Is There a Difference in Pulmonary Functions and Craniovertebral Angle Among Adolescents Based on Their Smartphone Usage Time? A Cross-Sectional Study

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KEYWORDS

Smartphones, Craniovertebral Angle, Pulmonary Function, Adolescent.

ABSTRACT

Background: People who use smartphones for extended periods run the risk of developing cumulative trauma. The purpose of this study was to examine the impact of using smartphones on pulmonary function and craniovertebral angle (CVA) among adolescents and compare addicted and nonaddicted ones. **Methods:** A cross-sectional study was carried out on 71 boys and 57 girls; Participants were categorized into two groups according to their scores on the Smartphone Addiction Scale-Short Version (SAS-SV) for adolescents. Addicted group (score > 32, n =37 M /27 F) while non-addicted group (score ≤ 32, n = 34 M/30 F). The outcome variables were craniovertebral angle (CVA), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and the FEV1/FVC ratio. **Results:** The findings of this study suggest a moderately strong negative relationship between smartphone addiction and CVA, as well as a weak negative association between smartphone addiction and the FEV1/FVC ratio. However, no significant correlations were found between smartphone addiction and FEV1 ($r = -0.128$, $p = 0.149$) or FVC ($r = -0.019$, $p = 0.835$). **Conclusion:** using smartphones for a long time had a bad impact on CVA and pulmonary function in adolescents.

1. Introduction

Smartphones are little computers that increase communication by utilizing Internet services. Nowadays, cell phones are among the most popular technological products. Cell phones are used for various purposes, including communication, access to social networking sites, informational Web searches, entertainment (such as games and movies), and education. Throughout the COVID-19 epidemic, these developments made it possible to continue with career and educational pursuits. This comes with the curse of technology, and young adults who were raised in the technological age are known as "digital natives"[1,2].

Cell phones have become an integral part of our lives due to their quick rise in prevalence [2]. Although smartphones are essential to our everyday lives, there are drawbacks and benefits to their increasing use[3]. Addiction today encompasses not only drug or chemical misuse but even smartphone addiction, which is categorized as behavioral addiction. Mostly observed in adolescent age groups [4]. Various disorders can be categorized as symptoms of smartphone addiction, these disorders include psychological disorders, such as sleep disturbances, personality disorders, musculoskeletal disorders like carpal tunnel syndrome, and other physiological disorders like migraine headaches and dry eyes[5].

According to the Egypt Business Directory, there were 105 million mobile connections in Egypt in January 2023. The smartphone penetration rate in Egypt reached around 97 percent of mobile phones. Egypt had 101.03 million mobile connections as of January 2021, and its average daily mobile internet usage was 4 hours and 20 minutes [6]. Students at universities make up 70% of internet users [7].

According to reports, children and adolescents are using smartphones more frequently, leading to a more sedentary lifestyle that may harm their musculoskeletal systems [8]. These drawbacks lead to reduced physical fitness, poor posture, overweight, and limitation of thoracic motion, which is linked to loss of pulmonary function [9].

People who use smartphones for extended periods of time run the risk of developing cumulative trauma disorder since using them requires them to hold their posture constantly. Because the head weighs one-seventh of the body weight, it requires 3.6 times more force to stay in a stationary position with the head leaned forward than it does to maintain a straight standing posture [10]. The small monitors on smartphones are usually kept down close to the laps, requiring users to bend their heads to view the screens. This increases the activation of the neck extensor muscles, which in turn loads the neck and shoulder, causing tiredness and affecting musculoskeletal symptoms [11].

It was stated that 300 seconds of smartphone use can result in slouched posture and higher cervical spine reposition error, supporting the idea that prolonged smartphone use alters proprioception and generates improper posture [2]. People bend their necks to stare at screens, which increases the workload on the neck extensor muscles, Specifically, the Cervical Erector Spinae (CES) as well as Upper Trapezius (UT)[12].

