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The Effects of Frequent Smartphone Use on Children's Upper Posture and Pulmonary Function

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The Effects of Frequent Smartphone Use on Children's Upper Posture
and Pulmonary Function

by

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A Dissertation submitted in partial satisfaction of
the requirements for the degree
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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Science.

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ABBREVIATIONS

CVA	Craniovertebral Angle
C7	Seventh Cervical Vertebra
FHP	Forward Head Posture
ROM	Range of Motion
CROM	Cervical Range of Motion
PFT	Pulmonary Function Test
FVC	Forced Vital Capacity
FEV1	Forced Expiratory Volume in 1 Second
FEV6	Forced Expiratory Volume in 6 Second
FEV1/FVC	Ratio of Forced Expiratory Volume in 1 second to Forced Vital Capacity
PEF	Peak Expiratory Flow
MVV	Maximal Voluntary Ventilation
MIP	Maximal Inspiratory Pressure
MEP	Maximal Expiratory Pressure
SD	Standard Deviation
BMI	Body Mass Index

ABSTRACT OF THE DISSERTATION

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Dr. Gurinder Bians, Chairperson

Children are experiencing an increase in sedentary lifestyle as a result of the rising utilization of technology, i.e. smartphones. With the prolonged use of smartphones, increased concerns have been raised regarding constant neck flexion, neck movements limitation, and decreases in pulmonary function due to potential changes in spinal posture. Therefore, the purpose of this research thesis was to evaluate changes in craniovertebral angles (CVA), cervical range of motion (ROM), and pulmonary function among boys and girls 8 to 13 years of age who use smartphones. A cross-sectional study was conducted on a sample of 50 participants (24 boys and 26 girls) with mean age 10.5±1.6 years and mean body mass index (BMI) 18.6±3.0 kg/m^2. Participants were assigned to 2 groups based on their scores on the Smartphone Addiction Scale Short Version for Adolescents (SAS-SV): addicted group (score > 32, n=32) and non-addicted group (score ≤ to 32, n=18). The CVA was measured to evaluate the changes in the cervical spine. Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), ratio of forced expiratory volume in 1 second to forced vital capacity (FEV1/FVC), and peak expiratory flow (PEF) were measured to evaluate pulmonary function. Maximal voluntary ventilation (MVV), maximum inspiratory pressures (MIP), and maximum expiratory pressures (MEP) were measured to assess respiratory muscles' strength. A significant difference in CVA measures was found between both groups; girls (p=0.02) and boys (p=0.03). Cervical ROM in extension was limited in addicted boys (p=0.04). Also, in addicted boys, FVC and FEV1 were significantly lower (p=0.04 and p=0.05 respectively). $FEV6_{\%}$ showed a significant lower value in addicted boys, compared to non-addicted boys (p=0.02). while addicted girls had significantly lower values in MIP when compared to non-addicted girls (p=0.05). We conclude that frequent use of smartphones could negatively affect cervical posture, as well as respiratory biomechanics among boys and girls. Pulmonary dysfunction has found to be associated with FHP as a result of constant neck flexion while viewing the phone. Therefore, education on proper posture while using the smartphone and education on the effects of prolonged usage of smartphones are necessary to preserve craniocervical function.

Keywords: Smartphone addiction, smartphone frequent use, cervical angle, craniovertebral angle, forward head posture, text neck, upper posture, pulmonary function, lung function, respiratory muscle weakness, respiratory muscle strength.

CHAPTER ONE

INTRODUCTION

The popularity of the smartphone has increased rapidly in the last ten years. By 2015, the United States was ranked second to South Korea in terms of numbers of smartphone users throughout the world.[1] It is estimated that by 2020, there will be an additional 3.5 billion of new smartphone subscriptions, resulting in a total of 6.1 billion worldwide. This represents almost 70% of the global population.[2] However, as adult users become increasingly addicted to their smartphones, their children are likely to imitate them. Also, many parents are working long hours and leading busy lives, they rely heavily on smartphone devices to manage their children and keep them busy. This increase in smartphone use is mostly linked to the increase in online access.[3] The obsession with smartphones in today's global society is essentially an issue of addiction, which is defined as enormous dependency on the use of a smartphone and its services.[4] Therefore, the extensive use of smartphones among children may lead them to become addicted, which is considered one of the greatest global health concerns among children.[5]

According to Common Sense Media, in 2013, access to smartphones among American children was greater than it had been two years before.[6] Children from eight to twelve years of age are more likely to spend an average of six hours per day using different types of media.[7] In 2015, Children's Media Use stated that smartphone usage grew almost twice as much among children aged from 12 to 14 years (55%) than among children from 6 to 8 years (30%). In the same age range of 12 to 14 years, 72% of girls used smartphones compared to 55% of the boys.[8]

This rise in smartphone usage in children in North America couples with declining opportunities to engage in physical play, resulted in an increase in sedentary lifestyles and its related health issues.[9] In 2015, Park et al.[10] found that when a person uses a smartphone for an extended period of time, the neck usually remains in a flexed position, and this may produce certain musculoskeletal disorders such as upper cross syndrome. This syndrome involves a tightening of the upper trapezius, levator scapula, and major and minor pectorals muscles, which results in weakening of the muscles used for cervical flexion and the lower trapezius and rhomboids muscles.[11] When this occurs, the posterior curve of the upper cervical vertebrae is increased and the lordosis of the lower cervical vertebrae is decreased. This condition is known as forward head posture (FHP).[12] Maintaining this faulty posture for extended periods of time may change muscles length and increase the load on the cervical discs to almost 60 pounds when the head is flexed forward at 60 degrees.[12]

Lin et al. (2014)[13] considered the excessive amount of time spent on smartphones and the frequency of their use to be a form of technological addiction. However, a study about smartphone use and addiction that was conducted by Haug et al. (2015)[14], published in the Journal of Behavioral Addiction, stated that the time spent on smartphones was a better indicator of addiction than the frequency of use. The cervical angle that was maintained while using the smartphone was found to be significantly affected by different postures and amounts of usage time.[15] Shaghayegh et al. (2015)[16] described the proper posture as a musculoskeletal balance that includes a minimal amount of stress and strain on the body. FHP is one of the most common cervical abnormalities seen when examining faulty head positions in a sagittal view, and it can lead to other musculoskeletal abnormalities.[17] FHP occurs when the cervical spine moves anteriorly to the imaginary vertical line that passes through the center of gravity (COG).[18] Measurement of the craniovertebral angle (CVA) to assess the head posture has become increasingly important in the clinical examination due to the potential associated problems with FHP such as, cervicogenic headache, neck pain, temporomandibular TMJ disorders, and other musculoskeletal abnormalities.[17] Studies have found that smaller CVA are associated with larger FHP,[19] and individuals with smaller CVA are most likely to complain of headaches, neck pain, reduced cervical range of motion (ROM) and mobility, and other neck disabilities.[20,21] A cervical angle of less than 50 degrees was determined by Diab and Moustafa (2012)[22] as a cut score to differentiate between participants who had FHP and those who did not. However, a CVA of less than 48 or 50 degrees was defined by Shaghayegh et al. (2015)[16] as being an indication of FHP.

Prolonged faulty head posture and FHP may eventually irritate the cervical joints, ligaments, and muscles.[23] This may then lead to reduction in the cervical spine's ROM, which can cause some cervical spine dysfunctions.[19] Reduction in cervical mobility may occur as a result of flexion of the lower cervical vertebrae and extension of the upper cervical vertebrae, which can cause the muscles to be imbalanced.[24,25] This reduces the effectiveness of the muscles strength, as more muscle force is needed to stabilize the neck in a neutral position,[24] resulting in a shortening of the posterior cervical muscles and lengthening of the anterior cervical muscles.[25]

In addition, a significant link was found between slumped postures and reduced in lung function, including lower values in forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and peak expiratory flow (PEF).[26] Faulty posture can increase the compression of the diaphragm and restrict the expansion of the rib cage during both inspiration and expiration.[27] Kapreli et al. (2009)[28] found a strong relationship between increased FHP and decreased respiratory muscle strength in patients who had FHP. In addition, a study by Han et al. (2016)[29] stated that FHP leads to loss of strength in the accessory respiratory muscles as well as reduced lung capacity. Cervical muscle imbalances and segmental spine instability have also been associated with changes in respiratory muscle strength.[28] In addition, individuals with musculoskeletal pain showed lower values in FVC, vital capacity (VC), and maximum voluntary ventilation (MVV).[30]

An excessive forward flexion of the cervical spine may develop from constantly flexing the neck to view the smartphone, and this eventually affects pulmonary function and respiratory muscle strength.[31] This prolonged improper posture increases the load on the cervical muscles and joints, which reduces the strength of the cervical and thoracic muscles.[21] This reduction in the strength of the cervical muscles is followed by a weakening in the respiratory muscles,[32] which alters the ability of the thoracic spine to expand normally during inspiration and to rest during exhalation.[26] Also, prolonged use of smartphones was found to have a negative effect on both posture and pulmonary function.[33,34]

Previous studies have shown an association between smartphone overuse and changes in cervical angles.[10,33,35,36] Some studies have also found that FHP is associated with reduced lung function and respiratory muscle weakness.[34,37] However, to our knowledge, the cervical angles, cervical ROM mobility, pulmonary function, and respiratory muscle strength were not investigated in children aged from 8 to 13 years who were addicted to smartphones. The purpose of our study, was as follows: (1) to evaluate the effects of smartphone use on the craniovertebral angles (CVA) and cervical ROM among children aged from 8 to 13 years, (2) to examine the differences in the cervical ROM between the boys and girls who had FHP and those who did not through separate comparisons for the addicted and non-addicted groups, (3) to make separate comparisons of the variables for the CVA and pulmonary function tests (PFTs) for the addicted and non-addicted boys and girls, and (4) to correlate the CVA and PFTs for addicted and non-addicted boys and girls separately.

