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(RESEARCH ARTICLE)

A cross-sectional study of the scapular muscles' endurance in young healthy smartphone addicts and smartphone non-addicts, using scapular muscle endurance test

Hetvi Vipul Shah * and Rajashree Vishnoo Naik

Department of Physiotherapy, P.T. Teaching and Treatment Centre, LTMMC & GH, Sion, Mumbai, India.

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Abstract

Background: Mobile phones have become an indispensable part of our day-to-day lives. The increasing dependency of people on smartphones has led to smartphone addiction among people. Extended use of smartphones in awkward postures with neck bent and arms unsupported requires significant stability of the scapular muscles to produce distal hand movements. The scapular muscles are thus under constant tension to achieve stability while transferring forces and motions along the kinetic chain requiring good endurance in the long run. The present study was thus aimed to compare the scapular muscle endurance of smartphone addicts versus non - addicts.

Methodology: Smartphone Addiction Scale - Short Version (SAS - SV) scores were used to categorize 242 subjects into two groups (121 subjects in each group); Group 1 - Smartphone Addicts and Group 2 - Smartphone Non - Addicts. Scapular muscles' endurance was assessed for all the subjects using the Scapular Muscle Endurance test and the time duration was noted.

Results: Independent t-test was used to test the statistical significance of Scapular Muscle Endurance in Group 1 and Group 2. The observed difference between Group 1 and Group 2 was 24.07 seconds (p-value = 0.000).

Conclusion: The scapular muscle endurance was significantly reduced in smartphone addicts as compared to smartphone non - addicts.

Keywords: Smartphone Addiction; Poor Posture; Scapular Muscle Endurance; Scapular Muscle Endurance Test

1. Introduction

Smartphone Addiction: Today, mobile phones have become an indispensable part of our day-to-day lives. Apart from sending and receiving calls and messages, the additional features of photography, internet access, gaming applications as well as social networking applications have led to the evolution of smartphones [1]. As per statistics, the number of smartphone users worldwide has been 6,259 million by 2021 [2]. The increasing dependency of people on smartphones, especially college students and young adults due to their handy features and convenient accessibility, may indicate the development of addiction in those people [3]. It is seldom the phone that creates the obligation but rather the gaming and social networking applications that create the urge to use the phone repeatedly [4]. Smartphones can be problematic when used excessively. For example, it can interfere with daily work, tends to decrease real social life interactions with people around, it creates difficulties in concentrating on work, relationship problems, etc. It also causes physical health issues such as pain in the wrists or back of the neck due to poor posture [5].

* Corresponding author: Hetvi Vipul Shah

Scapular Kinematics and Kinetics: The scapula is the principal component involving the upper extremities as it promotes a connection between the central segments of the body and the upper distal segments. The upper and lower trapezius muscles along with the serratus anterior muscle are the pre-eminent contributors to the scapular stability and mobility. The activation of the lower trapezius muscle plays a vital role in the stability of the arm in the overhead position and in lowering the arm from a position of maximum elevation. The rhomboids work with the trapezius in stabilizing the scapula, thereby directing medial and lateral scapular translation. The steady force couples for scapular stabilization include the upper and lower trapezius muscles working in synchrony with the rhomboid muscles, paired with the serratus anterior muscle [6, 7]. The scapula acts as a link between the trunk and the arm, forming a part of the kinetic chain. The kinetic chain signifies the mechanical linkages of the body segments that allow for the sequential transfer of forces and motions. Any disruption or break in this kinetic chain, such as inadequate muscle strength or endurance can lead to impaired function or injury [8, 9]. Considering this kinetic chain, even when there is no direct participation of the shoulder during a movement, there is increased activity of the major shoulder and scapular stabilizers during fine movements of the hand. While texting and gaming on smartphones, the movements come from the forearm, wrist and fingers while the shoulder provides the power. Thus, the stability of the shoulder girdle and scapula is required for the activity of distal parts such as fingers, wrists and elbows. This increased activity of major shoulder stabilizers during fine hand movements results from the co-activation of proximal and distal muscles [10, 11, 12, 13]. Thus, while using smartphones for prolonged periods, the scapular muscles are under constant tension to achieve stability while transferring forces and motions along the kinetic chain requiring good endurance in the long run.

