**A Cross-Sectional Study on Smartphone Usage and Craniovertebral Angle: Key Predictors of Neck Pain in Adolescents**

Abstract

Purpose: Smartphone use and craniovertebral angle (CVA) have been linked to neck pain in adolescents. However, the multifactorial contributors to neck pain remain unclear. Identifying its predictors is essential for informing preventive strategies. This study investigated smartphone use, craniovertebral angle, and other factors as predictors of neck pain in school-aged adolescents.

Study design: Cross-sectional study

Place and Duration of Study: Sample: six public high schools from the state education network in Pernambuco, Brazil, under the jurisdiction of the Education Department of Pernambuco.

Methodology: Adolescents (14-19 years), were divided into neck pain (69, 62,7%)  and no pain (41, 37,3%). They completed a questionnaire on smartphone use and musculoskeletal symptoms. Pain was assessed using the Visual Analog Scale and the Neck Disability Index, while physical activity was evaluated with the IPAQ short version. CVA was analyzed using CorelDraw software. Binomial logistic regression was performed to identify predictors of neck pain, reporting odds ratios (OR) with 95% confidence intervals (CI). The model’s explanatory power was assessed using Nagelkerke’s R², which estimates the proportion of variance in neck pain explained by the predictors.

Results: Excessive smartphone use (>4 hours/day) was a predictor of neck pain (OR = 5.06, p = 0.001), along with a smaller craniovertebral angle (OR = 0.90, p = 0.023) and upper limb musculoskeletal symptoms (OR = 3.18, p = 0.014). Tablet possession was associated with lower odds of neck pain (OR = 0.37, p = 0.046). The model explained 17.6% of the variance in neck pain ( R² = 0.176).

Conclusion: Excessive smartphone use, a smaller craniovertebral angle, and upper limb musculoskeletal symptoms were predictors of neck pain in adolescents, highlighting the need for preventive strategies to reduce modifiable risk factors.

Keywords: *Smartphone*, teen, musculoskeletal pain, posture

1. Introduction

Neck pain is a common musculoskeletal complaint among adolescents, with a rising prevalence in recent years (Jahre et al., 2020; Fandim et al., 2021; Souza et al., 2021). Understanding the predictors of neck pain in this population is crucial for developing preventive and therapeutic strategies (Lin et al., 2023).

Adolescents are exposed to various risk factors that may contribute to the development of neck pain, many of which are associated with lifestyle behaviors. Prolonged use of electronic devices, particularly smartphones, is a concern, as it is often related to discomfort in the cervical spine and linked to forward head posture (Neumann, 2017; Gustafsson et al., 2017; Kim et al., 2018).

The craniovertebral angle (CVA) is a widely recognized postural measure of head position relative to the cervical spine. A reduced CVA indicates a forward head posture, which has been associated with increased mechanical strain on the neck muscles and soft tissues. This altered posture is believed to contribute to the onset and persistence of neck pain (Mostafaee et al., 2022). However, the role of CVA as a predictor of neck pain in adolescents, especially in the context of smartphone use, requires further investigation.

In addition to primary predictors, other musculoskeletal symptoms contribute to neck pain. Symptoms like upper limb discomfort, neck heaviness, stiffness, burning, numbness, and tingling are interconnected and may increase neck pain risk through shared biomechanical and neural pathways (Sleijser-Koehorst et al., 2021).

Other potential predictors of neck pain include physical activity levels, body mass index (BMI), ergonomic factors, and the use of other devices such as tablets and computers. Biological factors, such as gender differences, may also influence susceptibility to neck pain (Giraldo-Jiménez et al., 2022; Gao et al., 2023).

All these factors interact to influence the onset of neck pain, necessitating a multifactorial approach to its assessment (Gao et al., 2023). However, previous studies on neck pain have primarily focused on the adult population or isolated risk factors (Gao et al., 2023; Fandim et al., 2021; Jahre et al., 2020), leaving a critical gap in understanding the combined contributors to neck pain in adolescents.

Addressing the multifactorial nature of adolescent neck pain is crucial for effective management. Current strategies primarily target sustained cervical spine flexion associated with smartphone use, often recommending assistive devices such as prism glasses and upper limb supports. While these approaches may help, a more comprehensive understanding of the predictors of adolescent neck pain is essential for identifying its underlying mechanisms, optimizing prevention strategies, and developing targeted, evidence-based interventions (Jahre et al, 2020; Fandim et al, 2021; Souza et al, 2021; Tapanya et al, 2021; Tang, Sommerich & Lavander, 2020).

Given this background, this study aims to investigate smartphone use, craniovertebral angle, and other factors as predictors of neck pain in school adolescents.