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CHAPTER TWO

THE EFFECT OF FREQUENT SMARTPHONE USE ON CHILDREN'S CERVICAL POSTURE AND RANGE OF MOTION

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Abstract

This study examined the effects of smartphones' frequent use on cervical posture and compared cervical range of motion (ROM) between addicted and non-addicted boys and girls, ages from 8 to 13 years. Craniovertebral Angle (CVA) was assessed using side view photographs, forward head posture (FHP) was measured using ImageJ 64 software, and cervical ROM in flexion, extension, right rotation, left rotation, right lateral flexion, and left lateral flexion were measured using cervical range of motion (CROM) device. Results of forward multiple regression showed that addiction score and body mass index (BMI) were significant predictors of CVA (R^2 =0.31, p<0.001). Twenty-three percent of the variability in CVA was related to addiction score. Findings of forward logistic regression showed that whether or not addicted to smart phone use and BMI were significant predictors of having FHP, and participants who were addicted were more than four times more likely to have FHP than those who were not (Odds Ratio (OR) with 95 % confidence interval (CI) =4.5 (1.2, 10.7); p= 0.03)). A significant reduction was found in mean cervical angle in addicted versus non-addicted boys (49.4±6.7 vs. 55.5±7.6, η^2=0.5, p=0.03) and girls (47.3±6.3 vs. 52.9±6.1, η^2=0.9, p=0.02). In addition, there was a significant limited cervical ROM in most neck movements in addicted participants with FHP versus participants without FHP. Children who are addicted to smartphones may develop faulty habitual posture due to constant head flexion downward while viewing the phone, which place them at high risk for spine abnormalities in the future.

Keywords: Smartphone, smartphone use, smartphone addiction, craniovertebral angle, cervical angle, forward head posture, cervical ROM mobility, cervical ROM limitations

Introduction

With the revolutionary development of smartphone technology, the number of smartphone users, according to the Statistics Portal report, has reached 222.9 million in the United States of America (U.S.A.) and 2.1 billion worldwide.[38] Those numbers are expected to increase to an estimated 236 million users in the United States and 5 billion worldwide by 2019.[38] Moreover, it has been reported that children in the United States are introduced to smartphones in their first year of life and the frequency of usage increases significantly with age.[39] A study in the U.S.A. examined an urban group of 350 children which stated that by age 4, three-fourth of the children own smartphones.[39] According to Common Sense Media's research survey (2013), the percentage of young children from age 0 to 8 years in the United States who use smartphones has doubled from 38% in 2011 to 72% in 2013.[6] It is no surprise, then, that teens from 13 to 18 years of age are spending almost 3 hours per day on smartphones.[7] Haug and colleagues[14] have suggested that the amount of time adolescents spend on smartphones could characterize them as addicts,[14] and about 50% of adolescents considered themselves to be "addicted" to their smartphones due to the overuse.[40,41] In a recent survey by Miner and Company,[42] 57% of parents reported that their children, 2 to 12 years old, prefer a device other than television and use mobile tablets as their first screen instead.[42]

The fact that young individuals are spending more time on their smartphones raises concerns for possible adverse health effects such as changes in the spinal posture, which may increase the symptoms of neck pain.[10,43] Over time, constant downward neck flexion for long periods while viewing the phone will likely cause musculoskeletal disorders. Therefore, frequently flexing the head downward at 60 degrees could increase the load on the cervical discs from 10 to 60 pounds.[12] Park and colleagues[44] have found that excessive use of smartphones increases the stress on the cervical spine, which eventually changes the cervical angle and results in increased levels of pain in the sternocleidomastoid and upper trapezius muscles.[44] The changes in the cervical angle may, then, lead to an increase in the posterior curve of the upper cervical vertebrae and a decrease in the lordosis of the lower cervical vertebrae, which is known as forward head posture (FHP).[12,45,46] FHP is also described as the head moves anteriorly to the vertical line through the center of gravity (COG)[25,47] while the lower cervical spine is flexed and the upper cervical spine is hyperextended.[48] In addition to having FHP, frequent smartphone users were also found to have slumped posture.[31]

It has been reported that FHP may impact the cervical spine as well as the thoracic spine and shoulder blades, causing a general imbalance in the musculoskeletal system.[10,44] De-la-Llave-Rincon et al. (2009)[20] found that a reduced CVA, which indicates larger FHP, might cause a reduction in the cervical range of motion (ROM).[20] Larger FHP was also associated with a decrease in cervical flexion and right and left cervical rotation.[49] As a result of the increased usage of smartphones among adolescents, there were significant decreases in all cervical ROM mobility because of muscular abnormalities to the cervical spine.[36] In addition, cervical ROM may be reduced due to the habitual FHP of those who frequently maintain neck flexion.[29]

An association between the frequent use of smartphones and FHP has been investigated in previous studies conducted on adult populations.[10,29,32,34,50] However, to our knowledge, no studies have been done for children in the U.S. from ages 8 to 13 years old, with respect to changes in cervical posture due to smartphone addiction.

Therefore, the objectives of this study were to:1) examine the effects of smartphones' frequent use, body mass index, gender, and age on cervical posture; 2) compare cervical ROM between addicted and non-addicted boys and girls, ages from 8 to 13 years; 3) assess the effect of group (addict versus non-addict), Body Mass Index (BMI), gender, and age on whether or not have FHP; and 4) compare the cervical ROM in all directions between children who had FHP and those who did not in both the addicted and the non-addicted groups.

Methods

This study was approved by the Institutional Review Board of Loma Linda University, Loma Linda, California. Participants were healthy children between 8 and 13 years of age who had BMI that were less than the 95th percentile and who had been using smartphones for more than 6 months. The participants were recruited from Southern California. A total of 53 children were recruited for the study; 50 met the criteria and 3 were excluded. Children were excluded if they had experienced musculoskeletal pain or had neurological diseases, congenital or acquired spinal deformities, neck and trunk hypotonia, children with cognitive disorders, or vision disorders not corrected by glasses. Participants were also excluded if their BMI was greater than the 95th percentile, because obesity was found to have increased kyphotic and FHP in school children.[51,52] The research team provided participants and their parents with an explanation of the study protocol. Both parents and participants signed informed consent and assent forms before starting the study.

Outcome Measures

Smartphone Addiction

Addiction levels to smartphones were assessed using the Smartphone Addiction Scale Short Version (SAS-SV). This 10-item self-reporting questionnaire was developed and validated for adolescents by Kwon et al.[53] The items use a six-point Likert-type scale, ranging from "strongly disagree" to "strongly agree." The SAS-SV addresses five content areas: daily life disturbances, withdrawal, cyberspace-oriented relationships, overuse, and finally tolerance. Participants were defined as smartphone addicts if they scored more than 32 on the SAS-SV questionnaire; otherwise, they were defined as non-addicts (score ≤ 32).[53] This cut-off point was used in the original study that examined the validity and reliability of the SAS-SV questionnaire.[53]

Craniovertebral Angle

The CVA was assessed using a digital camera (SONY Alpha NEX-5R 16.1). The camera was placed 1.5 m away from participant's right side to take a lateral photographic view of the participant's head and neck in a seated position. The CVA is the angle between the horizontal line passing through the 7th Cervical Vertebra (C7) and a line extending from C7 to the tragus of the ear. The resulting FHP was determined using ImageJ 64 software. A CVA of less than 50º was defined as FHP. The reference angle of 50º was established in a study conducted by Diab and Moustafa (2012).[22] The assessors who obtained the CVA measurements were blinded to group assignment.

Cervical Range of Motion

The cervical ROM in all directions (flexion, extension, right rotation, left rotation, right lateral flexion, and left lateral flexion) was measured using a CROM device (CROM instrument, Sammons Preston, Oklahoma, U.S.A.). This device has good test-retest reliability (ICC, 0.89 and 0.98).[54]

Procedures

Weight (kg), height (m), and BMI (kg/m^2) were measured to calculate the BMI percentile. Parents answered a demographic questionnaire that included their children's age, gender, ethnicity, school grade level, if they own or using their parent's smartphone, and the number of hours per day that they had spent using a smartphone device in the past week before participating in the study. The participants answered the SAS-SV questionnaire, and according to their scores they were assigned to one of two groups: addicted group (score >32, n=32) or non-addicted group (score ≤32, n=18). Participants had their CVA measured to evaluate the changes in the angle between addicted and non-addicted group. Each participant was seated on a chair without an armrest, with his/her knee and hip joints at 90° and feet flat on the floor. They were then instructed to assume the posture they normally adopted while using their smartphones. Afterwards, three photographs were taken to calculate the CVA averages. The cervical ROM were measured in all directions (flexion, extension, right rotation, left rotation, right lateral flexion, and left lateral flexion) by using CROM. The CROM device was placed on the participants' heads with the neck in a neutral position. Participants were asked to move their heads as far as they could without experiencing a feeling of being stretched or having any pain. Three measurements were recorded to calculate an average for each direction (Figure 1.1).