Effect of Smartphone Addiction on Posture: Smartphone addiction is known to have a substantial impact on posture. Smartphone use in a static position and with arms unsupported elicits poor alignment of the neck and the shoulders. The small monitors of the smartphones that are usually held downward near the laps, require the users to bend their heads to see the screens, giving rise to faulty postures such as the forward head posture, rounded shoulders and scapular dyskinesis [14], increasing activity in the neck extensor muscles overloading the neck and shoulders, bringing about muscle fatigue, decreased work capacity and affecting the musculoskeletal system [15]. Forward shoulder posture has been linked to muscle imbalance in the form of shortening of the anterior shoulder muscles like the pectoralis minor and major, serratus anterior along with the upper trapezius and lengthening of the posterior shoulder muscles, middle as well as lower trapezius and rhomboids [16]. Smartphone use demands stabilization by the shoulder and scapular muscles to perform movements of the elbows, wrists and hands distally based on the kinetic chain perspective [10]. This demands an increased endurance level of the scapular muscles to be able to function as a link in proximal-to-distal sequencing of velocity, energy, and forces of shoulder function [6]. Measurement of submaximal static muscle endurance entails assessment of muscular capacity [15]. However, there has been very limited research on the scapular muscle endurance in smartphone addicts. This research work was thus focused on understanding the scapular muscles' endurance levels in smartphone addicts versus smartphone non - addicts.

2. Materials and methods

The Institutional Ethics Committee approval was taken before proceeding with the study. The subjects were selected by the Convenience Sampling Method.

An informed consent was taken from all the subjects and the procedure was properly explained.

Cognitive impairments among the subjects were ruled out using Mini - Cog Tool. The subjects were included based on the remaining selection criteria. Based on the SAS - SV score, the subjects were categorized into Group 1 or Group 2.

2.1. Inclusion Criteria

(1) Asymptomatic young adults between the age group 18 - 25 years. (2) Individuals using smartphones for at least 1 year.

- Group 1: Smartphone Addicts - Subjects scoring more than the cut-off values on the Smartphone Addiction Scale - Short Version (SAS - SV).
- Group 2: Smartphone Non - Addicts - Subjects scoring less than or equal to the cut-off values on the Smartphone Addiction Scale - Short Version (SAS - SV).

2.2. Exclusion Criteria

(1) Individuals undergoing structured fitness training. (2) Individuals with clinically diagnosed impaired cognition. (3) Those involved in occupations requiring continuous stress on the neck/ shoulder girdle/ upper extremities in the past 6 months. Example: carpenter, wall painter, electrician.

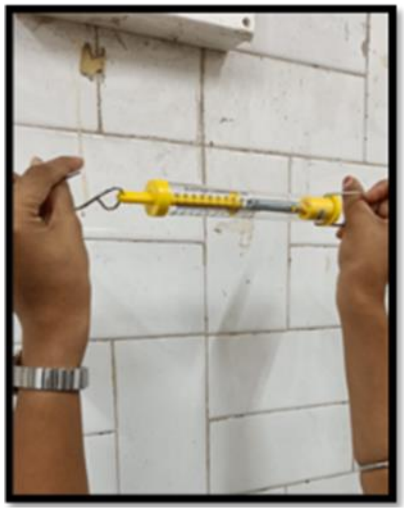
Smartphone Addiction Scale - Short Version (SAS - SV) [17, 18]:

Permission had been taken from the developer for the use of the scale for the research. Like the Mini - Cog test, Smartphone Addiction Scale - Short Version (SAS - SV) was translated into Hindi and Marathi languages and face validity was done before its use in the study. Subjects fulfilling the inclusion and exclusion criteria were provided with the SAS - SV. The subjects were then divided into two groups: Group 1 - Smartphone Addicts and Group 2 - Smartphone Non - Addicts based on the SAS - SV scores. The subjects scoring greater than the cut-off values were classified into group 1 as smartphone addicts and the others as smartphone non - addicts. The cut-off values were SAS - SV score > 31 for boys and SAS - SV score > 33 for girls. 121 subjects were taken in each group. The scores of each item were added to produce the final SAS - SV score.

Subjects in both groups were asked to perform the Scapular Muscle Endurance Test.

