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Analysis of the Association between Forward Head Posture, Sex, and Height in University Students

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Abstract

Background: Anterior head translation (AHT) is a quantitative measure of the anterior displacement of the head relative to the trunk and is commonly used to assess forward head posture (FHP). Although FHP has been associated with neck pain and cervical musculoskeletal dysfunction, evidence regarding these relationships remains inconsistent across populations. This study investigated the associations among AHT/FHP, cervical sagittal alignment, sex, and height in university students.

Methods: This cross-sectional screening study included 300 randomly selected students (150 females and 150 males) from Islamic Azad University, Mashhad, Iran. All 300 participants underwent photographic postural screening using Posture Pro V software. To minimise unnecessary radiation exposure, only 28 participants underwent radiographic assessment: the 14 participants with the lowest and the 14 participants with the highest PPV-derived forward head posture values. Radiographic AHT, C2–C7 cervical lordosis, and C1–C2 upper cervical angle were assessed using lateral cervical radiographs. Normality testing, independent-samples t-tests,

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Hedges' g, 95% confidence intervals (CIs), and Pearson correlation coefficients were used for analysis.

Results: Compared with the minimal-FHP group, the high-FHP group showed lower C2-C7 lordosis (23.44 ± 6.26° vs. 38.29 ± 5.24°; mean difference = -14.85°, 95% CI = -19.34 to -10.36; $p < 0.001$; Hedges' g = 2.50, large) and greater radiographic AHT (27.93 ± 11.39 mm vs. 10.07 ± 8.12 mm; mean difference = 17.86 mm, 95% CI = 10.14 to 25.58; p = 0.001; Hedges' g = 1.75, large). AHT was negatively correlated with C2-C7 lordosis (r = -0.607, p = 0.001).

Conclusion: In this selected university-student sample, higher AHT was associated with reduced C2-C7 cervical lordosis, whereas C1-C2 upper cervical curvature did not differ significantly between groups. Exploratory associations with sex and height should be interpreted cautiously because of the small extreme-groups radiographic sample and potential selection bias.

Keywords: Forward head posture; Posture; Cervical Vertebrae; Students; Sex Factors; Body Height; Radiography.

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1. Introduction

Forward head posture (FHP) is generally described as an anterior position of the head relative to the trunk and may involve lower cervical flexion with compensatory upper cervical extension. Although FHP is frequently discussed in relation to neck pain, recent systematic-review evidence indicates that this association is complex and may vary according to age, symptom status, and clinical population (1). In university students, prolonged sitting, screen exposure, and reduced physical activity may increase the relevance of objective head-neck posture assessment, even in individuals without clinically diagnosed musculoskeletal disorders (2).

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The clinical rationale for evaluating head-neck posture extends beyond local neck symptoms. Cervical musculoskeletal dysfunction and postural alterations have been reported in chronic migraine and chronic tension-type headache populations (3). In addition, FHP may be related to increased tissue mechanosensitivity in cervical structures, although this does not establish a direct causal relationship between posture and pain (4). These findings support the value of objective posture assessment while also requiring cautious interpretation in asymptomatic or generally healthy students.

Anterior head translation (AHT) provides a quantitative measure of anterior head displacement, whereas radiographic parameters such as C2–C7 cervical lordosis and the C1–C2 upper cervical angle describe internal sagittal alignment. Contemporary cervical-alignment literature emphasises that sagittal cervical parameters vary according to age, population, imaging position, and measurement method (5). Non-radiographic methods, including photographic and application-based approaches, may be useful for screening, but their reliability and validity vary by method and landmarking procedure (6, 7).

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Despite substantial literature on FHP, limited evidence has combined photographic postural screening with radiographic cervical alignment assessment in university students while exploring whether FHP-related findings differ according to sex or height. The primary objective of this cross-sectional study was to compare cervical sagittal alignment between the minimal-FHP and high-FHP groups identified using PPV-derived FHP scores. The secondary objective was to explore associations of FHP with sex and height. We hypothesised that greater FHP would be associated with reduced C2-C7 cervical lordosis, whereas associations with sex and height were considered exploratory.

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2. Methods

The Human Ethics Research Committee approved this study under code IR.UOZ.REC.1403.018. All procedures were conducted in accordance with the Declaration of Helsinki, and all participants provided written informed consent. This observational study was reported in accordance with the STROBE guidelines (8).

