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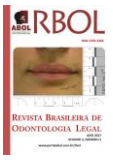

Forensic Anthropology

ACCURACY OF ESTIMATING AGE FROM CERVICAL VERTEBRAL MATURATION AND MANDIBULAR MOLAR MATURATION.

A confiabilidade da estimativa de idade pela maturação óssea das vértebras cervicais e mineralização de molares inferiores.

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ABSTRACT

Age estimation is required for forensic cases such as minors without documentation and age disputed by asylum seekers. Cervical vertebral maturation (CVM) has potential to estimate age as a new method of analysis of shape change during adolescence and adulthood. The aim of this study was to assess the accuracy of estimating age using Lamparski's method of cervical vertebra maturation, the mandibular second (M2) and third molars (M3) in a group of males. The test sample consisted of lateral cephalograms of 60 boys from the Bolton-Brush online collection and 53 from Burlington online collection aged 10 to 15 years. CVM age was calculated from age category and mean age and transition age of CVM stages, calculated from raw data of 69 boys (aged 9 to 15 years) studied by Lamparski (1972). Dental age was calculated using mandibular second and third molar stages from Liversidge (2009). The mean difference and absolute mean difference between CVM age and dental ages and chronological ages was calculated. CVM and molar tooth stage assessment reliability was assessed by duplicate readings by the first author. Results show that Lamparski's method of CVM mean age was most accurate and had considerably smaller standard deviation and smallest absolute mean difference than other method of M2 or M3 (mean difference -0.49, SD 0.23, absolute mean difference 0.49 years). CVM has potential as a possible method of estimating age for this age group, particularly when M2 is mature or M3 is missing.

KEYWORDS

Forensic dentistry; Age determination by teeth; Age determination by skeleton; Spine; Data accuracy.

INTRODUCTION

Shape changes during the maturation of cervical vertebrae reflect the pubertal growth spurt and were first associated with age by Lamparski (1972)[1]. The author compared the shape of the second to sixth cervical vertebrae (C2 to C6) seen in Lateral Cephalograms (LC) of pre-adolescents (10-15yrs) and categorised CVM in six age related stages. The author showed that the pubertal spurt was evident from both CVM and hand wrist maturation using the Greulich and Pyle atlas (1959)[2],

removing the need for hand wrist radiographs.

Hellsing (1991)[3] studied the dimensions of C2-C6 in relation to stature in children from 8-15 years and young adults and also showed that some dimensions in males continue to develop after 15 years. Shape changes of CVM continue throughout adulthood. Other authors also analysed the shape changes of cervical vertebrae according to age, quantitatively.

Israel (1973)[4] showed from a longitudinal study that the width of C3 increased with age of adult women (24-47yrs). This change in the antero-posterior diameter of C2 was also observed in a cross sectional study of C2, C3 and C7 in adults aged 20-80 years[5].

Tooth development has been compared to Lamparski's CVM stages. Heravi et al. (2011)[6] showed a good correlation between Demirjian's dental maturity (1973)[7] and CVM stages of Lamparski in Iranian children (10-15yrs).

Sachan et al (2011)[8] compared three indexes in Indian children (10-13yrs): Nolla's (1960)[9] method for the calcification stages of the mandibular right canine, Lamparski's method for the CVM stages and Fishman's method (1979)[10] for the hand wrist maturation. The results showed that there was a strong correlation between HWM and CVM and a good correlation between HWM and canine calcification.

Mack et al. (2013)[11] compared the relationship between body mass index, Lamparski's skeletal maturity method and Demirjian's dental maturity in adolescents (8-17yrs). Results showed that both indices were more advanced with increased BMI (body mass index).

Lamparski's method has not previously been used to estimate age. The aim of this study was to assess the accuracy of estimating age using Lamparki's stages of CVM as well as the mandibular second (M2) and third (M3) molars.

MATERIALS AND METHODS

Lamparski (1972) described a new method of cervical vertebral growth based on the changing size and shape of C2 to C6 in 69 boys and 72 girls. The author grouped CVM stage into age categories from 10 to 15 years of age and tabulates the raw data. The age distribution of the boys in this reference sample is shown in Table 1 and CVM stages plotted against age in Figure 1.