Scapular Muscle Endurance Test [19]:

The scapular muscle endurance test was based on the strengthening exercise for the shoulder girdle muscles as described by Shirley Sahrmann. This test assessed the endurance of the trapezius and serratus anterior muscles. For this test, the subjects were asked to stand facing the wall with their shoulders and elbows flexed to 90 degrees. There was no contact between the subject's arms and the wall. The subjects were then told to hold a spring balance [20] between their hands and an adjustable spacer (appropriate size stick from 10 sticks of different sizes ranging from 18 - 36 centimeters) between their elbows to maintain the test position.

		
Figure 1 Subject being prepared to perform the Scapular Muscle Endurance Test	**Figure 2** Arm position during the Scapular Muscle Endurance Test	**Figure 3** Hand position for holding the spring balance while performing the Scapular Muscle Endurance Test

The scapulae were neutrally positioned. The subject was then asked to externally rotate the shoulders to attain a 1-kg load and to maintain this force, which was displayed on the spring balance. The endpoint of the test was when the subject was unable to maintain the resistance and dropped the adjustable spacer, failed to maintain 90 degrees of shoulder flexion or reported an unacceptable increase in discomfort. The time for which the subject was able to maintain the test position was recorded using a stopwatch. External rotation of the shoulder in the test position has been shown to produce co -activation of the trapezius and serratus anterior muscles, which has been suggested to be important in the control of scapula orientation and posture [21, 22, 23, 24].

Figure (4) Figure (5) Figure (6)

Figure 4, 5, 6 Subject performing the Scapular Muscle Endurance Test

3. Results

242 subjects were assessed and divided into two groups (Group 1/ Group 2) by Convenience Sampling technique based on SAS - SV score cut-off values. Subjects in Group 1 (N = 121) were smartphone addicts and in Group 2 (N = 121) were smartphone non - addicts. Subjects in both groups 1 and 2 performed the scapular muscle endurance test and the duration was recorded for each subject in seconds.

- All the data analysis was performed using IBM SPSS statistical software (version 26).
- Results were analyzed keeping a 95% confidence interval and significance at a p-value of 0.05.
- To compare the scapular endurance between Groups 1 and 2, an Independent t - test was used.

Table 1a Group Statistics of Age for Group 1 and Group 2

Group Statistics					
	Group	N	Mean	Standard Deviation	Std. Error Mean
Age	Group 1	121	21.45	2.168	0.197
	Group 2	121	20.90	2.170	0.197
*Group 1 - smartphone addicts Group 2 - smartphone non - addicts					

Interpretation: For age, in Group 1, the mean age of smartphone addicts was 21.45 years with a Standard Deviation (SD) of 2.168 years and for Group 2, the mean age of smartphone non - addicts was 20.90 years with SD of 2.170 years.

Table 1b Independent t-test to determine the difference of age between Group 1 and Group 2

Independent t-test									
Age	**Levene's Test for Equality of Variances**		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Group 1	0.240	0.624	1.956	240	0.052	0.545	0.279	-0.004	1.095
Group 2			1.956	240	0.052	0.545	0.279	-0.004	1.095
* Group 1 - smartphone addicts Group 2 - smartphone non - addicts									

Interpretation: By the statistical comparison of age for the two groups 1 and 2 using Independent t-test, the observed difference in mean age between Group 1 and Group 2 was 0.545 years with the lower limit of 0.004 years and upper limit of 1.095 years. The p-value is statistically insignificant as p = 0.052 which is greater than 0.05 (p > 0.05) suggesting that both the groups were comparable by age (at 95% confidence interval).

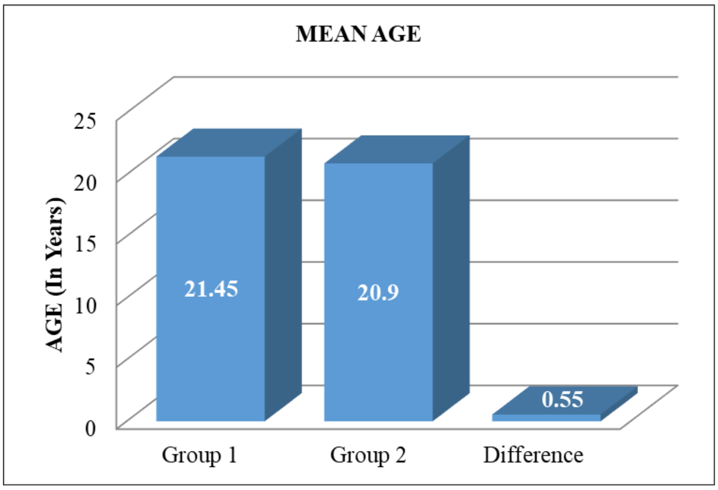


Figure 7 Representing the mean age between Group 1 and Group 2. Statistical analysis shows that both the groups are comparable (p > 0.05).

