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Excessive screen time on posture, musculoskeletal pain, and quality of life in generation Z adolescents: a cross-sectional study with comparison between the sexes

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Abstract

Objectives: Excessive use of electronic devices can cause postural changes, pain, and negatively impact generation Z adolescents' quality of life (QoL). The goals of this study were to evaluate and compare between sexes the static posture, postural self-perception, screen time, musculoskeletal pain, and QoL in generation Z adolescents.

Methods: Cross-sectional study with adolescents. Postural analysis was conducted using the Software SAPo, self-reported posture, back pain, and screen time were assessed with the BackPei-CA, and QoL was evaluated using the Kidscreen-27 questionnaire. Statistical analyses included t-test or Mann–Whitney U test, Spearman's correlation, and adjusted logistic regression, with correction for multiple comparisons ($p \le 0.05$).

Results: 408 adolescents were included (204 of each sex), with a mean age of 14.58 ± 1.98 years (males) and 14.56 ± 1.84 years (females). Postural assessment revealed head anteriorization and pelvic misalignment, with females showing greater head and pelvic angular deviations. No significant associations were found between cell phone use and cervical or pelvic alignment. Cell phones/tablets were the most frequently used devices, with higher daily use among females. Musculoskeletal pain was highly prevalent, particularly in the cervical and lumbar regions, and more frequent in females; however, cell phone use was not independently associated with musculoskeletal pain after adjustment. The total sample of adolescents has a good QoL.

Conclusions: Adolescents, especially females, showed head anteriorization and pelvic misalignments, high screen time, and self-perceived inadequate postural habits. Musculoskeletal pain was frequent and more prevalent among females, despite good quality of life. Screen time alone was not associated with postural changes or pain, indicating a multifactorial etiology.

Keywords: adolescents; posture; musculoskeletal pain; quality of life; screens

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Introduction

Generation Z teenagers, born between 1997 and 2012, belong to a generation characterized by digital fluency and constant connection with the media, and may present postural changes and musculoskeletal pain due to excessive use of electronic devices [1, 2]. With technological advancements, there has been an exponential increase in the use of electronic devices (ED) such as tablets, cell phones, televisions, and computers in most of the population, especially among young people, where approximately nine to ten adolescents currently have access to technology [3]. The sedentary activity of ED use can be problematic when introduced too early or when there is minimal control by those responsible, and may be related to increased delay or deficit in development, postural changes, negative impact on quality of life (QoL) and poor sleep quality in adolescents and even in subsequent adulthood [4, 5].

Theoretically, all screen times should be supervised by a responsible adult [6]. According to the World Health Organization (2019) [7], the recommended screen time for adolescents is up to 3 h per day. However, in the current reality, the daily use of screens exceeds the established target. According to Frata et al. (2021) [8], adolescents use ED on average 4–5 h a day. The rampant use of ED has a negative impact on the QoL of its users, directly affecting intrapersonal relationships, such as isolation and decreased self-esteem and reduced interpersonal relationships with family and friends, including emotional bonds, social interaction, communication, and trust [9].

Furthermore, the use of ED has been the cause of several postural problems that originate in adolescence, during the growth and development of the body. In these phases, individuals are more vulnerable to engaging in behaviors that aggravate these problems, which may be related to excessive time spent on screens and inappropriate postures when using devices, such as watching television or using computers and cell phones while lying down [5, 10]. Previous studies indicate that postural alignment during adolescence may vary according to sex, with females showing a higher prevalence of certain postural deviations, such as forward head posture and alterations in pelvic and lumbar alignment, resulting from maturational and hormonal differences during puberty [11, 12]. Using a smartphone in the typing position, for example, causes the head to tilt forward and has been associated with longer use time, male sex, cervical dysfunction, and impaired sleep [13–15]. ED use and the resulting neck flexion are associated with a greater risk of musculoskeletal disorders in the cervical region, as an increase in this flexion causes biomechanical changes and muscle and joint overload in this region [16]. The head angle in the neutral position creates an overload of approximately 5 kg in the neck [16, 17]. This overload increased according to the flexion angle, reaching a load of 27 kg at a 60° flexion [16, 17].

Among the postural changes commonly observed in excessive ED users, the most notable are forward head position, accentuated thoracic kyphosis, and shoulder protraction [18]. Furthermore, pain and stiffness in these regions are a common complaint, especially in the shoulders, owing to the tension caused by holding a tablet or cell phone [18]. A one-year prospective study conducted with 1,393 adolescents aged 14–18 years identified risk factors predicting new episodes of low back pain, including being female, having mental health problems, using a tablet while sitting, using a cell phone while lying down, and using tablets/cell phones for an average of three or more hours per day [19]. According to Paranjape e Ingole, (2018) [20] the higher incidence of pain found in female adolescents may be due to differences in pain thresholds and hormonal changes induced by puberty. Authors of a systematic review with meta-analysis also pointed to cultural issues in which girls demonstrate greater pain perception than boys, as well as specific anatomical and functional characteristics of females in the pubertal development phase [21]. These differences appear to result from a multifactorial interaction of biological factors, including pubertal hormonal influences on pain sensitivity and musculoskeletal tissue regulation, as well as psychosocial and cultural factors, such as gender-related behaviors and postural habits [22–25].