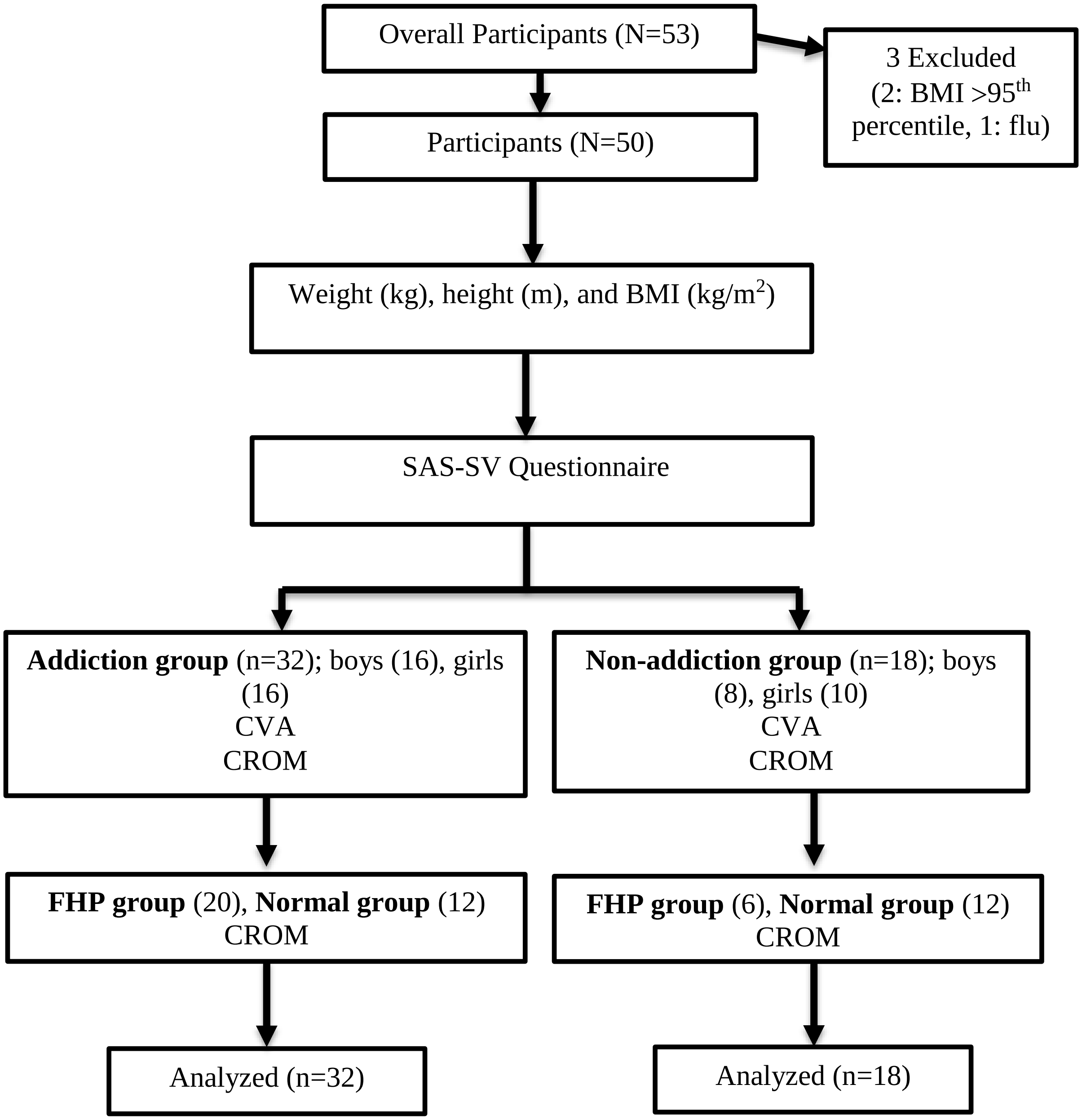

Fig 1.1. Flow Diagram of the Study Procedure.
Abbreviation: BMI: Body Mass Index; SAS-SV: Smartphone Addiction Scale Short Version; CVA: Craniovertebral Angle; CROM: Cervical Range of Motion; FHP: Forward Head Posture. Participants were placed into one of two groups (addicted vs. non-addicted) according to their score on SAS-SV. Addicted and non-addicted groups, then were divided to FHP or Normal group depends on their CVA angle. If the CVA angle is less than 50° they were considered to have FHP, and placed in the FHP group. If the angle was more than 50% they were placed in the normal group.

Data Analysis

Estimates based on the sample size of 50 participants were made using a medium effect size of 0.50, a power of 0.80, and a level of significance of 0.05. Data was analyzed using SPSS Statistics Software version 22.0 (IBM Corp, Armonk, NY). Mean$\pm$SD was calculated for quantitative variables and frequencies (%) for categorical variables. The normality of quantitative variables was assessed using the Shapiro-Wilk test and box plots. The following were compared separately for the boys and girls: mean age (years), height (m), weight (kg), BMI (kg/m^2), number of hours using smartphones, CVA (degree), and cervical ROM (degree) in all directions (flexion, extension, right rotation, left rotation, right lateral flexion, and left lateral flexion), in terms of addicted versus non-addicted, using the independent t-test. The distribution of gender by group type was examined using Fisher's Chi Square test. Forward multiple regression was conducted to examine the effect of addiction score, BMI, gender, and age on cervical angle. In addition, forward stepwise logistic regression was used to assess the effect of gender, age, BMI, and group (non-addicted vs. addicted) on whether or not having forward head posture. Independent t-test was used to compare the cervical ROM in all directions for the addicted and non-addicted participants who had FHP and those who did not. The level of significance was set at $p \leq 0.05$ (2-tailed).

Table 1.1. Mean (SD) of Characteristics of Participants by Gender and Study Group (N=50)

	Boys (N_1=24)			Girls (N_2=26)		
Variable	Addicted (n_1=16)	Non-Addicted (n_2=8)	*p*-value*	Addicted (n_1=16)	Non-Addicted (n_2=10)	*p*-value*
Age (year)	10.4 (1.6)	10.8 (1.5)	0.65	9.9 (1.6)	9.5 (1.8)	0.59
Height (m)	1.4 (0.1)	1.5 (0.1)	0.27	1.4 (0.1)	1.4 (0.1)	0.90
Weight (kg)	37.2 (9.9)	42.1 (6.1)	0.21	35.5 (12.3)	35.0 (11.7)	0.92
BMI (kg/m^2)	18.3 (2.9)	19.3 (2.2)	0.41	18.0 (3.5)	18.0 (3.1)	0.96
Hours/day∧°	1.4(0.6,4.6)	2.6(0.3,4.0)	0.67	2.1(0.5,6.0)	2.6 (0.7,3.0)	0.70

Abbreviation: SD, Standard Deviation; BMI: Body Mass Index
BMI= weight in kilograms (height in meters)^2
* Independent t-test
∧ Median (min, max), °Mann-Whitney U test

Results

The study included 50 participants with mean age of 10.1±1.7 years and BMI of 18.3+3.0 kg/m^2. Fifty-two percent were females (n=26). There were no significant differences in mean age (years), height (m), weight (kg), BMI (kg/m^2), and number of hours spent using smartphones between addicted and non-addicted boys and girls ($p>0.05$, Table 1.1). Results of forward multiple regression showed that addiction score and BMI were significant predictors of CVA (R^2 =0.31, $F_{2, 47}$=10.4, $p<0.001$). Twenty-three percent of the variability in CVA was related to addiction score. Females had lower CVA, however, not statistically significant ($p=0.06$, Table 1.2).

Table 1.2. Effects of Addiction Score, BMI, Age, and Gender on Cervical Angle (N=50).

Variables	B (95% CI)	t	*p*-value
Addiction Score	-o.3 (-0.5, -0.2)	-4.0	<0.001
BMI	-0.7 (-1.2, -0.1)	-2.5	0.03
Gender	0.2 (-1.2, 5.9)	-1.9	0.06
Age	0.03 (-1.4, 1.0)	0.2	0.82

Abbreviation: BMI: body mass index; CI: confidence interval

In addition, there was a significant difference in the mean CVA between addicted and non-addicted participants during sitting: boys (49.4±6.7 vs. 55.5±7.6, η^2=0.5, p=0.03) and girls (47.3±6.3 vs. 52.9±6.1, η^2=0.9, p=0.02). The difference in mean cervical ROM in flexion between addicted and non-addicted boys was clinically important (63.6±12.9 vs. 69.0±10.3, η^2=0.5, p=0.20). The mean cervical ROM in extension was significantly different between addicted and non-addicted boys (p=0.04). Among boys and girls, there were no significant difference in mean cervical ROM in flexion, right rotation, left rotation, right lateral flexion, and left lateral flexion between those who were addicted and those who were not addicted (p>0.05, Table 1.3).

Table 1.3. Mean (SD) of the Cervical ROM Variables by Group (Addicted vs. non-addicted) and Gender (N=50).

	Boys (N_1=24)				Girls (N_2=26)			
Variable	Addicted (n_1=16)	Non-addicted (n_2=8)	*p*-value*	Effect size	Addicted (n_1=16)	Non-addicted (n_2=10)	*p*-value*	Effect size
CVA-sit	49.4 (6.7)	55.5 (7.6)	0.03	0.9	47.3 (6.3)	52.9 (6.1)	0.02	0.9
CROM-Flex	63.6(12.9)	69.0(10.3)	0.16	0.5	55.1(12.0)	55.0 (7.8)	0.50	0.0
CROM-Ext	65.2(12.2)	75.0(15.6)	0.04	0.7	59.8(12.5)	55.1(12.5)	0.19	0.4
CROM-R-R	60.6(11.1)	64.0 (6.6)	0.22	0.4	64.1(11.9)	60.5(16.4)	0.26	0.3
CROM-L-R	68.4 (8.7)	69.3 (4.9)	0.41	0.1	64.0(10.7)	62.7(12.2)	0.41	0.1
CROM-R-La	40.8 (9.9)	39.3 (9.0)	0.36	0.2	40.7(12.7)	42.4 (7.7)	0.35	0.2
CROM-L-La	44.3 (9.0)	46.3 (10.4)	0.32	0.2	45.6 (13.3)	42.9 (9.5)	0.30	0.2

Abbreviation: SD: Standard Deviation; CVA: Craniovertebral Angle; CROM: Cervical Range of Motion; Flex: Flexion; Ext: Extension; R-R: Right Rotation; L-R: Left Rotation; R-L; Right Lateral Flexion; L-L: Left Lateral Flexion

* Independent t-test

Results of forward logistic regression indicated that whether or not addicted to smart phone use and BMI were significant predictors of having FHP (-2 Log likelihood= 58.5, $p<0.01$). Participants who were addicted were more than four times more likely to have FHP than those who were not (Odds Ratio (OR) with 95 % confidence interval (CI) =4.5 (1.2, 10.7); p= 0.03)). In addition, participants with a higher BMI tend to have more FHP (OR = 1.4 (1.1, 1.7); p=0.02).

In the non-addicted group, mean cervical ROM in extension was significantly different between those who had FHP and those who did not (p=0.05, Table 1.4). However, in the addicted group, mean cervical ROM in right rotation and right lateral flexion were significantly different between participants who had FHP and those who did not ($p<0.05$, Table 1.4). Mean cervical ROM in left lateral flexion was lower in participants who had FHP compared to those who did not; however, this was not statistically significant (p=0.07).

Table 1.4. Mean (SD) of the Cervical ROM Variables by Group (Addicted vs. non-addicted) and FHP (N=50).

