DOI: 10.4274/jbuch.galenos.2024.49260
J Dr Behcet Uz Child Hosp 2024;14(3):160-166

Original Article

Determining the Chronological Age of Children Living in the Mediterranean Region Using Different Radiological Methods and Age Estimation Methods

Akdeniz Bölgesinde Yaşayan Çocukların Kronolojik Yaşlarının Farklı Radyolojik Yöntemler ve Yaş Tahmin Yöntemleri Kullanılarak Belirlenmesi

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ABSTRACT

Objective: The aim of this study was to evaluate the suitability of three age estimation methods, using different radiological techniques, for estimating the chronological age (CA) of children living in the Mediterranean region, and whether these methods can be used in forensic procedures.

Method: A total of 1296 digital orthopantomographic and hand-wrist radiographs of 648 children aged between 7 and 16 years were evaluated. Fishman, Willems and Nolla age estimation methods were used to estimate CA.

Results: Chronological and dental age correlated with the Nolla and Willems methods (NM and WM) in both boys and girls. There was no statistically significant difference between upper canine age estimation and CA using the NM in children aged 7-11 years in boys and in girls. There was no statistically significant difference between the NM upper canine age estimation and CA in children aged 12-14 years in boys.

Conclusion: The WM may be suitable for estimating CA in boys and girls aged 7 and 14 years. The Fishman method may be suitable for estimating CA in girls aged 12-14 years. The NM of upper canine age estimation can also be used to estimate CA.

Keywords: Nolla method, Fishman method, Willems method, age determination, age estimation

ÖZ

Amaç: Bu çalışmanın amacı, Akdeniz bölgesinde yaşayan çocukların kronolojik yaşlarını tahmin etmek için farklı radyolojik teknikler kullanan üç yaş tahmin yönteminin uygunluğunu ve bu yöntemlerin adli prosedürlerde kullanılıp kullanılamayacağını değerlendirmektir.

Yöntem: Yaşları 7 ile 16 arasında değişen 648 çocuğa ait toplam 1296 dijital ortopantomografik ve el-bilek radyografisi değerlendirildi. Kronolojik yaş tahmini için Fishman, Willems ve Nolla yaş tahmini yöntemleri kullanıldı.

Bulgular: Kronolojik ve dental yaş hem erkek hem de kız çocuklarda Nolla ve Willems yöntemleri ile korelasyon gösterdi. Erkeklerde ve kızlarda 7-11 yaş arası çocuklarda Nolla yöntemi ile üst kanin yaş tahmini ve kronolojik yaş arasında istatistiksel olarak anlamlı bir fark yoktu. Erkeklerde 12-14 yaş arası çocuklarda Nolla yöntemi ile üst kanin diş yaşı tahmini ile kronolojik yaş arasında istatistiksel olarak anlamlı bir fark bulunmadı.

Sonuç: Willems yöntemi 7 ve 14 yaşlarındaki kız ve erkek çocuklarda kronolojik yaş tahmini için uygun olabilir. Fishman yöntemi 12-14 yaş arası kız çocuklarında kronolojik yaş tahmini için uygun olabilir. Nolla üst kanin diş yaşı tahmin yöntemi de kronolojik yaşı tahmin etmek için kullanılabilir.

Anahtar kelimeler: Nolla yöntemi, Fishman yöntemi, Willems yöntemi, yaş tayini, yaş tahmini

Received: 09.08.2024
Accepted: 02.10.2024

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Cite as: Kuter B, Sağlam C, Ertuğrul F, Güler N. Determining the Chronological Age of Children Living in the Mediterranean Region Using Different Radiological Methods and Age Estimation Methods. J Behcet Uz Child Hosp. 2024;14(3):160-166

INTRODUCTION

Estimation of chronological, skeletal and dental age is important for both identification and treatment of children[1]. Determining the compatibility of skeletal and dental age with chronological age (CA) by age estimation methods helps to correctly resolve legal and ethical issues, especially in children, during growth and development periods[2].