Furthermore, the study conducted by Warda; Nwakibu; Nourbakhsh (2023) [26], reported several other consequences of excessive ED use in adolescents from generation Z, such as headache, ocular and auditory symptoms, psychological problems such as depression and anxiety, and peripheral neurological symptoms such as tingling and numbness in the hands, which can lead to poor academic performance and reduced quality of life (QoL). Health-related quality of life is a multidimensional health model that describes aspects of well-being and physical, emotional, mental, social, and behavioral functions identified by individuals and others [27]. Moreover, the sedentary lifestyle of adolescents from Generation Z associated with prolonged screen exposure may exacerbate mental health problems, especially among girls, contributing to emotional distress, poorer body image, and lower self-esteem [6, 28].

The scarcity of studies that integrate static postural assessment with self-reported postural habits during ED use, along with screen time, musculoskeletal pain, and quality of life, highlights the relevance of this research. By addressing these multiple dimensions together and analyzing potential gender differences, this study fills an important gap, offering a more complete picture of how technology impacts the physical and motor health of Generation Z adolescents. These findings provide new evidence that can inform targeted guidance and support preventive strategies in the school environment. Thus, this study aimed to evaluate and compare between sexes the static posture, postural self-perception, screen time, musculoskeletal pain, and quality of life in generation Z adolescents.

Methods

Study type and sample

This research qualifies as a cross-sectional observational study and was conducted with a convenience sample composed of adolescents from public schools in South Brazil. This study followed the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [29] and was approved by the Ethics Committee for Research Involving Human Beings of the Santa Catarina State University – CEPSH/UDESC; CAAE: 3993823.2.0000.0118).

Initially, the project was submitted to the State Department of Education to present the study and obtain permission to invite schools to participate. After authorization, the institutions that agreed were included in the research, and a schedule of activities was defined in conjunction with the school administrators. Subsequently, the parents or legal guardians of the students were contacted through the schools' official communication channels to present the study and request their consent to participate. Thus, adolescents aged 11–17 years, enrolled in public elementary and secondary public schools participated in the study. Literate adolescents who understood the assessment instruments were included. Participants with any syndrome and/or motor and/or cognitive impairment that could interfere with data collection and those who refused to undergo biophotogrammetry were excluded. The parents and/or legal guardians of the participants signed the Free and Informed Consent Form and the Consent Form for Photographs, Videos and Recordings and the adolescents signed the Assent Form.

Instruments and data collection procedures

Data collection was carried out by a team of trained researchers and took place in a school setting, in private rooms provided by the administrations of the participating schools. The assessments were previously scheduled on the days and times of the school shift. First, each adolescent was evaluated individually, and anamnesis, anthropometric measurements and biophotogrammetry were performed. They subsequently responded to the BackPEI-CA and KIDSCREEN-27 questionnaires.

The anamnesis was prepared by the researchers, which contained the identification data, physical activity profiles, and musculoskeletal pain complaints of the participant. The anthropometric measurements were performed by the same trained evaluator, in a single measurement. Body mass was measured using a digital scale (Multilaser®, HC021, Brazil) with the students barefoot and wearing light clothing, positioned in the center of the scale, and height in meters was measured using a measuring tape with the students standing barefoot, with proper posture and their heads oriented at 90° in relation to the ground. Body mass and height values were used to classify the relationship between body mass and height squared, known as Body Mass Index (BMI).

Postural assessment of the students was performed using biophotogrammetry and followed the recommendations of the Postural Assessment Software v0. 68® (SAPo) [30]. A digital camera (SONY Cyber-shot®, DSC-S950, Japan) was used, positioned parallel to the floor, leveled on a tripod with a bubble level at a 90 cm height, and at a 3 m horizontal distance from the place where the individual was positioned. The adolescents were photographed in frontal and sagittal planes by the same trained evaluator, and the image was calibrated using a plumb line. Three pictures of each position (frontal and sagittal planes) were taken, and the picture with the best posture was considered [30]. The photographs were taken with the participants barefoot, with the boys shirtless and the girls wearing a bikini top or a crop top, with white spherical markers measuring 1 cm in diameter carefully placed in the anatomical regions. The identification, anatomical marks positioning, and the capture of photographic images were performed by a single, previously trained physiotherapist evaluator, following the recommendations of the SAPO Protocol [30] and according to Souza et al. (2011) [30]. In the anterior view: the right and left tragus, right and left acromion, glabella, right and left epicondyles, and right and left anterior superior iliac spine (ASIS) in the posterior view: the right and left tragus, right and left acromion, right and left inferior angles of the scapula, right and left acromion, right and left posterosuperior iliac spine, and the C7 and T3 spinous processes finally, in the left and right lateral views: the glabella, left and right tragus, left and right acromion, left and right lateral epicondyles, left and right posterosuperior iliac spines, left and right ASIS, and spinous processes were marked (C7 and T3).

Postural analysis was performed using Postural Assessment Software (SAPo), version 0.68®, by two independent assessors, both previously trained. The SAPO protocol is valid and reliable, demonstrating good reliability for both intra-rater and inter-rater assessments, with an intraclass correlation coefficient ranging from 0.80 to 0.90 [30]. The software's inherent margin of error is considered small and clinically irrelevant, as an angle mean error analysis of approximately 0.11° and distance measurements mean error analysis of approximately 1.8 mm [31].

The SAPO protocol angles corresponded to the horizontal and vertical alignments of the head, horizontal alignment of the acromions, horizontal alignment of the anterior-superior iliac spines, angle between the two acromions, angle between the two anterior-superior iliac spines, frontal angle of the right and left limbs, horizontal asymmetry of the scapula in relation to T3, and horizontal alignment of the pelvis (Figure 2).