This was a cross-sectional screening study with a nested extreme-groups radiographic comparison. The screening sample comprised 300 randomly selected students (150 females and 150 males) enrolled in a general physical education course at Islamic Azad University, Mashhad, Iran. The sample-size calculation was performed using G*Power with alpha set at 0.05, an anticipated effect size of 0.30, and statistical power of 95%, indicating a minimum sample of 262 participants. A total of 300 students were screened to improve the robustness of the initial sampling stage.

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To minimise unnecessary radiographic exposure, all 300 participants were ranked according to their PPV-derived FHP scores, and the 14 participants with the lowest scores were allocated to the minimal-FHP group, whereas the 14 participants with the highest scores were allocated to the high-FHP group; this rank-based allocation was not based on validated clinical severity thresholds or diagnostic cut-off values.

2.1 Outcome measures

In the present study, FHP refers to the clinical postural pattern of anterior head positioning relative to the trunk, whereas AHT refers to the quantitative measure of anterior head displacement used to assess this posture. The primary radiographic outcome was C2-C7 cervical lordosis. Secondary outcomes were radiographic AHT, C1-C2 upper cervical angle, PPV-derived

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FHP output, PPV-derived load/overload index (LOD), sex, height, weight, and body mass index (BMI). BMI was calculated as body mass divided by height squared (kg/m^2).

2.2 Radiographic assessment of AHT and cervical angles

The DaVinci Premium system was used for lateral cervical radiographic image acquisition. Participants stood in a relaxed neutral position for lateral assessment. Radiographic AHT was measured as the horizontal distance between the posterior superior edge of C2 and a vertical reference line drawn from the posterior inferior edge of C7, following published cervical radiographic measurement procedures (9, 10)(Figure 1).

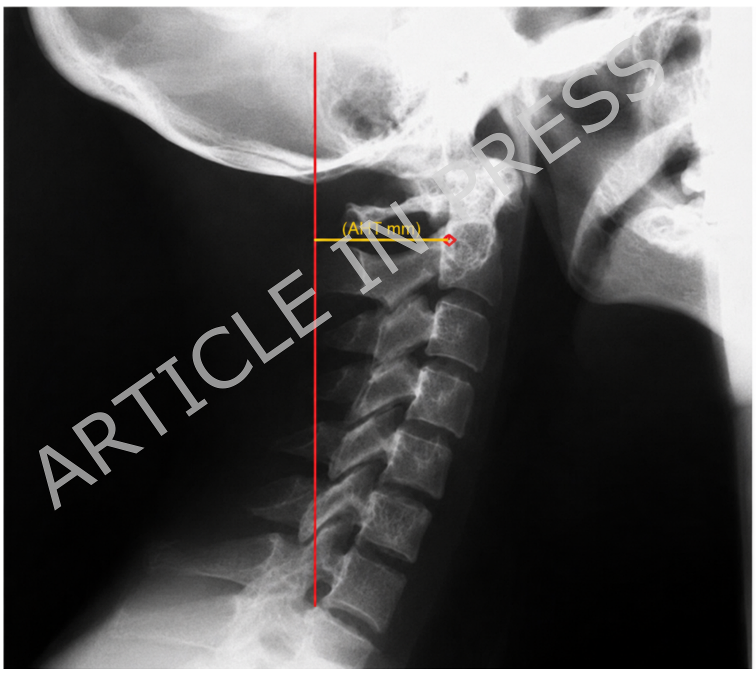

Figure 1. AHT Measurement

Previous radiographic work has reported AHT values in millimetres; therefore, millimetre and inch values should not be used interchangeably. All radiographic AHT values are reported in millimetres, and the findings are interpreted cautiously because reference values may vary according to the measurement method, imaging position, and population (5, 9, 10).

The C2-C7 angle was measured using the Harrison posterior tangent method, in which lines are drawn along the posterior vertebral body margins. This method was selected because it allows subaxial cervical alignment to be assessed separately from upper cervical alignment and is supported by radiographic reliability literature (10, 11)(Figure 2).

