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Assessment of skeletal age using the cervical vertebrae in Ghanaian orthodontics patients

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Abstract

Background: Skeletal age refers to the general degree of maturation of a part of the skeleton that subjects of a population manifest with growth. Assessing skeletal age involves visually inspecting bones on a radiograph. The hand-wrist and cervical vertebral maturation methods have been used widely to determine skeletal age. Using vertebral development to evaluate skeletal maturity is advantageous because it requires only one radiograph, the lateral cephalogram, which orthodontists routinely use for diagnosis and treatment planning.

Objective: This study aimed to determine the skeletal age according to cervical vertebral maturation (CVM) and its correlation with chronological age.

Methods: Lateral cephalometric radiographs of 70 Ghanaian orthodontic patients aged 9 - 18 years, involving 41 females and 29 males, were taken. Skeletal age was assessed according to Hassel and Farman's CVM method. The correlation between the chronological and skeletal ages was determined using the Spearman rank-order correlation coefficients.

Results: The mean chronological age of the sample was 12.97 ± 2.74 years; 59% (n = 41) were females and 41% (n = 29) were males. The most prevalent CVM stage was stage 4 (31%, n = 22), and stage 6 (3%, n = 2) was the least prevalent. CVM stages significantly correlated with chronological age (r = 0.759). CVM stages consistently occurred earlier in females than males, indicating that skeletal maturation was more advanced in females than males. The mean pubertal growth spurt (CVM stage 3) occurred for the total sample at 11.98 ± 3.06, 10.46 ± 0.6 years in the females and 16.51 ± 0.00 years for the only male recorded at this stage. Consequently, every child must be treated as an individual based on their level of skeletal maturation.

Conclusion: The lateral cephalograms can be used as initial diagnostic tools for determining the skeletal maturity stage and estimating patients' age. However, further studies on this topic with a more representative sample to corroborate the findings of this study are required.

Keywords: Skeletal age, skeletal maturation, chronological age, cervical vertebrae maturation.

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INTRODUCTION

Skeletal age is the measure of how much a skeleton has developed, and it is determined by observing the size, shape, and degree of mineralisation of the bones [1,2,3]. Every bone in the body shows a relatively consistent and organised ossification and can be viewed radiographically [4]. Given that the intrinsic timing system, which regulates various physiological states and processes, differs among individuals, the timing of skeletal changes also exhibits variation. Therefore, skeletal age may be the same, greater or less than chronological age [2]. Other factors that affect skeletal changes are genetic differences, environmental conditions, and regional and climatic variations [5].

Assessing skeletal age involves visually inspecting bones on a radiograph, their appearance and subsequent changes in shape and size. About twenty-nine skeleton areas have

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been used in growth studies, including the foot, ankle, hip, elbow, hand, wrist and cervical vertebrae [5]. In orthodontic research, the hand-wrist and cervical vertebrae methods have been used widely to determine skeletal age [6]. Using vertebral development to evaluate skeletal maturity is advantageous because it requires only one radiograph, the lateral cephalogram. Routinely, orthodontists examine lateral cephalograms for diagnosis and treatment planning. The optimal timing for orthodontic treatment is linked intimately to identifying periods of craniofacial growth that can contribute significantly to treating patients with skeletal discrepancies. The use of radiographic analysis to estimate the skeletal maturation stage is a widely used method for predicting the timing of pubertal growth [7,8]. The cervical vertebral maturation (CVM) method has been effectively used to assess the potential onset of the pubertal growth spurt. It involves estimating growth using the morphology of the second, third and fourth cervical vertebrae, which is visible on the lateral cephalometric radiographs [9]. The morphological features of the cervical vertebrae at different developmental stages relate to varying growth rates in facial structures.