The measurement of cranial-vertebral angle is used to assess an individual's head posture. It is the angle formed by the straight line in addition the line drawn from the tragus of the ear to the C7 vertebrae's spinous process. A healthy cervical vertebra has an anteriorly oriented lordotic curve. There is a forward tilt while the user is using their smartphone. The cervical vertebrae carry significant stress and weight due to the extensive presence of CES and UT on the posterior part of the neck[12]. The pressure on the cervical spine caused by prolonged smartphone use eventually alters the cervical angle and raises pain levels in the sternocleidomastoid as well as UT muscles [13]. Forward head posture (FHP) can result from this shift in the cervical angle, which can cause the leading to an increase in the curve of the upper cervical vertebrae along with a decrease in the curve of the lower cervical vertebrae [14]. It has been demonstrated that certain postures, such as kyphosis and forward head posture, change the breathing process, affecting diaphragm mobility and respiratory muscle weakness [15, 16].

Excessive forward flexion of the lower cervical spine, which is caused by continuously bending the neck forward when looking at a smartphone, has been linked to a decline in respiratory muscle strength and lung function [17, 18]. Furthermore, variations in the thoracic and cervical spine's mechanics impact the chest wall's capacity to rest during expiration and inflate correctly during inspiration [9, 17]. Furthermore, anomalies of the cervical spine that affect the structure or posture, including scoliosis or FHP, can impair the respiratory muscles' ability to operate. The presence of muscle imbalance has been associated with misalignment of the cervical as well as thoracic spine, which in turn leads to weakness in the auxiliary respiratory muscles [9, 19].

Regarding all the previous aspects, the purpose of this study was to examine the impacts of smartphone usage time on pulmonary function as well as craniovertebral angle among adolescents.

2. Methodology

Study Design: **Cross-sectional design**

This research was conducted from May 2023 to January 2024 in the pulmonary function lab as well as the physical therapy clinic at Egyptian Chinese University in Cairo, Egypt. The outcome evaluators did not know which participants were considered addicted to mobile use and their cervical angle, using a single-blind methodology.

Ethical approval: The study protocol has had a research Ethical Committee, Cairo University ID: P.T.REC/012/003908 and has the identifier NCT05847127 from ClinicalTrial.gov, where it was registered in compliance with the World Medical Association's (Declaration of Helsinki) Code of Ethics for human experimentation.

Participants: A total of 128 adolescents, comprising both males and females, who were well-developed, were included in this study. Both participants along with their parents were given a detailed description of the study's protocol. Prior to the commencement of the study, the participants along with their parents provided their agreement and assent by signing the relevant forms.

They were recruited from many preparatory and secondary schools with inclusion criteria: They were between the ages of 14 and 18 with normal development. According to the Smartphone Addiction Scale-Sort version (SAS-SV), they were divided into two categories: addicts as well as non-addicts. whereas exclusive criteria included those who were athletic participants, had genetic spinal deformity, had suffered injury to the neck, had a history of inflammatory joint illness, had a history of surgical intervention at the neck or upper extremities, or had neuropediatric disorders.

The sample size was determined using the G*Power software (version 3.0.10). To determine the difference among two independent means using a t-test, with a power of 0.80, α level of 0.05 (two-tailed), as well as effect size of 0.5, a minimum sample size of 128 participants is necessary. This includes 64 people in each group.

Procedure includes of craniovertebral angle and pulmonary function testing was done. Pulmonary function testing was done by using Micromedical Gold standard fully computerized portable auto spirometer. Forced Vital Capacity (FVC), Forced expiratory volume in one second/ Forced Vital Capacity (FEV1/FVC). craniovertebral angle (CVA) using (Image J) image processing, and was analyzed in Java system. Body Mass Index (BMI) was calculated by using the following formula, BMI = weight (kg)/ (height in meters)

Study Randomization by SMARTPHONE ADDICTION SCALE – SHORT VERSION (SAS_SV)

Adolescents who are being recruited are all evaluated using SAS-SV. The self-reporting questionnaire for adolescents which was created and validated by Kwon et al., comprises of 10 items that make up the scale [20]. The items employ a six-point Likert-type scale, spanning from "strongly disagree" to "strongly agree." Daily life disturbances, withdrawal, cyberspace-oriented relationships, overuse, as well as tolerance were the five content categories that the SAS-SV was constructed from. Participants were classified as smartphone addicts if their score on the SAS-SV questionnaire above 32; otherwise, they were classified as non-addicts (score < 32). For its validity as well as reliability analysis, the original SAS-SV questionnaire study employed this cut-off point.