	Addicted (N_1=32)				Non-addicted (N_1=18)			
Variable	FHP (n_1=20)	Normal (n_2=12)	*p*-value*	Effect size	FHP (n_1=06)	Normal (n_2=12)	*p*-value*	Effect size
CROM-Flex	58.1(14.0)	61.3(11.3)	.25	0.3	61.5 (9.2)	61.1(12.5)	.47	0.04
CROM-Ext	61.5(13.4)	64.3(10.9)	.27	0.2	53.0(14.5)	69.4(15.8)	.05	1.1
CROM-R-R	64.0 (6.6)	68.3 (7.6)	.01	1.0	60.2 (2.2)	63.0(15.7)	.34	0.3
CROM-L-R	64.5(10.5)	68.8 (8.4)	.12	0.5	67.3 (4.4)	64.7(11.9)	.30	0.3
CROM-R-Lat	36.8 (9.4)	47.3(11.1)	.04	1.0	42.7 (8.5)	40.2 (8.4)	.28	0.3
CROM-L-Lat	42.7(10.8)	48.8(11.2)	.07	0.6	40.8(14.5)	46.2 (6.3)	.14	0.5

Abbreviation: SD, Standard Deviation; CVA: Craniovertebral Angle; CROM: Cervical Range of Motion; Flex: Flexion; Ext: Extension; R-R: Right Rotation; L-R: Left Rotation; R-L; Right Lateral Flexion; L-L: Left Lateral Flexion
* Independent t-test

Discussion

The objective of this study was to evaluate the effects of smartphone addiction, comparing those who were addicted to those who were not, on CVA and cervical ROM among children who used smartphones aged between 8 and 13-year old. The CVA and cervical ROM were measured to determine the effects of prolonged usage of smartphones on cervical posture. In both boys and girls, the FHP was larger in the addicted group than in the non-addicted group, which was shown by the smaller cervical angles. In addition, among those who had FHP and those who did not, the mean cervical ROM were significantly lower in the addicted group than in the non-addicted group.

Results showed that there was a strong relationship between smartphone addiction score and BMI with CVA. We found that addiction score and BMI were strong predictors of FHP. Participants who were addicted to smartphone were 4 times more likely to develop FHP, and those with higher BMI had larger FHP. Our results are in a good agreement with Park et al. (2015) who reported that heavy smartphone users tended to have more FHP.[10] Beside, Song et al. (2014) stated that obese school male children developed more FHP compared to normal weight male children.[51] Our participants in the addicted group tended to have larger FHP, which reduced their cervical ROM mobility in comparison to the non-addicted group. In this study, a cervical angle of less than 50º degree, that was differentiated by Diab and Moustafa[22], was used as an indicative of FHP. Also, participants who were addicted to smartphones had lower CVA, which is consistent with the results that were reported by Park et al. (2015),[44] who found that the CVA was significantly higher in adults who used their smartphones frequently than regular users.[44] The results of our study are also consistent with the findings by Lee et al. (2016),[15] which indicate that among the adult population the CVA was affected by different postures (standing, chair sitting, and floor sitting) and by the amounts of time spent using smartphones. CVA results were noted to be lower in the standing position than in other positions.[15] However, it was noted in our study that the CVA of the children was low in the sitting position.

In this study, both boys and girls in the addicted group had significantly lower mean CVA than those who were non-addicted. Moreover, the lower CVA for boys and girls were clinically significant, as indicated by the large effect size. However, gender differences were observed in other studies. Ruivo et al. (2014)[46] and Hakala et al. (2006),[55] found that girls had more FHP than boys when the postural alignment of the adolescents' heads and shoulders were examined in a natural standing position only.[46,55] Chiu et al. (2002)[56] reported similar findings in adults, where females had more FHP than males during computer use.[56] On the other hand, Gold et al. (2011)[57] reported that boys showed larger FHP while typing on smartphones than girls did.[57] However, McEvoy et al. (2005)[58] and Van Niekerk et al. (2008)[59] did not find gender differences in adolescents and pre-adolescents for habitual cervical posture.[58,59]

It appears that the causes of cervical spine angle abnormalities occurred in participants who consistently flexed their heads forward. Hansraj (2014)[12] showed that the load on the cervical spine increases dramatically as the head flexion increases.[12] Fredriksson et al. (2002)[60] and Park et al. (2015)[44] found that head forward flexion at different degrees increases the stress on the cervical spine, which changes the natural curve and surrounding structure of the cervical angle.[44,60] Therefore, a reduction in the cervical angle may cause cervical dysfunction. Kim et al. (2015)[32] reported that frequent smartphone users complained of mild neck pain due to larger flexion of the cervical spine.[32] Quek et al. (2013)[49] found an association between larger neck flexion and cervical ROM deficits.[49] Moreover, Kee et al. (2016)[36] detected limited cervical ROM in adolescents who were addicted to smartphones because of their poor habitual posture.[36] Kim et al. (2016)[21] reported that smartphone users complained of stiffness and imbalance in the muscles around the neck due to continual neck flexion.[21] Constant head flexion results in lengthening of the anterior cervical muscles and shortening of the posterior cervical muscles, which is known as upper crossed syndrome.[25] Therefore, it is important to maintain a neutral cervical spine while using smartphones, to avoid neck abnormalities.

This study found that addicted boys had significantly limited cervical ROM in extension only, however, addicted girls had no cervical ROM limitation (Table 1.3). Results showed that cervical ROM in addicted participants who had FHP was significantly limited in right rotation and right lateral flexion when compared to those without FHP. We believe this is probably due to hyperflexion as they constantly view their smartphones. These findings are similar to De-La-Llave-Rincon et al. (2009),[20] Moawd et al. (2015),[61] and Kee et al. (2016)[36] findings who found limitation in cervical ROM in most neck movements except for left lateral flexion.[20,36,61] As FHP compresses the cervical facet joints, it may affect the biomechanics of the neck, thus resulting in less cervical ROM mobility, as reported by Shah and Varghese (2016).[19]

However, no significant changes were noted between participants with versus without FHP in cervical ROM in flexion and left rotation. This finding was not consistent with Quek et al.(2013),[49] who found that t usage of smartphones in adults affects cervical ROM in flexion.[49] In addition, Yoo and colleagues[24] showed that cervical ROM in right and left rotation was not significantly limited. They also reported that in individuals with neck pain the cervical ROM in extension tends to be limited, but that this was not found in flexion.[24]

The findings of this study also support the published recommendation by Reid Chassiakos et al. (2016)[41] regarding the effects that smartphone usage can have on adolescents if it is not monitored properly. They stated that adolescents and their parents need to be educated on the effects of prolonged smartphone usage and on the need for balance between the time spent using smartphones and doing other physical activities.[41] Maintaining proper posture while using smartphones is highly important as well, because this could lead to improved cervical spine posture and help prevent future impairment or pain.[62]

Limitations

This study has a few limitations. First, the cervicothoracic angle, thoracic kyphosis, and lumbar lordosis were not measured during smartphone use. The spine is a linked system in which the degree of lumbar lordosis and thoracic kyphosis may affect the degree of cervical flexion.[63] Also, this study did not investigate children' levels of activity and their homework loads. Therefore, it is not clear whether the school activity levels, extracurricular activities, and workloads at home could affect the spinal development and posture of the participants.

Recommendations

To our knowledge, most previously reported studies focused primarily on adults. Therefore, there is a strong need for more studies on smartphone use among young children and its effects on their overall health. Also, further research is recommended to clarify the role that gender plays in cervical posture and to investigate the possible relationship between neck pain and frequent use of smartphones in children. In addition, the cervical repositioning errors in children who frequently use smartphones have not, to our knowledge, been studied. Future studies are also recommended to investigate the effects of smartphone exposure among a younger age group (toddler and preschool) and on different sitting styles. There are other causative reasons why children might develop FHP that should be investigated, such as backpack use, time spent sitting for schoolwork, video game usage, and poor body image.

Conclusion

Smartphone addiction affects significantly CVA and may lead to reduction in cervical ROM mobility among both boys and girls. Because of the increased neck flexion that occurs while viewing smartphones, there might be larger FHP and less cervical ROM mobility. Therefore, it is recommended that the hours spent on smartphones need to be minimized. In addition, education about proper posture is essential for children who use smartphones to help them preserve their craniocervical function.

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CHAPTER THREE

THE EFFECTS OF SMARTPHONE ADDICTION ON CHILDREN'S CERVICAL ANGLE AND PULMONARY FUNCTION

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Abstract

Rationale: With the prolonged use of smartphones among children, increased health concerns regarding forward head posture (FHP) have been raised. Potential changes in spinal posture occur, which may affect the function of the lung. Thus, the purpose of this study was to compare craniovertebral angles (CVA) and pulmonary function between addicted and non-addicted boys and girls 8 to 13 years of age who use smartphones. Methods: A cross-sectional study was conducted on 24 boys and 26 girls with mean age 10.5±1.6 years and body mass index 18.6±3.0 kg/m^2. Subjects were assigned to 2 groups based on their scores on the Smartphone Addiction Scale Short Version for Adolescents: addicted group (score > 32, n=32) and non-addicted group (score ≤ to 32, n=18). The outcome variables were CVA, forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), peak expiratory flow (PEF), maximal voluntary ventilation (MVV), maximum inspiratory pressures (MIP), and maximum expiratory pressures (MEP). Results: There was a significant difference in mean CVA between addicted and non-addicted boys (49.4±6.7 vs. 55.5±7.6, η^2=0.9, p=0.03) and girls (47.3±6.3 vs. 52.9±6.1, η^2=0.9, p=0.02). Mean FVC, FEV1, and FEV6 were significantly lower in addicted versus non-addicted boys (p=0.04, p=0.05, and p=0.02 respectively). MIP was significantly less in addicted versus non-addicted girls (55.2±16.4 vs. 65.3±13.8, η^2=0.7, p=0.05). Conclusion: Frequent use of smartphones can negatively affect cervical posture and pulmonary function among children. Therefore, education on proper posture while using smartphones is essential to children’s postural and pulmonary function status.

Keywords: Smartphone, smartphone addiction, smartphone frequent use, cervical angle, craniovertebral angle, forward head posture, kyphotic posture, pulmonary function, lung function, respiratory muscle strength, respiratory muscle weakness.

