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To study the effect of handgrip exercises over hand function and pinch grip in smartphone addicted undergraduates - A randomized clinical trial

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Abstract
Background: In the past decade there has been a rapid increase in the use of mobile devices, particularly smartphones, for communication and internet browsing. Extensive use of smartphones can be linked with physical health-related problems such as pain in the wrist and neck, and can lead to musculoskeletal disorders of the hand and thumb. A repetitive stress injury, also known as overuse syndrome is where a person has his/her hand positioned in the same fashion and posture for sustained periods of time. The incidence of musculoskeletal disorders (MSD) of hand, wrist, forearm, arm and neck has been increasing all over the world due to prolonged, forceful, low amplitude, repetitive use of hand-held devices (HHDs). Therefore, in this study, with the help of Hand and Pinch strengthening exercises we are trying to improve the respective grips of the affected population.
Purpose of Study: To study the effect of Hand grip exercises over Pain, Handgrip and Pinch grip in smartphone addicted population.
Materials and Methodology: 63 participants were recruited and screened from College of Physiotherapy, Wanless Hospital, Miraj aged between 18-25 years, classified as 'addicted' according to SAS-SV and self-reported Pain (NPRS) after Smartphone use. Study design was randomized clinical trial with purposive sampling method. After taking written consent from them, their Handgrip as well as pinch grip were measured by Hand-held dynamometer and Pinch meter respectively. A 4-week Grip strengthening protocol was followed and post intervention Pain and Grip was assessed.
Results: There is a significant statistical reliable difference between the pre & post treatment values in NPRS, Hand Grip strength (HGS), Pinch strength (PS) with p-value is less than the 5% significance level (i.e., 0.001 < 0.05) in the study.
Conclusion: There is significant decrease in the NPRS values and a significant increase Hand grip and Pinch grip on dominant hand who underwent hand muscle strengthening exercises. So, the strengthening exercises are beneficial to improve HS, GS and Pain.

Keywords: smartphone addiction, pinch grip, hand grip, pain, smartphone, hand dynamometer, Theraputty

1. Introduction

In the past decade there has been a rapid increase in the use of mobile devices, particularly smartphones, for communication, gaming, internet browsing [1]. The continued decrease in the price of these devices suggests that the use of smartphones will also increase [1]. Extensive use of smartphones can be associated with physical health-related problems such as pain in the wrist and neck [2], and it also exposes hands to intense stresses that may lead to pain and musculoskeletal disorders of the hand and thumb [1]. A study has revealed that there are more than six billion smartphone users worldwide [3].

The incidence of musculoskeletal disorders (MSD) of hand, wrist, forearm, arm and neck has been increasing all over the world due to prolonged, forceful, low amplitude, repetitive use of hand-held devices (HHDs)[4]. In addition, it has been reported that university students spend, on average, > 3.5 hours/day texting, emailing, scheduling and internet browsing on their mobile phones, and frequently have pain at the base of their thumb [5].

Single hand-held smartphone use compels individuals to engage in repetitive flexion/extension of the wrist [2, 6]. The musculoskeletal disorder due to hand-held devices (HHDs) has been coined as 'SMS thumb'[8], which can cause discomfort in the hand[7] and first metacarpophalangeal arthritis [9]. Placing the thumb in these static postures likely puts unfavorable static loads on the extrinsic and intrinsic musculature of the thumb [5]. The use of single-hand mainly relies on the thumb movement to reach for the keys for pressing, whereas, the rest of the hand is used for grasping [6]. Long-term repetitive movements of the thumb and fingers are the main identified risk factor for disorder of the thumb and its musculature [4]. Till date, various studies have been conducted proving that the prolonged effects of extensive smartphone use enlarges the Median nerve, causes pain in the thumb, and decreases pinch strength and hand functions [10].

The study reported that the higher frequency smartphone users had reduced hand and pinch-grip strength compared to the lower frequency smartphone users. Another study reported no difference in pinch-grip strength between high frequency and low-frequency smartphone users among young adults [11].

The previous study on SAS-SV showed good reliability and validity for the assessment of smartphone addiction. They concluded that smartphone addiction scale-short version (SAS-SV) could be used efficiently for the evaluation of smartphone addiction in community and research areas [12].