The authors have used the raw data to calculate mean age within stage and age of transition into stages for boys. Age of transition was calculated using probit regression with one year age groups[12,13].

Thus the present study have three methods to estimate age using CVM from this reference sample: age category, mean age and transition age (see Table 2). The test sample was lateral cephalograms of 113 boys aged 10 to 15 years from the Bolton-Brush online and Burlington Collection (http://www.aaoflegacycollection.org/aaof_collection.html?id=CASEBolton, http://www.aaoflegacycollection.org/aaof_collection.html?id=UTBurlington).

Table 1 - age distribution of the boys in this reference sample.

Age	**CVM stages**								**Total**
	1	2	3	4	5	6	7	8	
9+		3							3
10+	1	5	6						12
11+		1	8	3	1				13
12+			1	5	8				14
13+					3	5	1		9
14+					1	3	9	2	15
15+						1	1	1	3
Total	1	9	15	8	13	9	11	3	69

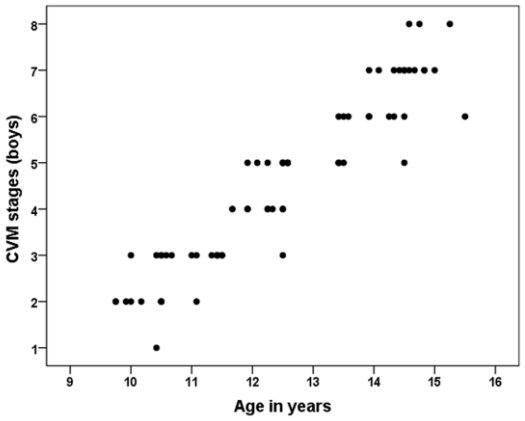

Figure 1 - CVM stages plotted against age.

Those collections were sampled from 1929 to 1959 and are available on line for researchers worldwide, therefore, there was no need for consent form. Similar number of each age category were selected and age and CVM stages of the test sample are shown in Table 3. CVM was assessed into Lamparski's stages and mandibular M2 and M3 were categorised into Moorrees et al.[14] stages by the first author.

Reliability of CVM and molar tooth stages was assessed by duplicate readings of 15 radiographs by the first author using Cohen's Kappa. The authors selected M2 and M3 because central and lateral incisors are mature by age 10 and the development of the canine and premolars is highly correlated in that age range.

Age was estimated using Lamparski's age category, mean age of CVM stages calculated using raw data from Lamparki (1972) and age of transition of CVM stages also calculated using raw data from Lamparki (1972). Dental age was calculated from the mandibular second and third molar formation stages after Moorrees et al. (1963) using reference data from Liversidge (2009).

For each boy, chronological age was subtracted from dental or CVM age. The mean difference, standard deviation (SD), root mean squared error and absolute mean difference for the five methods was calculated.

Table 2 – CVM stage according to age category, mean age and transition age.

CVM stage	Main descriptor	Age category	Mean age, SD*	Age of transition, SD*
1	Inferior border convex			
2	Inferior border flat	10	10.24, 0.44	
3	Inferior border C2 slight concavity	11	11.06, 0.63	10.48, 0.52
4	Inferior border C2 definitely concave, others flat	12	12.17, 0.30	11.79, 0.37
5	Inferior border C3 concave	13	12.79, 0.72	12.31, 0.44
6	Inferior border C3 concave, slight concavity on C4, bodies rectangular	14	14.10, 0.65	13.54, 0.51
7	C4 concavity deeper, C5 slight, bodies square	15	14.51, 0.32	14.30, 0.70

Table 3 - CVM stages of the test sample.

Age	Lamparski CVM stages						Total
	< stage 3	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	
10+	13	3	1				17
11+	6	12	2	2			22
12+		4	13	2			19
13+	1	1	4	13	4	1	24
14+				3	16	2	21
15+						10	10
Total	20	20	20	20	20	13	113

RESULTS

Reliability according to Cohen's Kappa showed moderate agreement for CVM with value of 0.590 and substantial agreement for M2 at 0.750 and 0.768 for M3. Distribution of CVM stage and M2 and M3 stage are plotted in Figure 2. This shows that M3 varies considerably with CVM stage whereas a trend is apparent between M2 and CVM. Ten individuals in the test sample had mature second molars and thus age could not be estimated using this tooth. Five individuals in the test sample did not have third molars forming and age could not be estimated for these individuals using third molars.

