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Holistic Approach for Markerless Head-Neck Posture Assessment

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Abstract

With the increasing digitization at work and in the private sphere, the use of digital devices also on the rise. Particularly when using smart devices, the user unconsciously adopts a posture that deviates from a low-strain posture. The problem here is that daily use, in some cases over long periods of time, can lead to symptoms of overuse. In this study, the postural assessment of the upper-body is performed, and functional relationships between different postures are analyzed. To that end, the Craniovertebral Angle (CVA), the Head-Tilt Angle (HTA), the Forward-Shoulder Angle (FSA), and the Adjusted Head-Position Angle (AHPA) were markerless determined in 78 subjects. The volunteers were asked to perform four different body postures with the following conditions: an upright sitting position, with maximum head protraction, looking at a smartphone, and with maximum flexion of the head. The result indicates a significant decrease in the calculated angles in the measured postures when compared to the neutral head position. It was found that the position adopted has a significant influence on all measured angles, CVA, HTA, FSA, and AHPA. Depending on the body posture class, the mean CVA values were 53.9° for upright sitting position, 7.9° for maximally flexed head posture, 28.6° for maximal forward head, and 26.5° for using smartphone posture.

Keywords: Head-Neck Posture; Spinal disorders; Physiology; Markerless

Abbreviations: CVA- Craniovertebral Angle; HTA- Head-Tilt Angle; FSA -Forward-Shoulder Angle;AHPA -Adjusted Head-Position Angle

Introduction

Today the use of smart devices is ubiquitous, both in the private and professional spheres. At the end of 2021, there were around 6.3 billion smartphone subscriptions, and it is predicted that worldwide smartphone subscriptions will increase to 7.8 billion by the end of 2027 [1]. Furthermore, according to preliminary data from the International Data Corporation, 40.5 million tablets were sold in the second quarter of 2022 [2]. With the increasing proliferation of smart devices, the time spent on them is also increasing rapidly. The study by [3] shows that out of 440 people 53.4% spend less than 5 hours, 36.8% between 5-10 hours, and 9.8% spend more than 10 hours in front of their smart mobile devices in a 24-hour-period.

When using a smart device, the user unconsciously adopts a position that deviates from the physiological upright posture. Such a non-physiological posture can lead to spinal overload and often associated pain as well as overuse injuries of the affected structures [4-8]. In order to gain a better understanding of the relationship between the posture adopted and possible loads and their effects, defined angles are measured, which provide information about the posture. For example, the craniovertebral angle (CVA) is a measure of the degree of protraction of the head in natural head posture. Smaller CVA indicates greater protraction of the head, and larger angles are more representative of 'ideal' sagittal plane head and neck alignment [9]. Often this angle is analyzed in a neutral seated posture and standing posture [10-17]. Another angle that is determined in a neutral seated posture is the head tilt angle (HTA). It should be noted that the term HTA is not a standardized angle, and thus researchers have varied in defining this angle. This means that the body points used to define the line that forms the angle are not necessarily the same. Most of the time the HTA is defined as the angle between the line through the tragus and canthus and the horizontal line through the tragus [17-23] (Figure 1(a)). But Mingels et al. [24], for example, define HTA as the angle between the line through the tragus and canthus and the vertical line through the tragus (Figure 1(b)), Ormos et al. [12] as the angle between the line of the tragus and the base of the nose and the horizontal line through the tragus (Figure 1(c)), and while Salahzadeh et al. [25] define it as the angle between the line through the tragus and manubrium and the line through the tragus and chin(Figure1(d)).