1. Methodology

2.1 Study design and settings

This cross-sectional study was conducted in six public high schools from the state education network in Pernambuco, Brazil, under the jurisdiction of the Education Department of Pernambuco. Schools were randomly selected, with one school representing each of the six Political-Administrative Regions (RPAs) of Recife, Pernambuco.

2.2 Participants

A total of 110 adolescents aged 14 to 19 years were included in the study. The inclusion criteria required participants to be actively enrolled in school and to own or regularly use a smartphone. Exclusion criteria comprised previous diagnoses of neurological or orthopedic conditions affecting cervical spine movement, cognitive deficits, cervical trauma or fractures within the past 12 months, neuromuscular diseases, or prior upper-limb surgeries.

2.3 Variables

**Dependent Variables**

**Neck pain**

Neck pain was assessed based on self-reported discomfort in the cervical region. Participants rated their pain intensity using the Visual Analog Scale (VAS), a validated tool for pain assessment (Bijur, Silver, & Gallagher, 2001). The VAS consists of a 10 cm horizontal line, with "no pain" (0 cm) at one end and "extreme pain" (10 cm) at the other. Participants indicated their pain intensity over the past seven days.

To classify participants, a VAS threshold was established, where individuals reporting a VAS score of ≥3 cm were categorized as experiencing clinically significant neck pain, while those with a VAS score of ≤2 cm were classified as having minimal or no pain. This cutoff ensured the study focused on clinically relevant symptoms, excluding mild or transient discomfort (MacDowall et al., 2018).

**Independent variables**

**Smartphone Usage Time**

Daily smartphone usage was objectively measured using the "Screen Time" feature on iOS devices and the "Digital Wellbeing" feature on Android devices. With prior parental consent, researchers accessed participants’ smartphones to review the weekly usage report, which provided total screen time over the previous seven days. To ensure data reliability, participants were instructed to report screen time from a typical week, avoiding atypical periods such as vacations, exams, or holidays, thereby minimizing recall bias (Ohme, Araujo, de Vreese, Piotrowski, 2020).

Data were categorized into two groups: moderate use (≤4 hours/day) and excessive use (>4 hours/day), following evidence from Santana et al. (2022), which link prolonged smartphone use to musculoskeletal discomfort and mental health disturbances. These studies highlight a 4-hour threshold as a critical point where negative health outcomes become more pronounced. Thus, this cutoff provides a scientifically grounded and methodologically consistent criterion for distinguishing between moderate and excessive use in alignment with existing literature.

**Craniovertebral Angle**

Craniovertebral Angle was assessed via photogrammetry, using a Multilaser DC 7.0 digital camera and CorelDRAW software (version 12.0). Reflective markers were placed on the tragus of the ear and the C7 spinous process. Participants stood barefoot in a natural upright posture, with eyes fixed on a horizontal target (Figure 1). The camera was positioned laterally at shoulder height, at a distance of 1.50–1.90 meters, under consistent lighting conditions (Kramer, Bauer, Matejcek, 2022).

Measurements were repeated three times, and the mean value was used in the analysis (Silva et al., 2014). A study assessing inter-rater and intra-rater reliability reported intraclass correlation coefficients (ICCs) ranging from 0.83 to 0.89, indicating excellent reliability (Gallego-Izquierdo et al, 2020).



**Figure 1**: Measurement of the craniovertebral angle.

**Sociodemographic and Schooling Characteristics**

A structured questionnaire collected data on age, sex (male/female), high school grade (1st, 2nd, or 3rd year), and parental education level (categorized as incomplete elementary school, incomplete high school, complete high school, incomplete higher education, or complete higher education).

**Anthropometric Measurements**

Height and weight were measured using a wall-mounted stadiometer and a calibrated digital scale. Body Mass Index (BMI) was calculated as weight (kg) / height² (m²) and categorized according to age- and sex-specific WHO percentiles (WHO, 2007).

**Physical Activity Levels**

The International Physical Activity Questionnaire (IPAQ) - Short Version was used to classify participants as very active, active, irregularly active, or sedentary, based on standard IPAQ scoring guidelines (IPAQ Research Committee, 2005).

**Sleep habits**

A structured questionnaire assessed sleep quality (good/bad) and sleep difficulties (e.g., difficulty falling asleep: yes/no). Average sleep duration was reported in hours.

**Use of Other Digital Devices and Backpack**

Participants reported the use of other electronic devices (e.g., computers, tablets, video game consoles; yes/no). Data on backpack use and smartphone ownership were also collected.

**Headache and Other Musculoskeletal Symptoms**

Participants reported headaches and other musculoskeletal symptoms (e.g., tingling, heaviness, cold sensations, burning, or numbness in the cervical region or upper limbs). Responses were categorized as Yes/No.