The repetitive movement while smartphone use causes constant muscle contraction which may give rise to

microscopic injury to the muscle leading to develop musculoskeletal disorder [13]. While text messaging in static position for prolonged period of time, requires overuse of the muscles of the hand leading to pain in the hand muscles [4]. The prevalence rate of hand pain in the shaded area are A, B, C, D, E, and F is 23.6%, 29.1%, 35.3%, 23.6%, 37.7%, and 29.4% respectively [14]. Ahmed et.al. reported that 29.2% physiotherapy students had pain in their thumb due to extended smartphone use [14]. The percentage of hand pain experienced and a hand map diagram of six shaded area of the hand in shown in Fig. 1 [14].

Pinch strength is the Quantification of ability to exert pressure with the Palm and digits. An individual forcefully exerts a two or three jaw chuck grip or squeeze or pinches a dynamometer, which can be measured in SI or metric unit of pressure [15]. In a pinch grip the MCP and PIP of the fingers are flexed, the thumb is abducted and the distal joint of both are extended bringing the pad of the fingers and thumb together[11].

Grip and pinch strength is the measurable ability to exert pressure with the hand, fingers, or both. It is measured by having a patient forcefully squeeze, grip, or pinch dynamometers; results are expressed in either pounds or kilograms of pressure [15].

Grip strength was chosen as the primary endpoint because strength is an integral part of hand [16]. Hand grip strength (HGS) is crucial to the human body for controlling objects [16]. The hand grip and pinch grip is an important and basic function for various movements [17]. Object manipulation with stable hand grip is one of the most frequent movements performed in activities of daily living and occupational fields [17].

2. Materials and Methodology

2.1 Materials

2.1.1 Digital hand-held Dynamometer
2.1.2 Pinch
2.1.3 Digiflex hand exerciser
2.1.4 Theraputty
2.1.5 Data collection sheet

2.2 Methodology

1) Type of Study was Experimental study. 2) Study Design implemented was Randomized clinical trial. 3) The Study Setting included Higher educational institutions in Miraj, Sangli. 4) Sample type employed was Purposive sampling method. 5) Study population was Smartphone addicted population aged 18-25 years. 6) This study was conducted over a duration of 6 months 7) Sample size – a total of 63 participants between the age group of 18-25 years were included in the study

2.2.1 Participants

Smartphone users were assessed using Smartphone Addiction Scale-Short Version, and those with scores more than 40 and who complained moderate to severe pain on Pain assessment post smartphone usage were included in the study. Subjects with fracture or dislocation, soft tissue injuries, entrapment neuropathy, tumour, epicondylitis or infections of upper limb were excluded along with those suffering from Neurological, Cardiovascular, Respiratory and Metabolic disorders.

2.2.2 Procedure

Study design was quasi experimental, pre-test and post-test type. For the study, 63 participants were selected who were willing to participate, both male and female. Participants were explained clearly about the procedure, informed consent was provided for signing, then the assessment sheet was filled by the investigator. Dominant hand pinch strength and hand grip was measured and hand muscle strengthening exercises were followed for 4 weeks. Outcome measures were NPRS scale, Pinch meter and Hand Dynamometer. Measurement of handgrip was taken by using a Hand grip dynamometer with Kilogram of force (Kgf) as SI unit. The handgrip strengths of dominant and hand were measured with the subjects seated on a chair, hips and knees flexed at 90°, feet kept on the floor, upper limbs in adduction position, elbows at 90° and wrists in neutral position. The pinch strength (PS) is for dominant hand in which four different pinch tasks with digit pulps were performed: the first pinch movement involved index finger and thumb (PS1); the second involved third finger and thumb (PS2); the third involved fourth finger and thumb (PS3); and the fourth involved fifth finger and thumb (PS4).

2.2.3 Exercise Protocol

The supervised exercises were performed by the patient in sitting position with her feet kept on the floor, followed by a series of exercises beginning with both free and motor-coordination tasks. Next, strengthening exercises were performed by Dominant Hand (DH) by means of Digiflex hand exerciser and Theraputty as shown below, with each session lasting 35 min on average. Both intensity and load of the strengthening exercises were increased every 1 weeks by adding repetitions to each series and adjusting the Digiflex load depending on the individual capacity of each patient.