In the previous view, the horizontal alignment of the head (HHA) represents the angle formed between the distance of the two tragus; a positive angle indicates that the head tilted to the right and a negative angle indicates that the head is tilted to the left [32]. The acromion horizontal alignment (HAA) represents the angle of inclination formed between the distances between the right and left acromions; a negative value indicates a greater elevation of the left acromion, and a positive value indicates right acromion elevation [33]. The horizontal alignment of the ASISs (HAASIS) represents the angle of inclination formed between the distances of the ASIS to identify the pelvic tilt; a negative value indicates a greater elevation of the left ASIS, and a positive value indicates right ASIS elevation [34]. The angle between the two acromions and the two ASIS (AAASIS) represents the inclination of the trunk; a negative value indicates a greater inclination of the trunk to the left, and a positive value indicates the inclination of the trunk to the right [33]. In the posterior view, the horizontal asymmetry of the scapula in relation to T3 (HAST3) represents the elevation of the scapula in relation to the T3 vertebra, the value of which represents the percentage of difference in proximity between the left and right lower edges of the spine's center; a negative value indicates greater elevation of the scapula on the left, and a positive value indicates elevation of the scapula on the right [35]. In the lateral view, the horizontal alignment of the head in relation to C7 (HHAC7) represents the angle formed by the tragus and a horizontal line from the C7 vertebra, indicating anteriorization of the head; the smaller the angle obtained, the greater the anteriorization of the head [32]. The vertical alignment of the head in relation to the acromion (VAH) occurs through the angle formed by the tragus, acromion, and a vertical line from the acromion and indicates anteriorization of the head; the greater the angle, the greater the anteriorization of the head [32]. The horizontal alignment of the pelvis (HAP) represents the angle obtained by the distance between the anterior and posterior superior iliac spines [34].

A postural self-perception evaluation and back pain was performed using the BackPEI-CA questionnaire, validated for the Brazilian population, which contains 29 closed questions. This instrument is self-administered by children and adolescents and contains a specific version for females and males that differs in specific photos [36]. It addresses issues related to pain in the cervical and lumbar spine in the last 3 months (occurrence, frequency, and intensity), socioeconomic data (education of parents/guardians and type of school), behavioral habits (physical activity, reading/studying in bed, hours/day watching television and using cell phones and computers, hours of sleep per day), postural habits (sitting to write and using cell phones and computers, carrying school supplies, sleeping, and sitting during class), and hereditary habits (occurrence of back pain in parents). Questions 9 to 14, which involve postural habits, are illustrated with photographs, and the participant must select the image that best represents their daily posture [36].

The KIDSCREEN-27 questionnaire was used, which consists of five dimensions to evaluate the QoL: (1) physical well-being (five items), (2) psychological well-being (seven items), (3) autonomy and parental relationships (seven items), (4) social support and peers (four items), and (5) school environment (four items) [27]. The 27 items had five response options according to intensity (not at all, little, moderately, a lot, and completely) and frequency (never, rarely, sometimes, often, and always), with a 1-week recall period. Scores were coded from 1 to 5, and items phrased with negative response categories (1, 9, 10, and 11) were reversed to follow the same direction as the positively phrased items. Good QoL was defined as a score equal to or greater than 80 points [27].

Data processing and analysis

The biophotogrammetry data reports generated in the Postural Assessment Software v0. 68® (SAPo) and data from the questionnaires were transferred to an electronic spreadsheet for interpretation and tabulation. Afterwards, the data from the present study were processed and analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Descriptive analysis data is expressed as absolute and relative frequency, mean, standard deviation or median and interquartile range. The normality of the data distribution was evaluated using the Kolmogorov–Smirnov test. The Independent t-test (normal distribution) and Mann–Whitney U test (non-normal distribution) was used to compare quantitative variables between sexes. A significance level of 5 % ($p \leq 0.05$) was adopted. For the comparisons between sexes of postural variables, the Bonferroni correction for multiple comparisons was applied to control the type I error rate. The significance level was adjusted from the conventional α=0.05 by dividing it by the number of comparisons performed (n=11), resulting in a corrected significance threshold of $p \leq 0.004$.

The relationship between cell phone usage time (>3 h) and postural alignment was assessed using Spearman's correlation coefficient. The Holm-Bonferroni method was applied to correct for multiple comparisons, thus reducing the risk of type I error ($p \leq 0.05$). Associations between cell phone usage time (>3 h) and the presence of musculoskeletal pain were examined using adjusted logistic regression models. All models were adjusted for potential confounding variables, including sex, age, and body mass index ($p \leq 0.05$).

Results

Of the total of 600 elementary and high school adolescents enrolled in three public schools, 408 (204 of each sex) were included in this study, representing an adherence rate of 68 % (Figure 1). The sample characteristics are presented in Table 1. There was no statistical difference in the comparison between sexes, indicating that the sample is homogeneous.

In the general postural assessment, anteriorization and lateral tilt of the head to the right and horizontal misalignments of the pelvis to the left, were observed (Table 2). When comparing sexes, there was a significant difference in the horizontal alignment of the head relative to C7 in the left ($p<0.001$) lateral view and in the horizontal alignment of the anterosuperior iliac spines in the right ($p<0.001$) and left ($p<0.001$) lateral views, and, with greater angulation in females in both cases. The association between cell phone usage time (>3 h) and postural alignment was analyzed using Spearman's correlation coefficient. No significant correlations were found between cell phone usage time and cervical alignment (right: ρ=0.02, p_raw=0.66; left: ρ=−0.01, p_raw=0.83) or pelvic alignment (right: ρ=0.01, p_raw=0.81; left: ρ=−0.00, p_raw=0.95). After adjustment for multiple comparisons using the Holm–Bonferroni method, all associations remained non-significant (p_holm=1.00).