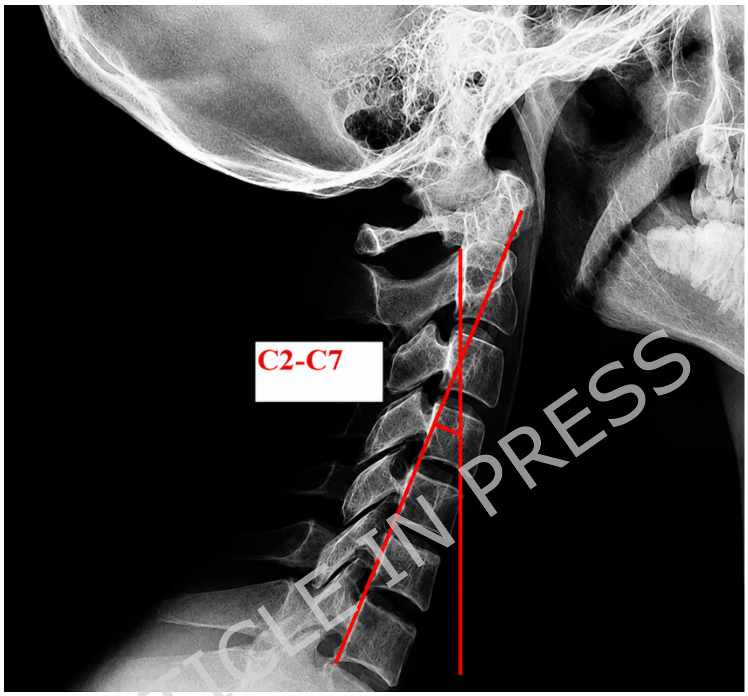

Figure 2. Measurement of C2-C7 cervical lordosis using the posterior tangent method.

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The C1-C2 angle was analysed as an exploratory upper cervical measure; because universally accepted normative thresholds for this exact measurement have not been established, it was not used to classify abnormality(Figure 3).

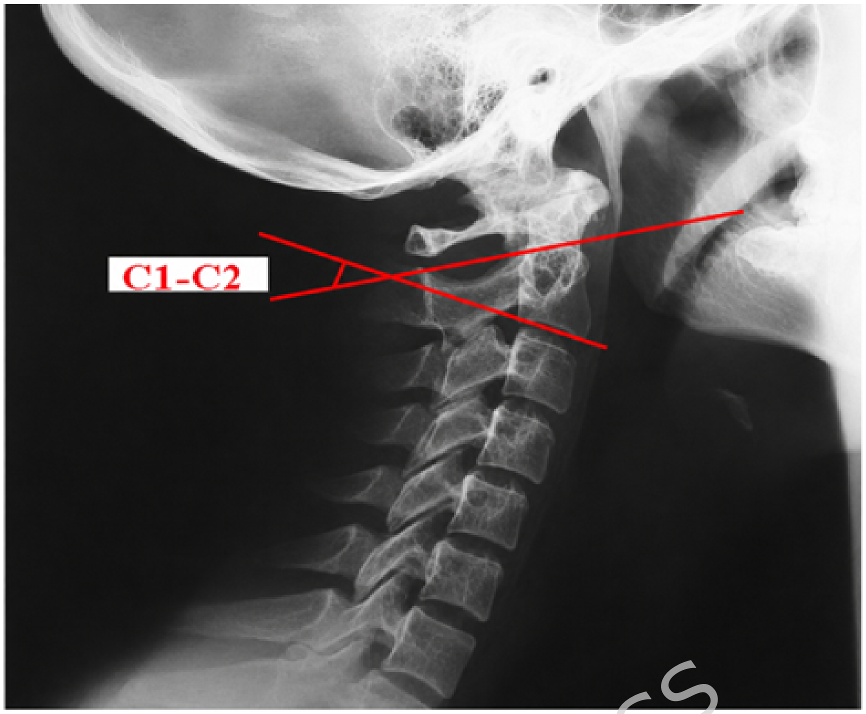

Figure 3. Measurement of the C1-C2 upper cervical angle.

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2.3 Photographic postural assessment

Digital lateral-view photographs were obtained in a relaxed standing position. Reflective markers were placed on the external auditory meatus, acromioclavicular joint, greater trochanter, knee joint line, and lateral malleolus. Images were imported into Posture Pro V (PPV) software, and head-position variables were extracted according to the software protocol(Figure 4). PPV was used as a photographic screening tool rather than as a diagnostic reference standard. Recent systematic-review evidence supports the general utility of photogrammetric posture assessment but also highlights heterogeneity in methods and reporting (6, 7).

LOD was defined as the PPV-derived estimated cervical load/overload index generated by the software. Because this variable is software-derived and not a universally standardised clinical measure, it was treated as exploratory.

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The reliability and objectivity of the PPV software outcomes were evaluated in this study. For this purpose, 20 participants were assessed twice by the primary researcher and once by an independent examiner. The measurement error was less than 2 degrees, and the correlation between the two examiners' results was r = 0.85, which was statistically significant at $P \leq 0.01$.