**Pain intensity and Disability**

Neck pain intensity was measured using the VAS, while neck-related disability was assessed using the Neck Disability Index (NDI). Both measures were analyzed as continuous variables, with higher scores indicating greater symptom severity (Silva et al., 2014).

**2.4 Statistical Analysis**

Descriptive statistics were used to summarize the sample. Categorical variables were expressed as frequencies (%), while continuous variables were reported as means ± standard deviations (SD). Data normality was assessed using the Kolmogorov-Smirnov test.  Comparisons between the neck pain and no neck pain groups were conducted using independent t-tests for normally distributed continuous variables, Mann-Whitney U tests for non-parametric continuous variables, and Chi-square tests for categorical variables. A binary logistic regression model was applied to evaluate associations between neck pain and predictor variables.

This preliminary analysis identified differences between groups and potential predictors for further modeling.(Kirkwood & Sterne, 2010). The regression model included both categorical and continuous variables identified in the univariate analysis with a p-value <0.20. (Hosmer et al, 2013)

Multicollinearity was examined using the Variance Inflation Factor (VIF), with values below 10 indicating no significant collinearity (Menard, 2002). The model’s fit was assessed using the Hosmer-Lemeshow test, while its discriminatory ability was evaluated through the area under the ROC curve (AUC >0.7) (Zou, O'Malley, & Mauri, 2007). The R² was reported to estimate the proportion of variance explained by the model.(Nagelkerke, 1991).

**2.5 Study Size**

The sample size was determined through an a priori power analysis using G\*Power software (Faul et al., 2007), with an alpha level of 0.05, a moderate effect size of 0.3, and a desired statistical power of 0.80. Based on these parameters, the required sample size was calculated to be 110 participants, ensuring sufficient statistical power to detect significant associations between smartphone usage and cervical pain.

 **2.6 Missing Data**

Missing data were addressed using an appropriate imputation method to maintain the integrity of the analyses. Participants with missing values in key variables, such as pain assessment, smartphone usage, or postural data, were excluded unless the missing data were minimal. In such cases, imputation was performed using the mean or mode of the available data to ensure consistency and minimize data loss (Little & Rubin, 2002). The final dataset included only complete cases, unless otherwise specified.

**2.7 Bias**

Several measures were implemented to minimize bias throughout the study. Selection bias was reduced by ensuring that the sampling frame was representative of the target adolescent population. Information bias was minimized through the use of standardized and validated questionnaires, as well as objective measurements (Kirkwood & Sterne, 2003). However, recall bias remains a potential limitation, particularly in self-reported pain intensity data, which may be influenced by subjective and retrospective perceptions. Despite utilizing objective tools to assess smartphone usage time, self-reported pain levels may still be susceptible to bias and variability. Additionally, the cross-sectional design limits the ability to establish causal relationships, and the presence of residual confounding factors cannot be entirely ruled out.

1. **Results**

The study included 110 adolescents aged 14 to 19 years, with 62.7% identifying as female. Participants were divided into two groups based on the presence of cervical pain: 69 participants reported cervical pain (62.7%), while 41 participants reported no pain (37.3%).

Table 1 presents the sociodemographic and schooling characteristics of the participants. No significant differences were found in school year, age, sex or anthropometric measures, including weight, height, and BMI, between the cervical pain and no-pain groups (p > 0.05). However, father's education level was significantly associated with cervical pain (p = 0.035). Adolescents with cervical pain had a higher prevalence of fathers with incomplete high school education (46.3%) compared to those without pain (14.6%). No differences were found between groups regarding mother’s education level.