Regarding the assessment of postural self-perception in different postures using electronic devices, using the BackPei-CA questionnaire, it was found that in the sitting position when using the computer, 91 (22.3 %) of the adolescents reported keeping their knee flexed at 90°, sitting on the coccyx and forming lumbar kyphosis, with 50 (24.5 %) males and 41 (20.1 %) females. To use a cell phone or tablet while sitting, 193 (47.3 %) of the individuals reported sitting under their coccyx, with their knees flexed above 90° and their head flexed at approximately 60°, this posture being more prevalent in both sexes (98 (48 %) boys and 95 (46.6 %) girls). Regarding posture when using a cell phone while standing, the most common posture, with 123 (30.1 %) responses, was characterized by using the cell phone below the eye line and flexing the head at approximately 45°, with greater prevalence in male (75 (36.8 %) boys vs. 48 (23.5 %) girls). However, among female participants there was a higher prevalence (n=86; 42.2 %) of the perception of maintaining a more pronounced cervical flexion angle (60°) when using a cell phone while standing up. Figure 3 shows the Daily screen time per electronic device according to sex. Cell phones/tablets were the most frequently used electronic devices. Among males, the most common daily usage duration was 4–5 h (n=61), whereas among females it was 6–7 h

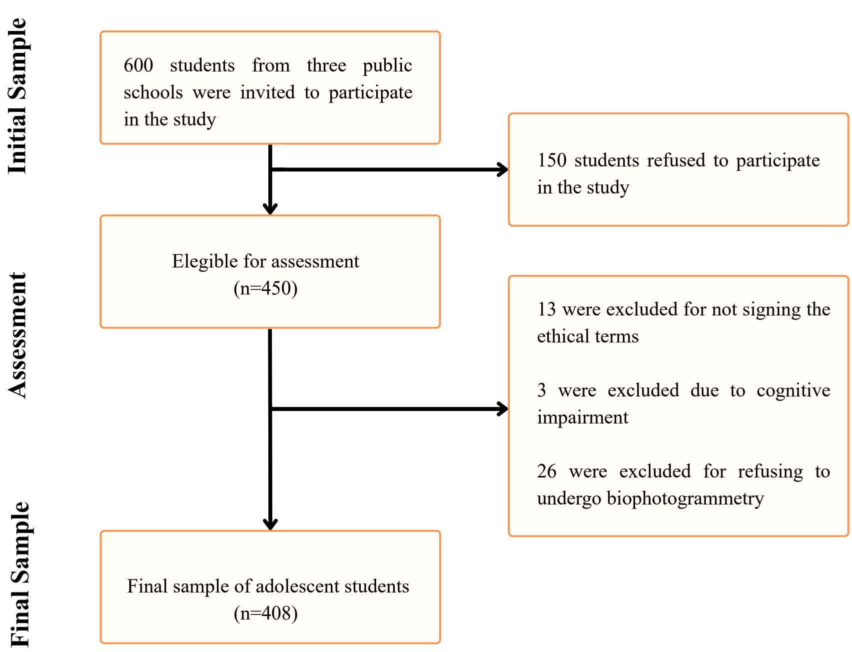

Figure 1: Flowchart of the sample selection adolescents.

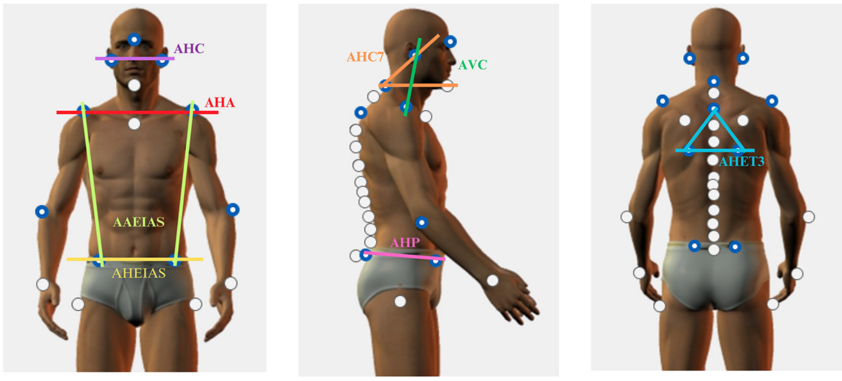

Figure 2: Angles obtained through biophotogrammetry. HHA, Horizontal head alignment; HAA, Horizontal alignment of the acromions; HAASIS, Horizontal alignment of the anterior superior iliac spines; AAASIS, Angle between the two acromions and two anterior superior iliac spines; HAST3, Horizontal asymmetry of the scapula in relation to T3; HHAC7, Horizontal head alignment (C7); VAH, Vertical alignment of the head (acromion); HAP, Horizontal alignment of the pelvis.

Table 1: Sample characteristics (independent t-test, n=408).

Variables	Male (n=204)	Female (n=204)	Total (n=408)	p-Value
Age, years	14.58 ± 1.98	14.56 ± 1.84	14.57 ± 1.91	0.89
Body mass, kg	60.57 ± 14.19	58.53 ± 12.57	59.55 ± 13.43	0.12
Height, cm	1.66 ± 0.10	1.64 ± 0.08	1.65 ± 0.98	0.09
BMI, kg/m^2	21.68 ± 4.15	21.57 ± 4.08	21.62 ± 4.10	0.80
Backpack weight, kg	3.32 ± 2.29	3.43 ± 1.26	3.08 ± 1.09	0.56
Practitioners of regular physical activity, %	149 (73.00)	125 (61.30)	274 (67.20)	
Musculoskeletal pain complaints, %	88 (43.13)	146 (71.60)	234 (57.40)	

Values are presented as mean±standard deviation or absolute (relative) frequency. Abbreviations: %, percent; kg, kilogram; cm, centimeters; m^2, square meters.