For intra-rater reliability, the primary assessor repeated radiographic measurements after a 10-day interval while blinded to the original values. Excellent intra-rater reliability was observed for all variables based on repeated measurements in a subsample of participants. The ICC for anterior head translation (AHT) was 0.91 (95% CI: 0.86–0.95), for C2–C7 cervical lordosis was 0.89 (95% CI: 0.83–0.93), and for C1–C2 upper cervical angle was 0.87 (95% CI: 0.80–0.92). The standard error of measurement (SEM) was 1.8 mm for AHT and 2.0° for angular measurements.

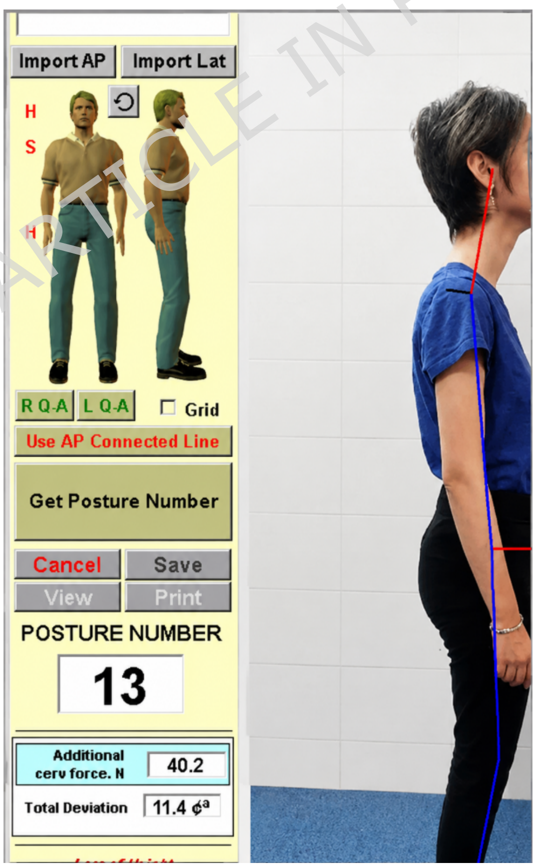

Figure 4. Digital lateral-view postural assessment in Posture Pro V software.

2.4 Statistical analysis

Data were analysed using SPSS version 26. Normality was assessed using Shapiro-Wilk tests and inspection of Q-Q plots. Between-group differences were analysed using independent-samples t-tests when assumptions were met; where assumptions were violated, non-parametric sensitivity analyses were performed. Mean

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differences were reported with 95% CIs and Hedges' g because the radiographic comparison groups were small.

Pearson correlation coefficients were calculated for AHT, C2-C7 lordosis, C1-C2 upper cervical angle, PPV-derived FHP output, LOD, and height. Correlation magnitude was interpreted using physiotherapy-specific thresholds, with $|r|$ values of approximately 0.30, 0.50, and 0.60 interpreted as small, medium, and large individual-difference effects, respectively (12). For group differences, Hedges' g values of approximately 0.10, 0.40, and 0.80 were interpreted as small, medium, and large effects, respectively (12). Statistical significance was set at $p < 0.05$.

Exploratory univariable linear regression was considered to estimate the association between AHT and C2-C7 lordosis. Multivariable regression including several covariates was not performed because the radiographic sample was small and such models would be at high risk of overfitting. Physical activity and screen time were not measured using validated instruments and therefore could not be included as covariates.

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3. Results

The descriptive characteristics of participants included in the radiographic comparison are presented in Table 1.

Table 1. Descriptive characteristics of participants.

Group	Sex	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m²)
Minimal-FHP	Female	160.85 ± 5.36	55.28 ± 5.85	22.42 ± 1.39	21.36 ±2.26
Minimal-FHP	Male	175.14 ± 3.53	60.71 ± 6.70	22.00 ± 3.16	19.80 ± 2.33
High-FHP	Female	163.28 ± 4.78	54.42 ± 5.44	22.45 ± 2.22	20.42 ± 2.36
High-FHP	Male	178.28 ± 4.78	60.50 ± 16.90	22.34 ± 2.16	19.04 ± 5.41

Note. BMI = body mass index; FHP = forward head posture

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Compared with the minimal-FHP group, the high-FHP group showed substantially greater radiographic AHT and lower C2-C7 cervical lordosis. The C1-C2 angle did not differ meaningfully between groups. Each p-value is accompanied by an effect-size estimate to support clinical interpretation (Table 2).