The exercise protocol prescribed is as follows[18]:

1. Motor coordination exercise consisting of finger extension on a sequential basis
2. Flexion-extension of wrist
3. Pronation-supination of wrist
4. Flexion-extension of the thumb interphalangeal joint
5. Radial and Ulnar deviation
6. Digiflex hand exerciser
7. Flexed fingers squeezing the Theraputty
8. Co-ordination movement of Flexion-extension of the fingers with the Theraputty
9. Exercises for intrinsic muscles with the Theraputty
10. Pulp to pulp finger pinch performed with all fingers pulling an elastic
11. Exercises for hand intrinsic muscles with elastic
12. Exercises for hand intrinsic muscles with modelling mass

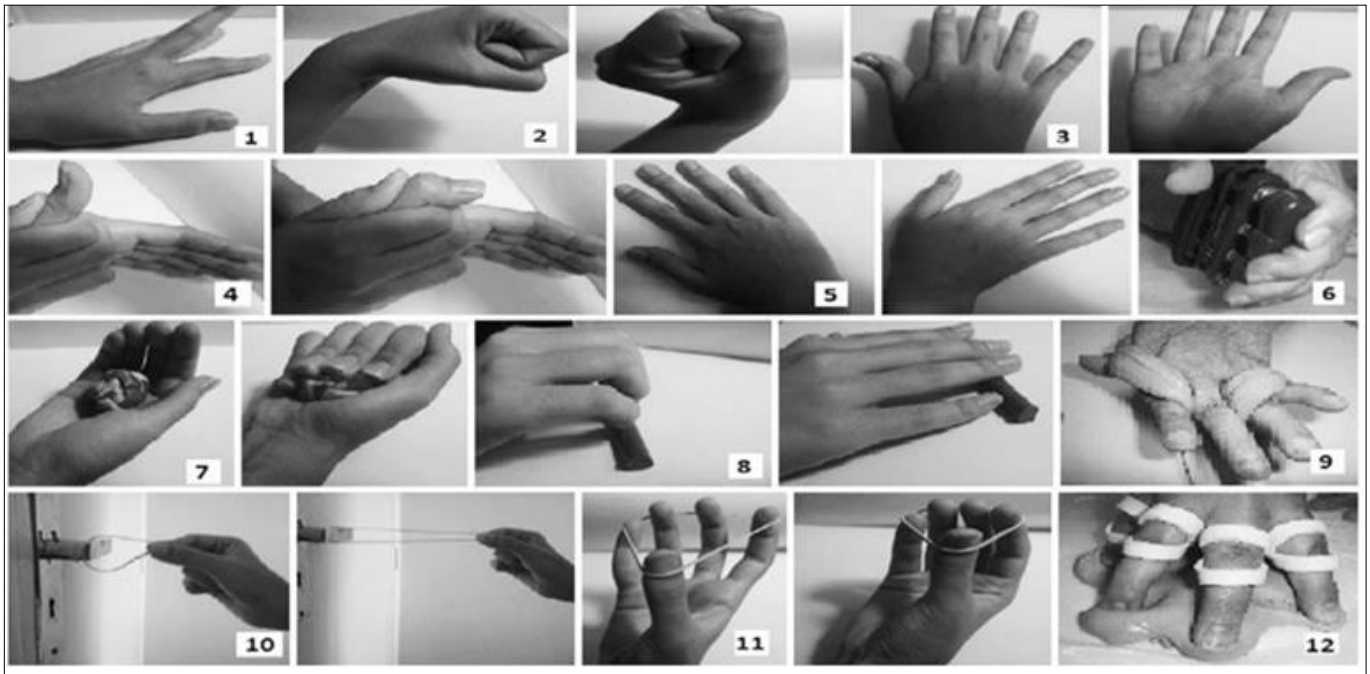


Fig. 1 Schema of exercises performed in Group 1. **1** Motor-coordination exercise consisting of finger extension on a sequential basis; **2** flexo-extension of the wrist; **3** prone-supination; **4** flexo-extension of the thumb interphalangeal joint; **5** radial and ulnar deviation; **6** digiflex hand exerciser; **7** flexed fingers squeezing the modelling mass; **8** co-ordination movement of flexo-extension of the fingers with the modelling mass; **9** exercises for intrinsic muscles with the modelling mass; **10** pulp-to-pulp finger pinch performed with all fingers pulling an elastic; **11** exercises for hand intrinsic muscles with elastic; **12** exercises for hand intrinsic muscles with modelling mass

3. Statistical Analysis

The normality testing of the data was done by Shapiro-Wilk test.