Table 2: Result of biophotogrammetry of adolescents and comparison of static posture between sexes (Mann-Whitney U test, n=408).

View	Angle	Male (n=204)	Female (n=204)	Total (n=408)	p-Value
Anterior	HHA	1.85° [2.04–2.66]	2.00° [2.31–2.90]	1.90° [2.27–2.69]	0.12
	HAA	1.50° [1.71–2.20]	1.50° [1.73–2.16]	1.50° [1.79–2.11]	0.84
	HAASIS	1.50° [1.60–1.99]	1.50° [1.61–2.01]	1.50° [1.66–1.94]	0.92
	AAASIS	−1.75° [1.92–2.38]	−2.10° [2.22–2.74]	−1.90° [2.14–2.49]	0.10
Posterior	HAST3	−11.10 % [11.93–14.89]	13.10 % [14.28–18.10]	12.75 % [13.59–16.01]	0.14
Right lateral	HHAC7	52.50° [51.05–52.81]	50.95° [49.99–51.96]	51.45° [50.79–52.11]	0.01
	VAH	14.85° [14.40–16.92]	16.75° [15.48–17.80]	15.90° [15.30–17.00]	0.12
	HAP	−8.70° [8.00–9.51]	−11.55° [10.25–11.86]	−9.95° [9.35–10.47]	<0.001[a]
Left lateral	HHAC7	50.75° [49.69–51.27]	48.05° [47.36–49.09]	49.30° [48.76–49.95]	<0.001[a]
	VAH	14.88° [14.50–16.91]	16.90° [15.75–17.82]	15.95° [15.37–17.22]	0.18
	HAP	−9.70° [8.89–10.39]	−12.65° [10.96–12.58]	−10.90° [10.14–11.26]	<0.001[a]

Values presented as median [interquartile range 25–75 %] in degrees and percentage (%) generated by SAPO software and processed using the SPSS software. Subtitles: HHA, horizontal head alignment; HAA, horizontal alignment of the acromions; HAASIS, horizontal alignment of the anterior superior iliac spines; AAASIS, angle between the two acromions and the two anterior superior iliac spines; HAST3, horizontal asymmetry of the scapula in relation to T3; HHAC7, horizontal head alignment (C7); VAH, vertical alignment of the head (acromion); HAP, horizontal alignment of the pelvis. Negative expresses deviation to the left and positive to the right. [a]Bonferroni correction was applied for multiple comparisons (α=0.05/11), with statistical significance set at p≤0.004.

(n=73). In contrast, most of the total sample reported using computers/laptops and televisions for no more than 1 h per day.

As demonstrated in Table 1, most of the total sample (n=234, 57.40 %) reported painful musculoskeletal complaints, which were more prevalent in females (n=146, 62.39 % girls and n=88, 37.60 % boys). As shown in Figure 4, it was possible to analyze the prevalence of musculoskeletal pain complaints in body regions according to sex, indicating the most painful body area. The cervical (n=70) and lumbar (n=69) regions showed the highest prevalence of pain. In both regions, pain was more frequently reported by females

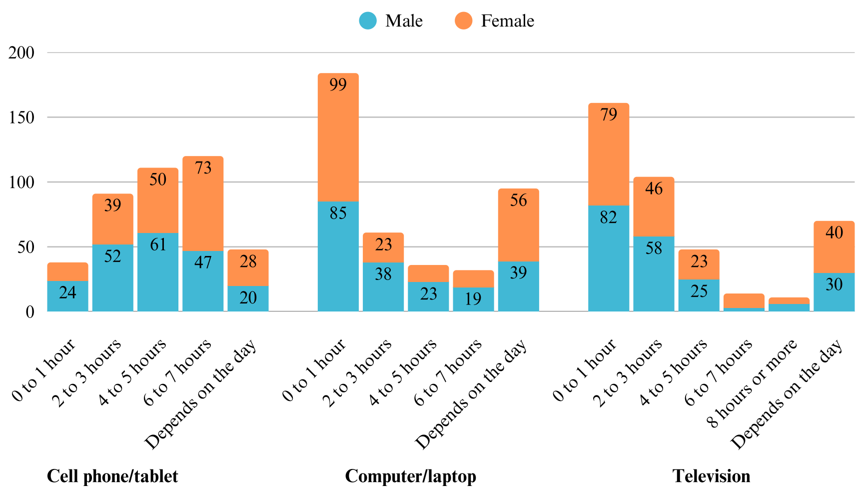

Figure 3: Daily screen time per electronic device by sexes. Values are presented as absolute frequencies (total n=408 for each electronic device). Due to the small sample size in some screen-time intervals, values are reported in the caption. For cell phone/tablet use, the 0–1 h category included 14 females. For computer/laptop use, the 4–5 h and 6–7 h categories included 13 females each. For television use, the 6–7 h category included three males and 11 females, and the≥8 h category included six males and five females.