Dental age estimation methods could provide an accurate assessment of CA[3]. Dental calcification stages are useful measures in age estimation because of a series of recognizable changes. The other method is skeletal age estimation based on the maturation indicators. Skeletal maturation indicators include 11 anatomical regions on the radius, phalanges, and sesamoids. There are many researchers working on this method. Fishman is also one of these researchers. Fishman developed a skeletal maturation assessment method based on hand-wrist radiographs[2], excluding the carpal bones. An important diagnostic tool for age estimation is the hand-wrist radiograph[2], which provides a comprehensive age assessment.

The Willems method (WM) revisited Demirjian's technique based on the developmental stages of teeth[4]. This method contains new charts for each gender, each tooth's score is added, and age is directly converted from the years. The Nolla method (NM) estimates dental age according to the degree of calcification in permanent teeth[5].

Both the maxillary and the mandibular teeth are evaluated according to developmental stage, the scores are added, and the sum is matched with the chart for the value that corresponds to dental age, or tooth age is converted directly to years with age conversion charts. Accurate age estimation with radiography is difficult due to the difficulty of grouping different sample sizes and comparing statistical analysis. Fishman method (FM), NM (canine and first molar) and WM have not previously been evaluated in the same study in children and adolescents.

The applicability of these three age estimation methods was evaluated in children living in the Mediterranean region in this study. In addition, it was evaluated whether canine or first molar maturation stages alone are sufficient to predict CA and whether these methods can be used for forensic procedures in children living in the Mediterranean region.

MATERIALS and METHODS

Subjects

For this study, 1296 digital radiographs of orthopantomographs and hand-wrist radiographs of 648 children were obtained from hospital records. The children whose radiographs were analysed were patients from the provinces of İzmir, Aydın, Manisa, Muğla, Kütahya and Balıkesir who came to the dental clinic with their parents for examination.

Selection Criteria of the Subjects

Inclusion Criteria

Subjects aged between 7 and 16 who visited the Department of radiology at the dental hospital were included in this study. The selection criteria included children with normal growth and development, no serious illness, no trauma to the dental and hand-wrist areas, no congenital or acquired malformations of the hand-wrist and dental regions, and no developmental or hormonal disorders. This study included radiographs taken on the same day and at the same intensity and distance.

Exclusion Criteria

The radiographs that were unclear, not in the proper position, and that had shape anomalies were excluded. When the left side was unsuitable for assessment, the radiographs were excluded. The radiographs without artifacts were evaluated. A total of 1296 digital radiographs of 648 children (383 girls and 265 boys) were evaluated after excluding the radiographs with artifacts.

Study Design and Procedures

This study was conducted retrospectively. Radiographs taken between January 01, 2011 and December 31, 2018 were gathered. It was evaluated by a physician between January 24, 2020 and March 10, 2020. The radiographs were randomly chosen from patients attending the dental hospital. All the radiographs were evaluated by an observer who did not know the children's CA. The ages of children were masked during the process of assessment. After this assessment, each child's CA on the date of the digital radiograph examination was calculated from the date of birth by another researcher. The radiographs were divided into groups according to age and gender. The apex developmental stages of the permanent canines and first molars were taken into account when dividing into the age groups 7-11, 12-14, and 15-16 years.

The skeletal maturation stage of each hand-wrist radiograph was determined according to the FM. A conventional radiograph of the left hand was rated for each subject by an observer, assigned according to the standards, and the average of the ratings was used as the hand-wrist maturation stage.

Dental age estimation was performed according to the WM: seven left mandibular permanent teeth were evaluated and determined according to their developmental stages, and the adapted maturity scores of seven teeth were added to directly obtain the dental age. This was converted into a dental age using published conversion charts for the method.

Radiographs of the upper (UCNM) and lower permanent left canine (LCNM), upper left first molar (UMNM), and lower left first molar (LMNM) were also assessed for dental age according to Nolla's calcification stages.

Ethics

Ethical approval for this study was obtained from the İzmir Democracy University Non-Interventional Clinical Research Ethics Committee (decision number: 2019/04-06, date: 09.12.2019). There was full accordance with ethical principles including those of the World Medical Association's Declaration of Helsinki as revised in 2013. Radiographs taken for treatment were used in this study and weren't taken for research purposes.