The comparison of pre and post intervention on NPRS, Hand grip and Pinch grip was done by paired sample Wilcoxon test.

Statistical analysis was performed using Statistical Package for Social Sciences [SPSS] software version 23.0.

4. Results

Descriptive Statistics

I) Comparison of pre and post intervention for NPRS by paired sample Wilcoxon test

Table 1: Shows Pre and post intervention Mean and SD for NPRS

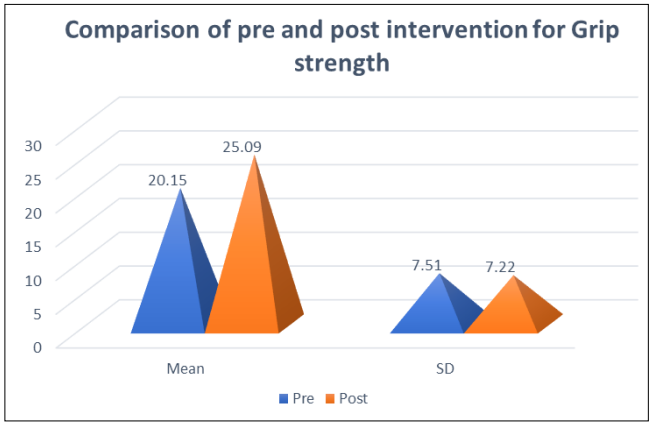
Times	Mean	SD	Mean Diff.	SD Diff.	Effect size	z-value	p-value
Pre-test	5.57	1.15	1.00	0.76	1.31	6.074	0.001*
Post-test	4.57	0.95					

*significant at 5% level

The NPRS mean value indicated changes post treatment and lower values are recorded for post treatment outcome and also the standard deviation shows the consistency with post treatment value which is equal to pre value. The effect size or Cohen's D indicates 1.31 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.

II) Comparison of pre and post intervention for Grip strength by paired sample Wilcoxon test

The Grip strength mean value indicated changes post treatment and higher values are recorded for post treatment outcome and also the standard deviation shows the consistency with post treatment value which is less than pre value. The effect size or Cohen's D indicates 4.39 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.



Graph no.1: Shows graphical presentation of Pre and Post intervention values of Mean and SD

III) Comparison of pre and post intervention for Pinch Strength 1 by paired sample Wilcoxon test

Table 2: Shows Pre and post intervention Mean and SD for PS1

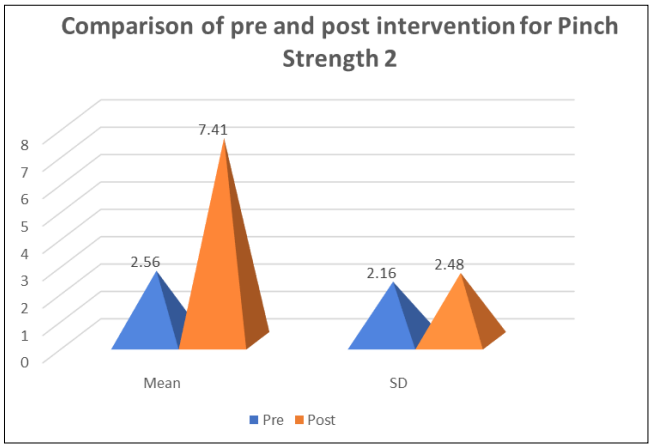
Times	Mean	SD	Mean Diff.	SD Diff.	Effect size	z-value	p-value
Pre-test	2.56	2.22	4.93	1.05	4.71	6.903	0.001*
Post-test	7.50	2.56					

*significant at 5% level

The Pinch Strength 1 mean value indicated changes post treatment and higher values are recorded for post treatment outcome and also the standard deviation shows the limited consistency with post treatment value which is more than pre value. The effect size or Cohen's D indicates 4.71 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.

IV) Comparison of pre and post intervention for Pinch Strength 2 by paired sample Wilcoxon test

The Pinch Strength 2 mean value indicated changes post treatment and higher values are recorded for post treatment outcome and also the standard deviation shows the limited consistency with post treatment value which is more than pre value. The effect size or Cohen's D indicates 4.49 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.