Introduction

Technology has developed enormously over the past ten years, and more people have access to smartphones in the United States and Europe, with this growth being somewhat less in developing countries.[1] According to the Pew Research Center, the United States has the second highest percentage of smartphone users after South Korea (72% and 88%, respectively). The Pew Research Center also reported that the percentage of smartphone users in emerging and developing countries rose rapidly from 21% in 2013 to 37% in 2015.[1] The number of smartphone subscriptions is expected to increase to 6.1 billion by 2020, which represents about 70% of the global population.[2] In the United States, Common Sense Media reported that about 79% of tweens (9-to-12 years) and 84% of teens (13-to-19 years) own smartphones by the time they are 12 years old, and they spend an average of five hours per day using their smartphones.[7] It has been reported that, as a result of this increase in smartphone usage, children and adolescents have more sedentary lifestyles and this could negatively affect their musculoskeletal systems.[9] In addition, reductions in basic physical fitness have been found to be associated with decreased pulmonary function,[9] and obesity, faulty posture, and thoracic restriction due to muscle imbalances are related to declines in pulmonary function.[64]

Musculoskeletal disorders are likely to develop over time, especially if users keep their heads in flexed positions while viewing their smartphones.[65] Changes in the cervical angles can also occur as a result of excessive use of smartphones, particularly when users do not maintain the appropriate posture since this may increase the stress on the cervical spine.[10,65] These changes in the cervical angles may lead to muscle pain and alter neck mobility, causing the subjects to develop forward head posture (FHP).[62,66] FHP can occur when the lower cervical spine is flexed and the upper cervical spine is extended, and this leads to a decrease in cervical lordosis.[67] This faulty head posture may affect the muscle balance of the cervical spine as well as the thoracic spine and shoulder blades.[44] Therefore, prolonged faulty posture may increase the load on the cervical discs from 10 pounds to more than 60 pounds when the head is flexed forward at 60 degrees.[12]

A previous study reported that continuous forward neck flexion while viewing a smartphone produces excessive forward flexion of the lower cervical spine, which can affect pulmonary function and respiratory muscle strength.[31] In addition, changes in the mechanics of the cervical and thoracic spine affect the ability of the chest wall to expand normally during inspiration and to rest during expiration.[26] A recent study conducted by Jung et al.[34] found that cervical posture and pulmonary function were negatively affected in people who were addicted to smartphones.[34] The results of this study showed that smartphone users have lower values in the following variables: Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), the ratio of forced expiratory volume in 1 second to forced vital capacity (FEV1/FVC), and peak expiratory flow (PEF). Also, structural or postural abnormalities of the cervical spine, such as scoliosis or FHP, may interfere with the function of the respiratory muscles.[68] It has been reported that misalignment of the cervical and thoracic spine that results from muscle imbalance can lead to weakness in the accessory respiratory muscles.[69] Dimitriadis et al.[70] revealed that loss of strength in the cervical muscles that is caused by improper posture is associated with a reduction in the strength of the respiratory muscles in both maximal inspiratory pressures (MIP) and maximal expiratory pressures (MEP)[70] and in the maximal voluntary ventilation (MVV).[71]

Previous studies have also shown that changes in cervical posture because of smartphone overuse are associated with both a reduction in pulmonary function and respiratory muscle weakness.[31,34,69] Continuous forward flexion of the neck may eventually change the cervical angle and produce FHP. Therefore, developing FHP may lead to a reduction in pulmonary function.[69,72]

To our knowledge, this is the first study to evaluate the effects that the frequency of smartphone use can have on the cervical angles and pulmonary function of children aged from 8 to 13 years. This study has two objectives: to compare the variables for the mean craniovertebral angles (CVA) and pulmonary function tests (PFT) in addicted and non-addicted boys and girls and to correlate the CVA and PFT variables.

Subjects and Methods

This study was approved by the Institutional Review Board of Loma Linda University, California. It is a cross-sectional study conducted on a sample of 50 subjects, including 26 girls and 24 boys with a mean age of 10.5±1.6 years and a mean body mass index (BMI) of 18.6±3.0 kg/m^2 (Figure 2.1). The majority of the subjects were Middle Eastern (n = 28.56%). Subjects were recruited based on being healthy and in the age range from 8 to 13 years, having BMIs that were less than the 95th percentile, and having used smartphones for more than six months. Criteria for exclusion were that they had had previous musculoskeletal pain, neurological diseases, respiratory disorders, congenital or acquired postural deformities, or vision disorders not corrected by glasses. Both subjects and their parents were provided with an explanation of the study's protocol. The informed consent and assent forms were signed by the subjects and their parents before the study was conducted.

Table 1.5. Frequency Distribution of Subjects' Characteristics (N=50)

Age (mean±SD)	10.5±1.6 years
Gender (n, %)	Boys (24, 48%) Girls (26, 52%)
Ethnicity (n, %)	Middle Eastern (28, 56%) White/Caucasian (9, 18%) Multiracial (6, 12%) Hispanic/Latino (5, 10%) Asian (2, 4%)
Smartphone Ownership (n, %)	Own a smartphone (35, 70%) Use parents' smartphone (13, 26%) Use siblings' smartphone (2, 4%)

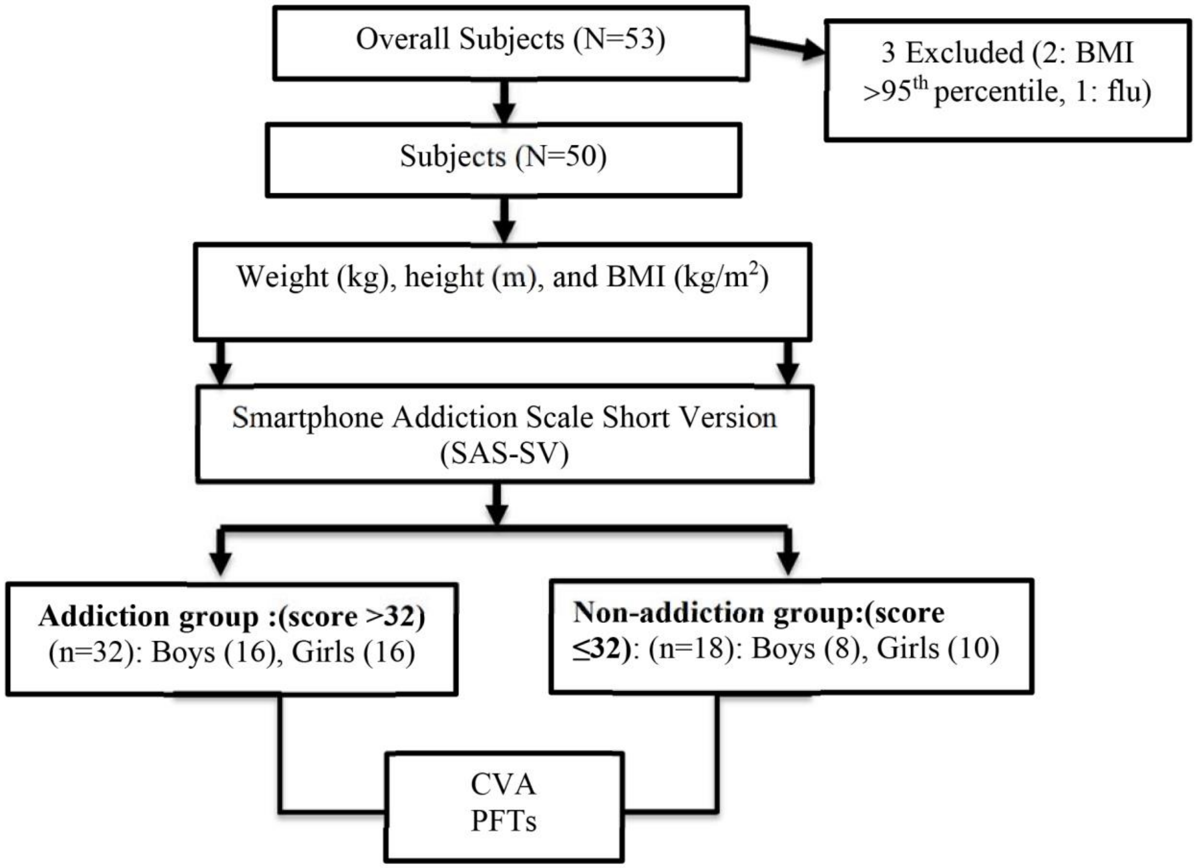

Figure 2.1. Flow Diagram of Study Procedures
Abbreviation: BMI: Body Mass Index; SAS-SV: Smartphone Addiction Scale Short Version; CVA: Craniovertebral Angle; PFTs: Pulmonary Function Tests

Procedures

Weight (kg), height (m), and BMI (kg/m^2) were measured to calculate the BMI percentile. Subjects who were at or above the 95^{th} percentile were excluded. The parents answered demographic questionnaires about the subjects' age, gender, ethnicity, school grade level, smartphone ownership, and the hours of smartphone usage per day. The majority of the subjects reported owning smartphones (n = 35, 70%) (Table 1.5).

The subjects answered the Smartphone Addiction Scale Short Version for Adolescents (SAS-SV) questionnaire, and based on their scores they were assigned to one of two groups: the addicted group (score > 32) or the non-addicted group (score ≤ to 32). The SAS-SV questionnaire, which was developed and validated by Kwon et al. (2013) for the evaluation of smartphone addiction among adolescents, consists of 10 items and addresses five different content areas: daily life disturbances, tolerance, cyberspace-oriented relationships, overuse, and withdrawal.[53]

The cervical angle is the angle between the horizontal line passing through the 7th Cervical Vertebra (C7) and a line extending from C7 to the tragus of the ear. A digital camera (SONY Alpha NEX-5R 16.1) was used to take pictures of the cervical angles of subjects in both groups to evaluate the changes in their head postures. The camera was placed 150 cm away from each subject's right side to take a lateral photographic view of the head and neck when the subject was in a seated position. Subjects were seated on an armless chair with their knees and hip joints at 90 degrees and their feet flat on the floor. Three photographs were taken, and the mean of the cervical angles was calculated to measure the FHP by using the ImageJ 64 software. This software has been shown to be valid and reliable.[73] Subjects with cervical angles of less than 50 degrees were defined as having FHP.[22]

The PFT were assessed using the Pony FX (XVIII Edition) to evaluate pulmonary function and respiratory muscle strength. After the subjects were seated, they were asked to wear nose clips to avoid breathing through their noses and to close their mouths tightly around a mouthpiece to prevent any air leakage. The subjects were then asked to inhale as much air as possible and exhale maximally against the resistance. Three measurements were recorded, and the best value was taken. The FVC, FEV1, FEV1/FVC, PEF, and MVV were measured to assess changes in pulmonary function. The MIP and MEP measures were taken to evaluate the strength of the respiratory muscles. The PFTs were measured using the American Thoracic Society/European Respiratory Society standards of spirometry.