**Table 1**: Comparison of Sociodemographic and Schooling Characteristics Between User Groups

|  |  |  |  |
| --- | --- | --- | --- |
| **Sociodemographic and Schooling Characteristics** | **Neck pain** | **Overall****(n=110)** | **P-value** |
| **Yes** | **No** |
| n= 69 | n= 41 |
| **School Year¹** - n (%) |  |  |  | 0.178 |
| 1stYear                                                               | 38 (55.1)  | 19 (46.3) | 57 (51.8) |
| 2nd Year | 12 (17.4) | 4 (9.8) | 16 (14.5) |
| 3rd Year | 19 (27.5) | 18 (43.9) | 37 (33.6) |
| **Age (in years)³** - Mean ± SD | 16.29 ± 1.22 | 16.29 ± 1.26 | 16.3 ± 1.24 | 0.991 |
| **Sex² -** n (%) |  |  |  | 0.112 |
| Female  | 49 (71) |  23(56.1) | 72 (65.5) |
| Male | 20(29) | 18(43.9) | 38 (34.5) |
| **Weight ³** (in Kg) - Mean ± SD |   59.16 ± 10.279  | 56.99 ± 10.084  | 58.3 ± 10.2 | 0.283 |
| **Height ³** (in cm) - Mean ± SD |   165.00 ± 0.0898  | 165.00 ± 0.0833 | 1.65 ± 0.0871 | 0.803 |
| **BMI** ³ (in Kg/m²) - Mean ± SD |   21.82 ± 3.364 | 20.81 ± 2.685 | 21.4 ± 3.15 | 0.104 |
| **Father’s education¹ - n(%)** |  |  |  | 0.035 |
| Incomplete elementary education | 12 (17.4) | 6 (14.6) | 18 (16.4) |
| Incomplete high school | 16 (23.2) | 19 (46.3) | 35 (31.8) |
| Complete high school or incomplete higher education | 10 (14.5) | 1 (2.4) | 11 (10) |
| Complete higher education | 31 (44.9) | 15 (36.6) | 46 (41.8) |
| **Mother’s education¹ - n (%)** |  |  |  |  |
| Incomplete elementary education | 13 (18.8) | 8 (19.5) | 21 (19.1) | 0.052 |
| Incomplete high school | 21 (30.4) | 21 (51.2) | 42 (38.2) |
| Complete high school or incomplete higher education | 11 (15.9) | 1 (2.4) | 12 (10.9) |
| Complete higher education | 24 (34.8) | 11 (26.8) | 35 (31.8) |

Legend: n (%) = Absolute frequency (n) and percentage (%); Mean ± SD = Mean value with Standard Deviation (SD); BMI: Body Mass Index; ¹ Chi-square test (Pearson’s); ² Chi-square test (Yates’ Correction); ³ Independent t-test.

The comparison of smartphone use, sleep habits, physical activity levels, and use of other digital devices and backpacks between the groups is shown in Table 2. Daily smartphone usage was significantly higher among adolescents with cervical pain, with a mean usage time of 8.2 ± 3.49 hours compared to 6.55 ± 3.63 hours in the no-pain group (p = 0.020). Excessive smartphone use (>4 hours daily) was also more prevalent in the cervical pain group (82.6%) than in the no-pain group (56.1%, p = 0.003).

Physical activity levels, as assessed by the IPAQ, did not differ significantly between groups (p = 0.274). The majority of participants were classified as very active or active (61.8%).

Sleep habits showed a significant relationship with cervical pain. Adolescents with cervical pain were more likely to report difficulty sleeping (88.4%) compared to those without pain (2.4%, p < 0.001). However, no significant differences were observed in perceived sleep quality (p = 0.601) or average sleep duration (p = 0.713).

Tablet use was also significantly associated with neck pain, with 41.2% of adolescents in the neck pain group reporting tablet use compared to 22% in the no-pain group (p = 0.032). No significant differences were observed between the groups regarding computer use (p = 0.872), video game use (p = 0.860), backpack use (p = 0.439), or smartphone ownership (p = 0.283).

**Table 2**: Comparison of Smartphone Use, Sleep Habits, Physical Activity Levels, and Use of Other Digital Devices and Backpacks Between Groups

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **Neck pain** | **Overall****(n=110)** | **P-value** |
| **Yes** | **No** |
| n= 69 | n= 41 |
| **Average Smartphone Use ¹ (hours/day) – Mean ± SD** | 8.2 + 3.49 | 6.55 + 3.63 | 7.59 + 3.62 | **0.020** |
| **Smartphone Use Classification ²  – n (%)** |  |  |  | **0.003** |
| >4 hours/day | 57 (82.6) | 23 (56.1) | 80 (72.7) |
| ≤4 hours/day | 12 (17.4) | 18 (43.9) | 30 (27.3) |
| **Physical Activity Level (IPAQ) ³ – n (%)** |  |  |  | 0. 274 |
| Very active/active | 39 (56.5) | 29 (70.7) | 68 (61.8) |
| Irregularly active (A and B) | 23 (33.3) | 8 (19.5) | 31 (28.2) |
| Sedentary | 7 (10.1) | 4 (9.8) | 11 (10) |
| **Good Sleep Quality ² – n (%)** |  |  |  |  |
| Yes | 42 (60.9) | 27 (65.9) | 69 (62.7) | 0.601 |
| No | 27 (39.1) | 14 (34.1) | 41 (37.3) |
| **Difficulty Falling Asleep ² – n (%)** |  |  |  |  |
| Yes | 61 (88.4) | 1 (2.4) | 62 (56.4) | **< .001** |
| No | 8 (11.6) | 40 (97.6) | 48 (43.6) |
| **Sleep Duration ² (hours) – Mean ± SD** | 6.67 + 2.18 | 6.49 + 6.64 | 6.60 +  2.35 | 0.713 |
| **Computer Use ² – n (%)** |  |  |  |  |
| Yes | 41 (59.4) | 25 (61) | 66 (60) | 0.872 |
| No | 28 (40.6) | 16 (39) | 44 (40) |
| **Tablet Use ² – n (%)** |  |  |  |  |
| Yes | 28 (41.2) | 9 (22) | 37 (33.9) | **0.032** |
| No | 40 (58.8) | 32 (78) | 72 (66.1) |
| **Video Game Use ² – n (%)** |  |  |  |  |
| Yes | 23 (33.3) | 13 (31.7) | 36 (32.7) | 0.860 |
| No | 46 (66.7) | 28 (68.3) | 74 (67.3) |
| **Backpack Use ²– n (%)** |  |  |  |  |
| Yes | 68 (98.6) | 41 (100) | 109 (99.1) | 0.439 |
| No | 1 (1.4) | 0 (0) | 1 (0.9 |
| **Backpack Use ² – n (%)** |  |  |  |  |
| Yes | 64 (92.8) | 40 (97.6) | 104 (94.5) | 0.283 |
| No | 5 (7.2) | 1 (2.4) | 6 (5.5) |