Statistical Analysis

Statistical analysis was reported by another researcher who did not evaluate the age determination. Data were analyzed using SPSS 18 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $p<0.05$. All analyses were performed with a 95% confidence interval. The mean, standard deviation, and standard error for all the groups were calculated, and all analyses were done for boys and girls separately. Since the assumption of the distribution's normality is severely violated for each method according to the Shapiro-Wilk normality test and distribution graphs, for testing the relationship between CA and all methods, Spearman's rank-order correlation coefficients were computed, and for testing the mean differences between CA and all methods, non-parametric tests were used. The differences between the groups were determined by the Mann-Whitney U test in the age variables. The Friedman test was used to evaluate the differences between the mean values of the chronological, skeletal, and dental ages as assessed by skeletal maturation, the first molar, and the canine calcification stages.

RESULTS

The subjects ranged in age from 7 to 16 years with a mean age of 13.06±1.65 years (13.29±1.60 for boys; 12.90±1.67 for girls). The gender and mean age distributions of the children are presented in Table 1.

UMNM and LMNM were not implemented in the children aged between 12 and 16, as they already had mature teeth that could not be used to predict age by assessing the calcification stage. The children aged 12-14 years were categorized into a separate group due to their ongoing canine maturation. The older age group comprised only children aged 15-16 years with delayed teeth.

Correlation Between CA and Age Estimation Methods

Each method showed a different outcome for each gender and age group. There was a correlation between chronological and canine dental ages in both boys and girls aged between 7 and 14 (Table 2).

Seven-eleven years: There were statistically significant correlations of the LCNM, the UCNM, the LMNM, the UMNM, and the WM with CA for boys. In the girls, there were statistically significant correlations between the LCNM, the UCNM, the WM with CA (Table 2).

Twelve-fourteen years: The LCNM, the UCNM, and the WM were statistically significant correlated with CA in both boys and girls (Table 2). FM was statistically significant correlated with CA in girls.

Fifteen-sixteen years: Using all three methods, there were no statistically significant correlations for either boys or girls (Table 2).

Mean Age Differences Between CA and Different Age Estimation Methods

Seven-eleven years: There were no statistically significant mean age differences between CA and the UCNM in both the boys (0.144) and the girls (0.426). There were no statistically significant mean age differences between CA and the WM in the boys (0.782) and the girls (0.352). There were statistically significant mean age differences in both genders between CA and FM, and between CA and the LCNM, the UMNM, the LMNM (Table 3).

Twelve-fourteen years: There was no statistically significant mean age difference between the UCNM and CA in boys (0.192). There were statistically significant

Table 1. Gender and mean age distributions of children

Gender (Age)		A	B	C	D	E	F	G
Boys (7-11)	Mean	10.52	12.03	9.24	9.97	10.00	10.06	10.56
	SD	0.83	0.85	1.96	2.45	1.41	1.24	1.75
Girls (7-11)	Mean	10.59	11.04	9.89	10.38	9.63	9.65	10.43
	SD	0.64	0.87	1.79	2.18	0.72	0.69	1.29
Total (7-11)	Mean	10.57	11.36	9.68	10.25	9.75	9.78	10.48
	SD	0.70	0.98	1.86	2.27	1.02	0.92	1.45
Boys (12-14)	Mean	13.07	12.63	11.67	13.26	-	-	12.56
	SD	0.78	1.28	1.54	1.97	-	-	1.51
Girls (12-14)	Mean	12.85	12.45	11.47	12.26	-	-	12.34
	SD	0.74	1.82	0.97	1.35	-	-	1.42
Total (12-14)	Mean	12.14	12.52	11.55	12.67	-	-	12.43
	SD	0.77	1.63	1.24	1.70	-	-	1.46
Boys (15-16)	Mean	15.32	13.91	12.57	14.38	-	-	13.88
	SD	0.46	2.04	1.02	1.28	-	-	1.23
Girls (15-16)	Mean	15.56	15.10	11.97	12.97	-	-	14.27
	SD	0.46	2.04	1.02	1.28	-	-	1.23
Total (15-16)	Mean	15.44	14.52	12.26	13.66	-	-	14.08
	SD	0.49	2.11	0.78	1.14	-	-	1.14
Boy total (7-16)	Mean	13.29	12.87	11.58	13.11	10.78	10.79	12.63
	SD	1.60	1.59	1.78	2.30	0.70	0.65	1.77
Girl total (7-16)	Mean	12.90	12.65	11.25	12.35	9.91	9.91	12.32
	SD	1.67	2.14	1.30	6.43	0.37	0.37	1.77
Total (7-16)	Mean	13.06	12.74	11.39	12.66	10.27	10.27	12.45
	SD	1.65	1.93	1.52	5.16	0.68	0.67	1.78