Graph no. 2: Shows graphical presentation of Pre and Post intervention values of Mean and SD

V) Comparison of pre and post intervention for Pinch Strength 3 by paired sample Wilcoxon test

Table 3: Shows Pre and post intervention Mean and SD for PS3

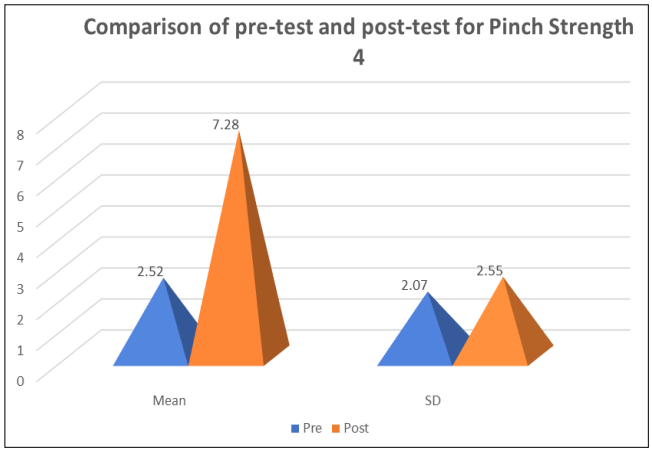
Times	Mean	SD	Mean Diff.	SD Diff.	Effect size	z-value	p-value
Pre-test	2.52	2.11	4.74	1.06	4.47	6.903	0.001*
Post-test	7.26	2.48					

*significant at 5% level

The Pinch Strength 3 mean value indicated changes post treatment and higher values are recorded for post treatment outcome and also the standard deviation shows the limited consistency with post treatment value which is more than pre value. The effect size or Cohen's D indicates 4.47 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.

VI) Comparison of pre and post intervention for Pinch Strength 4 by paired sample Wilcoxon test

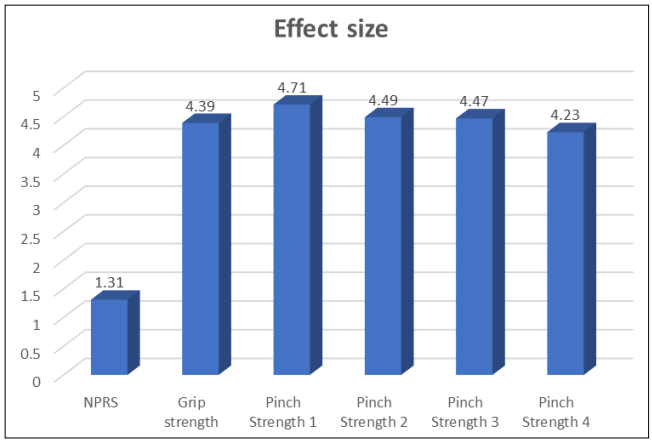
The Pinch Strength 4 mean value indicated changes post treatment and higher values are recorded for post treatment outcome and also the standard deviation shows the limited consistency with post treatment value which is more than pre value. The effect size or Cohen's D indicates 4.23 value which is assumed to be very high in effect size as per the standard parameters of reference. Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values with p-value is less than the 5% significance level (i.e. 0.001 < 0.05) in the study and therefore it justifies the improvements in health outcome post intervention.



values of Mean and SD

Graph no. 3: Shows graphical presentation of Pre and Post intervention

Comparison of Effect size of outcome variables



Graph no. 4: Shows graphical representation of the Effect size of Outcome variables

The aforementioned graph shows that the magnitude of difference between the groups or the Effect size amongst Strength is maximum for PS1 followed by PS2, PS3 and PS4. Amongst the four Pinch grips, PS1 has the highest magnitude of difference. Comparing the Pain and Strength outcome variables, Pain has lesser value of Effect size (1.31).