Table 2 Chi-square test to determine the difference of Gender distribution between Group 1 and Group 2

Gender Group Cross - Tabulation						
			GROUP		Total	Test Statistics
			Group 1	Group 2		
GENDER	Females	Count	75	83	158	Chi square = 1.167 p-value = 0.280
		% within Group	62.0%	68.6%	65.3%	
	Males	Count	46	38	84	

		% within Group	38.0%	31.4%	34.7%	
Total		Count	121	121	242	
		% within Group	100.0%	100.0%	100.0%	
* Group 1 - smartphone addicts Group 2 - smartphone non - addicts						

Interpretation: The total number of males in Group 1 and Group 2 were 46 and 38 respectively which made up 38.0% and 31.4% respectively within each group. The total number of females in Group 1 and Group 2 were 75 and 83 respectively which accounted for 62.0% and 68.6% respectively within each group. No statistical difference was seen between both the groups on analysis using the Chi-square test since p-value was found to be 0.280 which is greater than 0.05 ($p > 0.05$). This suggested that the gender distribution amongst males and females was comparable in both the groups and this was by mere chance.

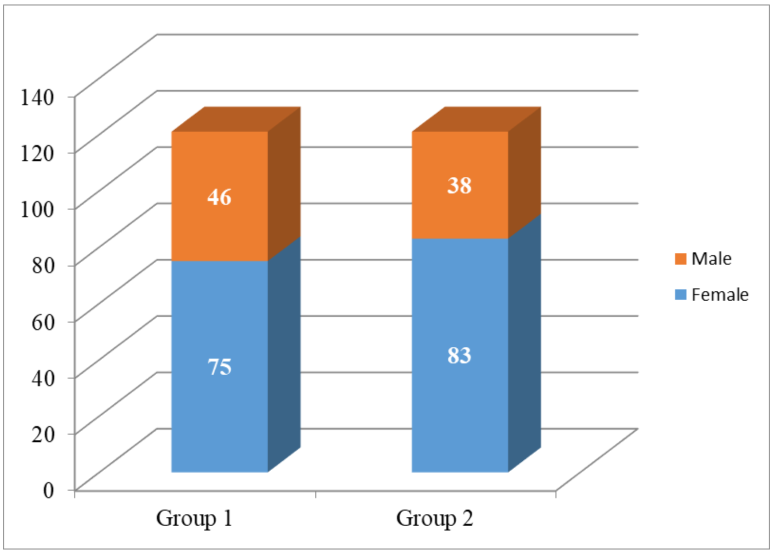


Figure 8 Representing the comparison of Gender distribution between Group 1 and Group 2. Statistical analysis shows that both the groups are comparable by Gender ($p > 0.05$).

Table 3a Descriptive statistics for Scapular Muscle Endurance in Group 1 and Group 2

Group Statistics					
	Group	N	Mean	Standard Deviation	Standard Error Mean
Endurance	Group 1	121	44.9229	16.47970	1.49815
	Group 2	121	68.9965	28.89064	2.62642
* Group 1 - smartphone addicts Group 2 - smartphone non - addicts					

Interpretation: For Group 1 the mean endurance is 44.92 seconds with SD of 16.48 seconds and for Group 2 these values are 69.0 seconds and 28.89 seconds respectively.

