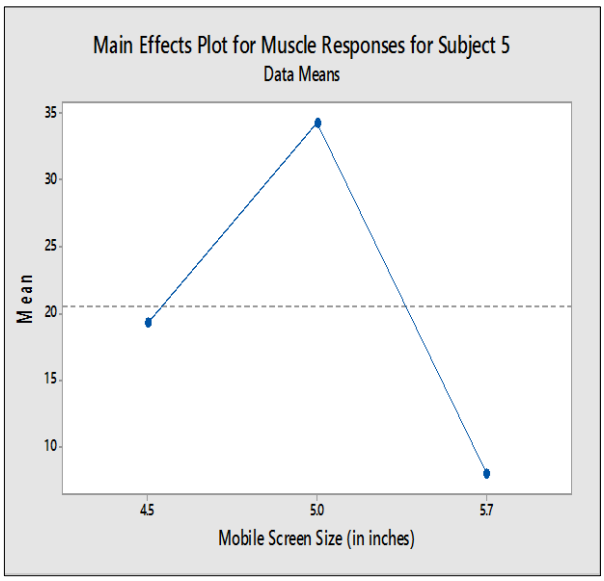

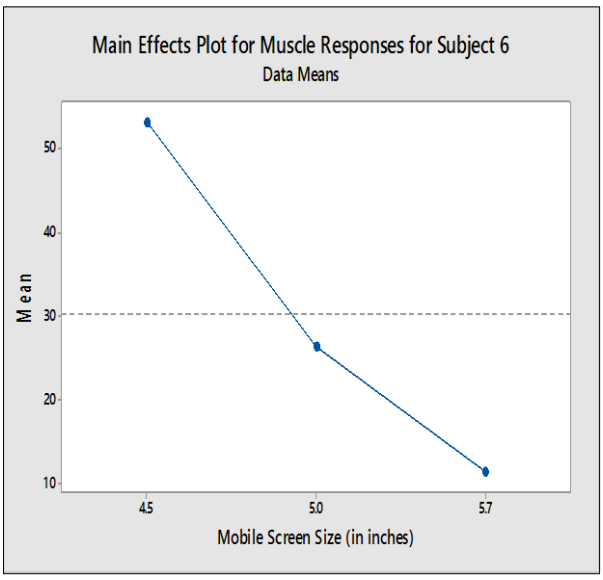

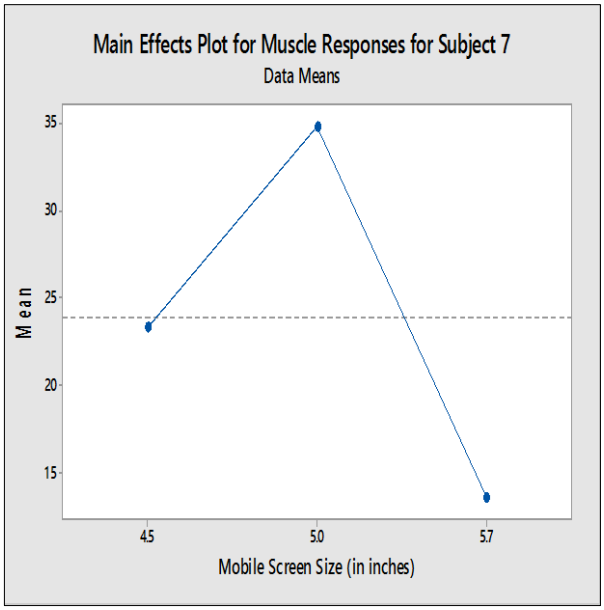

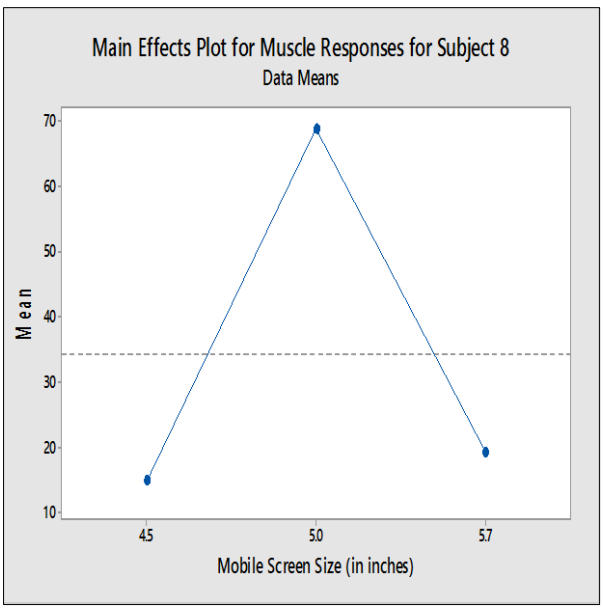

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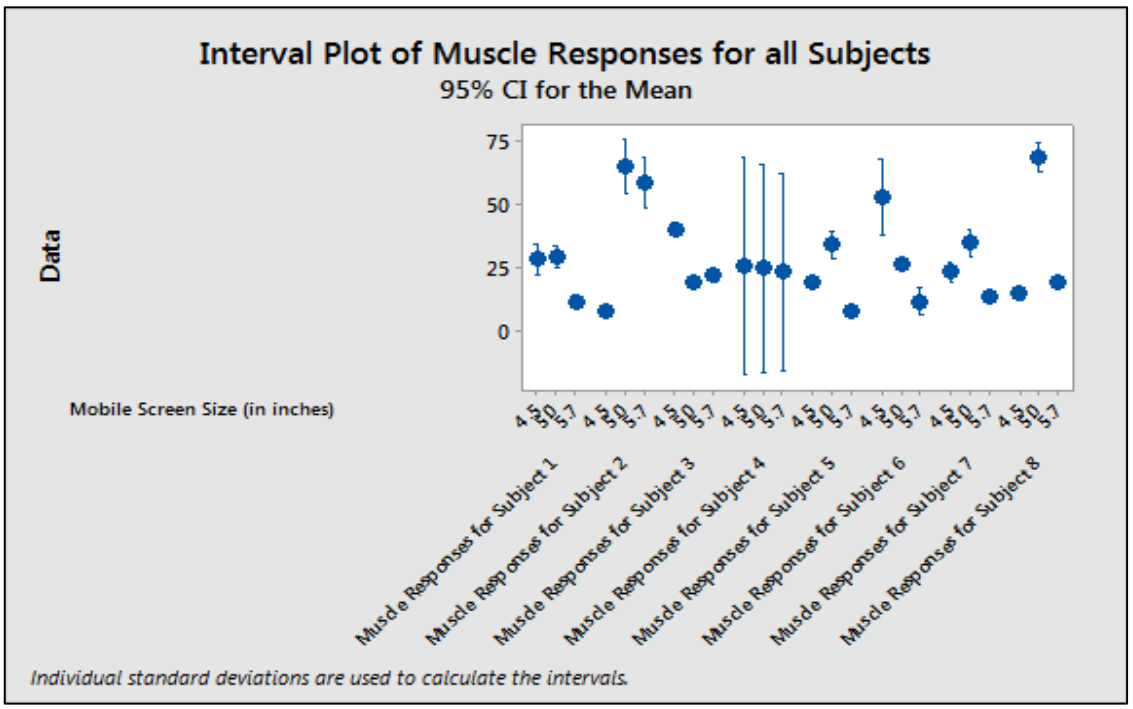

6. RESULTS AND DISCUSSIONS

The analysis demonstrates that the mobile screen size does affect the thumb muscles associated with it. From the outputs obtained, it is clear that the 5.7inch mobile phone is the optimum screen size for most of the subjects. Irrespective of the hand length, 5.7inch is the optimum size. It was also observed that subjects with minimum hand and thumb length got adapted to the bigger screen size in very short time span.

7. APPLICATIONS

As the study was not focussed only on one particular screen size, the study was generalized to a wide range of population using mobile by one hand. The results of this study could be used for designing the mobile interfaces, such as gaming, web and applications to make the interface more user-friendly. The results could also be used to study the effects on thumb muscles due to prolonged use of mobile phone.

8. FUTURE SCOPE

During the experiment, the details of the subjects such as hand anthropometry, ethnicity, and dominant hand were recorded. Some important facts were observed after the analysis. The subjects with small hand lengths had the significant mobile of screen size 5.7 inches. Whereas, some subjects with greater hand lengths had the significant screen size of 5.5 and 4.5 inches. So, the future scope will be having hand and thumb length as the main factors which would be the deciding factors for the purpose.

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