Legend: Mean ± SD = Mean value with Standard Deviation (SD); n (%) = Absolute frequency (n) and percentage (%); IPAQ = International Physical Activity Questionnaire; ¹ Independent t-test; ² Chi-square test (Yates’ Correction); ³ Chi-square test (Pearson’s); Bold values indicate statistically significant results (p < 0.05).

Table 3 presents the comparison of headache prevalence and other musculoskeletal symptoms between adolescents with and without neck pain.  Headache was strongly associated with cervical pain, with 82.6% of participants in the cervical pain group reporting headaches, compared to only 2.4% in the no-pain group (p < 0.001).

Participants with cervical pain also reported a significantly higher prevalence of a heavy feeling in the arms (56.5%) compared to the no-pain group (37.5%, p = 0.043). Other symptoms, such as tingling, burning sensation, numbness, or feeling cold, showed no significant differences between groups (p > 0.05 for all comparisons).

**Table 3**. Comparison of Headache and Other Musculoskeletal Symptoms Between User Groups

|  |  |  |  |
| --- | --- | --- | --- |
| **Musculoskeletal Symptoms, Posture, and Sleep Characteristics** | **Neck pain** | **Overall (n=110)** | **P-value¹** |
| **Yes** | **No** |
| n= 69 | n= 41 |
| **Headache – n (%)** |  |  |  |  |
| Yes | 57 (82.6) | 1 (2.4) | 58 (52.7) | **< .001** |
| No | 12 (17.4) | 40 (97.6) | 52 (47.3) |
| **Tingling – n (%)** |  |  |  |  |
| Yes |  32 (46.4) | 19 (46.3) | 51 (46.4) | 0.997 |
| No | 37 (53.6) | 22 (53.7) | 59 (53.6) |
| **Heavy Feeling – n (%)** |   |  |  |  |
| Yes | 39 (56.5) | 15 (37.5) | 54 (49.5) | **0.043** |
| No | 30 (43.5) | 25 (62.5) | 55 (50.5) |
| **Feeling Cold – n (%)** |  |  |  |  |
| Yes | 4 (5.8) | 1 (2.4) | 5 (4.5) | 0.414 |
| No | 65 (94.2) | 40 (97.6) | 105 (95.5) |  |
| **Burning Sensation – n (%)** |   |  |  |  |
| Yes | 21 (30.4) | 12 (29.3) | 33 (30) | 0.897 |
| No | 48 (69.6) | 29 (70.7) | 77 (70) |
| **Numbness – n (%)** |   |  |  |  |
| Yes | 26 (37.7) | 10 (24.4) | 36 (32.7) | 0.151 |
| No | 43 (62.3) | 31 (75.6) | 74 (67.3) |
| Legend: n (%) = Absolute frequency (n) and percentage (%); ¹ Chi-square test (Yates’ Correction); Bold values indicate statistically significant results (p < 0.05). |

The neck pain intensity, disability, neck posture, and craniovertebral angle between adolescents with and without neck pain are summarized in Table 4. Adolescents with neck pain reported significantly higher levels of pain intensity (Mean = 6.54 ± 1.77) and Neck Disability Index (NDI) scores (Mean = 8.97 ± 4.97), while those without neck pain scored 0.00 on these scales.