Lamparski first described a system of skeletal maturation determination using the cervical vertebrae [10], which was later modified by Hassel and Farman [5]. They described each stage of cervical maturation in detail and analysed skeletal maturity based on the shape of the vertebral bodies of C2, C3 and C4 vertebrae on lateral cephalometric radiographs and then classified them into six stages: initiation, acceleration, maturation, transition, deceleration and finalisation/completion. The vertebrae at each stage had a specific characteristic related to their shape, which indicated skeletal maturity and growth potential. Baccetti et al. [11] also improved Hassel and Farman's work by relating the cervical vertebrae changes to the increment in total mandibular length. This study aimed to determine the skeletal age using Hassel and Farman's method of cervical vertebrae maturation (CVM) to determine the correlation between the chronological age and the skeletal age. The Hassel and Farman cervical vertebrae maturation index was used for skeletal age because of its simplicity and reliability in predicting skeletal maturity [12].

MATERIALS AND METHODS

A cross-sectional study evaluated consecutive orthodontic patients, aged 9 to 18, recruited from the University of Ghana Dental School Clinic. Following ethics approval (KBTH-STC/IRB/ 000103/2020), 70 Ghanaian patients (41 females and 29 males) with good-quality lateral cephalograms were included in the study. A pilot study was performed to assess recruitment challenges, standardise the grading of the radiographs, and design a data collection sheet. Twenty-five patients who consented satisfied the inclusion criteria and took lateral cephalometric radiographs were included in the pilot study. The participants' radiographs were graded on two separate occasions by the investigator (a specialist orthodontist), two weeks apart, to assess the intra-examiner reliability. A reviewing consultant orthodontist graded the same radiographs to assess inter-examiner reliability. The inter-examiner and intra-examiner agreements were assessed using the Cohen Kappa agreement [13] statistics. Convenience sampling was employed in this study, wherein consecutive patients who satisfied the inclusion criteria and consented to participate were recruited until the sample size was obtained. Although convenience sampling may introduce some bias, efforts were made to mitigate this by applying strict inclusion and exclusion criteria, sampling over different times and days, and ensuring demographic matching to the larger population. These measures were taken to ensure that the sample was as representative as possible of the Ghanaian orthodontic population.

The chronological age for each participant was estimated by subtracting the birthdate from the date the radiographs were taken. Hassel and Farman's approach was used to determine skeletal age based on the cervical vertebral maturation (CVM) on lateral cephalograms [5]. The digital radiographs were viewed on the laptop screen in a darkened room. The image was cropped and enlarged to show the cervical vertebrae C2 to C4. The lower borders of the vertebrae were evaluated first. At CS1, all the lower borders of all three cervical vertebrae were flat. At CS2, the lower border of C2 was notched. At CS3, the notch was on both C2 and C3. At CS4, 5 and 6, the notches were observed on all three studied vertebrae. The vertebrae's body of C3 and C4 typically changes in sequence from a trapezoidal shape to rectangular horizontal to square, then to rectangular vertical. From stage CS1 to CS3, most vertebrae have a trapezoid shape except in a few people where the C3 would have a rectangular horizontal shape. C2 and C3 are rectangular horizontal in CS4, square in CS5 and rectangular vertical in CS6. Based on these features, samples were classified into CS1, CS2, CS3, CS4, CS5 and CS6. Only five lateral radiographs were analysed in a day. The examination and grading of the lateral cephalograms were carried out separately by both the investigator and a reviewing consultant. In a few cases where there was a difference in the observations, the radiographs were reviewed together to arrive at a consensus.

The data was captured with Microsoft Access and analysed using the R Studio programming tool. The results were summarised using descriptive statistics and presented in tables. The independent sample T-test was used to determine the difference between the means of chronological age (CA) and skeletal age(SA). The linear relationship between chronological age and CVM stages was assessed using Spearman's correlations. For all tests, a p-value of < 0.05 was considered statistically significant.

RESULTS

Cohen Kappa statistic was used to assess the intra-examiner and inter-examiner agreement for the CVM stages. The reliability coefficients ranged from 0.69 to 0.89, indicating a substantial to near-perfect agreement as shown in Table

1. The differences in the kappa values for the CVM stages can be attributed to the subjectivity and difficulty encountered when classifying the shape of the vertebral bodies. From Table 2, the mean chronological age of the entire sample was 12.97 ± 2,74 years. The mean age of males was 12.99 ± 2.94 years, and that of females was 12.95 ± 2.63 years. Of the seventy participants in this study, 59% (n = 41 were females, while 41% (n = 29) were males.