A: Chronological age, B: Skeletal age by the Fishman method, C: Lower canine age (Nolla method), D: Upper canine age (Nolla method), E: Lower first molar age (Nolla method), F: Upper first molar age (Nolla method), G: Age determined by Willems method, SD: Standard deviation

Table 2. Correlation between chronological age and age estimation methods

Gender			A	B	C	D	E	F	G
			Sro*/p**	Sro/p	Sro/p	Sro/p	Sro/p	Sro/p	Sro/p
Boys	A	7-11	1	0.149/0.407	0.503/0.003	0.462/0.007**	0.640/0.000**-	0.688/0.000**	0.542/0.001
		12-14		0.143/0.073	0.295/0.000**	0.274/0.000**	-	-	0.319/0.000**
		15-16		0.197/0.122	0.020/0.876	0.68/0.597		-	0.204/0.108
Girls	A	7-11	1	0.120/0.321	0.466/0.000**	0.483/0.000**	0.209/0.080	0.218/0.068	0.442/0.000**
		12-14		0.361/0.000**	0.256/0.000**	0.246/0.000**	-	-	0.316/0.000**
		15-16		0.113/0.365	0.200/0.108	0.200/0.108	-	-	0.138/0.268

*Sro: Spearman's rank-order correlation coefficients, **p: p<0.05 (significant), A: Chronological age, B: Skeletal age by the Fishman method, C: Lower Canine age (Nolla method), D: Upper canine age (Nolla method), E: Lower first molar age (Nolla method), F: Upper first molar age (Nolla method), G: Age determined by Willems method

Table 3. Significant values (p*) for differences between means of CA and age estimation methods						
Gender	**A-B**	**A-C**	**A-D**	**A-E**	**A-F**	**A-G**
Boys (7-11)	0.000	0.000	0.144	0.007	0.007	0.782
Girls (7-11)	0.001	0.000	0.426	0.000	0.000	0.352
Boys (12-14)	0.000	0.000	0.192	0.000	0.000	0.000
Girls (12-14)	0.000	0.000	0.000	0.000	0.000	0.000
Boys (15-16)	0.000	0.000	0.000	-	-	0.000
Girls (15-16)	0.745	0.000	0.000	-	-	0.000

*p<0.05 (There is a statistically significant difference between means), A: Chronological age, B: Skeletal age by the Fishman method, C: Lower canine age (Nolla method), D: Upper canine age (Nolla method), E: Lower first molar age (Nolla method), F: Upper first molar age (Nolla method), G: Age determined by Willems method

mean age differences between CA and the other methods (Table 3).

Fifteen-sixteen years: There were statistically significant mean age differences between CA and the other methods (Table 3). There was no statistically significant mean age difference between CA and the FM in girls (0.745).

DISCUSSION

Three different age estimation methods for Mediterranean children with a wide range of ages were evaluated in this study using two different statistical approaches. The results obtained with the three age estimation methods for different age groups varied.

Skeletal age did not show a high correlation with CA in all age groups in either boys or girls in this study. Mohammed et al.[6] reported that there was significant correlation between skeletal age and CA for boys and girls, and, that skeletal age evaluation using the FM could be used as an alternative method for the assessment of mean age. There was only a correlation between CA and skeletal age evaluated by the FM in girls aged 12-14 years in this study. Patil et al.[7] study also reported little correlation between CA and skeletal age evaluated by FM. Ramos et al.[8], who found weak correlation between CA and skeletal. Alkhal, who showed a weak correlation between CA and the FM, and stated that skeletal age was not suitable to estimate CA.[9] Other studies have reported that the FM was suitable to predict CA children in Yemeni[10] and in Bogotanian.[11] Safer et al.[12] also stated that FM could be recommended to estimate CA. Although a significant correlation between CA and skeletal age has been reported, it was stated that there was a significantly lower age estimation with FM in another study[6]. Kiran et al.[1], also reported that there was a significant difference between estimation of skeletal age with FM and estimated CA. The assessment of hand-wrist radiographs for accurate age estimation has been questioned. The research supported by Fishman[2], who devised the method and also reported a significant difference between mean CA and skeletal age. The FM could be said to be the most appropriate method for CA only in girls aged 15-16, in this study.