Table 3b Independent t-test to test the statistical significance of Scapular Muscle Endurance in Group 1 and Group 2

Independent t-test									
Endurance	**Levene's Test for Equality of Variances**		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	27.261	.000	-7.962	240	.000	-24.074	3.02367	-30.029	-18.117
Equal variances not assumed			-7.962	190.61	.000	-24.073	3.02367	-30.038	-18.109

Interpretation: The observed difference between Group 1 and Group 2 was 24.07 seconds and the difference ranges from 18.11 to 30.03. This difference was statistically significant as p-value was found to be 0.000 which is less than 0.05 ($p < 0.05$). This suggests that higher scapular muscle endurance is observed in Group 2 as compared to group 1.

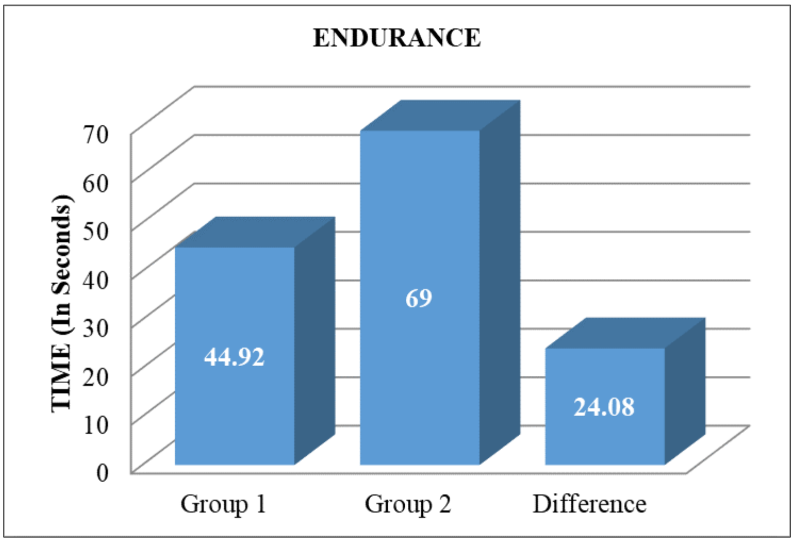


Figure 9 Representing the comparison of scapular muscles' endurance between Group 1 and Group 2. Statistical analysis shows a significant difference between both the groups ($p = 0.000$).

4. Discussion

The present study was conducted to analyze the influence of smartphone addiction on scapular muscles' endurance. Our study incorporated 242 young healthy subjects. The subjects were categorized into two groups based on their smartphone addiction scores, such that 121 subjects were included in each group: Group 1 comprising smartphone addicts and Group 2 comprising smartphone non - addicts. J. A. Oslan et al, in their meta-analysis, have found that adolescents and young adults between the age group of 15 - 35 years usually tend to have the highest screen time and smartphone ownership rates [25]. That being the case, we decided to choose subjects in the age group of 18 - 25 years. Each subject in both the groups performed the scapular muscle endurance test and the time was recorded in seconds.

As observed in Table 1a, Table 1b and Figure (7), the mean age of Group 1 was 21.45 years with a standard deviation of 2.168 years, whereas the mean age of Group 2 was 20.90 years with a standard deviation of 2.170 years. The subjects in these two groups did not show any statistically significant difference ($p > 0.05$) in their age (in years) as analyzed using an independent t-test. This shows that age is homogeneous between the participants of the two groups suggesting that the ages in both the groups were comparable. This indicates that this parameter of scapular muscles' endurance which had a possibility of influencing the results did not influence our study [26, 27].

Table 2 and Figure (8) display the gender distribution of subjects in both groups. The number of males in Group 1 and Group 2 were 46 and 38 respectively which made up 38.0% and 31.4% respectively within each group. The number of females in Group 1 and Group 2 were 75 and 83 respectively which accounted for 62.0% and 68.6% respectively within each group. The gender distribution between the two groups did not show any statistical significance ($p > 0.05$) as evaluated using Chi - square test. This suggests that subjects in both groups were comparable concerning gender distribution and this was by mere chance.

Horobeanu et al concluded in their study that the performance values of shoulder rotator muscles in males were about 50% higher than in females [28]. However, our findings are not in line with this study as despite more number of males in Group 1 (smartphone addicts), the scapular muscle endurance values were found to be lesser in that group as compared to Group 2 (smartphone non - addicts), probably the cause being smartphone addiction.