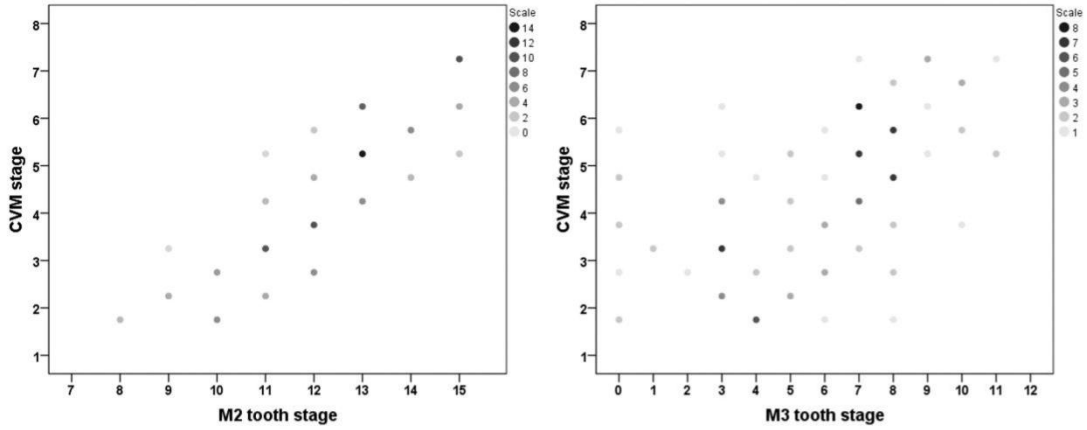

Figure 2 - Distribution of CVM stage and M2 and M3 stage.

Results of age estimation methods for the test sample of 113 boys aged 10-15 years are shown in Table 4. Mean values of accuracy for the whole sample were similar for CVM age category, CFM mean age and M2, while CVM transition age underestimated age considerably and M3 overestimated age. The M2 was better than M3 at estimating age. The most striking finding was the small standard deviation of CVM mean age at less than half the other methods. In addition, the mean absolute difference was least for CVM mean age.

Table 4 - Results of age estimation methods for the test sample of 113 boys

Method	N	Mean difference, SD	RMSE	Mean absolute difference
Whole test sample				
CVM age category	113	-0.49 0.73	0.69	0.71
CVM mean age	113	-0.49, 0.23	0.16	0.49
CVM transition age	96	-0.94, 0.76	0.64	1.03
M2	97	-0.47, 0.95	0.94	0.82
M3	105	0.50, 1.43	1.40	1.18
Selected test sample				
CVM age category	90	-0.46, 0.75	0.72	0.71
CVM mean age	90	-0.43, 0.16	0.14	0.43
M2	90	-0.43, 0.94	0.92	0.80
M3	90	0.58, 0.58	1.48	1.27

The mean difference in estimated age for each method is illustrated in Figure 3 and the distribution of absolute differences are shown in Figure 4. CVM mean age estimated age to within 1 year of chronological age whereas other methods showed considerable variation. A summary of results is shown in Figure 5 where the mean difference in years (mean ± 1.96 x SD) showing that CVM mean age is the most accurate method. This finding that CVM mean age performed best was also observed in the 90 boys for whom data of CVM, M2 and M3 were all available.