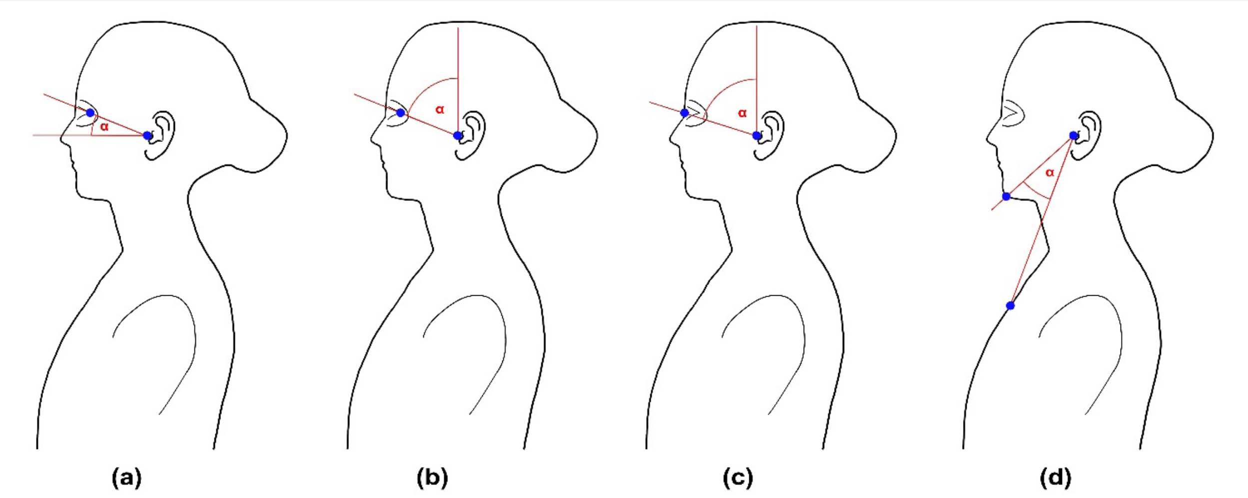

Figure 1: Variations of HTA determination: All researchers use the tragus as a prominent point to determine the HTA. In (a) and (b) and the canthus is used to draw a line between it and the tragus, whereas in (b) the base of the nose is used as a prominent point. The HTA is spanned in (d) by the two straight lines passing through the tragus and chin apex and through the tragus and manubrium.

Other standard angles that are widely used to analyze the upper body sitting posture are the shoulder angle, the arm angle, and the thoracic angle. Ormos et al. [12] defines the shoulder angle as the angle between the line through the points of the C7 spinous process and acromion and the horizontal line through the acromion. The arm angle is defined as the angle between the line through the midpoint of the humerus and the lateral epicondyle of the elbow, and the vertical line through the midpoint of the humerus [20]. The angle between the line through the spinous process C7 and the manubrium and the line through the spinous process of T8 and the manubrium defines the thoracic angle [20]. Another angle that is often used to assess the head posture is the gaze angle. It is defined as the angle of the horizontal line through the canthus, and the viewing distance to the smartphone [21,25].

However, most of the studies, especially the cited studies, deal with analyzing a limited range of postures and specify a small number of possible angle measurements or analyses. Furthermore, to the best of our knowledge, no study has analyzed multiple different postures simultaneously with and without using a smart phone.

Therefore, we present a study in which different angles in various poses are examined both when and when not using a smart phone.

Materials and Methods

Participants

Table 1: Demographic characteristics of participants (n = 78).

Variable name	Number / Average	SD	Maximum	Minimum
Male participants	43	–	–	–
Female participants	35	–	–	–
Height (cm)	173	10	196	142
Weight (kg)	70.6	13.1	102	45
BMI (Body weight in kg / (height in m)^2)	24	2.9	31	16
Smartphone usage (hours per day)	4.4	2.8	14	0.5

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78 volunteers between the age of 18 and 61 participated in the dataset collection. The demographic characteristics of the participants are presented in Table 1. Furthermore, the participants were asked for how many hours per day they were using their smartphones and if they had been diagnosed with spinal disorders in the last six months. On average, participants were using their smartphones for 4.4 hours a day. The maximum value of the usage time was 14 hours, and the lowest value was 0.5 hours per day. In total, six subjects have reported diagnosed spinal disorders, and 72 did not have any spinal disorders diagnosed in the last six months (Table 2).

Table 2: Further personal data differentiated by gender (n = 78).