The craniovertebral angle was significantly smaller in the neck pain group (Mean = 47.2° ± 5.53°) compared to the no-pain group (Mean = 49.5° ± 4.42°; p = 0.029). There was no significant difference in the prevalence of anteriorization of neck posture between the neck pain group (52.2%) and the no-pain group (39%; p=0.182).

**Table 4**. Comparison of pain intensity, disability, neck posture and craniocervical angle between the groups of users.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **Neck pain** | **Overall (n=110)** | **P-value** |
| **sim** | **não** |
| n=69 | n=41 |
| **Neck Pain Intensity ¹ – Mean  ± SD** | 6.54 + 1.77 | 0.0  + 0 | 4.10 ± 3.47 | **< .001** |
| **Neck Disability (NDI)¹ – Mean  ± SD** | 8.97 + 4.97 | 0.0  + 0 | 5.63 ± 5.87 | **< .001** |
| **Craniovertebral angle ¹ (in °) – Mean  ± SD** | 47.2 + 5.53 | 49.5 + 4.42 | 48 ± 5.24 | **0.029** |
| **Neck Posture – Anteriorization² – n (%)** |  |  |  |  |
| Yes | 36 (52.2) | 16 (39) | 52 (47.3) | 0.182 |
| No | 33 (47.8) | 25 (61) | 58 (52.7) |
| Legend:  Mean ± SD = Mean value with Standard Deviation (SD); n (%) = Absolute frequency (n) and percentage (%); IPAQ = International Physical Activity Questionnaire; ¹ Independent t-test; ² Chi-square test (Yates’ Correction); Bold values indicate statistically significant results (p < 0.05). |

The binomial logistic regression analysis, summarized in **Table 5**, identified several predictors of neck pain. Increased smartphone usage of more than 4 hours per day was a significant risk factor (Odds Ratio [OR] = 5.06, 95% Confidence Interval [CI] = 1.914–13.38, p = 0.001). A smaller craniovertebral angle was associated with an increased likelihood of neck pain (OR = 0.90, 95% CI = 0.82–0.98, p = 0.023). Possession of a tablet was associated with reduced odds of neck pain (OR = 0.37, 95% CI = 0.14–0.97, p = 0.046). Additionally, the presence of upper limb musculoskeletal symptoms significantly increased the likelihood of neck pain (OR = 3.18, 95% CI = 1.26–8.06, p = 0.014).

The regression model demonstrated good fit (Hosmer-Lemeshow test, p = 0.176) and acceptable discrimination ability (Area Under the Curve [AUC] = 0.82). The model explained approximately 17.6% of the variance in neck pain (Nagelkerke R² = 0.176).

**Table 5**. Binary Logistic Regression Model for Neck Pain

|  |
| --- |
| **Neck Pain** |
| **Predictor** | **β** | **SE** | **Z-value** | **P-value** | **OR** | **95% CI** |
| **Intercept** | 4.478 | 2.2445 | 1.99 | **0.046** | 88.025 | 1.082 – 7163.033 |
| **Craniovertebral Angle (°)** | -0.106 | 0.0468 | -2.27 | **0.023** | 0.899 | 0.820 – 0.985 |
| **Smartphone Use > 5h/day** | 1.621 | 0.4966 | 3.26 | **0.001** | 5.056 | 1.910 – 13.382 |
| **Owns a Tablet**  | -1.006 | 0.5051 | -1.99 | **0.046** | 0.366 | 0.136 – 0.984 |
| **Upper Limb Pain**   | 1.158 | 0.4737 | 2.45 | **0.014** | 3.185 | 1.259 – 8.059 |
| Nagelkerke R² = 0.176; Hosmer-Lemeshow test, p = 0.176 (Good Fit); Area Under the Curve [AUC] = 0.82 (Acceptable). |

Legend:  β (Beta Coefficient; SE (Standard Error); OR (Odds Ratio); 95% CI: 95% Confidence Interval; Bold values indicate statistically significant results (p < 0.05).

1. Discussion

This study suggests that smartphone use over four hours daily, increased craniovertebral angle, upper limb pain, and tablet use are strong predictors of adolescent neck pain. These findings highlight the multifactorial nature of cervical pain, involving behavioral, postural, and musculoskeletal factors. Addressing these risks requires comprehensive strategies for prevention and management.

Given the multifactorial nature of cervical pain, interventions should not only focus on ergonomic adjustments but also address behavioral and musculoskeletal factors, promoting awareness of posture, appropriate screen time management, and strengthening exercises to mitigate cervical strain. These considerations are particularly relevant in the context of increasing technology use among adolescents. (Jahre et al., 2020; Fandim et al., 2021; Souza et al., 2021; Tapanya et al., 2021; Tang, Sommerich & Lavander, 2020).

