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Effect of Smartphone Addiction on Pulmonary Function and Functional Capacity in School-Age Children

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Abstract

Excessive use of smartphones can lead to prolonged neck bending and potential alterations in the spine posture, which may negatively affect pulmonary function and overall physical ability. Accordingly, we aim to investigate the effect of smartphone addiction (SPA) on pulmonary function, functional capacity, and head posture in school-age children. This observational cross-sectional study enrolled 56 school-age children aged 10–12 years from both sexes, with body mass index < 95th percentile. The children were assigned equally into groups A and B, which involved non-addicted and addicted smartphone users, respectively. The SPA level was determined to be > 32 on the Smartphone Addiction Scale-Short version. The pulmonary functions [forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) FEV_1/FVC ratio, maximal voluntary ventilation (MVV), and peak expiratory flow rate (PEF)], functional capacity, and Forward head posture (FHP) were assessed for all children by computerized spirometry, 3-minute step test (3MST), Kinovea software, respectively. The results showed that group A had a significantly higher FVC, FEV_1, MVV, PEF, and craniovertebral angle (CVA) than group B ($p < 0.001$), with a nonsignificant difference in FEV_1/FVC between the two groups ($p > 0.05$). Both groups significantly differed in functional capacity in favour of group A ($p < 0.001$). Altogether, SPA adversely affects pulmonary function, functional capacity, and head posture in school-age children.

Keywords: Functional capacity; Head posture; Pulmonary function; Smartphone addiction; School-age children.

Full length article**Corresponding Author: Yasmine M. Eletreby** , e-mail: yeletreby@horus.edu.eg

1. Introduction

The GSM Association and the Mobile Society Research Institute have found that young children in the community are increasingly using various electronic devices, including smartphones, tablets, computers, and televisions [1]. Smartphones have become essential to modern living by offering many entertainment possibilities, including internet surfing, gaming, and communication, altering lifestyles worldwide [2-3]. The same holds for the 3.668 billion people who used smartphones worldwide in 2016. Statista projected that by 2026, the number will have climbed to 7.516 billion, up from 6.378 billion in 2020 [4]. With 101.03 million mobile users in January 2021, Egyptians spent about 4.2h daily on mobile Internet [5]. Smartphone addiction (SPA) develops when people rely on their smartphones for lengthy periods, both for everyday tasks and for accessing the Internet and making mobile phone calls [6]. Moreover, SPA can cause various health problems, such as musculoskeletal disorders and early-onset neck pain, and is related to personal, professional, and social problems, as well as increased irritability and aggression when unable to use phones [7-8]. Consequently, children and adolescents lead increasingly inactive lives, which has a detrimental impact on their musculoskeletal health and functional capacity [9]. Users consistently maintaining a flexed position while viewing their smartphones are at a higher risk of developing musculoskeletal diseases over time.

The incorrect head positioning may disrupt the natural muscle balance in the cervical spine [10]. The alterations in the angles of the cervical spine can result in muscular discomfort and impair the movement of the neck. This eventually causes a forward head posture (FHP) attributed to a bent lower cervical spine and an extended upper cervical spine, reducing the natural curvature of the neck, known as cervical lordosis. The craniovertebral angle (CVA) represents the most dependable and accurate measure of FHP among children [11]. The efficient pulmonary system function is influenced by internal and external factors that directly affect the lungs or bronchial tubes and control chest respiratory movements, respectively. Correct body posture is essential for the respiratory system to work at its best [12]. Prolonged FHP elevates thoracic kyphosis and cervical lordosis, which negatively affects the main muscle involved in breathing and the functioning of the diaphragm. An improper posture disrupts the optimal functioning of the diaphragm, leading to heightened activity in the upper respiratory tract [13]. Alternations in cervical and thoracic spine mechanics affect the capability of the chest wall to expand sufficiently during inhalation and relax during exhalation [14]. Smartphone-addicted children experienced detrimental effects on their cervical posture and lung function [15]. The increased sedentary activities due to SPA necessitate prolonged periods of sitting, resulting in a lack of physical activity, and are associated with several health issues, including decreased lipid profiles and glucose uptake, increased calorie consumption and waist circumferences, and a higher mortality risk [16–18]. Accordingly, we hypothesized that SPA will not affect previous outcomes. Therefore, we aimed to examine the effect of SPA on pulmonary function, functional capacity, and head posture in school-age children.