From Table 3, the most prevalent CVM stage was stage 4 (31%) and was observed in all the age group categories, and the least prevalent was stage 6 (3%). The age range for the CVM stage 1 ranged from 9 - 12.99, with the mean chronological age at 10.38 ± 0.94 years. The CVM stage 3 was seen at an approximate age of 11.98 ± 3.06 years for both males and females, 10.46 ± 0.6 years for the females and 16.51 years for the one male recorded at this stage. CVM stage 6 was observed only in the 15 - 16.99 age group but not in the 17 - 18.99 age group. Only two participants were found in CVM stage 6, and both were females. There were eight participants in the 17 - 18.99 age group consisting of five males and three females; seven (88%) were in CVM stage 4, and the remaining one (12%) was in CVM stage 5.

From Table 4, there was no significant difference in mean chronological age between males and females for most CVM stages ($p > 0.01$), except for CVM Stage 4, where males were significantly older than females ($p = 0.0031$). For stages with insufficient male participants, a valid comparison could not be made. From Table 5, the correlation coefficient was 0.885 and 0.771 in the males and females, respectively and 0.7575 in the total sample, which is highly significant ($p = 0.001$).

Table 1. Inter and Intra-examiner reliability for CVM stages using the Cohen Kappa method

Observers	Kappa Score		
	Index	95% CI	p-value
Intra-examiner			
CVM Stages	0.894	(0.76,1.0)	0.001
Inter-examiner			
CVM Stages	0.69	(0.49, 0.90)	0.001

Table 2. Gender distribution, mean, standard deviation, minimum, and maximum ages of participants

Variables	Count (%)	Mean Age ± SD	Min	Max
Gender				
Male	29 (41)	12.99 ± 2.94	9.33	18.10
Female	41 (59)	12.95 ± 2.63	9.04	18.04
Total	70 (100)	12.97 ± 2.74	9.04	18.10

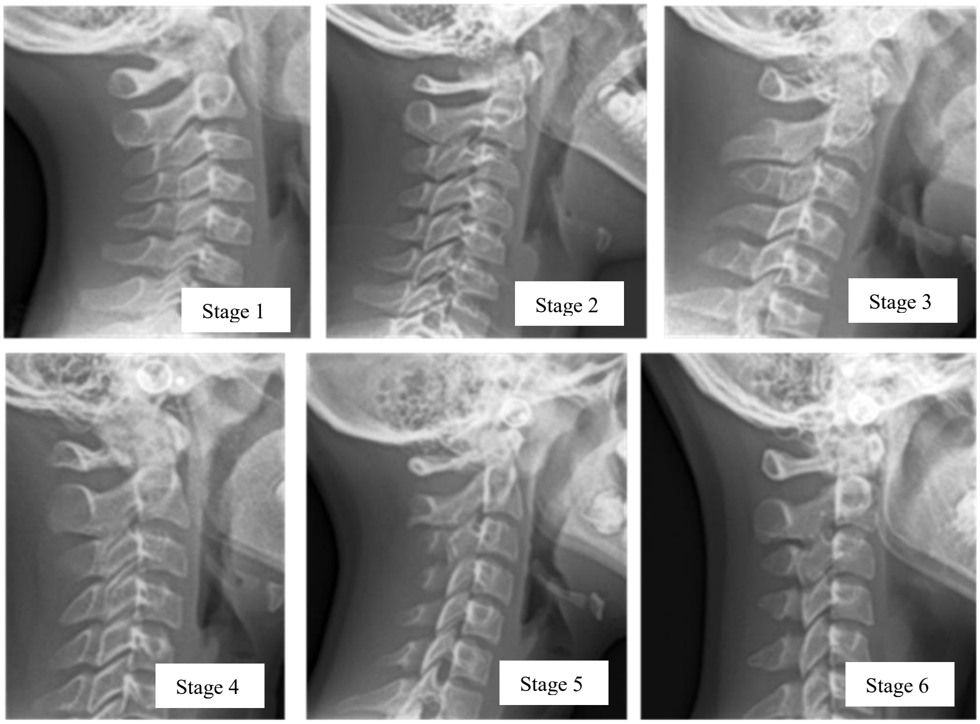

Figure 1. Cervical Vertebral Maturity from stages 1 to 6 from the study sample according to Hassel and Farman's CVM stages