The association between four hours of daily smartphone use and cervical pain aligns with studies showing that prolonged device use causes biomechanical strain on the cervical spine due to sustained flexion, head anteriorization, and lack of rest (Gustafsson et al., 2020; Hussain, Griffiths & Sheffield, 2017; Nunes et al., 2021, Vitta et al, 2021).

In our study the mean daily smartphone usage time differed significantly between adolescents with and without cervical pain. Participants reporting cervical pain had a mean smartphone usage time of 8.2 ± 3.49 hours, while those without cervical pain reported a lower mean usage time of 6.55 ± 3.63 hours.  Furthermore, adolescents who used smartphones for more than four  hours per day (82.6%) were found to be 5.07 times more likely to experience neck pain compared to those with lower usage times (56.1%).

These results underscore a clear behavioral pattern, where excessive screen time is strongly associated with the prevalence of cervical discomfort in adolescents. This aligns with studies that describe a dose-response relationship, where increased screen time correlates with higher rates of musculoskeletal complaints (Gustafsson et al., 2020). Adolescents, due to their developing musculoskeletal systems, may be particularly vulnerable to the cumulative effects of  sustained flexion and poor posture.

Regarding head posture, our study identified that poorer cervical alignment, characterized by a smaller craniovertebral angle and indicative of forward head posture, increases the risk of pain. Specifically, for each 1-degree increase in the craniovertebral angle, the odds of developing neck pain decrease by 10%. Studies have consistently demonstrated that for every degree of forward flexion, the relative load on the cervical spine significantly increases, amplifying musculoskeletal stress and predisposing individuals to pain (Neumann, 2017; Straker et al., 2009).

This relationship occurs because forward head posture increases the moment arm of the head's weight, substantially amplifying the load on cervical muscles. Over time, this additional strain contributes to muscle fatigue, ligament tension, and overall cervical discomfort.

Regarding other musculoskeletal symptoms, our study found that individuals with upper limb pain are 3.18 times more likely to experience neck pain compared to those without such symptoms. This finding highlights the interconnected nature of musculoskeletal complaints, emphasizing how discomfort in one region can influence or exacerbate pain in another

Upper limb symptoms, such as pain, tingling, or numbness, may result from postural imbalances and prolonged static positions during smartphone or tablet use. These findings align with studies suggesting that musculoskeletal strain often extends beyond the cervical region, impacting the upper limbs due to shared biomechanical and neurological pathways (Eitivipart, Viriyarojanakul & Redhead, 2018).

On the other hand, possession of a tablet was inversely associated with neck pain (OR=0.37, 95% CI: 0.14–0.97, p=0.046), suggesting a potential protective effect.  This finding could reflect differences in usage patterns between tablets and smartphones. Tablets are often used in more ergonomically favorable positions, such as resting on a stand or table, reducing the prolonged cervical flexion commonly associated with smartphone use (Berolo et al., 2011). The larger screen size of tablets may also promote more neutral head and neck postures, contributing to reduced strain.

Beyond ergonomics, this association could also be influenced by differences in screen time and usage purposes. Tablet use is often associated with activities such as reading, studying, or media consumption, which may involve less sustained handheld use compared to smartphones, thereby reducing static loading on the cervical spine. Moreover, individuals who frequently use tablets may have greater awareness of posture or access to adjustable workstations, further contributing to the protective effect. These results highlight the need for further research on the ergonomic implications of tablet use and its potential role in mitigating neck pain.

Other factors, although not identified as predictors in the present study, were more frequently observed in individuals with neck pain. These factors included difficulty sleeping,  paternal education level,  headache prevalence and heavy sensation.

The strong association between cervical pain and difficulty sleeping (88.4% in the pain group vs. 2.4% in the no-pain group, p < 0.001) highlights the potential bidirectional relationship between sleep disturbances and musculoskeletal discomfort. However, sleep quality and duration did not differ significantly between groups, indicating that sleep disruption may be more closely linked to pain perception than objective measures of sleep (Finan et al., 2013).

The association between paternal education level and cervical pain (p = 0.035) may reflect broader social determinants of health. Lower education levels may correspond with reduced access to ergonomic tools or awareness of healthy device use habits (Marmot and Wilinson, 2005).

Additionally, headache prevalence (82.6% in the pain group, p < 0.001) and a heavy sensation (56.5%, p = 0.043) are consistent with referred pain patterns observed in cervical spine dysfunction.  Referred pain occurs when pain is perceived in a location other than its origin due to shared neural pathways, particularly in the cervical spine and head region (Bogduk & Govind, 2009).