Table 2. Between-group comparison of radiographic and PPV-derived variables.

Variable	**Minimal-FHP Mean ± SD**	**High-FHP Mean ± SD**	**Mean difference (95% CI)**	**t**	**p**	**Hedges' g**	**Interpretation**
LOD	5.33 ± 5.16	70.00 ± 77.05	64.67 (20.12 to 109.22)	-2.97	0.006	1.15	Large; exploratory software-derived index
AHT (mm)	10.07 ± 8.12	27.93 ± 11.39	17.86 (10.14 to 25.58)	-4.77	0.001	1.75	Large
C1-C2 (°)	24.07 ± 6.70	24.86 ± 6.41	0.79 (-4.30 to 5.88)	-0.317	0.75	0.12	Trivial
C2-C7 (°)	38.29 ± 5.24	23.44 ± 6.26	-14.85 (-19.34 to -10.36)	9.36	<0.001	2.50	Large

Note. AHT = anterior head translation; FHP = forward head posture; LOD = Posture Pro V–derived load/overload index. Mean differences were calculated as High-FHP minus Minimal-FHP.

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Pearson correlation analysis showed a large negative correlation between AHT and C2-C7 lordosis ($r = -0.607$, $p = 0.001$), indicating that greater anterior head translation was associated with lower C2-C7 lordosis. AHT had a small positive correlation with C1-C2 angle ($r = 0.388$, $p = 0.042$) and a small-to-medium positive correlation with LOD ($r = 0.447$, $p = 0.011$). There was a weak positive, non-significant correlation between C2-C7 cervical lordosis and C1-C2 upper cervical angle ($r = 0.178$). Height showed a large negative correlation with AHT ($r = -0.605$, $p = 0.001$) and a small positive correlation with C2-C7 lordosis ($r = 0.414$, $p = 0.028$) (Table 3).

Table 3. Pearson correlations among postural, radiographic, and anthropometric variables.

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Relationship	r	p	Effect-size interpretation
AHT vs C2-C7 lordosis	-0.607	0.001	Large negative
AHT vs C1-C2 angle	0.388	0.042	Small positive
AHT vs LOD	0.447	0.011	Small-to-medium positive
C2-C7 lordosis vs C1-C2 angle	0.178	0.365	Weak positive; not significant
Height vs AHT	-0.605	0.001	Large negative
Height vs C2-C7 lordosis	0.414	0.028	Small-to-medium positive

Note. LOD = Posture Pro V–derived load/overload index; AHT = anterior head translation (12).

Sex-specific comparisons indicated that the female group showed significantly greater anterior head translation (AHT) than the male group (25.67 ± 11.63 vs. 11.31 ± 10.98, respectively; mean difference = 14.36, 95% CI: 5.57 to 23.15; t = 3.343, p = 0.003). The magnitude of this difference was large (Hedges' g = 1.23). In contrast, C2-C7 cervical lordosis was significantly lower in the female group compared with the male group (23.13 ± 12.05 vs. 33.77 ± 8.97, respectively; mean difference = -10.64, 95% CI: -18.93 to -2.35; t = -2.613, p = 0.015), with a large effect size (Hedges' g = 0.97)(Table 4).

Table 4. Sex-specific comparison of AHT and C2-C7 lordosis

Variable	Women Mean ± SD	Men Mean ± SD	Mean difference (95% CI)	t	p	Hedges' g
AHT (mm)	25.67 ± 11.63	11.31 ± 10.98	14.36 (5.57 to 23.15)	3.343	0.003	1.23
C2-C7 lordosis (°)	23.13 ± 12.05	33.77 ± 8.97	-10.64 (-18.93 to -2.35)	-2.613	0.015	0.97

4. Discussion

The main finding of this study was that students in the high-FHP group demonstrated substantially lower C2-C7 cervical lordosis than students in the minimal-FHP group, whereas the C1-C2 angle

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did not differ significantly between groups. The negative correlation between AHT and C2-C7 lordosis suggests that anterior head translation in this sample was more closely related to subaxial cervical alignment than to upper cervical curvature. This finding is biomechanically plausible because FHP is commonly described as involving lower cervical flexion with compensatory upper cervical extension; however, the cross-sectional design does not allow causal inference (5, 13).

