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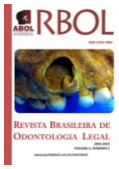

Forensic Anthropology

SKELETAL AGE ESTIMATION COMPARING TWO RADIOGRAPHIC METHODS

Estimativa da idade esquelética comparando dois métodos radiográficos

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ABSTRACT

Introduction: Skeletal age estimation plays an important part as a tool for predicting human development. In the forensic context age estimation is essential during the creation of anthropological profile of victims, enabling reconstructive human identifications. Objective: To evaluate the association between the chronologic and skeletal ages from the predictions obtained through the methods of Greulich & Pyle (GP), 1959, and Eklöf & Ringertz (ER), 167. Material and Methods: The study sample consisted of 97 hand-wrist radiographs, from male and female Brazilian children, aged between 4 and 16 years old. The methods of G&P and E&R were applied. Statistical analysis consisted of ANOVA and Pearson's correlation coefficient (significance rate: $p<0.05$). Outcomes were compared to detect the most accurate method for skeletal age estimation. In addition, both methods were discussed in face of potential advantages and limitations. Results: Differences between estimated and chronologic ages, as well as the differences between both methods, were not statistically significant ($p>0.05$). From a practical scope, the method of G&P revealed higher practicality due to the direct comparison with atlas figures. On the other hand, the large age interval between the standard atlas figures was considered a relevant limitation. Yet the method of E&R revealed less subjectivity due to the digital software management. However, bone measurement may also consist of a limitation,

depending on the examiner's experience. Conclusion: Despite the limitations, both methods revealed accurate age estimations, encouraging forensic experts on further applications and validations.

KEYWORDS

Growth and development; Age determination by skeleton; Radiography; Carpal bones.

INTRODUCTION

The chronological age is not a reliable marker of the human growth. Mostly, the development in children and adolescents is affected by internal and external variables, such as genetics, hormones, ancestry, nutrition and environment[1], culminating in a discrepancy between the chronological and biological ages. Based on that, the skeletal development plays an important part in the routine of forensic anthropology, in which a biological profile of victim is built with identifications purposes[2]. Apart of forensics, the skeletal age is also assessed in other medical fields such as Pediatrics, Orthopedics, Orthodontics, and Maxillofacial surgery, becoming a complementary tool for treatment planning[3].

In this context, the methods of Greulich & Pyle[4] (G&P), 1959, and Eklöf & Ringertz[5] (E&R), 1967, arose as reliable pathways for the skeletal age estimation, becoming commonly used in clinical and forensic caseworks. Specifically, the methods are performed assessing the development of hand and wrist bones through carpal radiographs. However, due to the fact of being developed decades ago, both methods were calibrated in children with different growth speed if compared to the children nowadays. Thus, validation studies to investigate the current applicability of these methods must be performed in population-specific surveys. Additionally, comparisons between outcomes of both G&P and E&R would potentially indicate methodological advantages and limitations, pointing out the best approach for skeletal age estimation.

Based on that, the present study aims to perform skeletal age estimations in a Brazilian sample with two different methods, comparing outcomes and exposing practical advantages and limitations.

MATERIAL AND METHODS

The present study was approved by the local Committee of Ethics in Research under the protocol number: 24530813.8.0000.0102.

The sample consisted of 97 carpal digitalized radiographs of the left hand, of Caucasian Brazilian male (n=42) and female (n=55) patients (Table 1), aged between 4 and 16 years-old (mean age: 9.32 years old; males: 9.48 years old; females: 9.16 years old). The images were obtained from the records of the Laboratory for Education and Research in Dental Radiology and Imaging (LABIM-UFPR) of the Federal University of Paraná, Curitiba, Brazil. All the images were obtained for dental treatment purposes using a Siemens 24 Orthopos® CD (Siemens®, Munich, Germany) device, and were chemically processed into a Revell® automatic processor (Revell®, Belo Horizonte, Brazil). Further on, the radiographs were scanned using a HP Scanjet G4050® scanner (Hewlett-Packard Comp.®, California, USA) in 150 dpi, and saved as TIFF files. The inclusion criteria consisted of selecting patients from the city of Curitiba, Paraná, Brazil, with known age and gender. All the included patients were in treatment at public services, and probably lived in low economic situation. The exclusion criteria consisted of previous medical report of malnutrition and/or history of systemic diseases.

The radiographs were blindly analyzed by a single examiner using a Macbook White, 13.3 inches, screen resolution: 1280x800 pixels (Apple Inc®, California, USA), under ambient light. The methods of G&P and E&R were applied in the total sample in three different moments, within time interval of 72 hours. Specifically, the method of E&R was applied using Radiocef Studio 2® (Radio Memory Ltda.®, Belo Horizonte, Brazil) software. Yet the method of G&P was applied through the direct comparison between digital radiographs and atlas' figures. The mean age estimation between the three analyses was considered as skeletal age. The examiner was considered highly trained once optimal intra-observer reproducibility was achieved between the analyses. The obtained data underwent parametrical analysis of variance (ANOVA) and Pearson's Correlation Coefficient using STATISTICA® 10.0

(StatSoft® Inc., Oklahoma, USA) package considering $p<0,05$ for statistical significance.

RESULTS

According to the ANOVA outcomes, there was no statistically significant difference between the means of the three different examinations for both methods ($p>0.05$). In addition, there was no statistically significant difference considering the gender distribution.