Table 3. CVM stages in different age groups for the entire population

Chronological Age Category	CVM STAGES 1 N (%)	2 N (%)	3 N (%)	4 N (%)	5 N (%)	6 N (%)	Total N (%)
9 - 10.99	12 (48)	10 (40)	2 (8)	1 (4)	0 (0)	0 (0)	25 (100)
11-12.99	4 (33)	3 (25)	1 (8)	2 (17)	2 (17)	0 (0)	12 (100)
13-14.99	0 (0)	1 (8)	0 (0)	7 (58)	4 (33)	0 (0)	12 (100)
15-16.99	0 (0)	0 (0)	1 (8)	5 (38)	5 (38)	2 (15)	13 (100)
17-18.99	0 (0)	0 (0)	0 (0)	7 (88)	1 (12)	0 (0)	8 (100)
Total	16 (23)	14 (20)	4 (6)	22 (31)	12 (17)	2 (3)	70 (100)

Table 4. Results of the independent samples t-test comparing mean chronological age between males and females for each cervical vertebral maturation stage

CVM Stage	Sex	Mean ± SD	Count	p-value
1	Male	10.55 ± 0.67	8	
	Female	10.22 ± 1.18	8	
	Total	10.385 ± 0.95	16	0.5101
2	Male	11.14 ± 1.28	10	
	Female	10.07 ± 1.19	4	
	Total	10.61 ± 1.32	14	0.1888
3	Male	16.51 ± 0.00	1	
	Female	10.46 ± 0.60	3	
	Total	11.98 ± 3.06	4	NA
4	Male	16.51 ± 1.17	9	
	Female	14.17 ± 2.07	13	
	Total	15.13 ± 2.09	22	0.0031
5	Male	15.7 ± 0.00	1	
	Female	14.59 ± 1.55	11	
	Total	14.68 ± 1.52	12	NA
6	Male	0.00 ± 0.00	0	
	Female	16.51 ± 0.40	2	
	Total	16.51 ± 0.040	2	NA
Total	Male	12.99 ± 2.94	29	
	Female	12.95 ± 2.63	41	
	Total	12.97 ± 2.74	70	0.9622

Table 5. Spearman's Correlation coefficients between chronological age (C.A) and skeletal age (S.A)

Gender	Correlation between C.A. and S.A. ('r' value)
Males	0.8849***
Females	0.7713***
Total sample	0.7595***

(*** Significant at 0.01)

DISCUSSION

The assessment of skeletal age showed acceptable reliability with a good concordance coefficient. Sigid Fu [14], in his thesis, assessed the intra and inter-examiner reliability for CVM stages. A kappa value of 0.88 and 0.82 was obtained for the intra and inter-examiner reliability, respectively. The intra-examiner reliability obtained in this study is similar to what was obtained in Sigid Fu's [14] work; however, the inter-examiner reliability was lower in this study. Montasser et al. [15] got a Kappa value of 0.90 for intra-examiner reliability. Mustafa et al. recorded 0.68 for intra-examiner and 0.92 for inter-examiner reliability for the CVM stages [16]. Hassan et al. [17] recorded a Kappa value of 0.86 for intra and inter-examiner reliability. The differences in the kappa values for the CVM stages in this study can be attributed to the subjectivity, and difficulty encountered when classifying the shape of the vertebral bodies [18], and the wide confidence interval could be due to the small sample size (n = 25) used for the pilot study.