A possible explanation for the association between greater AHT and lower C2-C7 lordosis is that sustained anterior head translation increases the external flexion moment acting on the cervical spine. This may require compensatory activity of posterior cervical muscles and alter the length-tension relationship of deep and superficial cervical stabilisers. Over time, sustained loading may contribute to fatigue, reduced proprioceptive accuracy, or tissue mechanosensitivity in susceptible individuals (4). However, because participants were not recruited on the basis of pain, disability, or diagnosed musculoskeletal disease, these mechanisms should be interpreted as plausible explanations rather than causal conclusions.

The sex- and height-related findings should be interpreted cautiously. Exploratory analyses suggested associations among height, AHT, and C2-C7 lordosis, but the radiographic sample consisted of only 28 participants selected from the extremes of the screening distribution. Therefore, these findings should not be presented as definitive evidence that female sex or shorter stature causes or strongly predicts FHP. Larger studies with balanced sex distribution, individual-level BMI, pain status, physical activity, and screen-time measures are required to clarify these associations (2, 14).

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The present study should not be interpreted as a clinical severity classification of FHP. The grouping procedure was based on participants’ ranks in the distribution of PPV-derived FHP

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scores and was not intended to represent validated clinical severity categories or diagnostic cut-off values.

Current cervical sagittal-alignment literature emphasises that clinically meaningful interpretation depends on the parameter measured, population, symptom status, and measurement method (5). Accordingly, our findings support an association between greater AHT and reduced C2-C7 lordosis in this selected sample, but they do not establish pathological severity or treatment thresholds.

Although corrective exercise was not examined in the present study, recent systematic reviews indicate that exercise-based interventions may improve FHP-related postural outcomes and cervical proprioception(15, 16). Therefore, the present biomechanical findings may help generate hypotheses for future intervention studies, particularly studies that stratify participants by AHT and cervical sagittal alignment.

This study has several limitations. First, although 300 students were screened, only 28 participants were included in the radiographic comparison. This extreme-groups design increases contrast between postural profiles but reduces statistical power, increases uncertainty around estimates, and limits generalisability. Second, selection bias is possible because participants with intermediate PPV-derived FHP scores were not radiographically assessed. Third, physical activity, sedentary behaviour, screen time, pain, disability, and psychosocial variables were not measured using validated instruments and therefore could not be included as covariates. Fourth, PPV-derived LOD is a software-derived exploratory index rather than a standard clinical or radiographic measure. Future studies should include larger samples, prospective designs, validated lifestyle and symptom measures, and multivariable modelling.

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5. Conclusion

This cross-sectional study suggests that, in a selected sample of university students, higher AHT is associated with reduced C2-C7 cervical lordosis, whereas C1-C2 upper cervical curvature does not differ significantly between the minimal-FHP and high-FHP groups. Exploratory associations with sex and height should be interpreted cautiously because of the small radiographic comparison sample and potential selection bias. Larger studies including pain, BMI, physical activity, and screen-time variables are needed to confirm these associations and determine their clinical relevance.

Ethics approval and consent to participate

Informed consent was obtained from all participants. This study was approved by the Human Ethics Research Committee under code IR.UOZ.REC.1403.018 and was conducted in accordance with the Declaration of Helsinki.

Availability of data and materials

The data for this study are presented within the manuscript and will be available to readers upon reasonable request.

Competing interests

The authors declare no competing interests.

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Author contributions

MSA and FK designed the study, developed methods, and collected data. MSA, FK, HA and AEA drafted and revised the manuscript. All authors reviewed, refined, and approved the final version.

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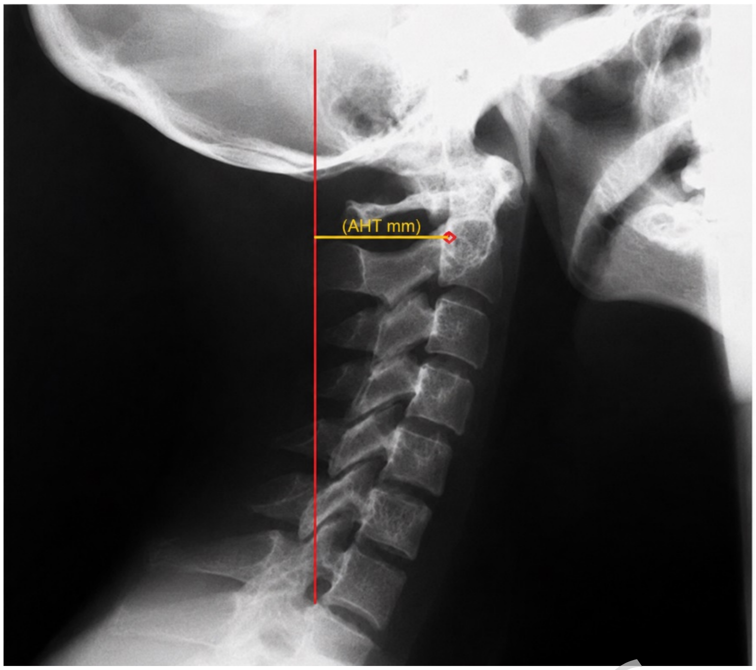