Variable name	Average / Number	SD	Maximum	Minimum
Smartphone usage (hours per day) total	4.4	2.8	14	0.5
Smartphone usage (hours per day) female	4.6	2.9	14	1
Smartphone usage (hours per day) male	4.2	2.7	12	0.5
Diagnosed spinal disorders male	4	–	–	–
Diagnosed spinal disorders female	2	–	–	–
Diagnosed spinal disorders total	6	–	–	–

Data Acquisition

To eliminate potential data biases, each participant was recorded three times in each posture. Therefore, the dataset of this study comprises 936 RGB images. The images were obtained by using Orbbec Astra Pro camera. The distance between the participants and the camera was fixed at 1.3m. The camera was placed on the tripod at a height of 1.2m from the floor. The resolution of the lateral images taken was 1080×720 pixels. The participants were asked to perform four pre-defined postures for 5 seconds.

Subjects were instructed to assume four different body positions (Figure 2):

i. an upright sitting position
ii. maximum head protraction
iii. looking at a smartphone
iv. maximum flexion

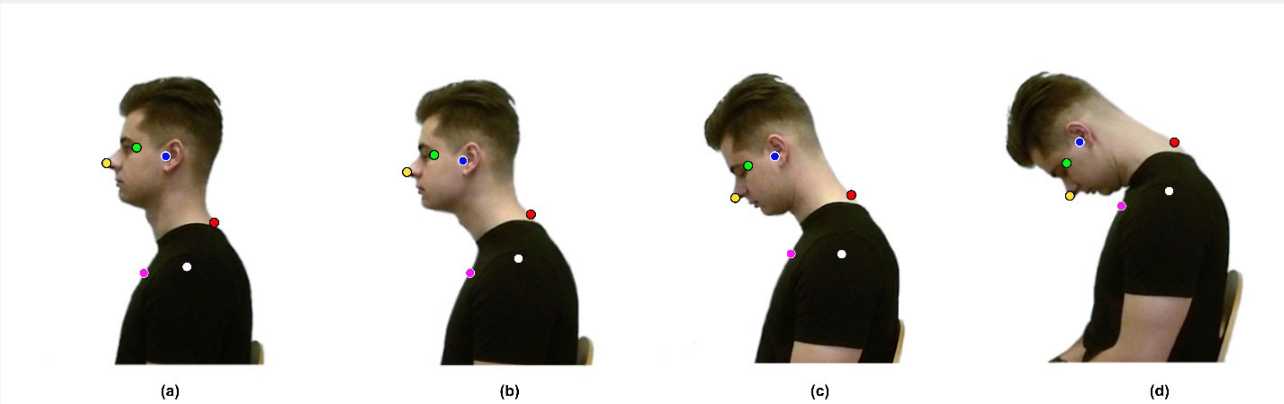

Figure 2: Posture classes used for analyzing each posture's effects concerning CVA, HTA, FSA and AHPA with illustration of set marker points on prominent body locations: upright sitting position (a), with maximum head protraction (b), looking at a smartphone (c) and with a maximum flexion of the head (d). The marker points are for illustration purposes only.

For all trials, the volunteers were seated on the same chair and were looking in the same direction. No further instructions were given to the subjects besides the one mentioned above. The height of the chair was 0.81m. The participants wore suitable clothing, and their hair was tied back so that the raters could detect the required anatomical landmarks.

The same camera and chair were used throughout the data collection to standardize the images.

Data Processing

In order to assess the forward head posture of the individuals four well established angles were used (Figure 3): Craniovertebral Angle (CVA) [9,13,26,27], Head-Tilt Angle (HTA) [28,13], Forward-Shoulder Angle (FSA) [8,28] and Head-Position Angle (HPA) [29,22]. In order to determine the HPA, we decided to use the tip

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of the nose as a prominent point instead of the chin. During the testing phase, we found that the chin point can be influenced by a mandible movement (by opening the mouth) and, therefore, is able to directly impact the HPA value. Thus, according to this finding, this site cannot be a valid point for determining the HPA. To distinguish this angle from the one reported earlier [29,22], in this study, we will use the following term for HPA - Adjusted Head-Position Angle (AHPA).