BODY MASS INDEX*:* was calculated using the Formulae – weight (kg)/ $(\text{height})^2$ m. Normal Range - 18.5 to 24.9 kg/m^2

Craniovertebral measures*:* In this study, we used the J image processing tool and ran the analysis on a Java system to determine the CVA, which is the angle formed by a line from the 7th cervical vertebra (C7) to the tragus of the ear [21]. The CVA was measured for both groups by a digital camera (SONY Alpha NEX-5R 16.1). The participant was directed to focus at a specific location at eye level while the camera was positioned 1.5 meters distant from their right side to get a lateral shot of their head and neck while they were seated and relaxing. Two markers will be utilized: one positioned on the C7 vertebra and the other on the tragus. The angle among the line connecting C7 to the tragus as well as a vertical line projecting from C7 will be measured.

Pulmonary Function Measures: Pulmonary functions test was measured for both groups by using Micromedical Gold standard fully computerized portable auto spirometer. After being seated, the participants were directed to put on nose clips to prevent nasal breathing and to firmly close their mouths over a mouthpiece to eliminate any air leakage. After that, the participants were instructed to breathe in as much air as they could and to expel as much as they could against the resistance. After recording three measurements in total, the best value was determined. The FVC, FEV1, and FEV1/FVC were calculated to evaluate alterations in lung function. All data was recorded and statistically analyzed.