Figure 1. AHT Measurement

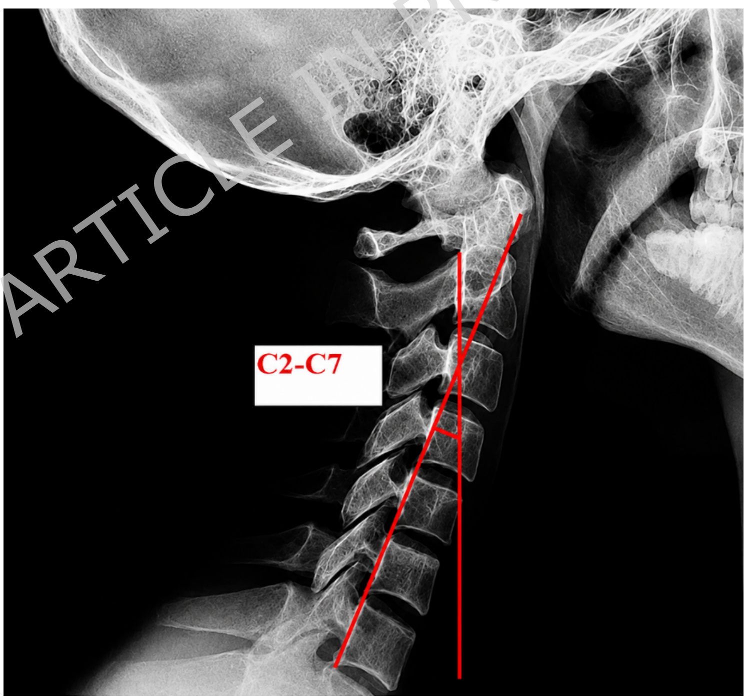

Figure 2. Measurement of C2-C7 cervical lordosis using the posterior tangent method.

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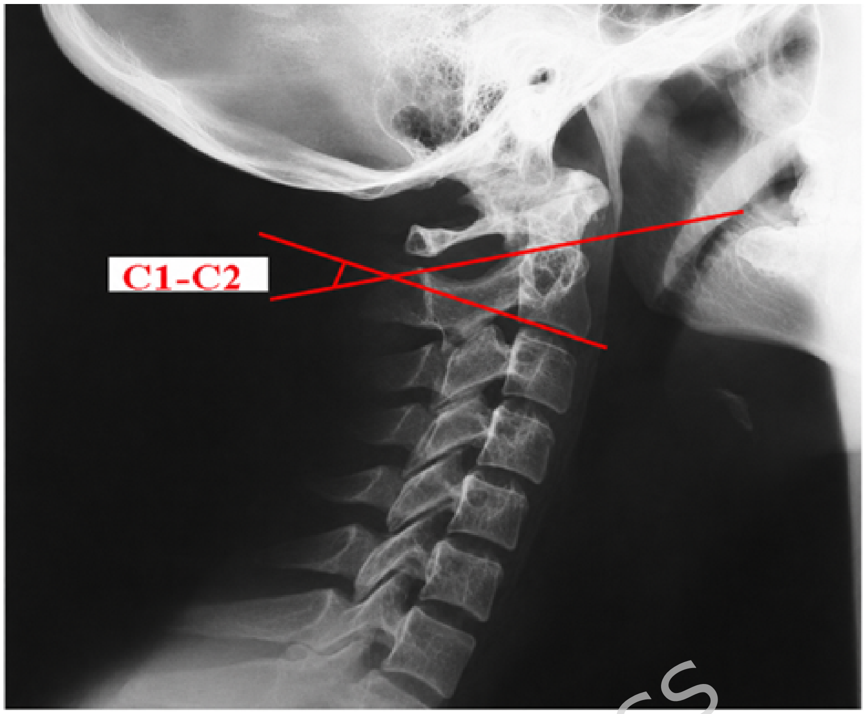

Figure 3. Measurement of the C1-C2 upper cervical angle.