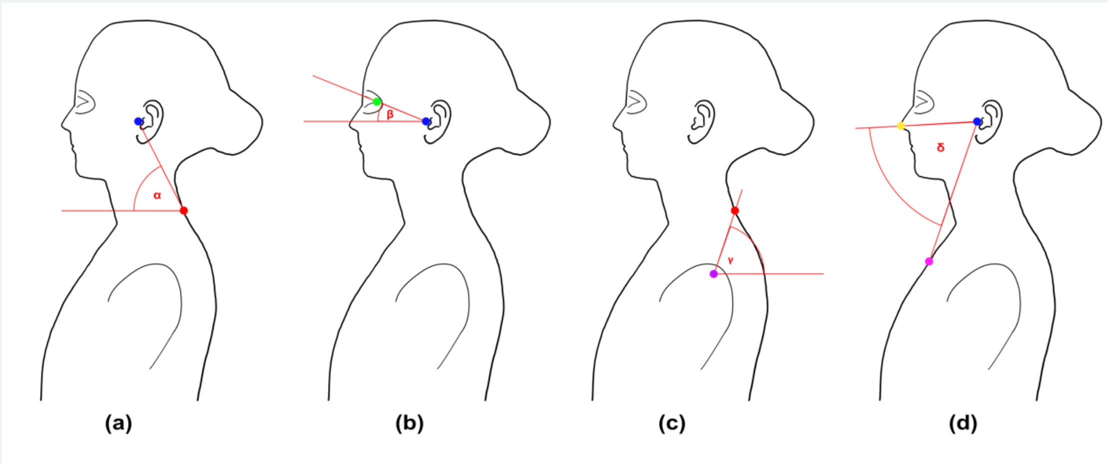

Figure 3: The angle used for analyzing the head-neck-posture are the Craniovertebral Angle (CVA) (a), Head-Tilt Angle (HTA) (b), Forward-Shoulder Angle (FSA) (c) and the Adjusted Head-Position Angle (AHPA) (d).

The open-source software Computer Vision Annotation Tool (CVAT) was used to annotate the required anatomical landmarks. In each image, six landmarks were set: ear tragus, C7 spinous process, eye canthus, manubrium, nose, and acromion. Additionally, the corresponding angles were measured automatically by a script using the 2D pixel positions of the annotated landmark points. The posture angles were calculated using the trigonometrical properties of the triangles spanned by the landmark points and the corresponding horizontals.

Results

The following results describe the posture angles for the recorded posture classes and compare the differences between measurements for the pre-selected posture classes. In certain posture classes, an extreme inclination of the head was observed, so the corresponding landmark point was located below the horizontal line. We defined this angle as negative for better differentiation and description of the measurements (Figure 4).

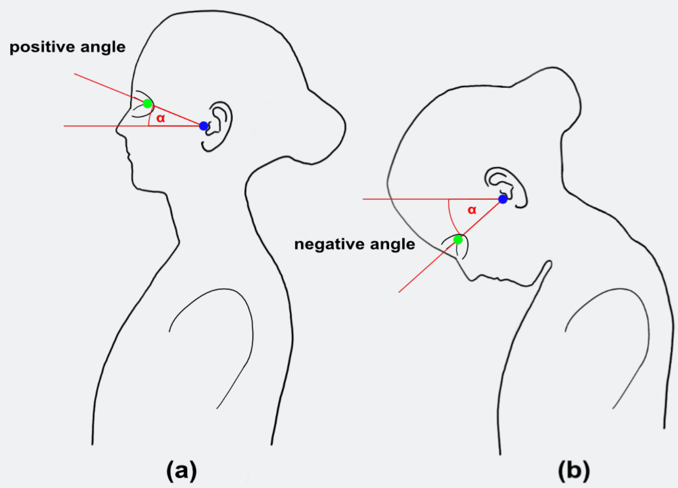

Figure 4: Differentiation of angle sign: in the upright head posture (a) the landmark of the tragus is above the horizontal, though in an inclination posture (b) this landmark may be below the horizontal. In this case the angle is defined as negative.