The majority of participants in this study are females, which is not surprising because studies have shown that females actively demand orthodontic treatment as they pay more attention to the aesthetics of their teeth than males

[19,20,21]. The findings of this study demonstrate that each of the CVM stages consistently occurred earlier in females than in males. This can be interpreted as skeletal maturation occurring earlier in females than males in this study. It also shows that participants of the same chronological age can have different skeletal maturation stages. These findings are in agreement with many other studies done across diverse populations [17,22,23]. Hagg et al. [24] reported in their research that skeletal development was more advanced in the beginning and peaked for the females; however, at the end of the growth spurt, skeletal development was higher in the males. The CVM stage 1 is the ideal time for rapid palatal expansion with facemask therapy in Class III malocclusions. During this period, the sutures are more open and less interdigitated, allowing maximum skeletal adaptations and fewer dentoalveolar changes in the midfacial region [25]. The pubertal growth spurt is at its peak in CVM stage 3, where about 25 - 65% of adolescent growth is expected. It is at this CVM stage that functional appliances are recommended for efficient functional treatment of skeletal Class II malocclusions [26]. In the present study, the CVM stage 3 occurred at a mean age of 11.98 ± 3.06 years for both sexes, 10.46 ± 0.6 years for the females and 16.51 ± 00 years for the one male that was recorded at this stage. This finding in the male participant is not strange because, according to Goyal et al. [23], exceptional cases outside the reported norms may occur. Growth decelerates dramatically at CVM stages 4 to 5, with little to insignificant growth expected. The findings in the females and the total sample are consistent with many other studies [15,23,27].

In this study, the period of active pubertal growth in females is approximately between 10 and 11 years of age. A definite conclusion cannot be made for males, considering that they can actively grow and may qualify for growth modulation treatment even at 16 years. There is a common assumption that the Pubertal growth spurt peaks at ages 12 and 14 years in males and 10 and 12 years in females [28], since it might be a year late for the females and may occur two years later for the males. However, a definite conclusion cannot be drawn because of this study's small sample size, particularly in the CVM stage [3]. In this study, the positive correlations between the two variables under study were highly significant. The correlation coefficient denotes a superior correlation in males than in females. Baidas et al. [27] reported a similar finding in their investigations, where the correlation was high and significantly better for females than males. However, their correlation coefficients were higher than what was recorded in this study (females (0.903) and males (0.896). Uysal et al. [29] recorded similar correlation values for the same correlation test, 0.72 for both sexes, 0.68 for males and 0.82 for females and further reported that females correlated better than males.

Each CVM stage consistently occurred earlier in female than in male subjects. This infers in this study that skeletal maturation occurs earlier in females than in males. Although the reliability and correlations of the CVM stages proved statistically acceptable, growth maturation assessment using the results of this study should be done cautiously. It should be considered alongside other features of maturity, such as peak height and secondary sexual characteristics, to give an improved and more precise evaluation of when to commence growth modification treatment.

Conclusion

The six stages of CVM proposed by Hassel and Farman were presented in this study. Each CVM stage consistently occurred earlier in female than in male subjects. The CVM was correlated highly significantly with chronological age. Peak growth was predicted to occur at 11.98 ± 3.06 years for the entire sample but at 10.46 ± 0.6 years for females. Although the reliability and correlations of the skeletal and chronological ages proved statistically acceptable, growth maturation assessment using the results of this study should be done cautiously. It should be considered alongside other features of maturity, such as peak height and secondary sexual characteristics, to give an improved and more precise evaluation of when to commence growth modification treatment. Further studies involving a more representative sample to corroborate the findings of this study are required.

DECLARATIONS

Ethical consideration

Ethical clearance was obtained from the Institutional Review Board, Korle Bu Teaching Hospital(KBTH-STC/IRB 000103/2020)

Consent to publish

All authors agreed on the content of the final paper.

Funding

None

Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Author contributions

The study concept and design were developed by RDP, GKA, MNN, TAN and GTMY. RDP collected the data. TAN performed the statistical analysis. RDP, GTMY GKA, AND MNN interpreted the results. RDP and GTMY drafted the manuscript. All authors revised the manuscript and approved the final submitted version.

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Availability of data

Data is available upon request to the corresponding author.

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