Table 3a, Table 3b and Figure (9) show the statistics for scapular muscle endurance in Group 1 and Group 2. For the scapular muscle endurance test, the subjects were expected to stand facing the wall with shoulders and elbows flexed to 90 degrees. A spring balance was given in their hands and they were asked to pull the ends of the spring balance to maintain a constant load of 1 kg with a stick of suitable size placed between the elbows. The subjects were asked to hold the position for as long as possible and the time was recorded in seconds. This hold time recorded in seconds was used as the measure of endurance [19]. The mean endurance for Group 1 was 44.92 seconds with a standard deviation of 16.48 seconds. Similarly, the values for Group 2 were 69.0 seconds and 28.89 seconds respectively. Independent t-test was used to compare the scapular muscle endurance between the two groups and the observed difference between the two groups was statistically significant ($p < 0.05$), suggesting that the scapular muscle endurance was higher in smartphone non - addicts as compared to smartphone addicts.

The increased popularity of smartphone use has led to many problems due to overuse [5, 29, 30, 31, 32]. Smartphones generally have small monitors. Most individuals use it in static postures with the head shifted forwards, neck bent and arms unsupported holding the smartphones near the waist or laps in sitting or standing positions [4, 15, 33, 34]. Users frequently hold the device with a single hand, forcing just the thumb to utilize the keypad while some of them tend to hold the smartphone with one hand and touch the screen with the other hand [34].

According to the kinetic chain perspective, all the segments in the extremities are related kinematically. It is assumed that even when the hand is in a neutral position, there is increased activity of major shoulder stabilizers resulting from co-activation of proximal and distal muscles. Thus muscle activity of proximal parts is necessary for activation of distal parts [10, 11, 12, 13].

Proximal joints generally perform the overall movement pattern of the arm, while distal joints primarily fine-tune movements to achieve the task goal [10, 11]. Smartphone addiction mainly revolves around using social networking applications for texting and playing games on smartphones. During these activities, most of the movements come from the forearm while the shoulder provides the power with movement occurring at the fingers and wrist [10]. Smartphone addicts usually spend longer hours on their smartphones which demands constant use of the handheld device associated with sustained activity of the scapular and shoulder girdle muscles to provide the proximal stability. This can probably lead to muscle fatigue and lead to reduced muscle endurance.

Fatigue refers to a decrease in force in response to the repeated intense contractile activity of the muscle. It is described as a transient decrease in the force-generating capacity of the muscle, which distinguishes this type of contractile failure from the longer-lasting effects of muscle damage [35]. The scapular muscle endurance test used in our study mainly focuses on the endurance of the trapezius and the serratus anterior muscles. The human trapezius muscle is composed of type I as well as type II fibres in different areas of the muscle, reflecting different functional demands on the trapezius muscle in various head, neck, and shoulder movements [36].

However, the serratus anterior muscle comprises mainly fast twitch muscle fibres increasing its vulnerability to age related atrophy [37]. These muscles are under constant tension to maintain the stability of the scapula and the shoulder girdle for promoting movement at the distal joints.

In such circumstances where the muscles are working at low intensity but for longer durations, fatigue occurs due to glycogen depletion and central fatigue mechanisms. Central fatigue implies the reduction in force due to reduced recruitment by the central nervous system, whereas peripheral fatigue involves any changes within the muscle that lead to a reduced response to neural excitation. According to Feher and Joseph, group III (thinly myelinated fibres) and group IV (unmyelinated fibres) carry afferent information from muscle fibres to the dorsal horn of the spinal cord and from there affect both spinal and supraspinal sites. The output of group III and IV fibres increases during exercise and stays increased while the muscles are under tension. Input from these fibres increases the blood flow to active muscles. This assures nutrient supply to the working tissues and helps prevent peripheral fatigue in these muscles. The output of group III and IV fibres appears to inhibit spinal motor neurons and, presumably, it is the group III and IV supraspinal effects that give rise to the subjective perception of fatigue [38, 39].

The performance during long duration but submaximal workloads depends on the size of the glycogen stores. Fatigue occurs when glycogen levels fall but before they go as low as zero. This led to the hypothesis of the 'glycogen shuttle' in which glycogenolysis is necessary to maintain ATP during contraction, and it is resynthesized during the rest period between contractions. When glycogen levels become low, it can no longer sustain ATP levels during contraction and the force of contraction reduces, even though glycogen is not completely used up. Thus low intensity, long duration exercise causes fatigue through glycogen depletion [38, 39].