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When comparing the values of the CVA of the different postures, it was found that some of them differ significantly from each other (Table 3). The largest deviation occurred between the straight sitting posture class at 53.9° and maximum flexion at 7.9°, which was to be expected. When comparing the values ”using smartphone” with those for ”maximal flexion”, it was found that, on average, a greater inclination occurs during smartphone use than during maximum forward head posture. The percentage deviation of the posture class ”maximal flexion” is 14.6%, that of ”using smartphone” 49.1%, and that of ”maximal forward head” 52.7% compared to the posture class ”straight sitting.” The most significant standard deviation (SD) results occured in the posture classes ”maximal flexed” at 16.8° and ”using smartphone” at 13.7°.

Comparing the mean values of HTA, the posture class ”maximal flexed” has the highest value of -45.0°, followed by the class ”using smartphone” with a value of -19.1° (Table 4). The posture class ”maximum forward head” with a value of 14.6° and the class ”straight sitting” with 20.8° show lower angle values. Compared to the previously described angles, the FSA values show relatively more minor deviations for the different posture classes (Table 5). The angles range from 99.0° to 118.6°. While the smallest differences between the posture classes ”straight head” and maximum protraction appear in CVA, the largest differences occur at HTA (Table 6).

Table 3: CVA angles [degree] of different posture classes.

Posture class	mean CVA	SD CVA	Maximum CVA	Minimum CVA
straight sitting	53.9	7.9	71.4	28.9
maximal flexed	7.9	16.8	72.2	-44.8
maximal forward head	28.6	11.3	56	-43.3
using smartphone	26.5	13.7	70.3	-11.3

Table 4: HTA angles [degree] of different posture classes.

Posture class	mean HTA	SD HTA	Maximum HTA	Minimum HTA
straight sitting	20.8	7.9	54.7	1.9
maximal flexed	-45	20.6	35.5	-108.4
maximal forward head	14.6	16.7	128.7	-111.7
using smartphone	-19.1	16.2	24	-137.1

Table 5: FSA angles [degree] of different posture classes.

Posture class	mean FSA	SD FSA	Maximum FSA	Minimum FSA
straight sitting	118.6	14	154.6	76.9
maximal flexed	99	15.8	149.3	40.3
maximal forward head	103.5	16.4	152.6	54.9
using smartphone	105.7	1.2	148.8	56.6

Table 6: AHPA angle [degree] of different posture classes.

Posture class	Mean AHPA	SD AHPA	Maximum AHPA	Minimum AHPA
straight sitting	73.5	9	104.9	28.4
maximal flexed	48	9.8	86.9	9.2
maximal forward head	91.1	10.8	114.9	58
using smartphone	59.5	8.2	85.9	8

In order to analyze the distribution of the angles, the quartiles over four presented postures were calculated and reported in Table 7. It was found that in the sitting position 50% of the participants had a CVA smaller than 54.4°. Considering the first quartile, the smallest CVA of -0.3° was observed in the maximally flexed head position.

In the posture ”using smartphone” 25% of the participants showed the CVA of 18.2°, which is 37% of the corresponding angle in the upright head sitting position and 81% of the CVA in maximal forward head posture.

Both for the HTA as well as the AHPA measurements in the sitting upright position 50% of the volunteers adopted angles smaller than 20.3° (15.6° for the first quartile) and 73.4° (68.4° for the first quartile), respectively. In the maximal flexed posture, the median values for those angles were -45.9° (-56.1° for the first quartile) and 47.4° (42.2° for the first quartile), respectively.

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Relatively small angle values were measured in the head-neck posture while using a smartphone: the head tilt angle of 50% of the participants was observed to be 39.3° lower than the correspondent value in the sitting posture class. In terms of shoulder angle, we could observe that 25% of the subjects in the upright sitting position showed an FSA greater than 126.6°. In contrast, the median value in the straight sitting position was 118.7° and decreased to 97.8° in the maximal flexed head posture. The FSA values in the smartphone usage posture class were smaller than 95.2° in the first quartile and larger than 116.8° in the third quartile.

Table 7: Distribution of measured angles [degree] for different posture classes.