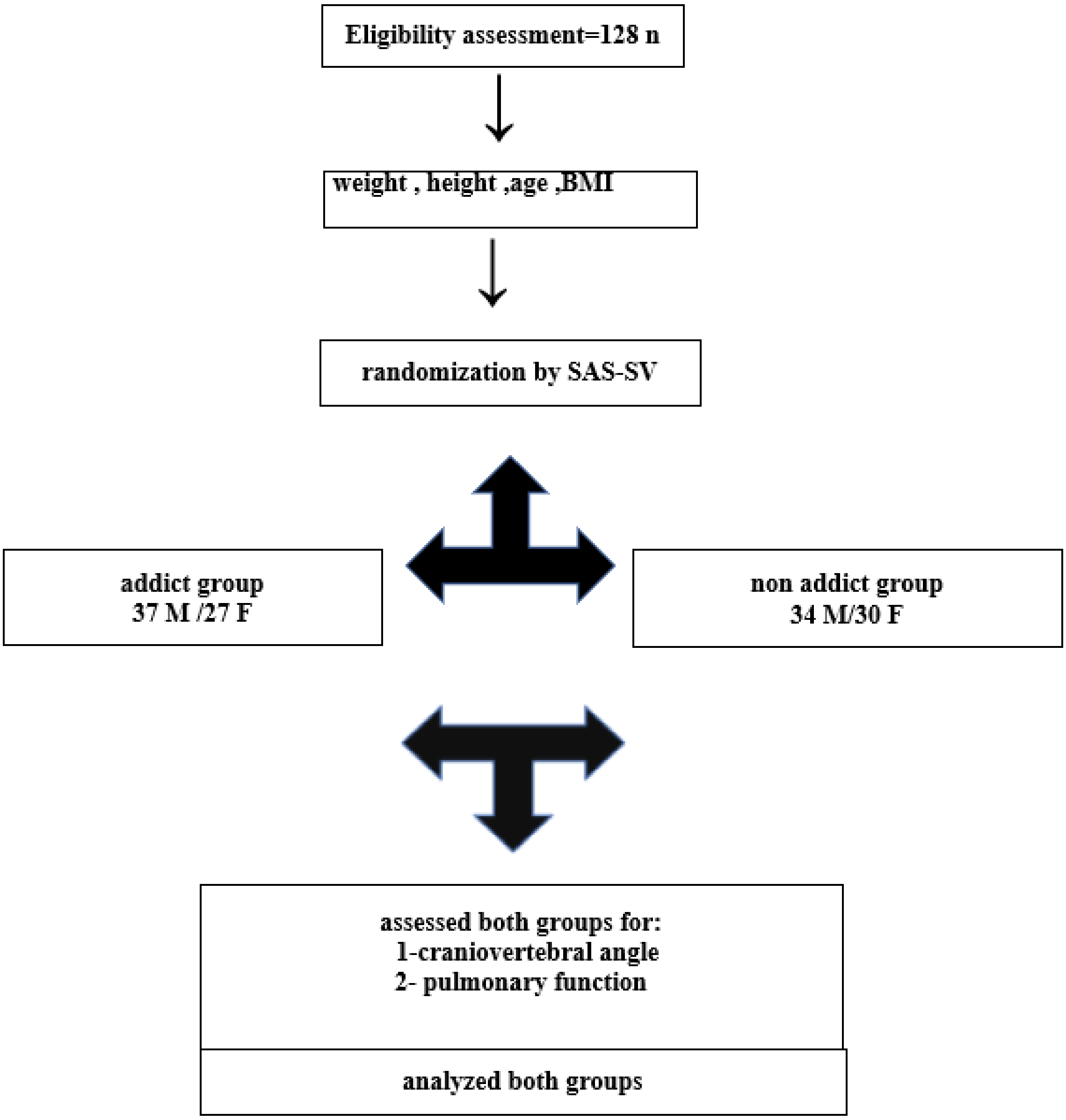

Fig 1: flow chart

3. Results and Discussion

The statistical analysis was conducted with IBM SPSS Statistics version (27). Baseline similarity between groups was assessed for demographic characteristics (age, height, weight, BMI) using independent samples t-tests, ensuring comparable starting points for the study groups. Gender distribution was compared between the two groups using Chi-Square Tests, revealing no significant differences as presented in (table 1).

Table 1: Demographic Characteristics by Smartphone Addiction Levels

Variable	Nonaddicts (n = 64) (Mean ± SD)	Addict (n = 64) (Mean ± SD)	p-value
Age	16.4 ± 1.1	16.5 ± 1.23	0.468
Gender (M/F)	34/30	37/27	0.594
Height	165.1 ± 6.54	165.8 ± 7.28	0.541
Weight	56.94 ± 5.2	56.64 ± 5.56	0.756
BMI	20.9 ± 1.33	20.6 ± 1.37	0.202

Comparison of CVA and Respiratory Functions:

Independent samples t-tests were employed to compare CVA as well as respiratory functioning. The statistical analysis showed a substantial difference in CVA among non-addicted (54.8 ± 2.76) as well as addicted adolescents (50.1 ± 3.35) with a mean difference of 4.72 ($p < 0.001$). However, no substantial differences were found in FEV1 ($p = 0.219$) or FVC ($p = 0.666$) among the two groups. The FEV1/FVC ratio was evaluated using an independent samples t-test, revealing a statistically substantial difference among non-addicted (84.6 ± 7.17) and addicted adolescents (79.17 ± 7.4) with a mean difference of 5.44 ($p < 0.001$, Table 2).

Table 2: Comparison of Craniovertebral Angle and Respiratory Functions by Smartphone Addiction Levels

Variable	Nonaddicts (Mean ± SD)	Addict (Mean ± SD)	Mean Difference	p-value
CVA	54.77 ± 2.76	50.06 ± 2.84	4.717*	< 0.001
FEV1	3.66 ± 0.77	3.48 ± 0.87	0.18	0.219
FVC	4.34 ± 0.86	4.41 ± 1.06	-0.07406	0.666
FEV1/FVC Ratio	84.61 ± 7.17	79.17 ± 7.4	5.44*	< 0.001
* Difference is significant				

Comparing the impacts of smartphone addiction on various variables between genders has revealed interesting patterns. In both the addicted as well as non-addicted subgroups, boys as well as girls showed small differences in CVA, FEV1, FVC, and FEV1 /FVC ratio, with p-values exceeding the significance threshold of 0.05 (Table 3). These findings suggest a possible uniform impact of smartphone addiction regardless of gender.