Data Analysis

The statistical software package SPSS version 24.0 (IBM Corp, Armonk, NY) was used to analyze the data. Estimations were made on a sample that included 50 subjects and using a power of 0.80, a medium-effect size of 0.50, and a level of significance of 0.05. Mean±standard deviation (SD) was calculated for quantitative variables and frequencies (percentage) for qualitative variables. The Shapiro-Wilk test and box plots were used to assess the normality of the quantitative variables. Comparisons of the variables for mean age, height, weight, BMI, CVA, PFT, and the numbers of hours of smartphone use per day between the addicted and non-addicted subjects were done for the boys and girls separately using the independent t-test. Fisher's chi-square test was used to examine the frequency distribution of gender in the entire group. Spearman and Pearson correlations were computed to assess the relationship between the CVA and PFT variables. The level of significance was set at $p \leq 0.05$.

Results

There were no significant differences in the mean age (years), height (m), weight (kg), BMI (kg/m^2), and number of hours of smartphone use per day between the addicted and non-addicted boys and girls ($p > 0.05$, Table 1.6).

Table 1.6. Mean (SD) of Characteristics of Subjects by Gender and Study Group (N=50)

	Boys (N_1=24)			**Girls (N_2=26)**		
	Addicted (n_1=16)	Non-Addicted (n_2=8)	*p*-value*	Addicted (n_1=16)	Non-Addicted (n_2=10)	*p*-value*
Age (year)	10.4 (1.6)	10.8 (1.5)	0.65	9.9 (1.6)	9.5 (1.8)	0.59
Height (m)	1.4 (0.1)	1.5 (0.1)	0.27	1.4 (0.1)	1.4 (0.1)	0.90
Weight (kg)	37.2 (9.9)	42.1 (6.1)	0.21	35.5(12.3)	35.0 (11.7)	0.92
BMI (kg/m^2)	18.3 (2.9)	19.3 (2.2)	0.41	18.0 (3.5)	18.0 (3.1)	0.96
Hours/day^°	1.4 (0.6,4.6)	2.6 (0.3,4.0)	0.67	2.1 (0.5,6.0)	2.6 (0.7,3.0)	0.70

Abbreviation: SD, Standard Deviation; BMI: Body Mass Index
BMI= weight in kilograms / (height in meters)^2
* Independent t-test
^ Median (min, max), °Mann-Whitney U test

Group Differences

Differences in the mean CVA and PFTs variables between the addicted and non-addicted boys and girls are displayed in Table 1.7. The results show that the mean CVA was significantly lower in the boys and girls who were addicted to smartphones than in those who were not when they were in the sitting position (boys: 49.4±6.7 vs. 55.5±7.6, η^2 = 0.9, p = 0.03 and girls: 47.3±6.3 vs. 52.9±6.1, η^2 = 0.9, p = 0.02, respectively). Among the boys, the mean FVC was significantly lower in those who were addicted than in those who were not (2.5±0.6 vs. 3.0±0.7, η^2 = 0.8, p = 0.04, respectively). Also, the mean FEV1 and FEV6 were significantly lower in addicted boys than in non-addicted boys (2.0±0.5 vs. 2.4±0.6, η^2 = 0.7, p = 0.05 and 1.5±1.3.6 vs. 2.6±1.2, η^2 = 0.9, p = 0.02, respectively). For the girls, the mean MIP was significantly lower in those who were addicted than in those who were not (55.2±16.4 vs. 65.3±13.8, $\eta^2 = 0.7$, $p = 0.05$). Among the boys and the girls, there were no significant differences in the mean FEV1/FVC, PEF, and MVV between the addicted and non-addicted groups ($p > 0.05$, Table 1.7).

Correlations

For boys, there was a significant positive correlation between the CVA and FVC ($\rho = 0.39$, $p = 0.03$), the CVA and FEV1 ($\rho = 0.41$, $p = 0.02$), the CVA and FEV6 ($\rho =$ 0.3 9, $p = 0.03$), the CVA and MVV ($\rho = 0.37$, $p = 0.04$), and the CVA and MEP ($\rho =$ 0.41, $p = 0.02$). However, among the girls, there was a significant negative correlation between the CVA and FVC ($\rho = -0.38$, $p = 0.03$), the CVA and FEV1 ($\rho = -0.40$, $p =$ 0.02), and the CVA and MVV ($\rho = -0.34$, $p = 0.05$).

Table 1.7. Mean (SD) of the PFTs Variables by Addiction Level and Gender (N=50).

Gender	**Boys (N_1=24)**				**Girls (N_2=26)**			
Variable	Addict (n_1=16)	Non-Addict (n_2=8)	*p*-value	Effect size	Addict (n_1=16)	Non-Addict (n_2=10)	*p*-value	Effect size
CVA (°)	49.4 (6.7)	55.5 (7.6)	0.03	0.9	47.3 (6.3)	52.9 (6.1)	0.02	0.9
FVC (L)	2.5 (0.6)	3.0 (0.7)	0.04	0.8	2.1 (0.6)	2.2 (0.6)	0.44	0.2
FEV1(L)	2.0 (0.5)	2.4 (0.6)	0.05	0.7	1.8 (0.6)	1.8 (0.6)	0.49	0.3
FEV1/FVC(%	81.8 (5.2)	81.0 (7.6)	0.40	0.1	84.2 (6.9)	82.2 (9.9)	0.27	0.2
PEF(L/s)	4.0 (1.5)	4.1 (2.1)	0.42	0.1	3.0 (1.3)	2.7 (1.4)	0.26	0.2
FEV6 (L)	1.5 (1.3)	2.6 (1.2)	0.02	0.9	1.1 (1.1)	0.8 (1.2)	0.29	0.3
MVV(L/min)	70.0(18.5)	83.0(31.4)	0.11	0.5	64.1(15.9)	62.0(14.8)	0.37	0.1
MIP(cmH2O)	68.8(17.4)	80.4(28.5)	0.11	0.5	55.2(16.4)	65.3(13.8)	0.05	0.7
MEP(cmH2O)	68.7(17.3)	73.3(13.6)	0.26	0.3	56.3(15.2)	60.9(14.8)	0.23	0.3

Abbreviations: SD, Standard deviation; caraniovertebral angle (CVA); Forced vital capacity (FVC); Forced expiratory volume in 1 second (FEV1); FVC/FEV1; Peak expiratory flow (PEF); Maximum inspiratory pressure (MIP)Maximum expiratory pressure (MEP); & Maximum voluntary ventilation (MVV). *significant difference between the 2 groups ($p < 0.05$)

Discussion

The aim of this study was to investigate the effects of smartphone addiction on cervical posture and pulmonary function in children who use smartphones. The results show that boys and girls who were addicted to smartphones tended to have larger FHP, which reflects a smaller cervical angle, than those in the non-addicted group. Our findings are consistent with the results of a study by Kee et al.,[36] who reported that adolescents who are addicted to smartphones had more FHP than those who are not addicted.[36] Neck flexion at different degrees was found to change the natural curve and structure of the cervical spine, which may alter the cervical angles of the smartphone users.[10]

Recent studies investigated the relationships between respiratory disorders and changes in the cervical spine.[30,69,71] One study conducted by Kang et al.[31] reported that the kyphotic posture that developed among frequent smartphone users can alter lung function.[31] A slumped posture could negatively affect lung function as well.[26] These changes in the cervical and thoracic spine can lead to a reduction in the functioning of the sternocleidomastoid, trapezius, pectoralis major, and scalene muscles.[74] Weakness in these muscles can also alter the balance of the cervical and thoracic spine as well as the biomechanics of the rib cage.[71] In addition, changes in the biomechanics of the rib cage could limit the function of the chest wall and affect the strength of the respiratory muscles.[70] As a result, the ability of the chest wall to expand normally during inhalation and to rest during exhalation could be affected.[26]

Our study found gender differences, with most of the PFTs variables among boys being statistically significantly lower than those of girls. Also, boys who were addicted to smartphones showed significantly lower values in their FVC, FEV1, and FEV6 than boys in the non-addicted group. Han et al. reported similar findings where subjects who had FHP, including both adult males and females, had lower values for their FVC and FEV1 than those who did not have FHP.[69] Therefore, an increase in FHP has been found to be associated with an increase in pulmonary dysfunction and a decrease in respiratory muscle strength.[28,75] Increases in the kyphotic posture in the upper thoracic region may also occur as a result of FHP, which increases the internal thoracic pressure during expiration and may change the dynamic mechanisms of the lung function. This change in the thoracic cage can create resistance during exhalation as well, and this could result in altered lung function.[69]

In addition, height is considered to be one of the greatest predictors of lung function.[76] Differences in height were found by Bucens et al.[77] to be a factor that could affect lung function among boys and girls from 8 to 14 years of age.[77] Hibbert, Couriel, Landau [76] studied the changes in lung function in children aged from 8 to 12 years and found that the airways and air spaces of boys and girls were not similar or equal. In addition, the authors observed differences in the chest walls of the boys and the girls as they grew.[76] Even though no significant differences in height were found in boys and girls who participated in our study, we believe that this factor contributed to the overall PFT findings.

Furthermore, the PEF values in the present study were not found to have been significantly affected in either boys or girls who were addicted to smartphones. This finding is in line with the results of Kang et al.,[31] who reported no significant changes in the PEFs among adults who used smartphones frequently.[31] However, this finding did not support the results of Jung et al.,[34] who reported that the PEF values in young adult smartphone users were significantly lower than among young adults who were not users.[34] On the other hand, Hellsing et al.[78] revealed that a reduction in the PEF can be related to the position of the head. When the head is in a flexed or extended position, this affects the size of the airway, and the PEF values may then be reduced.[78]

The mean MVV was lower in boys who were addicted to smartphones than in boys who were not addicted, but this was not significant, in addition to having a positive correlation with the CVA. An increase in FHP was also found to be associated with increased respiratory muscle weakness.[28] Dimitriadis et al.[30] and Kapreli et al.[28] found similar results, reporting that individuals with FHP showed a significant decline in MVV.[28,30] Budhiraja et al.[79] reported similar findings, with boys showing higher MVV values than girls in similar age groups to those in our study.[79] Even though the decrease among addicted boys was not statistically significant in comparison to those who were not addicted, the lower values between groups remains a concern, especially when it shows a positive correlation with the CVA.