Apart from that accumulation of metabolites such as lactic acid and magnesium ions from the biochemical reactions occurring in the cells, can also induce fatigue by interfering with the release of calcium ions from the sarcoplasmic reticulum or through a reduction in the sensitivity of troponin to calcium ions [35].

The fact that smartphone tasks require the users to stare sharply downward with arms in front to read the screen makes the head move forward. The maintenance of this position decreases the cervical lordosis in the lower cervical vertebrae and creates a kyphosis in the upper thoracic vertebrae to maintain balance, giving rise to a forward head posture [4]. According to Singla and Veqar, forward head posture is associated with shortened levator scapulae, sternocleidomastoids, upper trapezius, and posterior cervical spine muscles and lengthened scapular retractors such as the middle trapezius [4, 16]. Significant increases were observed in the upper trapezius and lower trapezius muscle activity along with reduced serratus anterior activation in forward head posture versus neutral head posture during isometric shoulder flexion as studied by J.-H. Weon et al. [40] Eitivipart et al., 2018 found that when using a smartphone, muscle activity increased and the pain pressure threshold reduced in the shoulder and forearm region. This is because increased muscle activity is linked to increased muscle fatigue and a lower pain pressure threshold [23]. Increased muscle activation to maintain a certain posture can result in localized muscle fatigue and may worsen signs and symptoms of repetitive injury in the cervical and shoulder regions [47]. Thus, forward head posture caused due to prolonged smartphone use can be attributed as one of the possible factors for lower scapular muscle performance in smartphone addicts as compared to the non - addicts.

Holding the smartphones near the waist or lap urges the user to bend the neck causing reduced lordosis in the lower cervical spine along with increased posterior curve in the upper thoracic spine [4]. Using smartphones also requires the shoulders to be adducted and internally rotated with the hands reaching the midline to use smartphone applications for texting or playing games further adding to the protraction and anterior tilting of the scapula. Eitivipart et al., 2018 proposed that abnormal scapular tilt can cause rounded shoulder posture by causing irregular lower trapezius and serratus anterior positioning [31]. The use of smartphones while sitting causes the typical rounded shoulders [14]. The scapular index is a measure of the degree of rounded shoulders. It is the ratio of the distance from the midpoint of the sternal notch to the medial aspect of the coracoid process (the length of the chest side) and the horizontal distance from the posterolateral angle of the acromion to the thoracic spine (the length of the backside). The lower the scapular index the higher the degree of rounded shoulders. It has been noticed in various studies that a lower scapular index has been positively correlated with smartphone addiction, thus implying that forwarded shoulder posture / protracted shoulders are commonly seen in subjects exposed to long hours of smartphone use [14, 41]. Forward shoulder posture could give rise to muscle imbalance in the form of shortening of the anterior shoulder muscles such as the pectoralis minor and major, serratus anterior, and upper trapezius and lengthening of the posterior shoulder muscles, middle and lower trapezius and rhomboids [16].

The strength of muscle contraction is based on the number of cross - links made between the actin and myosin chains within the sarcomeres. Any alterations in the actin and myosin chains also influence the muscle's force of contraction. The maximum number of cross - links between actin and myosin myofilaments leading to maximum contractile force in the sarcomere occurs when the full length of the actin strands at each end of the sarcomere are in contact with the myosin molecule. This length is operationally defined as the resting length of the muscle. The sarcomere can shorten slightly from this point, maintaining the maximum cross - linkages. However, increased shortening causes the actin strands to interfere with each other, thus reducing the number of available sites for cross - bridge formation. This eventually decreases the force of contraction. Similarly, when the sarcomere is stretched from the resting length, the contact between the actin cross - links which can be made again diminishes, thus decreasing the force of contraction [42]. Faulty postures attained during prolonged smartphone use cause a similar change in the muscle lengths leading to decreased force of muscle contraction which possibly demands increased muscle activity leading to early fatiguability [31].

5. Conclusion

Our study concludes that there was a significant difference in the scapular muscle endurance between young healthy smartphone addicts and smartphone non - addicts.

The scapular muscle endurance was significantly reduced in smartphone addicts as compared to smartphone non - addicts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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