Table 3: Comparison of Craniovertebral Angle and Respiratory Functions by Group (Addicted / non-addicted) and Gender

Subgroup Comparison	Variable	Mean Difference	p-value
Non-Addicted Male vs. Non-Addicted Female	CVA	1.211	0.080
	FEV1	0.264	0.169
	FVC	0.363	0.094

	Ratio	-1.194	0.511
Addicted Male vs. Addicted Female	CVA	-0.819	0.339
	FEV1	0.145	0.515
	FVC	0.245	0.366
	Ratio	-1.503	0.427

Correlation Analysis:

Correlation analyses were conducted via Spearman's rank correlation coefficients to evaluate the relationship among smartphone addiction and health parameters. The findings revealed notable negative correlations with both CVA ($r = -0.5$, $p < 0.001$) and the FEV1/FVC ratio (- 0.288, $p = 0.001$) among adolescents. These results point to a moderately strong negative relationship among smartphone addiction as well as CVA, in addition a weak negative relationship with the FEV1/FVC ratio. However, FEV1 nor FVC were substantially correlated with smartphone addiction in the research ($r = -0.128$, $p = 0.149$ and $r = 0.019$, $p = 0.835$, respectively), as detailed in (Table 4).

Table 4: Correlation between Smartphone Addiction Scale Scores and CVA/Respiratory Function Parameters

Correlation Analysis	Correlation Coefficient (r)	p-value
Smartphone Addiction vs. CVA	-0.5**	<0.001
Smartphone Addiction vs. FEV1	-0.128	0.149
Smartphone Addiction vs. FVC	-0.019	0.835
Smartphone Addiction vs. FEV1/FVC	-0.288**	0.001
** Correlation is significant.		

Discussion

The purpose of our study was to investigate the relationship among smartphone addiction as well as craniovertebral angle (CVA) alongside respiratory functions, including forced expiratory volume in one second (FEV1), forced vital capacity (FVC), in addition the FEV1/FVC ratio, among adolescents.

We found a substantial variation in CVA among non-addicted as well as addicted adolescents. The measurement CVA was lower in the addict one's in comparison to the non-addict as the statistical analysis revealed a substantial difference in CVA among non-addicted as well as addicted adolescents

Various studies have examined the effects of using smartphones on different parts of the body. For example, Werth and Babski-Reeves (2014) found that Mobile Touch Screen Devices (MTSDs) are linked to various musculoskeletal exposures, such as different postures or muscle activity [22]. This can lead to different risks for musculoskeletal symptoms compared to traditional devices. MTSDs can be utilized in several unconventional workplaces and positions because of their portability. The design of touch screens, which prevents the wrist and fingers from resting on the screen surface, can lead to additional strain on the neck, shoulders, and muscles in the upper extremities[23,24].

In addition, studies have found that there is increased activity in the neck/shoulder muscles and decreased activity in the wrist extensor muscles when using MTSDs compared to standard electronic devices [25- 28]. The variations in positions and perspectives when using tablets and desktop computers are likely to have influenced the degree of neck flexion. Furthermore, research has demonstrated a correlation between the utilization of a touch screen and heightened activity in the UT muscle. This could be attributed to the inability of the wrists and fingers to completely rest on the screen[23,24].

In 2015, Park et al. discovered that using a smartphone for long periods of time commonly results in the neck remaining in a flexed position, which can lead to specific musculoskeletal problems such upper cross syndrome [14].

It was observed that scapular dyskinesis as well as the CVA always decrease as a result of smartphone addiction; this finding may be explained by the fact that many smartphone users use their phones while seated with their heads forward and the device positioned close to their laps or waists, maintaining a forward posture of the head reduces the curvature of the lower cervical vertebrae and causes a backward curve in the upper thoracic vertebrae for keeping balance, resulting in a decrease in the CVA [29-32].

When an individual utilizes a smartphone, it results in the elimination of the natural curvature of the neck known as cervical lordosis, leading to damage in the soft tissues surrounding the neck. The UT as well as erector spinae muscles of the cervical spine are under more strain in order to maintain a neutral neck posture [33]. When the head is positioned forward or slouched, it puts more strain on the extensor muscles as well as connective tissues. As a result, this incorrect posture can cause harm to the soft tissues along with the structure surrounding the spine, leading to changes in the proprioceptors inside the ligaments and muscles [34].