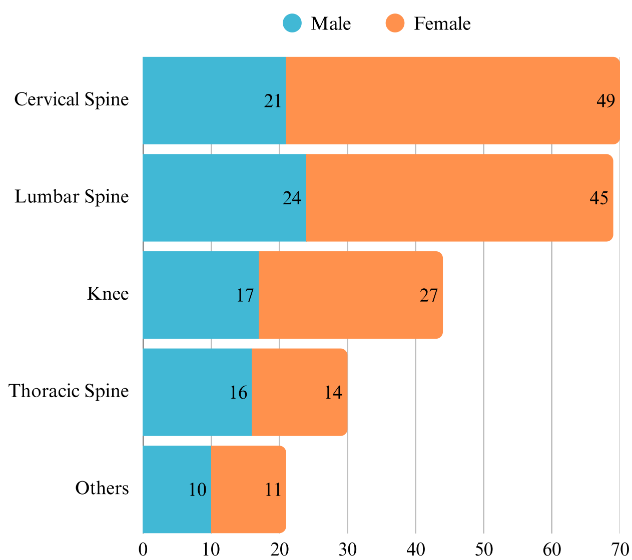

Figure 4: Prevalence of musculoskeletal pain complaints by sexes. Values presented as absolute frequencies (male n=88; female n=146; total n=234). Others: Refers to regions with less than 5 % of the sample, such as shoulders, hands, and feet.

(cervical: n=49; lumbar: n=49) than by males (cervical: n=21; lumbar: n=24). Regarding the self-reported pain scale of these complaints, 73 (31.2 %) participants reported mild pain, 116 (49.6 %) moderate pain, 43 (18.4 %) severe pain, and 2 (0.9 %) extreme pain. Associations between cell phone usage time (>3 h) and musculoskeletal pain were analyzed using adjusted logistic regression models controlling for sex, age, and body mass index. After adjustment, cell phone usage time was not independently associated with the presence of musculoskeletal pain (OR=0.95; 95 % CI: 0.83–1.08; p=0.44).

The participant's QoL is presented in Table 3, where the median score, by domain and overall, obtained by the participants is shown. Regarding the control of the potential influence of pain on the perception of physical well-being, the Mann–Whitney U test was applied to compare the raw scores of the physical well-being domain between adolescents with pain and those without pain. No statistically significant difference was observed (p=0.12; with pain: 15 [14.24–15.33] vs. without pain: 16 [14.59–15.90]). When the analysis was stratified by sex and by the presence or absence of pain, no significant differences were found either (boys: p=0.98; with pain: 17 [15.39–16.98] vs. without pain: 17 [15.39–17.11]; girls: p=0.77; with pain: 14 [12.90–14.90] vs. without pain: 14 [11.74–14.72]).

Discussion

This study evaluated and compared static posture, postural self-perception, screen time, musculoskeletal pain and quality of life in generation Z adolescents between sexes. Postural changes were observed through biophotogrammetry and complaints of self-reported musculoskeletal pain, mainly in females, as well as body self-perception maintaining postures harmful to the spine when using electronic devices and executive use of screens in both sexes.

According to Cheon and Park (2017) [37], HHAC7 values<53° are indicative of a forward head posture. In this study, it was observed that both groups, males and females, were below this threshold, indicating a forward head position. However, when analyzing the differences between the sexes, the female sex presented greater angular deviations in the alignment of the head in relation to C7, indicating a greater anteriorization of the head. Similar results were reported by Miranda (2022) [11], who used photogrammetry in an adolescent population and found a higher degree of head anteriorization among females.

Table 3: Quality of life of students (Mann-Whitney U test, n=408).

Domain	Male (n=204)	Female (n=204)	Total (n=408)	p-Value
Physical well-being	17 [15.84–16.69]	15 [14.43–15.28]	16 [15.25–15.87]	<0.001[a]
Psychological well-being	20 [20.13–20.95]	20 [20.24–21.06]	20 [20.31–20.88]	0.47
Autonomy and relationship with parents	25 [24.28–25.87]	23 [22.15–23.88]	24 [23.45–24.64]	<0.001[a]
Social support and peer group	15 [14.80–15.75]	15 [13.76–14.91]	15 [14.43–15.18]	0.03[a]
School environment	13 [13.16–13.90]	13 [12.40–13.22]	13 [12.89–13.45]	<0.001[a]
Overall score	92 [89.03–92.37]	85 [83.89–87.48]	89 [86.95–89.44]	<0.001[a]

Total raw scores are presented as median [interquartile range 25–75 %]. [a]Statistically significant difference, p≤0.05.

Cervical anteriorization is characterized by less flexion and greater cervical extension, which leads to an increase in compressive loads on the cervical spine, contributing to tissue deformities, reduction of the cranio-vertebral angle and the appearance of neck pain and chronic migraines [26, 38, 39]. This posture is associated with prolonged use of electronic devices, especially in adolescents from generation Z [38, 40]. However, in the present study, no association was found between excessive cell phone use (>3 h) and cervical alignment. A systematic review [41] investigating the influence of electronic screen use on head and neck posture in adolescents reported inconclusive evidence regarding a causal relationship between technology use and postural alterations, primarily due to methodological limitations of the included studies. Nonetheless, prolonged exposure to electronic devices, when combined with extended sitting time during academic activities and a sedentary lifestyle may predispose individuals to cervical postural changes [41, 42].

Furthermore, in this present study, female adolescents presented greater pelvic misalignment. The study by Lemos et al. (2012) [12], also evaluated the static posture of adolescents and associated the female sex with pelvic misalignment and lumbar hyperlordosis, due to differences in the anatomy and physiology of each sex, in addition to external factors such as physical activity and physical capacity. This data differs from the study by Souza et al. (2022) [43] where no significant differences were found in the angles analyzed by the Postural Assessment Software (SAPo), however this study was carried out with children. According Martinelli et al. (2011) [34], the key to the quality of global postural alignment is pelvic alignment. If there is an imbalance in this area, posture will be affected. The physiological position of the pelvis leads to good positioning of the abdomen, trunk, and the upper and lower limbs.