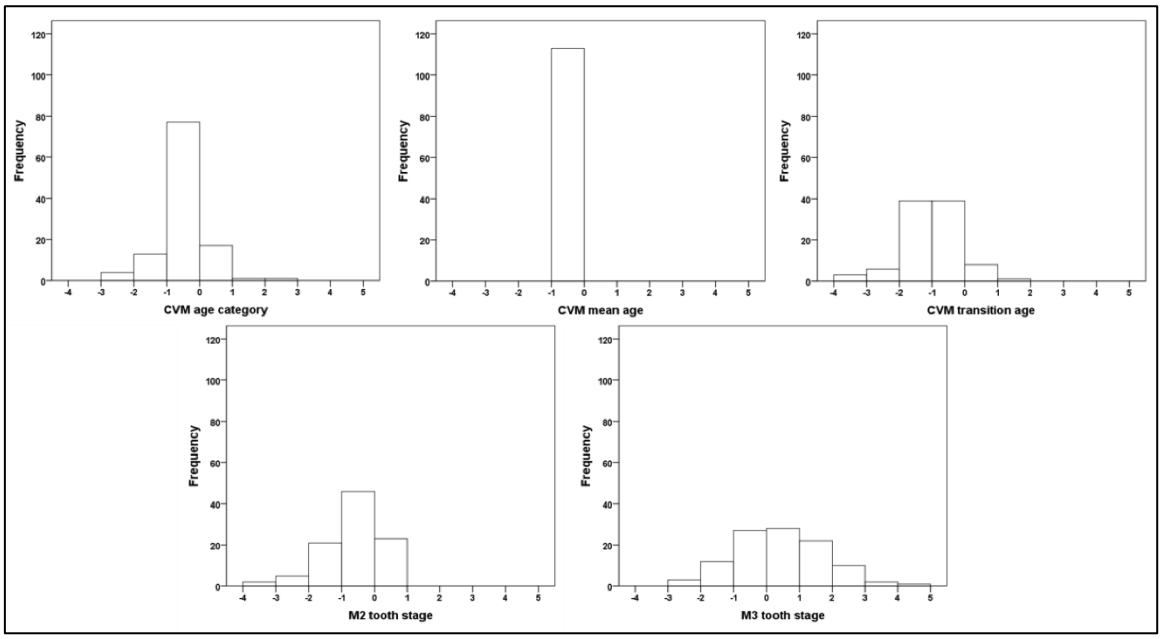

Figure 3 - The mean difference in estimated age for each method.

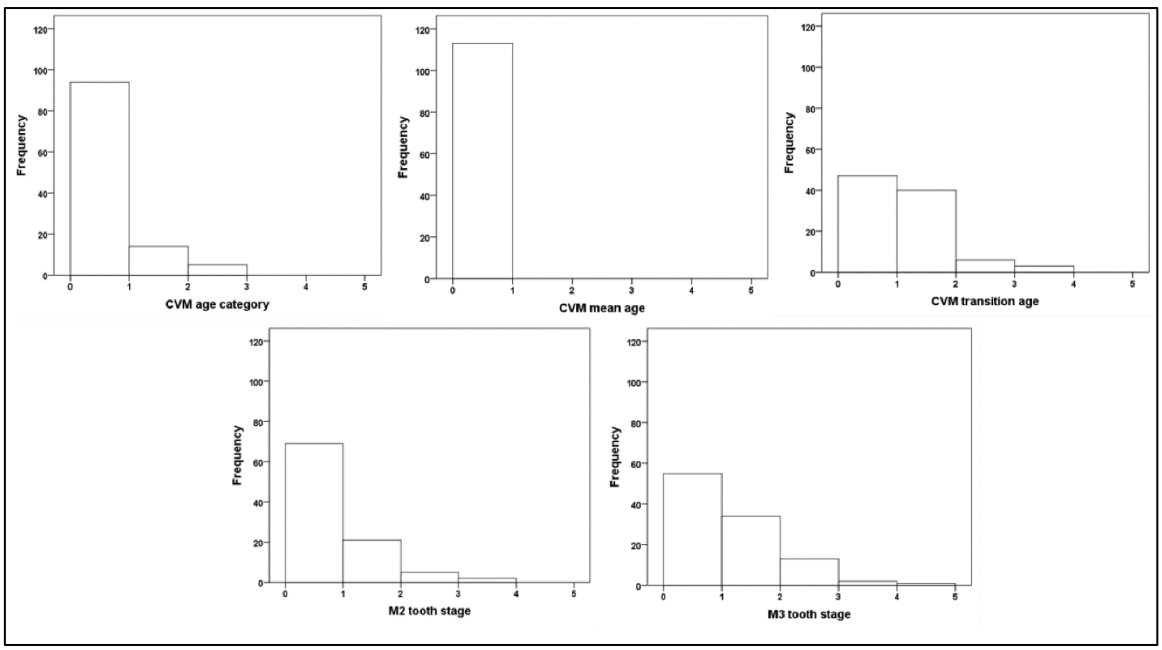

Figure 4 - The distribution of absolute differences.