2. Materials and methods

2.1. Study design and ethical concern

This cross-sectional observational study was conducted at private primary and preparatory schools at El Mansoura Educational Administration (Egypt) from July 2022 to January 2023. The Faculty of Physical Therapy Ethical Committee at Cairo University, Egypt, approved the study protocol (No: P.T.REC/012/003600). Before data collection, we obtained the parents signed informed consent, which authorized the children to participate.

2.2. Sample size estimation

Herein, we employed G*POWER statistical software (version 3.1.9.2) for determining the sample size for a comparative study involving two groups. According to the forced vital capacity (FVC) data obtained from Alonazi et al., (2021), the calculation determined that 28 participants for each group were needed. The calculations were performed with $\alpha = 0.05$, power = 80%, effect size = 0.77, and an allocation ratio N2/N1 = 1 [10].

2.3. Subjects

This study enrolled 56 school-age children of both sexes selected from private primary and preparatory schools at El Mansoura Educational Administration (Egypt). The children aged 10–12 years, with the same socioeconomic level and body mass index (BMI) of < 95th percentile, according to WHO (2007) [19]. They were divided equally into two groups based on Smart Phone Addiction Scale short version (SAS-SV) scores: group A included non-addicted (score ≤ 32) smartphone users, while group B included addicted (score > 32) smartphone users [20]. The children exhibited a cooperative attitude and adhered to the given directions. A specialized physician evaluated all the included subjects and excluded children with neurological problems, respiratory disorders, congenital abnormalities, uncorrected vision disorders, or involvement in competitive sports.

2.4. Determination of smartphone addiction

The SAS-SV was employed to evaluate SPA because of its strong reliability, validity, and efficiency in assessing SPA in community and research settings. The internal consistency and concurrent validity of SAS were confirmed using 0.911 Cronbach's alpha coefficient. The survey includes ten items rated on a scale ranging from 1 (indicating "strongly disagree") to 6 (indicating "strongly agree"), calculating the overall score by adding the values for each category, ranging from 10 to 60. A higher score indicates a more severe SPA level. The cutoff value was set at 32; individuals who obtained scores above the cutoff value were classified as at high risk for SPA. The participants underwent the SAS-SV questionnaire and were categorized as either addicted (score > 32) or non-addicted (score < 32) based on their scores [20].

2.5. Evaluation of forward head posture through craniovertebral angle (CVA)

The CVA has emerged as the predominant measure for quantifying the severity of FHP due to its strong test-retest reliability, as indicated by intraclass correlation values of 0.88–0.98 [21]. The CVA refers to the angle formed by the horizontal line intersecting the seventh spinous process (C7) and a line from the ear tragus to C7. The measurement was conducted using photometry [22] through Kinovea Software (version 0.8.24), a dependable and accurate software technique with an intra-class correlation coefficient ICC value of 0.99–1.00 [23]. Participants were positioned on a chair without armrests, with their hip and knee joints flexed at 90° and their feet resting flat on the floor. A Canon 700D digital camera was positioned 1.5 meters away from the participant and used to capture three photographs. The average of the CVA was then used to determine the FHP; children with cervical angles < 50° are classified as having FHP [10].

2.6. Evaluation of pulmonary functions

Spirometry is a widely used, accurate, dependable, secure, and non-intrusive technique for assessing pulmonary function. It offers insights into potential obstructions or limitations in individuals with suspected pulmonary dysfunction [24-25]. Herein, we assessed the pulmonary function through computerized spirometry (smartSOFTmee version 2.14.21). The children had elucidated the research method, advantages, and necessity in a language they most effectively comprehended. Children are recommended to wear loose, comfortable clothes because tight clothing can limit the movement of the chest wall, resulting in erroneous results. The record sheet included basic demographic data such as name, age, and gender.

Weight and height scales were utilized for measuring their weight and height. The children underwent forced expiratory and maximum voluntary ventilation (MVV) tests in a seated position with the trunk at a 90° angle and were directed to inhale deeply while exhaling forcefully through a piece of paper. After inserting a sterile mouthpiece with an attached flow monitor, their noses had been secured to avoid air escape. In the forced expiratory test, children took deep breaths and held their breath for as long as necessary to seal their lips completely around their mouthpiece. Lastly, they expired as strongly and forcefully as they could until they could no longer expel any air, encouraging the children to blow it they showed up on screen. In the MVV test, the child was asked to inhale and exhale as fast as possible for 10 sec to achieve maximal ventilation. Each child performed each assessment three times, with their highest score being recorded [26].