For MIP and MEP values, girls who were addicted showed significantly lower values only in the MIP, while boys who were addicted had lower values in the MIP and MEP variables, although these were not significant. These findings are consistent with results reported by Dimitriadis et al.[70] and Kapreli et al.[28,70] and can be explained by the fact that girls' chest walls usually do not develop as early as those of boys and that girls are less able to compress their lungs completely.[76] Also, weaknesses in the neck muscles can be associated with weaknesses in the respiratory muscles.[70] FHP leads to ineffective contraction of the diaphragm and abdominal muscle, which can then alter the respiratory system and reduce the strength of the respiratory muscles.[80] Our findings showed a strong relationship between FHP and respiratory muscles weakness. Although, rather surprisingly, Okuro et al.[81] reported that the mean MIP and MEP improved in children with FHP, this can be explained by the fact that individuals with signs of FHP have adopted this position to increase airflow and improve pulmonary function.[81] In such cases, FHP might work as a compensatory mechanism to improve respiratory muscle strength.[28]

Overall, a reduction in the MVV, MIP, and MEP values was found to be associated with cervical muscle weakness.[28,70] The weakness of the sternocleidomastoid, trapezius, and scalene muscles may lead to muscle imbalances and spinal instability, which could affect respiratory muscle function.[28,30] Changes in the position of the head could shorten the antagonist trapezius muscles and lengthen the sternocleidomastoid and scalene muscles.[82] Structural abnormalities of the cervical spine or thoracic cage, such as scoliosis, can restrict the action of the respiratory muscles, which may interfere with the testing of pulmonary function.[83]

It is interesting to note that girls in our study showed negative correlations between the CVA and FVC, FEV1, and MVV. Manzke et al.[84] stated that the prediction equations for growth and lung function are different for boys and girls aged from 6 to 16 years.[84] Possible explanations for this inverse relationship might be factors such as the effects of puberty on lung function in both genders. The FVC and FEV1 values usually increase by 16% in boys and 10% in girls, respectively, during puberty.[85]

Limitations

The present study has some limitations. Because we had a small sample size with a limited age range from 8 to 13 years, it was difficult to generalize the findings to a larger population. In addition, one of the predicted values of the lung function tests is ethnicity[86]; however, the vast majority of the children in the present study were Middle Eastern.

Recommendations

Further research is needed to clarify whether changes in cervical posture could improve respiratory muscle strength. Also, because the strength of the isometric neck muscles works as a predictor for both MIP and MEP, it is recommended that isometric neck muscle strength be measured in smartphone users. Furthermore, additional studies are needed to combine computed topography (CT) scans and magnetic resonance imaging (MRI) with PFT in frequent smartphone users to detect changes in cervical and thoracic structures and function over time. Finally, educating children about the correct posture to maintain while using their smartphones and then adding a follow-up to measure the children's PFT values every three months could give us more valuable data on changes in the children's lung function as they grow older.

Conclusion

Frequent use of smartphones can negatively affect cervical posture as well as lung function and respiratory muscle strength among boys and girls. Abnormalities in pulmonary function were found to be associated with an increase in FHP resulting from constant neck flexion while viewing smartphones. Therefore, education about posture while using smartphones and the effects of prolonged smartphone use are essential to preserve craniocervical and lung function among children.

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CHAPTER FOUR

DISCUSSION

Children throughout the world are becoming addicted to their smartphones, which can lead to poor habitual posture and other physical abnormalities. Those who use smartphones frequently are often found to have faulty posture, such as FHP and kyphotic posture.[10,32,50] Therefore, the purpose of this research thesis was to investigate the effects of smartphone addiction on the cervical angle, cervical ROM, pulmonary function, and respiratory muscle strength in children.

The findings of this study showed that both boys and girls who were addicted to smartphones tended to have a smaller cervical angle, as indicated by a larger FHP, than those who were not addicted. The results of this study are consistent with those of Kee et al.[36] and Park et al.[44], who reported that individuals who are addicted to smartphone had more FHP than regular smartphone users. Neck flexion at different degrees increases the stress on the cervical spine, which changes the natural curve and structure of the cervical angles of smartphone users.[10]

Moreover, other studies have found gender differences in regards cervical posture. Ruivo et al.[46] stated that girls had larger FHP than boys, while Gold et al.[57] reported that boys had more FHP than girls. However, McEvoy et al.[58] and Van Niekerk et al.[59] reported no gender differences in relation to FHP was found. We suggest that the reasons for the different findings relate to the differences in the musculoskeletal systems of boys and girls, which may affect their neck angles.[46] A reduction in cervical angles may lead to cervical dysfunction. Other study have reported that mild neck pain was found in frequent smartphone users as a result of larger FHP.[32] An association was also found between larger FHP and cervical ROM deficits.[49]

In addition, our study found significant reductions among addicted boys in terms of their cervical ROM in extension, right rotation, and right lateral flexion. These findings were consistent with those of Kim et al.[21] and Moawd et al.,[61] who found the same results in adults, and of Kee et al.,[36] whose results for adolescent smartphone users were similar. However, Quek et al.[49] found that cervical ROM was limited in flexion and left rotation among participants who had FHP, which is different than our findings. In addition, Yoo et al.[24] found that cervical ROM in individuals with FHP was reduced in extension but not in flexion. Smartphone users commonly complain of stiffness and pain in the muscles around the neck, which is can be due to constant neck flexion.[21] This constant flexion may lengthen the anterior cervical muscles and shorten the posterior cervical muscles, which can cause FHP. When FHP occurs, it compresses the cervical facet joints, and this can cause a reduction in cervical mobility.[43] However, addiction to smartphones may affect not only the musculoskeletal systems of the individuals but also their lung function.[34]

Our findings showed lower values for FVC and FEV1 in addicted boys and girls, and this agrees with studies by Kang et al.[31] and Han et al.,[69] who reported similar findings in adults. Also, increases in the kyphotic posture of the upper thoracic region may occur as a result of frequent smartphone usage.[34] These changes in the mechanics of the cervical and thoracic spine may affect the ability of the chest wall to increase during inspiration and to rest normally during expiration.[26] In addition, height is considered to be one of the greatest predictors of lung function in children.[87] Although our study found no significant differences in the mean heights, we believe that height made a significant contribution to the overall findings, especially when the height is considered one of the predictors of the lung function. Moreover, Bucens et al.[77] stated that differences in height were a factor that could affect lung function in boys and girls aged from 8 to 14 years.[77] Furthermore, other studies found that an increase in FHP was found to be linked to a decrease in pulmonary function and respiratory muscle strength.[71,75]

In our study, the values for MVV, MIP, and the MEP were lower in boys and girls who were addicted to smartphones than in those who were not addicted. These results are consistent with those of Dimitriadis et al.[30,70] and Kapreli et al.,[28] who found that adults with FHP also showed lower values for MVV, MIP, and MEP. We suggest that this is due to a weakness in the neck muscles which is usually associated with weakness of the respiratory muscles. Changes in the cervical and thoracic spine may lead to weakness of the neck muscles, which can result in weakness of the accessory respiratory muscles.[70] Spinal instability and cervical muscle imbalance can affect the strength of the sternocleidomastoid, trapezius, and scalene muscles.[28,30] Also, Gossman, Sahrmann, Rose [82] indicated that the antagonist trapezius muscles could be shortened and the sternocleidomastoid and scalene muscles lengthened as a result of changes in the head position. In addition, one study reported differently, stated that girls are less able than boys to squeeze their lungs completely because their chest walls may not have developed as early as boys which can make their lung function less than boys.[76]

However, it is interesting to note that an increase in FHP was found to be connected with greater respiratory muscle strength. A study conducted by Okuro et al.[81] found that the MIP and MEP improved in children from 8 to 12 years who had FHP. Further research is needed to explain whether the changes in cervical posture could improve the strength of the respiratory muscles.

Conclusions

Our findings indicate that children who were addicted to smartphones adopted larger FHP than children who were not addicted to the smartphones. A smaller cervical angle can negatively affect cervical ROM as well as pulmonary function and respiratory muscle strength. Therefore, we strongly recommend reducing the numbers of hours spent on smartphones to avoid adapting habitual faulty posture and to maintain good cervical angle. Also, education about posture is recommended so that children maintain neutral head positions while viewing their smartphones for extended periods.

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APPENDIX A

DATA COLLECTION SHEETS

Smartphone Addiction Scale Short Version Questionnaire

	SAS-SV	Ranging from 1 : ‘strongly disagree’ to 6 : ‘strongly agree’					
1	Missing planned work due to smartphone use.	1	2	3	4	5	6
2	Having a hard time concentrating in class, while doing assignments, or while working due to smartphone use.	1	2	3	4	5	6
3	Feeling pain in the wrist or at the back of the neck while using a smartphone.	1	2	3	4	5	6
4	Won’t be able to stand not having a smartphone.	1	2	3	4	5	6
5	Feeling impatient and fretful when I am not holding my smartphone.	1	2	3	4	5	6
6	Having my smartphone in my mind even when I am not using it.	1	2	3	4	5	6
7	I will never give up using my smartphone even when my daily life is already greatly affected by it.	1	2	3	4	5	6
8	Constantly checking my smartphone so as not to miss conversations between other people on Twitter or Facebook.	1	2	3	4	5	6
9	Using my smartphone longer than I had intended.	1	2	3	4	5	6
10	The people around me tell me that I use my smartphone too much.	1	2	3	4	5	6

Qualtrics Parent Demographic Questionnaire

ID: _______

1. What is your child age?

- 8
- 9
- 10
- 11
- 12
- 13

2. What is your child race/ethnicity?
Select all that apply

- Middle Eastern
- Asian
- Pacific Islander
- Black/ African American
- Caucasian/ White
- Hispanic/ Latino
- Multiracial
- Other

4. What is your child's gender?

- Male
- Female

3. What grade is your child currently in?

- Grade 3
- Grade 4
- Grade 5
- Grade 6
- Grade 7
- Grade 8

5. Does your child use a smartphone device?
(Tablet, Smartphone, etc) Select all that apply

- Yes. They own a device.
- Yes. They use their parent's device.
- Yes. They use their siblings' device.
- No.