The NM and the WM correlated with CA in the Mediterranean children in this study. However, there was no correlation between CA and any of the three methods in children aged 15-16 years. There was a correlation between the UCNM and CA and between the LCNM and CA both in the girls and in the boys aged 7-14 years in this study. These results are in line with those of Kiran et al.[1] and Al-Balbeesi et al.[13], showing that the dental development of canines increases with CA. In this study, CA and both UMNM and LMNM were correlated only in boys aged 7-11.

The WM results were correlated to CA and had similar age estimations in both boys and girls aged 7-11, and there were fewer age estimation differences between the WM results and CA for East Mediterranean children compared to other methods in this study. It was reported that their research results were used for dental age estimation in Belgian individuals and were validated in that population but would not be valid in other populations because of dissimilar dental development in various populations[4]. Other studies have reported that the Willems dental maturity scale was the most accurate method for estimating age[14] and had more accurate age estimations than other methods.[15] Esan et al.[16] found that the Demirjian method overestimated CA compared to WM in either gender. For children from North Macedonia, Ambarkova et al.[17] found that Demirjian's method was unsuitable and that the WM showed the most accurate age estimation. In a study in the same region as our study, Ozveren and Serindere[18] reported that the WM had the most accurate outcome for both genders in all age groups. Moreover, Akkaya et al.[19] reported that the WM could be suggested for CA estimation of Turkish children in forensic practice. Turhal et al.[20] also recommended WM for Turkish children of both genders.

Kiran et al.[1] found no significant difference between CA and dental age when the NM was used to estimate age and stated that the reason why the NM age estimation was closer to the CA for children was probably due to pubertal growth changes. Cortes et al.[21] reported that the NM could be used for estimating CA in children of Spanish origin. However, the NM age estimation was not found to be accurate for children of Southern India[22], and Singh et al.[23], reported similar findings. A study on children in North India found that the permanent mandibular second molar was suitable for age estimation[12]. Khanal et al.[24] found that there was a delayed tooth age in the NM compared to the CA in their research on age estimation for children aged 5-15 in Nepal. However, UCNM predicted a similar age to CA in both boys and girls aged 7-11 in this study and was also the most effective method for similar age estimation to CA in boys aged 12-14.

Güler et al.[25] reported that the skeletal age estimation method gave more accurate results than the dental age method in children of both sexes in their study using different age estimation methods (Cameriere's method).

Study Limitations

Estimation of CA only by calculating canine calcification stages on radiographs could be sufficient for children and adolescents. However, this study's limitation was the lack of sufficient sample size for the children of all Mediterranean countries for dental age estimation.

CONCLUSION

The UCNM and the WM were more accurate estimation methods for CA compared to other methods, which is in agreement with previous research. The WM predicted a similar age to CA in both boys and girls aged 7-11. There were both correlations and similar age estimations to CA with the WM in this age group. The UCNM predicted a similar age estimation to CA in girls aged 7-11 and in boys aged 7-14.

The NM-assessed canine calcification stages on radiographs have the advantage of using a low radiation dose. The estimation of CA by only canine calcification stages on radiographs is easier and cheaper than hand-wrist radiographs. Furthermore, the equipment required are often present in dental clinics.

The NM and the WM could be used for forensic procedures in the Mediterranean region.

- The permanent canine maturation stages by NM could be used to estimation of CA.
- WMs could be used to estimation of CA children in the Mediterranean region.
- The permanent first molar maturation stages by NM could not be a suitable method for estimation of CA.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the İzmir Democracy University Non-interventional Clinical Research Ethics Committee (decision number: 2019/04-06, date: 09.12.2019).

Informed Consent: Retrospective study.

Author Contributions

Concept: B.K., F.E., Design: B.K., F.E., Data Collection and Processing: B.K., C.S., Analysis and Interpretation: B.K., C.S., N.G., Literature Search: B.K., F.E., Writing: B.K.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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