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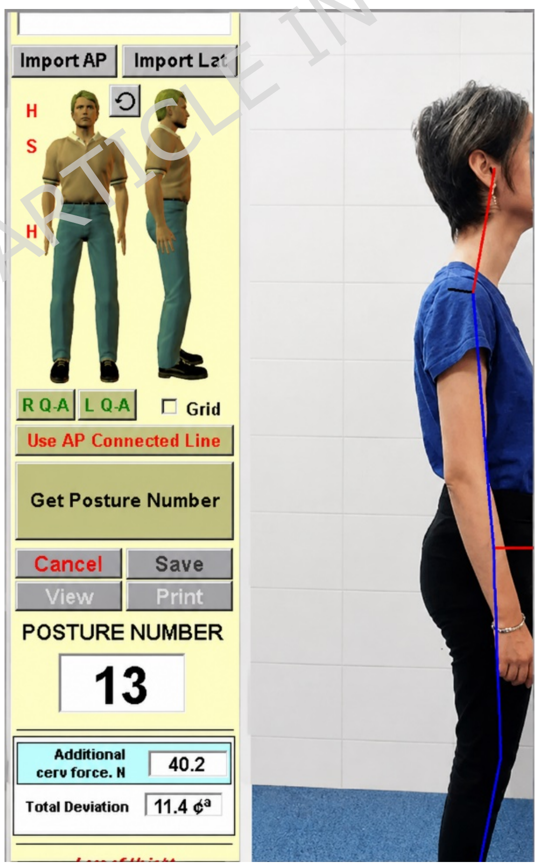

Figure 4. Digital lateral-view postural assessment in Posture Pro V software.

Table 1. Descriptive characteristics of participants.

Group	Sex	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m²)
Minimal-AHT comparison	Female	160.85 ± 5.36	55.28 ± 5.85	22.42 ± 1.39	21.36 ±2.26
Minimal-AHT comparison	Male	175.14 ± 3.53	60.71 ± 6.70	22.00 ± 3.16	19.80 ± 2.33
High-AHT	Female	163.28 ± 4.78	54.42 ± 5.44	22.45 ± 2.22	20.42 ± 2.36
High-AHT	Male	178.28 ± 4.78	60.50 ± 16.90	22.34 ± 2.16	19.04 ± 5.41

Note. AHT = anterior head translation; BMI= body mass index

Table 2. Between-group comparison of radiographic and PPV-derived variables.

Variable	Minimal-AHT comparison Mean ± SD	High-AHT Mean ± SD	Mean difference (95% CI)	t	p	Hedges' g	Interpretation
LOD	5.33 ± 5.16	70.00 ± 77.05	64.67 (20.12 to 109.22)	-2.97	0.006	1.15	Large; exploratory software-derived index
AHT (mm)	10.07 ± 8.12	27.93 ± 11.39	17.86 (10.14 to 25.58)	-4.77	0.001	1.75	Large
C1-C2 (°)	24.07 ± 6.70	24.86 ± 6.41	0.79 (-4.30 to 5.88)	-0.317	0.75	0.12	Trivial
C2-C7 (°)	38.29 ± 5.24	23.44 ± 6.26	-14.85 (-19.34 to -10.36)	9.36	<0.001	2.50	Large

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Note. LOD = Posture Pro V–derived load/overload index; AHT = anterior head translation.

Table 3. Pearson correlations among postural, radiographic, and anthropometric variables.

Relationship	r	p	Effect-size interpretation
AHT vs C2-C7 lordosis	-0.607	0.001	Large negative
AHT vs C1-C2 angle	0.388	0.042	Small positive
AHT vs LOD	0.447	0.011	Small-to-medium positive
C2-C7 lordosis vs C1-C2 angle	0.178	0.365	Weak positive; not significant
Height vs AHT	-0.605	0.001	Large negative
Height vs C2-C7 lordosis	0.414	0.028	Small-to-medium positive

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Note. LOD = Posture Pro V–derived load/overload index; AHT = anterior head translation (12).

Table 4. Sex-specific comparison of AHT and C2-C7 lordosis

Variable	Female Mean ± SD [verify]	Male Mean ± SD [verify]	Mean difference (95% CI) [verify]	t	p	Hedges' g
AHT	25.67 ± 11.63	11.31 ± 10.98	14.36 (5.57 to 23.15)	3.343	0.003	1.23
C2-C7	23.13 ± 12.05	33.77 ± 8.97	-10.64 (-18.93 to -2.35)	-2.613	0.015	0.97

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