Musculoskeletal development during adolescence is influenced by hormonal changes characteristic of puberty, especially by the effects of estrogen and testosterone, which act differently between the sexes [22, 24, 44, 45]. Recent evidence demonstrates that estrogen, predominant in girls, plays a fundamental role in bone maturation, increased joint flexibility, and body fat distribution, factors that can contribute to changes in postural alignment, such as greater anterior pelvic tilt and lumbar hyperlordosis [22, 24]. Furthermore, girls tend to reach skeletal maturity earlier than boys, which may explain the observation of larger postural angles in the female sample throughout growth [24, 44]. In contrast, testosterone, which is predominant in boys, is associated with increased muscle mass and strength, favoring greater trunk stabilization capacity [22, 24, 44, 45].

Regarding the evaluation of the HHA, HAA, HAASIS, and AAASIS angles, it was noted that the studied population presents slight misalignment considering ideal alignment between 0° and 1° [46]. Our results showed a head slightly horizontal to the right, a slightly higher right acromion, a slightly higher right ASIS and a slightly more inclined trunk to the right, in both sexes. These results corroborate those of Miranda et al. (2021) [47], who evaluated the static posture by biophotogrammetry of healthy adolescents (control group).

When evaluating postural self-perception in different postures using electronic devices, most adolescents reported maintaining postures that were harmful to the spine. The study by Da Rosa et al. (2017) [46], also assessed postural self-perception using the BackPei-CA questionnaire and provided high prevalence of inadequate postural habits among adolescents when using a computer, with a significant tendency to head forward and thoracic hyperkyphosis. Szczygieł et al. (2022) [38] evaluated the association between the use of computers and smartphones in the sitting position and changes in thoracolumbar kyphosis, lumbar lordosis and pelvic asymmetry in adolescents with low back pain. The thoracolumbar kyphosis angle increased significantly after using the computer and smartphone in a sitting position for 30 min. A one-year longitudinal study of 1,393 adolescents aged 14 to 18 concluded that there is a high prevalence of thoracic spine pain associated with female sex, mental health problems, and inappropriate use of electronic devices in incorrect positions [25].

Lima et al. (2021) [48] mentioned that the most preferred posture of users is neck flexion during a long period of screen use. The term “text neck” is a modern condition of the 21st century and refers to the posture of excessive flexion of the head with protrusion and internal rotation of the shoulders when using screens and mobile devices for prolonged periods, resulting in overload and misalignment of the cervical spine, pain, headache and musculoskeletal injuries [16, 17, 40]. Furthermore, it is associated with a sedentary lifestyle, obesity, eye and hearing problems, psychological problems and poor academic performance [15, 26, 39]. Although the present study identified self-perception of excessive cervical flexion during the use of electronic devices, the cross-sectional design does not allow us to establish cause-and-effect relationships between the use of electronic devices and posture.

In this study, the device used for the longest time was the cell phone/tablet, with ~30 % of participants reporting using it for between 6 and 7 h per day. As these were questions with options for use within a range of hours, it was not possible to precisely define the number of hours per participant. Furthermore, because there was an option to depend on the day, it was not possible to define a precise range of hours. However, considering the responses obtained and the minimum value of 1 h for those who indicated that it depended on the day on one or two devices, it can be stated that all participants exceeded the 3-h limit recommended by the Brazilian Societies of Pediatrics and International Societies of Pediatrics [6]. Other studies also found dependence on cell phones in teenagers from generation Z, with usage time averaging 5–8 h per day [16, 40, 49, 50].

Fontenele et al. (2023) [40] evaluated smartphone addiction and cervical postural alterations in Generation Z adolescents and identified increased head anteriorization during smartphone use, with male sex, greater height, and higher body mass index as contributing factors, which may negatively affect quality of life and predispose individuals to early cervical pain and long-term postural alterations. Although excessive screen time has been associated with craniovertebral alterations and musculoskeletal pain in students [51], the present study found no independent association between cell phone usage time greater than 3 h per day and musculoskeletal pain after adjustment for sex, age, and body mass index (OR=0.95; 95 % CI: 0.83–1.08; p=0.44), suggesting that screen time alone does not explain pain occurrence in this population.

In the present study, a high prevalence (57.35 %) of complaints of musculoskeletal pain was found. A study by Junior et al. (2015) [52] corroborates the present study about the areas with the most pain complaints, which are the lumbar and cervical spines. However, while the study by Junior et al. (2015) [52] identified a higher incidence of mild pain, participants in the present study predominantly reported moderate pain intensity. Furthermore, this study found a higher prevalence of self-reported pain in female adolescents. Studies report that the higher incidence of musculoskeletal pain complaints in girls may be associated with cultural factors and specific anatomofunctional characteristics of female pubertal development [20, 21, 25].

Sex differences in pain perception are influenced by hormonal, neurobiological, and psychosocial factors, with girls exhibiting greater sensitivity and prevalence of pain, particularly in the cervical and lumbar regions, mediated by both biological and social mechanisms [53]. This increased sensitivity is associated with stronger neural responses, a higher occurrence of chronic pain, and pubertal hormonal changes, such as increased estrogen and progesterone levels, whereas testosterone appears to have a protective effect in boys [53–57]. In addition, psychosocial factors and gender role expectations influence pain expression, with girls reporting pain more frequently due to coping strategies and socialization processes [25, 58].