5. Discussion

The primary objective of this study was to investigate the efficacy of Hand grip exercises over Pain, Handgrip and Pinch grip. In this study, NPRS, grip strength and pinch strength were assessed before and after completion of Exercise protocol (4 weeks). When the subjects were screened with SAS-SV and NPRS, it was observed that smartphone addicted undergraduates had reduced Grip strength and Pinch strength in addition to experiencing mild to moderate Pain after smartphone usage. A study conducted by Ahmad Osailan (2021) demonstrated an inverse association between prolonged use of smartphones with hand-grip and pinch-grip strength. His results indicated that more prolonged use of smartphones was weakly associated with weaker hand-grip and weaker pinch-grip[19]. The results of current study reveal that increasing smart phone addiction increases the Pain, decreases hand grip strength and pinch grip strength which is consistent with previous studies[19]. The percentage of females (59%) were more than that of males (41%). The mean age taken was 21.96 years with minimum 19 years and maximum 25 years. Mean smart phone addiction score found was 42 out of total 60 with minimum 14 and maximum 57 scores. A study was conducted by Dr Sevia Chabungbam (2022) on 30 tennis players where the objective of the study was to evaluate the effects of resisted exercises (Theraputty) in the improvement of grip strength. The findings of the study revealed that exercises done with the Theraputty showed significant increase in grip strength post 3 weeks after performing the given exercises. Exercise with hand Theraputty significantly improved all the three types of pinch and grip strength. It was also previously found that the arm of an experienced tennis player was able to exert a greater force than the untrained arm. Theraputty delivered an effective resistance-based training which helps to develop a strong grip. The study concluded that, the resisted exercises were effective for improving the hand grip strength in tennis players[20]. Based on the results of the present study, the hand grip was increased by 4.94 Kilograms of force units and the four pinch grip value (PS1, PS2, PS3, PS4) were increased by 4.93, 4.85, 4.74 and 4.77 respectively, after 24 sessions (4 weeks) of Exercise protocol. The results also noted the decrease in NPRS values and significant increase in Hand grip and Pinch grip (all 4) in dominant hand. It was noted that amongst all the pinch grips PS1 had the most significant increase. In addition, the grip and pinch strength was found to be positively correlated.

Based on the results of the test analysis at 5% significance level, there is a significant statistical reliable difference between the pre & post treatment values of NPRS, Hand grip and Pinch grip with p-value is less than the 5% significance level (i.e. $0.001 < 0.05$) in the study and therefore it justifies the improvements in health outcome post intervention. Handgrip training is a form of finger and grip strength training. It can be formed into various shapes, providing a well-balanced exercise program. Theraputty delivers a simple and effective resistance-based training which helps to develop a strong, capable grip [6]. The results of the present study indicated that there was considerable improvement in grip strength with the hand exercises. A study conducted by Beachle and Earle (2000), showed that there are different proposed reasons why muscle strength increases. It is stated that grip strength may initially increase due to neuromuscular adaptation of the muscle being trained. This means that more motor units are recruited in a muscle to increase the force generation in the contracted muscle. The order in which different motor units, such as high and low threshold units, are recruited also changes with higher threshold motor units being recruited first and therefore an increased maximal force is generated in the muscle sooner. Further strength improvement during strenuous resistance training is stated to occur due to muscle hypertrophy, although it only begins to contribute meaningfully to strength increase once a change in muscle circumference has become clearly visible[21]. Another theory on muscle strength increase is due to the change in the type of muscle fibers in the strenuously resistance trained muscle, from Type 1 muscle fibers to Type 2 muscle fibers which comparatively generate more force in the muscle and have a larger circumference. This also has the effect of contributing to muscle hypertrophy. However, this is less likely to occur than a change in muscle fiber Type from Type 2B to 2A but it is not certain how much this affects the overall increase in muscle strength (Whyte, 2006)[22]. Another study done by Sathya *et al*. observed that following resistance exercise, there is a brief increase in protein synthesis within muscle. Performing exercise with increased resistance caused more protein synthesis in the muscles and increased the total volume of muscles[23]. S. Mohamed Altaf *et al* concluded that Grip strengthening exercises are more effective on Hand grip than tendon gliding exercises for smartphone users in young male adults[16]. A study conducted by Jean-Pierre' Legg (2008) concluded that there was an improvement in grip strength in the overall study population. Thus he noted that over the twelve training sessions with the Powerball™ the average grip strength of the participants in the study increased[24].

6. Conclusion

From this study two conclusions can be drawn. Firstly, there is significant decrease in the NPRS values post intervention and a significant increase Hand grip and Pinch grip post

intervention on dominant hand who underwent hand muscle strengthening exercises. Secondly, the intragroup analysis showed that, as compared to NPRS, the Hand grip and Pinch grip has comparatively more significant improvement in smartphone addicted population.

7. Suggestions

1. Larger sample size can be tested for intervention.
2. We can use more non slippery dynamometer
3. Warming up exercises can be introduced before intervention.
4. Readings can be done at the same time of the day for all the subjects
5. Older sample group can be included in this study.

8. Acknowledgement

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