Kim et al., 2015 noted that those who use smartphones frequently have expressed concerns about experiencing moderate neck pain as a result of increased flexion of the cervical spine [35]. Quek et al., 2013 discovered an association among increased neck flexion as well as reduced ROM in the cervical spine [36]. Moreover, Kee et al., 2016 discovered that adolescents who were dependent on their smartphones had restricted ROM in their cervical spine as a result of their poor postural habits[37]. Also, De-la-Llave-Rincon et al., 2009 discovered that a decrease in CVA, which signifies an increase in FHP, could lead to a decrease in the ROM of the cervical[38]. Greater FHP was also correlated with a reduction in cervical flexion along with Rt/Lt cervical rotation [36].

Over time, the cervical joints, ligaments, as well as muscles may become irritated as a result of prolonged defective head posture as well as FHP[39]. This may subsequently result in a decrease in the range of motion (ROM) of the cervical spine, which in turn diminishes the effectiveness of the muscles' strength, this is due to the fact that a greater amount of muscle force is required to maintain the neck in a neutral position, which leads to a shortening of the posterior cervical muscles as well as a lengthening of the anterior cervical muscles in the cervical spine [40,41,42].

Our findings regarding CVA and pulmonary function tests show a significant difference of FEV1/FVC ratio between non-addicted and addicted adolescents. Also, the findings revealed notable negative correlations with both CVA and the FEV1/FVC ratio among adolescents. These results point to a moderately strong negative relationship among smartphone addiction as well as CVA, in addition to a weak negative relationship with the FEV1/FVC ratio.

FEV1 and FVC were lower among the addicted group compared to the non-addicted one throughout the study, with values not statistically significant, as no significant differences were found in FEV1 or FVC between the two groups.

The FEV1/FVC ratio was assessed via an independent samples t-test, showing a substantial difference among non-addicted and addicted adolescents which can be explained from a mathematical point of view, as a non-significant value divided by another non-significant value will result in a significant ratio.

These findings concerning pulmonary function tests were supported by the work of El-Etreby YM et al., (2023) who demonstrated substantial differences between smartphone children who were addicted and those who were not addicted in terms of CVA, FVC, FEV1, peak expiratory flow (PEF), as well as maximal voluntary ventilation (MVV). However, there was no substantial difference in FEV1/FVC[43].

In another study to clarify our findings, the work of Shah M et al., 2023 found a strong negative correlation of NPRS (Numeric pain rating scale), NDI (Neck Disability Index) as well as CCA (Cranio-Cervical Angle) with PFT (Pulmonary Functions Tests) measures FEV1, FVC & MVV in chronic neck pain patients. Although the correlation between NPRS, NDI, and CCA with FEV1/FVC was moderately negative, patients suffering from chronic neck pain had a substantial reduction in PF measures such as FEV1, FVC, as well as MVV in comparison to healthy individuals of the same age and sex. However, the reduction in FEV1/FVC was not statistically substantial [44]. In individuals suffering from chronic neck pain, Kapreli et al., 2009 also found substantially decreased (MVV, FVC, FEV1, & PEF). Although those with neck pain had lower values of FEV1/ FVC, the difference was Non-significant [45].

Furthermore, Pranoti et al., 2023 have shown that maintaining a bad ergonomic posture when using mobile devices for a long time might result in the development of FHP, which dramatically reduces the ventilatory functions FEV1, FVC, as well as PEF among young adults [46].

Our findings are consistent with the study conducted by Kim et al., 2017 which demonstrated a substantial correlation between FHP as well as respiratory functions. Specifically, there were positive correlations seen between CVA as well as FVC, FEV1, PEF, in addition MVV [47]. However, there was no significant difference in FEV1/FVC among smartphone-addicted children as well as non-addicted children. The observed outcome could be attributed to musculoskeletal disorders along with chest wall restriction, which are classified as restrictive lung disorders. These conditions lead to a decrease in both FEV1 and FVC values, hence accounting for the normal FEV1/FVC ratio. This aligns with the findings of Widjanantie et al., 2020, who found that people experiencing FHP together with tightness along with weakness in their muscles exhibited either normal or higher FEV1/FVC levels [48].