Considering the minimum score of 80 points, defined by da Silveira et al. (2021) [27], to classify good quality of life (QoL), the results indicate that most students presented adequate QoL, in addition, musculoskeletal pain did not significantly influence self-reported physical well-being in this population. This result differs from the findings of Agathão et al. (2018) [59], who observed negative QoL among students from public schools, particularly in the domains of autonomy and relationship with parents. In that study, boys also obtained higher scores than girls in the physical activity domain, a result corroborated by the present study. According to Oliveira et al. (2010) [60], boys are encouraged from an early age to participate in intense physical exertion and sports, while this stimulus is considerably less for girls, with a greater focus on domestic tasks and games involving manual activities. This is confirmed in the current study when observing the prevalence of physical activity practitioners among the participants, as the boys performed more physical activity than girls. Although the sample for both sexes was above the cutoff point for a good QoL, it verified that girls have a statistically significant difference in QoL in relation to boys. This finding confirms the relationship suggested by Alves et al. (2016) [61], which showed that boys have higher scores in most domains and general scores, indicating a higher QoL than girls.

Therefore, screen time alone does not explain postural changes or musculoskeletal pain among the adolescents evaluated, reinforcing evidence in the literature that these outcomes have a multifactorial etiology with modifiable biological, behavioral, psychosocial, and environmental risk factors [5, 62, 63]. In this context, Postural Education Programs implemented in schools through theoretical–practical teaching strategies may improve knowledge about posture and health, enhance body awareness, improve quality of life and promote the incorporation of postural care into daily activities, including the use of electronic devices [5, 10, 62–67]. Furthermore, the school is an important socio-educational space for implementing health education actions, as it influences social integration and the development of healthy habits and attitudes, contributing to the formation of more conscious behaviors related to posture, movement, and the use of technology [5, 66].

The strength of this study lies in its choice of a current topic with a significant impact on public health, investigating adolescents from Generation Z, a group highly exposed to the use of electronic devices. This study evaluated a representative sample of adolescents from public schools and integrated multiple dimensions of health, combining objective postural measurements with self-reported data on screen use, musculoskeletal pain, and quality of life, broadening the understanding of the phenomena and reinforcing the importance of self-care. Information about adolescents' self-perception highlights the need for preventive and educational interventions in the school environment. Furthermore, we distributed individual postural reports for the participants and also the ones with identified postural alterations were referred for free physiotherapy care treatment, ensuring an ethical return to the school community reinforcing the clinical and public health relevance of this study.

Some limitations also should be highlighted. A limitation of this study is the refusal of the participants, most of whom were girls, to undergo biophotogrammetry, causing the loss of almost 18 % of possible participants for this study. The withdrawal was due to shame and shyness due to the request for appropriate clothing for data collection. Furthermore, the paucity of quantitative studies on postural analysis is highlighted with normative values for adolescents from the analyzed angles which makes it difficult to discuss the data. As a limitation of the BackPei-CA instrument, the impossibility of objectively determining the time used for screening stands out. The cross-sectional design does not allow for the establishment of cause-and-effect relationships between the use of electronic devices, postural alignment, and musculoskeletal pain in adolescents, since exposure and outcomes are assessed simultaneously. However, this design is suitable for estimating prevalence and identifying associations in a large population, providing a comprehensive overview of these variables at a specific time point. New longitudinal studies are suggested to investigate the occurrence of postural changes and the variables associated with these conditions to allow for the early detection of possible problems and the adoption of preventive strategies.

Conclusions

Through this study, postural changes such as anteriorization of the head and misalignments of the pelvis were found in adolescents from Generation Z, especially females. Excessive screen time and self-perception of inadequate postural habits when using electronic devices were observed in both sexes. Furthermore, musculoskeletal pain was reported by adolescents, predominantly in the cervical and lumbar regions, and more frequently among females, despite an overall good quality of life. Screen time alone does not explain alone postural alterations or musculoskeletal pain among the adolescents evaluated, suggesting a multifactorial etiology for these outcomes. These findings highlight the need for health promotion in schools to promote better posture and reduce screen time among adolescents.

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Research ethics: The present study was approved by the Human Research Ethics Committee of the Santa Catarina State University – CEPSH/UDESC, under protocol number CAAE: 3993823.2.0000.0118 (approval date: October 31, 2023).

Informed consent: The parents and/or legal guardians of the participants signed the Free and Informed Consent Form and the Consent Form for Photographs, Videos and Recordings and the adolescents signed the Assent Form.

Author contributions: All authors gave their final approval and agreed to be responsible for all aspects of the work (Gabriella Lavarda do Nascimento: Conceptualization; Methodology; Data collection; Data processing; Investigation; Validation; Formal analysis; Supervision; Writing – original draft; Writing – review & editing. Aline Silveira Cardoso: Data collection; Data processing; Investigation; Writing – review & editing. Gabriely Vitória Claudino: Data collection; Data processing; Investigation; Writing – review & editing. Giovanna da Silva Rangel: Data collection; Data processing; Investigation; Writing – review & editing. Matias Noll: Methodology; Writing – review & editing. Aline Faquin: Methodology; Data curation; Writing – review & editing. Anelise Sonza: Conceptualization; Methodology; Data curation; Investigation; Validation; Formal analysis; Supervision; Funding acquisition; Visualization; Project administration; Resources; Writing – original draft; Writing – review & editing).

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