6. Approximately how many hours per day did your child use their smart device last week?

Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	

7. Would you consider this to be the typical usage of the device?

- Yes
- Maybe
- No

Investigators Form

Subject ID:

Age:

Height: **Weight:** **BMI:**

Cervical Range of Motion (CROM):

Trails	1	2	3	Average
Flexion				
Extension				
R. Rotation				
L. Rotation				
R. Lateral Rotation				
L. Lateral Rotation				

Craino-Vertebral Angle (CVA):

Trails	1	2	3	Average
CVA Angle Degree				

APPENDIX B

INFORMED CONSENT (CHILDREN 8-13 YEARS OLD)

The Effect of Smartphone Frequent Use on Children's Upper Posture and Pulmonary Function

Principal Investigator: Abdullah Alismail, M.S, RCP, RRT-NPS, SDS

Dear Parent,

Your child is invited to participate in a graduate student research study. This study is about measuring the levels of smartphone frequent usage and effects on children's posture and lung function. Please take the time to read carefully and understand what the study includes. To be part of this study, your child must be a healthy male or female aged 8-13 years old, and have bene using a smartphone for more than six months. Children with a history of muscle or joint pain, nerve disease, breathing issues, vision disorders not corrected by glasses, obese (BMI equal to or greater than the 95th percentile), or born with spinal deformity will be excluded. However, no data will be collected before obtaining the informed consent.

*Body Mass Index (BMI) is calculated using weight and height measurements and is an indicator of body fatness

<u>WHY IS THIS STUDY BEING DONE?</u>

The purpose of this study is to examine the degree of change on the upper neck angle that occurs in children after long hours of using smart devices. Also, how slouching/bending over the phone may affect the neck range of motion flexibility, lung function, and respiratory muscle strength.

HOW WILL I BE INVOLVED?

If your child meets the screening requirements and you have chosen to let your child take part in this study, then the study will take place at predesignated location at the school, university, or clinic. This study will take approximately one hour for one session only. At the first visit, you will complete a survey about your child's age, gender, grade, and hours spent using smartphone per week. Then, your child will answer questions on the Smartphones Addiction Scale Short Version for Adolescents (SAS-SV) questionnaire. This survey will measure your child level of dependency on smartphone use, and the scores they get from answering the questionnaire will place your child into categories (mild, moderate, or severe).

After that, your child will go through measurements at four stations:

1. First, a sticky reflective mark will be placed on outer ear and lower neck vertebra. Then, taking a side view photograph of your child's head and neck to measure the head posture angle. Three pictures will be taken, and the mean will be recorded.
2. Second, your child will place a cervical range of motion device (CROM) on the top of their head with the head in neutral position. This device is neither invasive nor going to hurt. The child will be asked to move the head in six directions (forward/backward, right and left lateral bending, and, right and left rotation). The CROM device has three separate inclinometers attached to a frame similar to eyeglasses. Also, as a part of the CROM device, a magnetic collar (necklace) will be placed on the shoulders to take into account any rotation of the trunk. Three measurements will be recorded for each motion, and the mean will be recorded.
3. Third, your child will be seated wearing nose-clip and mouthpiece to take the pulmonary function test PFT (Lung function test). Then, the child will be asked to perform some breathing exercise to a portable hand-held device. Each test will be performed three times, and large value will be recorded.
4. Finally, your child will be seated wearing nose-clip and will use a portable mouth pressure meter to evaluate respiratory muscle strength. Then, your child will be asked to close their mouth firmly around the mouthpiece to hold it in place to prevent any air leaking. The child will be asked to inhale as much as possible and exhale maximally against the resistance. This test will be performed three times, and large value will be recorded.

WHAT ARE THE REASONABLY FORESEEABLE RISKS OR DISCOMFORTS I MIGHT HAVE?

The risks of this study are no greater than those encountered in daily life. There might be a risk of breach of confidentiality. Also, during the PFT, the child will be given a time between tests to recover and not get tired.

WILL THERE BE ANY BENEFIT TO OTHERS OR ME?

Your child will not benefit directly from participating in this study, but the study should give us a better understanding of how limit smartphone usage time can help other children avoid improper effects on posture and lung functions. Also, you as a parent will have an idea of how your child's lung function is and have an idea of the frequent usage level.

WHAT ARE MY RIGHTS AS A SUBJECT?

Your child participation in this study is entirely voluntary. Your child may refuse to participate or withdraw once the study has started. Your decision whether or not your child will participate or terminate at any time will not affect your future medical care with the researchers. Your child does not give up any legal rights by participating in this study.

1. If you or your child decides to pull out from this study, you should notify the research team immediately.
2. The research team may also end your child's participation in this study if your child does not follow the instructions.
3. The research team may contact you afterward for further research participation.

CONFIDENTIALITY:
All records, reference photos, and research materials that identify your child will be labeled with a code linked to identifier, and will be held confidential and stored in a locked cabinet in a locked room at Loma Linda University. Any published document resulting from this study will not disclose your child identity without your permission. Also, any publication resulting from this study will refer to your child's ID number and not by your child's name. Your child's photo/image will not be disclosed at any time, and will be deleted immediately after measuring your child's neck angle. Upon request, you may also request a free copy of the PFT results once the research is completed.

WHAT COSTS ARE INVOLVED? AND WILL I BE PAID TO PARTICIPATE IN THIS STUDY?

There is no cost for participating in this study. Your child will receive a $10 gift card for his/her participation. In order to receive such payment, one of the parents may be asked to provide their name and their SSN or home address.

WHO DO I CALL IF I AM INJURED AS A RESULT OF BEING IN THIS STUDY?

If you feel your child have been injured by taking part in this study, consult with a physician or call 911 if the situation is a medical emergency. No funds have been set aside nor any plans made to compensate you for time lost for work, disability, pain or other discomforts resulting from your participation in this research.

WHO DO I CALL IF I HAVE QUESTIONS?

If you wish to contact an impartial third party not associated with this study regarding any complaint you may have about this study, you may call the Office of Patients Relations, Loma Linda University Medical Center, CA 92354, phone 909-558-4647 for information and assistance.

INFORMED CONSENT STATEMENT:
I have read the contents of the consent form and have listened to the verbal explanation given by the investigator. My questions regarding this study have been answered to my satisfaction. This study has been explained to my child in a manner appropriate to his/her age. By signing this form, I give permission for my child to participate in the study. Signing this consent document does not waive my child's rights nor does it release the responsibilities of the principal investigator, Abdullah Alismail, or Loma Linda University for their responsibilities. You may call Abdullah Alismail during routine office hours at (909) 558-1000 ext: 47119 or leave a voice message at this number during non-office hours.

I give voluntary consent for my child to participate in the study.

I understand I will be given a copy of this consent form after signing it.

Signature of Minor Subject (13-17)	Printed Name of Subject (13-17)
Signature of Parent/Guardian	Printed Name of Parent/Guardian
Date	

Investigator's Statement:
I have reviewed the contents of this consent form with the person signing above. I have explained potential risks and benefits of the study.

Signature of Investigator

Printed Name of Investigator

Date

APPENDIX C

PROTECTED HEALTH INFORMATION

INSTITUTIONAL REVIEW BOARD
Authorization for Use of Protected Health Information (PHI)

Per 45 CFR §164.508(b)

RESEARCH PROTECTION PROGRAMS
LOMA LINDA UNIVERSITY | Office of the Vice President of Research Affairs
24887 Taylor Street, Suite 202 Loma Linda, CA 92350
(909) 558-4531 (voice) / (909) 558-0131 (fax)/e-mail: irb@llu.edu

TITLE OF STUDY:	"The Effect of Smartphone Frequent Use on Children's Upper Posture and Pulmonary Function"
PRINCIPAL INVESTIGATOR:	Abdullah Alismail, M.S, RCP, RRT-NPS, SDS
Others who will use, collect, or share PHI:	Asma Alonazi

Only using personal information relating to your health may perform the study named above. National and international data protection regulations give you the right to control the use of your medical information. Therefore, by signing this form, you specifically authorize your medical information to be used or shared as described below.

The following personal information, considered "Protected Health Information" (PHI) is needed to conduct this study and may include, but is not limited to: name, birth date, social security number, phone number, email, and <u>medical records and charts, including the results of all tests and procedures performed</u>.

The individual(s) listed above will use or share this PHI in the course of this study with the Institutional Review Board (IRB) and the Office of Research Affairs of Loma Linda University.

The main reason for sharing this information is to be able to conduct the study as described earlier in the consent form. In addition, it is shared to ensure that the study meets legal, institutional, and accreditation standards. Information may also be shared to report adverse events or situations that may help prevent placing other individuals at risk. All reasonable efforts will be used to protect the confidentiality of your child PHI, which may be shared with others to support this study, to carry out their responsibilities, to conduct public health reporting and to comply with the law as applicable. Those who receive the PHI may share with others if law requires them, and they may share it with others who may not be required to follow national and international "protected health information" (PHI) regulations such as the federal privacy rule.

Subject to any legal limitations, your child has the right to access any protected health information created during this study. You may request this information from the Principal Investigator named above but it will only become available after the study analyses are complete.

- This authorization does not expire, and will continue indefinitely unless you notify the researchers that you wish to revoke it.

You may change your mind about this authorization at any time. If this happens, you must withdraw your permission in writing. Beginning on the date you withdraw your permission, no new personal health information will be used for this study. However, study personnel may continue to use the health information that was provided before you withdrew your permission. If you sign this form and enter the study, but later change your mind and withdraw your permission, you will be removed from the study at that time. To withdraw your permission, please contact the Principal Investigator or study personnel at (909) 558-1000 ext.: 47119.

You may refuse to sign this authorization. Refusing to sign will not affect the present or future care your child receive at this institution and will not cause any penalty or loss of benefits to which you are entitled. However, if you do not sign this authorization form, you will not be able to take part in the study for which you are being considered. You will receive a copy of this signed and dated authorization prior to your participation in this study.

I agree that my personal health information may be used for the study purposes described in this form.

Signature of Patient *or* Patient's Legal Representative	Date
Printed Name of Legal Representative (if any)	Representative's Authority to Act for Patient
Signature of Investigator Obtaining Authorization	Date