Kim MS,2015 and Jung SI et al., 2016 as they noted that, using smartphones for extended periods of time negatively impacts posture and lung function [35, 49]. A possible explanation for the little reduction in pulmonary functions is that prolonged neck flexion when looking at a smartphone can lead to an overly flexed cervical spine, which weakens the respiratory muscles and therefore reduces pulmonary function [50]. Prolonged poor posture leads to an increased burden on the cervical muscles as well as joints, resulting in a decrease in the strength of the cervical as well as thoracic muscles [51]. The decline in the cervical muscles' strength is subsequently accompanied by a decrease in the respiratory muscles' power [35]. Additionally, an extended FHP leads to the weakening of some accessory respiratory muscles, which has a detrimental impact on ventilatory function [44].

Hojat and Mahdi, 2011 demonstrated that the decrease in ventilatory function associated with smartphone addiction is caused by alterations in the mechanics of the cervical as well as thoracic spine, which can impact the chest wall's capacity to expand during inhalation and contract properly during exhalation [52].

Geete et al., 2021 have demonstrated that extended periods of using smartphones in certain positions, such as having a FHP along with rounded shoulders, can cause physical misalignments. These misalignments can compress the ribs and hinder lung expansion, as shown in their study. It hinders the downward motion of the diaphragm, leading to changes in lung volumes and therefore impacting the ability to function [53].

Several studies have shown that alterations in the cervical as well as thoracic spine can result in diminished functionality along with strength of the trapezius & sternocleidomastoid muscles, as well as the pectoralis major in addition scalene muscles. The alterations in the posture of the head may result in the contraction of the antagonist trapezius muscles along with the elongation of the sternocleidomastoid as well as scalene muscles, thereby impacting the functioning of the respiratory muscles [54-56].

In our study, both the addicted as well as non-addicted subgroups, boys & girls showed small differences in CVA, FEV1, FVC, and FEV1 /FVC ratio, with p-values exceeding the significance threshold of 0.05, these findings suggest a possible uniform impact of smartphone addiction regardless of gender.

These results came in the same line with the work of Alonazi etal., 2021 concerning CVA, she asserted that the mean CVA was substantially lower in both boys and girls who were addicted to smartphones compared to those who were not, while they were in a seated position. However, she disagreed with our findings concerning ventilatory function tests, as she demonstrated that among boys, the average FVC was substantially lower in those who were addicted compared to those who were not. Furthermore, the average FEV1 and FEV6 were substantially lower among boys with addiction compared to boys without addiction. However, among girls, the average PI max was substantially lower in those who were addicted compared to those who were not. Mean FEV1/FVC, PEF, and MVV values were not substantially different between the addicted as well as non-addicted groups for both boys and girls. Neither group showed a statistically significant change in PEF values [57].

Han et al. corroborated our results, indicating that individuals with FHP, comprising both adult males and females, exhibited reduced values for their FVC as well as FEV1 compared to those without FHP [58].

Factors such as the impact of puberty on pulmonary function in both genders may serve as potential explanations for these disparate outcomes. Typically, the FVC as well as FEV1 values of boys and girls increase by 16% and 10%, respectively, during puberty [59]. Furthermore, lung function is significantly predicted by height. As it was found that variation in height could influence pulmonary function in children between the ages of 8 and 14 [60].

4. Conclusion and future scope

This study's outcome indicated that using a smartphone for a lengthy period may have adverse effects on respiration and CVA. These findings might be utilized to raise awareness about the use of smartphones. When using cellphones, we need to be mindful of our posture and the length of time we spend using them in terms of health.

Limitations:

Our study was subjected to certain confounding factors like size of smartphone screen, weight of smartphone, using a tablet instead of smartphone, or different body positions while using smartphone.

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Author contribution all authors shared in all steps of writing, applying, and publishing the paper.

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