Yet Pearson's Correlation Coefficient for the analysis between: chronological age (CA) x Greulich & Pyle (G&P); chronological age (CA) x Eklöf & Ringertz (E&R); and Greulich & Pyle (G&P) x Eklöf Ringertz (E&R) were higher than 0.8 ($p>0.05$), showing close interaction between chronological and estimated skeletal ages.

Specifically, the diagrams of dispersion (Figures 1 and 2) express a general overview of the power of relation between the method of G&P and E&R according to gender distribution. In both situations the two methods were closely related (Male: 0.954; Female: 0.932).

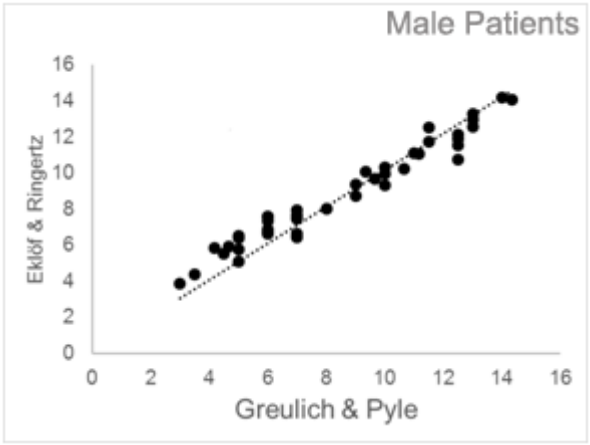

Figure 1 - Overview of the relation between the method of Greulich and Pyle[4] and Eklöf & Ringertz[5] considering male patients (Relation value: 0.954).

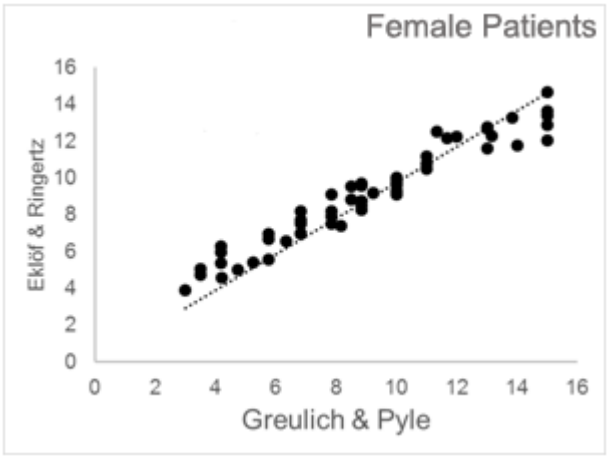

Figure 2 - Overview of the relation between the method of Greulich and Pyle[4] and Eklöf & Ringertz[5] considering female patients (Relation value: 0.932).

DISCUSSION

Since the development of G&P method, several population-based surveys were performed. Recently, the method was validated in Turkish[6], Danish[7], and Portuguese[8] samples, revealing high practicality, reproducibility, and accuracy in relation with

chronological ages. In the clinical environment these findings indicate that G&P method is highly applicable, even for non-experienced professionals. Considering the Brazilian population, specific studies compared the method of G&P with E&R for skeletal age estimations. Both in 2003[9] and 2006[10] the methods revealed close relation with chronological ages. Despite detected, discrepancies between chronological and skeletal ages were not statistically significant for both methods. In accordance, in the present research non-significant statistical differences were observed through the association between the chronological ages and addressed methodologies. However, the difference between the present study and previous reports is the fact that our associations revealed underestimations for the comparison between chronological and estimated ages, while other authors presented overestimations[9]. Possibly, it is justified due to the heterogeneity within our sample distribution. Despite a similar distribution between genders, the sample addresses a few number of patients aged near to the higher range limit (from 15 to 15.9 years old). An additional limitation of the present study concerns the small sample size, which should be enlarged to become statistically representative for the population of sample collection.

Additional explanations for the discrete differences between estimated and chronological age remain in ancestry. The addressed methods were respectively designed within American and German populations, which represent a very distinct social and economic reality if compared to the Brazilian sample. On the other hand, differences were discrete, indicating that both methods revealed high accuracy and reliability for application in the selected sample. As previously stated, regression formulas aiming to correct and adapt internationally calibrated statistical models arises as a solution for making age estimations applicable worldwide[10].

From a qualitative technical analysis, both methods were highly reproducible. Specifically, G&P method allows quick and precise performance through the comparison between radiographs and atlas photographs. On the other hand, the method reveals limitations at a certain point, in which the time

interval found in the atlas ranges from 3 up to 14 months, hampering more precise comparisons. Yet, in E&R the age intervals do not exceed 3 months. However, the limitation of this method consists on the measurement of radiographs, which can be more complex, unpractical, and subjective, depending on the examiner's experience. Additionally, the method does not allow for age estimations in children aged above 15 years old. In the present study, the limitation related to bone measurement was overcome using computer-based software, making the process less exhaustive when performed manually.

Based on the presented findings, forensic experts and clinicians should perform both methods in order to become able to select the most suitable in relation to their own concern. Specifically in forensics, both methods should be performed combined allowing optimal skeletal age estimations and providing mean ages based on two scientific approaches.

CONCLUSIONS

The obtained outcomes were valid for the selected sample. Proportionally, larger samples are required for more representative results into the Brazilian territory. Subjectively, the present study encourages forensic experts and clinicians to perform any of the addressed methods in order to assess skeletal ages.

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