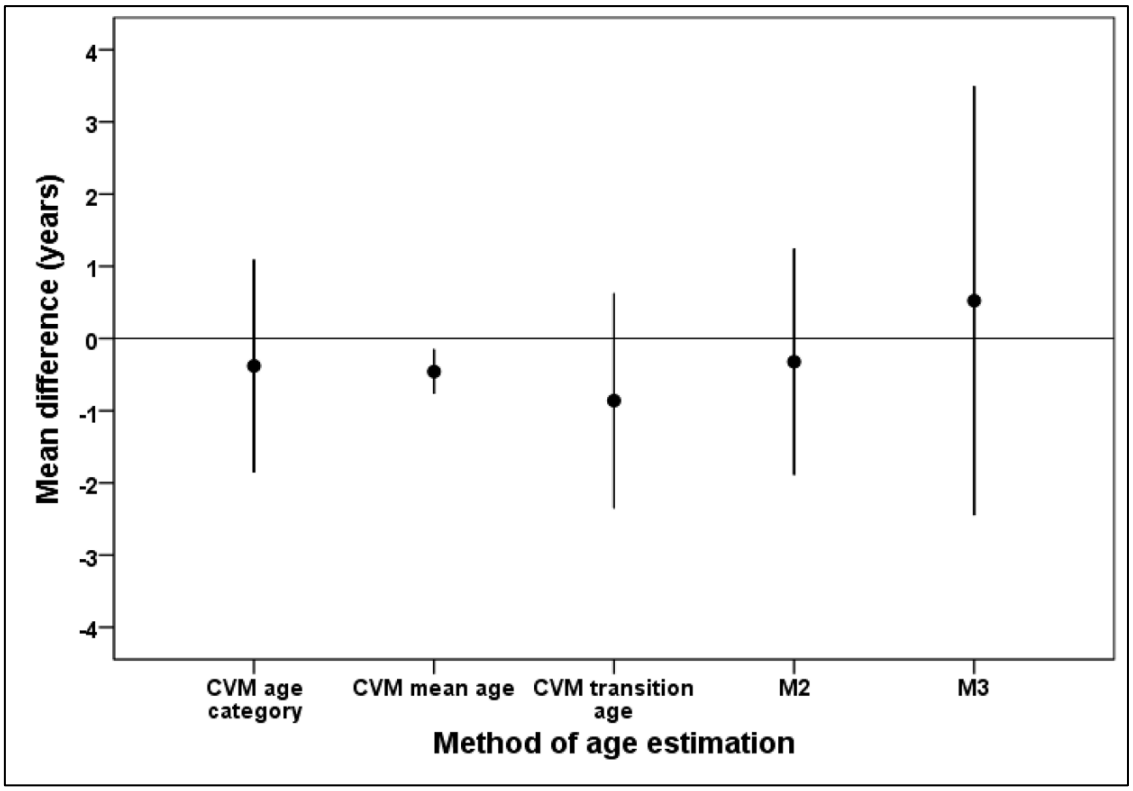

Figure 5 - Summary of results.

DISCUSSION

The strength of this study is that the present study demonstrate that Lamparski CVM mean age is an accurate and alternate method estimating age in boys for ages 10-15 years. This is particularly valuable when M2 is mature and/or M3 is absent. Assessing performance of an age estimation method relies on several factors.

These include the nature of the reference sample and how accuracy is expressed. Lamparski's method of CVM is based on 69 boys and 72 girls and raw data for boys is illustrated in Figure 1. It is evident that for CVM stages 3, 5 and 6 vary considerably with regard to age whereas stage 4 varies less. It is evident from Figure 1 and Table 1 that this reference sample is small.