Cervical spine dysfunction can irritate or compress the nerves originating from the cervical region, leading to pain that radiates toward the head and mimics primary headache disorders. This phenomenon is particularly linked to cervicogenic headaches, which are characterized by unilateral pain that originates in the cervical spine and refers to the frontal, temporal, or orbital regions (Bogduk, 2001; Fernández-de-las-Peñas et al., 2008).

The sensation of heaviness in the neck is similarly tied to cervical muscle strain or joint dysfunction, both of which are exacerbated by prolonged static postures, such as those adopted during smartphone use. The postural stress leads to overactivation of cervical and shoulder girdle muscles, resulting in fatigue and discomfort often perceived as heaviness (Treleaven, 2008).

These findings highlight the importance of considering cervical dysfunction in the differential diagnosis of headaches and neck discomfort, especially in populations with high screen usage.

Contrary to expectations, other factors such as physical activity levels and anthropometric measures did not differ significantly between groups (p > 0.05). These findings suggest that neck pain in adolescents may be more influenced by behavior and posture than by overall fitness or body composition. The high percentage of active participants (61.8%) highlights the need to explore how different activity types affect cervical health (Sitthipornvorakul et al., 2010).

The present study also found no significant difference in the prevalence of neck pain between male and female adolescents. This finding aligns with studies suggesting that sex differences in neck pain may not appear in adolescence, as musculoskeletal issues typically become more pronounced in females after puberty due to hormonal, anatomical, and behavioral factors.

However, other studies have reported higher rates of neck pain in female adolescents, attributing this to factors such as increased sensitivity to pain, greater exposure to psychosocial stressors, and different patterns of physical activity compared to males. (Houda Ben Ayed et al, 2019) The lack of sex differences in our study may reflect the specific characteristics of our sample or the cross-sectional nature of the analysis, which does not capture temporal changes in pain prevalence. Further research, particularly longitudinal studies, is needed to better understand how sex influences neck pain development during adolescence.

The study’s rigorous methodology, including the application of binomial logistic regression, reinforces the reliability of its findings. The incorporation of objective assessments, such as the craniovertebral angle and smartphone usage data, further enhances result precision. Moreover, by focusing on adolescents—a critical yet understudied population—the study provides valuable insights into behavioral patterns, musculoskeletal symptoms, and postural factors contributing to neck pain during a pivotal stage of musculoskeletal development.

However, several limitations should be acknowledged. The cross-sectional design limits the ability to establish causal relationships between predictors and neck pain. The reliance on self-reported data for variables such as pain levels and sleep quality may introduce recall bias or subjective inaccuracies. Notably, self-reported pain levels are inherently subjective, which may affect data reliability. Additionally, the study did not account for potential confounders such as psychosocial factors, family history, or other daily habits beyond those assessed by the IPAQ.

Future research should focus on longitudinal studies to establish causal pathways and monitor the progression of neck pain over time. Experimental studies testing interventions, such as reducing smartphone use or implementing posture correction strategies, could provide actionable insights. Additionally, evaluating psychosocial influences on musculoskeletal health would further enrich the understanding of the complex interplay of factors affecting neck pain in adolescents.

1. Conclusion

The findings of the present study provide strong evidence that smartphone use for more than 4 hours per day and a reduction in the craniovertebral angle are significant predictors of neck pain in adolescents. However, tablet possession was inversely associated with neck pain, suggesting a potential protective effect due to its ergonomic differences in handling compared to smartphones.

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Compliance with Ethical Standards

Conflict of Interest: the authors declare that they have no conflict of interest.

**Ethical approval and consent**

The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and complied with the ethical principles outlined in the Declaration of Helsinki and Resolution 466/12 of the National Commission for Research Ethics (CONEP) of the Brazilian Ministry of Health. Ethical approval was obtained from the Research Ethics Committee of the Health Sciences Center at the Universidade Federal de Pernambuco (UFPE) (CAAE: 70089917.5.0000.52088).

Prior to participation, all adolescents provided informed assent (IAF), while those aged 18 and above signed informed consent forms (ICF). Parental or guardian consent was obtained for all minors.

Disclaimer (Artificial Intelligence)

The authors declare that generative AI technologies, specifically Large Language Models, were used during the editing of the manuscript. The model used was GPT-4 from OpenAI, accessed via the ChatGPT platform. The prompts provided to the AI included text editing requests and revisions of specific sections of the manuscript.

Details of the AI usage are given below:

1. The editing of the manuscript was supported by ChatGPT AI in content review and structure.

2. Artificial intelligence was employed to enhance the text editing, ensuring greater fluency and consistency.

3. Assistance from artificial intelligence was used in revising and optimizing certain sections of the manuscript.

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