2.7. Evaluation of functional capacity

The 3-minute step test (3MST) is a submaximal test conducted to measure functional capacity or cardiorespiratory fitness in children aged 6–12 years, besides being safe and well-validated with excellent intra-rater reliability for determining exercise tolerance in healthy children aged 7–11 years [27-28]. Herein, we performed the 3MST using a standardized approach. Initially, children were equipped with a wearable heart rate monitor and remained seated in a chair until they attained a stable resting heart rate. During the experiment, the subjects repeatedly walked onto and off a 30 cm step at a pace of 24 times/min/3 min, monitoring the heart rate every minute. The pace of stepping was coordinated with a metronome set at a rate of 96 beats/min and continuously observed during the testing process. After 3 min of stepping, participants immediately sat in a chair while monitoring their heart rate recovery for 1min [29]. Then, the recorded data was compared to standardized reference [30].

2.8. Statistical analysis

The statistical analyses were conducted through the SPSS software package version 25 for Windows (IBM SPSS in Chicago, IL, USA). An unpaired t-test was employed for comparing the characteristics of participants as well as for comparing the CVA, pulmonary functions, and functional capacity between groups. A chi-squared test was used to compare sex distribution and functional capacity. The data underwent a screening process to assess whether they met the normality assumption. The Shapiro-Wilk test for normality indicated that all measured variables followed a normal distribution ($p > 0.05$). Levene's test was deployed for assessing variance homogeneity among the groups. $P < 0.05$ indicated a significant difference.

3. Results

3.1. Subject characteristics

The results revealed a nonsignificant difference in age, weight, height, BMI, and sex distribution between the two groups ($p > 0.05$) (Table 1). Moreover, group A had a significantly higher CVA, FVC, FEV1, PEF, and MVV than group B ($p < 0.001$), with a nonsignificant difference in FEV1/FVC ($p > 0.05$). The results demonstrated that the groups had a significant difference in excellent functional capacity, as group A showed a higher percentage of functional capacity than group B ($p < 0.001$) (Table 2).

4. Discussion

Our aim was to determine the impact of SPA on FHP, pulmonary function, and functional capacity in school-age children. Our findings showed significant differences between addicted and non-addicted smartphone children regarding CVA, FVC, FEV1, PEF, and MVV, with no significant difference in FEV1/FVC. In addition, functional capacity exhibited a significant difference between both groups in favor of group A. Moreover, CVA significantly differed between both groups; the higher CVA angle among the addicted group may be due to the FHP that children exhibit while using the smartphone for a long period. This aligns with Pardeshi et al., (2021) who have reported that an elevation in smartphone usage can derogate the CVA angle [31]. Smartphone users often adopt a posture where they bend their heads downwards to view the screen, placing their heads in an ergonomically unfavorable position for extended durations. This can result in FHP, where the spinal bones form a forward curve that can lead to musculoskeletal diseases and an imbalance in the body [32]. Herein, significant differences existed between addicted and non-addicted smartphone children regarding FVC, FEV1, PEF, and MVV. These results may be because the alignment of the cervical and thoracic spine is crucial to breathing. After all, healthy respiration requires cooperation between the musculoskeletal and neurological systems. Impaired respiratory function usually occurs with spinal misalignment or muscular imbalance. The mechanical disadvantage of having FHP can have various harmful effects, including muscular imbalance, changes in the shape of the thoracic cavity, and restriction of the chest wall movement. Therefore, continuing in this improper posture could affect how well you breathe. In addition, Koseki et al., (2019) have provided evidence that FHP causes upper thorax expansion and lower thorax contraction, decreasing the FEV1 and respiratory function. Constriction of the lower thorax due to FHP might limit its expansion during inhalation and decrease FVC [33]. Furthermore, Pranoti et al., (2023) have elucidated that sustaining poor ergonomic posture while using mobile technologies for a prolonged period can lead to the development of FHP, which causes the pulmonary functions FEV1, FVC, and PEF to be significantly lower in young adult [34]. Moreover, prolonged FHP causes weakness of some accessory respiration muscles, negatively affecting pulmonary function [35]. The previous result aligns with Kim et al., (2017) who have found a significant correlation between FHP and respiratory functions, with positive correlations between CVA and FVC, FEV1, PEF, and MVV [36]. Nonetheless, FEV1/FVC showed a nonsignificant difference between addicted and non-addicted smartphone children. This result may be because the musculoskeletal disorder and chest wall restriction can be considered among restrictive lung disorders that reduce FEV1 and FVC values, which explains the normal FEV1/FVC ratio. This is in line with Widjanantie et al., (2020) who have reported that individuals with FHP and muscle symptoms of weakness and tightness demonstrated normal or elevated FEV1/FVC values [37]. Consequently, FHP leads to a condition characterized by restricted lung function.