Posture	Measured angle	1. quartile	2. quartile (median)	3. quartile
straight sitting	CVA	48.7	54.4	59.0
	HTA	15.6	20.3	25.5
	FSA	109.0	118.7	126.6
	AHPA	68.4	73.4	78.6
maximal flexed	CVA	-0.3	9.0	15.7
	HTA	-56.1	-45.9	-35.7
	FSA	88.8	97.8	109.7
	AHPA	42.2	47.4	53.0
maximal forward head	CVA	22.4	29.6	36.3
	HTA	8.9	14.3	20.3
	FSA	94.2	102.4	114.2
	AHPA	83.6	91.8	99.2
using smartphone	CVA	18.2	26.6	35.5
	HTA	-27.5	-19.0	-9.9
	FSA	95.2	105.9	116.8
	AHPA	55.3	59.1	64.6

Table 8: Comparison of present study CVA (degree) neutral seated posture.

Author	Year of publication	Subjects No.	Mean CVA	SD CVA	CVA Range
Current study	2022	78	53.9	7.9	28.9-71.4
Brunton [3]	2003	29	45.6	4.5	33.0-55.0
Kawasaki [14]	2022	26	50.9	-	42.2-58.2
Mingels [18]	2015	12	33.3	6.9	-
Niekerk [31]	2008	40	52.7	11.2	22.3-71.3
Rajalaxmi [24]	2022	15	57.7	4.7	-
Shaghayeghfard [29]	2016	20	46.5	3	-
Sohn [30]	2010	42	42.3	-	-
Vasavada [32]	2015	32	51.3	3.9	-

To determine the severity of the head down position while using a smartphone, we compared how the head inclination in this posture differed from other posture classes recorded in this study. In doing so, the measured angles for the relaxed sitting position, maximum forward and maximum flexed head postures were compared with the angle for the ”using smartphone” posture class based on their average values.

As presented in Figure 5, in comparison to other postures, slight deviations were observed between the maximum forward head and head down position of the ”using smartphone” posture. For example, the average CVA for the maximum forward head position was 2.1° greater than in the smartphone using posture, whereas the FSA was 2.2° smaller. The results from the diagram indicate slight a “using smartphone” difference of 6.7° between the posture and maximum flexed head posture in terms of the FSA. On the other hand, the mean AHPA value in the maximum flexed head position was 11.42° greater than the corresponding value when using a smartphone. Furthermore, significant differences are observed between straight sitting posture and the head

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position while using a smartphone. The value for the FSA is 12.9° greater for the upright head than its corresponding angle in the ”using smartphone” posture class. The corresponding deviations for the AHPA, CVA, and HTA values were: 14.0°, 27.4°, and 39.9°, respectively.