Our test sample showed that the minimum and maximum in some stages exceeded those from the reference sample. In particular, stage 6 occurred in the test sample of 13 and 14 year old boys only, in contrast the reference data. The existence of a population difference is possible, however few studies compared bone age between ethnic groups appropriately[15].

Using Lamparski's reference data as a method to estimate age has one major drawback - the age range. The small age range dictated the age range of our test sample and this is a limitation of our study. However, our study highlights an area of future research documenting shape change in the maturation of cervical vertebrae. The small age range of Lamparski's method also highlights the need for good reference data based on adequate size and a wide age range. Moreover, there is no possibility of checking the real age of those boys from the

collections and the authors had to assume that the recorded age was correct.

Accuracy can be expressed as the mean difference between biological and chronological ages and shows accuracy for the group. However, age is usually estimated for an individual and the standard deviation and mean absolute error reflect performance better at the individual level. In this regard the results from this study are promising and are considerably better than a previous study assessed the accuracy of estimating age using CVM by Cameriere et al. (2014)[16], although the age ranges of these studies differed. They compared the ratio of anterior and posterior heights of C4 in 5-15 year olds and report a mean absolute error of 1.34 years and root-mean-square error (RMSE) of 1.65 in boys.

Discordance of up to 11 months between bone and chronological age was found between African and Asian in late childhood and adolescence[17]. As an example, bone age using the standards of Greulich and Pyle[2] must be done with reservations particularly in black and Hispanic girls and in Asian and Hispanic boys in late Childhood and adolescence, where bone age may exceed chronological age by 9 months to almost a year[18]. CVM mean age was more accurate than CVM transition age in our study, however, age at transition has been found to predict age better than mean age, percentiles or ranges using other bones[19]. Possible reasons for this include the close association between CVM and age and/or the small age range.

Skeletal age estimation is an important tool for predicting human development[20]. This study, presented again cervical vertebra as one of the markers that could be more explored by science.

CONCLUSIONS

Although this study assessed maturity in a sample of limited age range of 10-15 year old boys, CVM mean age was the most accurate method to estimate age with the smallest standard deviation and mean absolute difference between estimated and chronological ages. This shows that CVM is a possible method to estimate age particularly if M2 is mature and/or M3 absent.

ACKNOWLEDGMENTS

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RESUMO

A estimativa da idade é necessária em casos forenses como os de menores sem documentação e disputa por comprovação de idade em caso de refugiados. A maturação óssea das vértebras cervicais (MOVC) tem potencial para estimar a idade pela análise de mudança de sua forma anatômica, durante a adolescência e vida adulta. O objetivo deste estudo foi avaliar a exatidão da estimativa de idade pela MOVC proposta por Lamparski (1972), além da análise da mineralização do segundo (M2) e terceiro (M3) molares mandibulares. O material de estudo consistiu em teleradiografias de meninos com idade entre 10 a 15 anos (60 da coleção Bolton-Brush e 53 da coleção Burlington). A idade pela MOVC foi calculada a partir da categoria, média e transição de idade de cada estágio da MOVC, tendo como base os valores encontrados dos 69 meninos (de 9 a 15 anos) estudados por Lamparski. A idade dental foi calculada utilizando os estágios de mineralização dos segundo e terceiro molares mandibulares de acordo com Liversidge (2009). A média da diferença e a diferença média absoluta entre a idade pela MOVC, a idade dentária e a idade cronológica foram calculadas. A confiabilidade das leituras das idades pela MOVC e a idade dentária foi avaliada pela repetição das mesmas pelo autor principal. Os resultados mostraram que a média da idade pelo método da MOVC segundo Lamparski foi mais preciso e teve consideravelmente

menor desvio padrão e menor diferença média absoluta do que os outros métodos através de M2 ou M3 (diferença média -0,49, SD 0,23, diferença média absoluta 0,49 anos). MOVC tem potencial como um possível método de estimativa de idade para essa faixa etária, especialmente quando M2 já está mineralizado ou M3 é ausente.

PALAVRAS-CHAVE
Odontologia legal; Determinação da idade pelos dentes; Determinação da idade pelo esqueleto; Coluna vertebral; Confiabilidade dos dados.

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