Our results demonstrated significant differences between both groups in functional capacity distribution. Group A (non-addicted smartphone children) showed a higher percentage of excellent cardiorespiratory fitness than group

B (addicted smartphone children), who had very good and good cardiorespiratory fitness. This aligns with Geete et al., (2021) who have illustrated that prolonged postures when using smartphones lead to physical misalignments such as forward head and rounded shoulders, resulting in compression of the ribs and thus impacting lung expansion [38]. It impedes the downward movement of the diaphragm, which impacts lung volumes and consequently affects functional ability. Furthermore, both SPA and problematic smartphone use had a harmful effect on overall health due to decreased physical activity levels [39]. Smartphones have become the main source of entertainment for most individuals, and there is a clear correlation between smartphone usage and sedentary behavior.

5. Limitations

Our study is subject to certain limitations: first, the long enrollment period of the non-addicted smartphone children; second, only a specific age group of 10–12 years was enrolled. Therefore, it is recommended that more research be conducted on different age groups. The impact of various treatment methods on FHP and its influence on pulmonary function in non-addicted smartphone children should be studied. Moreover, further cohort studies must investigate the long-term impacts of SPA on students.

Table 1: Subject characteristics of groups A and B.

	Group A	Group B			
	Mean ±SD	**Mean± SD**	**MD**	**t-value**	**p-value**
Age (years)	12.14 ± 1.40	12 ± 1.36	0.14	0.38	0.70
Weight (kg)	40.82 ± 8.69	39.14 ± 4.43	1.68	1.37	0.17
Height (cm)	148 ± 5.21	147.28 ± 7.01	0.72	0.43	0.66
BMI (kg/m²)	18.58 ± 1.21	18.04 ± 1.53	0.54	1.46	0.15
SAS-SV	23.35 ± 5.66	43.21 ± 5.85	–19.86	–12.89	0.001
Sex, n (%)					
Girls	15 (54)	12 (43%)		(χ^2 = 0.64)	0.42
Boys	13 (46%)	16 (57%)			

SD=standard deviation; MD=mean difference; χ2=Chi squared value; p value=probability value.

Table 2: Comparison of CVA, pulmonary functions, and functional capacity between both groups.

	Group A	Group B			
	Mean ± SD	**Mean ± SD**	**MD**	**t-value**	**p-value**
CVA (degrees)	47 ± 3.12	33.82 ± 5.04	13.18	11.75	0.001
FVC (L)	2.12 ± 0.47	1.59 ± 0.34	0.53	4.79	0.001
FEV1 (L)	2.02 ± 0.46	1.52 ± 0.33	0.5	4.64	0.001
FEV_1/FVC (%)	95.45 ± 5.01	95.93 ± 5.05	–0.48	–0.35	0.72
PEF (L/S)	4.59 ± 0.82	2.63 ± 0.71	1.96	9.57	0.001
MVV (L/min)	70.32 ± 12.69	43.05 ± 9.65	27.27	9.04	0.001
Functional capacity					
Excellent	18 (64.3%)	0 (0%)			
Very good	10 (35.7%)	13 (46.4%)		(χ^2 = 33.39)	0.001
Good	0 (0%)	15 (53.6%)			

SD=standard deviation; MD=mean difference; χ2=Chi squared value; p value=probability value

6. Conclusions

Collectively, SPA negatively affects pulmonary function, functional capacity, and head posture in school-age children.

Conflicts of interest

The authors declare no conflict of interest.

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Authors' Contribution

A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

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