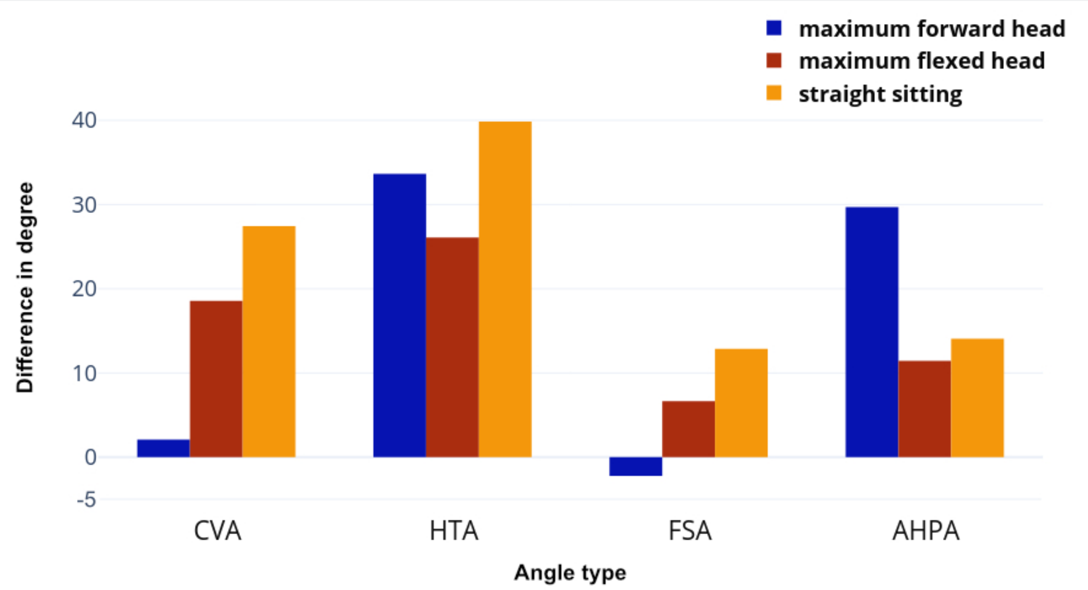

Figure 5: Angle differences between a ”smartphone using” and other measured posture classes.

Discussion

The results of other studies show that the values for the CV angle range from 57.70° to 42.26° (Table 4). The average angle of 53.90° of the current study is in the same order of magnitude as Kawasaki [16], Niekerk [20] and Vasavada [25]. It should be noted that the previous studies analyzing the CV angle had a significantly smaller number of adult participants. In the study by Ormos et al. [12] the CVA values for the group of 9-year-old children were determined to be 52.35° for 12-year-old children 50.4° and for 16-year-old children 52.35°. It was found that neck posture worsened with age, and neck mobility was significantly reduced in 16-year-olds compared to 9- and 12-year-olds. Although the study by Ormos [12] had a large number of 428 volunteers, the participants were school children. Therefore, the study was excluded from comparing the CVA values measured here and those reported in the literature.

According to Brunton et al. [9], the value of the CV angle is used as a measure of the degree of head protraction in natural head posture. Therefore, the forward head posture is also defined by other researchers using the craniometrical angle [10,30,23]. While larger CV angles correspond more to the recommended ”ideal” alignment of head and neck in the sagittal plane, smaller CV angles indicate a stronger protraction of the head [9,17]. In order to analyze at what point a head forward position occurs, the classification of Salahzadeh et al. [13,31] is used. They represent CV angles less than 50° when FHP occurs and angles greater than 50° when there is no FHP. Based on our data, it could be concluded for the average CV angle (53.9°) that there was no FHP in the posture class ”straight sitting” (Table 8). A FHP was observed in all other posture classes. While using a smartphone, the CVA value of 26.5° was clearly below the angle of 50°. This means that, according to [25] the gravitational demands on the neck muscles are 3–5 times higher than during a seated neutral posture.

The minor differences between the average CVA values for the maximum forward head and the head down position when using a smartphone were detected. Furthermore, the average FSA and AHPA in the maximum head flexion and “using smartphone” postures also showed minor deviations. Therefore, the forward and downward head inclination could produce similar strain in the head-neck segments, leading to poor postural alignment with extensive smartphone usage time. When considering the head tilt (HTA) in both maximum flexed (-45.0°) and “using smartphone” (-19.1°) postures, both angles were way below the horizontal line drawn through the ear tragus point. Despite the difference of 25.9° between these angles, it can be seen that the subjects took a non-physiological posture while using the smartphone, which is close to the posture of maximum head tilt. In this case, the head does not have the full support of the neck and the upper back, which strengthens the risks of musculoskeletal disorders [9].

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Conclusion

In contrast to previous studies that primarily focused on the measurements of one particular posture, this study performed a holistic upper posture analysis for several posture classes in sitting positions with and without a smartphone. It was shown that the postural position adopted by the subjects significantly affected all measured angles, i.e., CVA, HTA, FSU, and AHPA. Additionally, the calculated angles of the head position while using a smartphone were compared to the postures where the head and neck were exceptionally poorly aligned (maximum flexed head and maximum forward head posture). The results indicate minor differences between selected angles in these postures, which may be a reason for spinal strain in the neck region thereby increasing the risk of musculoskeletal disorders.

Conflict of Interest

The authors declare no conflict of interest.

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