A BAYESIAN METHOD FOR AGE ESTIMATION IN FORCED MIGRANT POPULATIONS

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Introduction

The continuous increasing volume of migratory flows has increased the need of age estimation process, particularly for individuals without identity documents and persistent doubts on their age. This process is not deterministic, can be influenced by the different maturation process characterizing migrant populations and should be accurate to appropriately address the different paths within the immigration law system and the recognition of fundamental rights.

Aim

In this study we provide and validate a statistical model estimating the chronological age and its distribution probability given the third molar maturity index value in forced migrant populations.

Methods

We analysed the orthopantomographs (OPTs) of 481 healthy White, Black African and Arab males between 15 and 24 years old to calibrate the model for age estimation (training sample). The OPTs were obtained from routine treatments received in the local dental offices during 2012 and 2013. A sample of 45 healthy White, Asian, Arab and Black African males were recruited from eight host centres of forced migrants in Marche Region. Subjects underwent a dental visit with an OPT between April and December 2018. The sample was used to test the model.

The third molar maturity index I_{3M} defined as the sum of the distances between the inner sides of the two open apices divided by the tooth length was used as age indicator [1].

Age estimation is based on the relationship between chronological age and dental maturity index (I_{3M}). This relationship is not linear [2] and could present one or more breakpoints, i.e., points where the relationship changes abruptly [3]. To better capture this behaviour and to reduce the linear regression bias in age estimation, a Segmented function combined with Bayesian Calibration method with a Normal density (SNBC) was used to estimate age [4]. A Normal density model for age estimation was assumed with constant variance (σ^2) and expected value as follows:

$$\mu(y,\beta) = \beta_1 + \beta_2 y + \beta_3 (y-\psi)_+.$$

where y is the chronological age of individuals, β_i, i =1, 2, 3 are the model parameters, ψ is the breakpoint and

$$(X)_+ = \begin{cases} X & X \geq 0 \\ 0 & X < 0 \end{cases}$$

Uninformative distributions were considered for both model parameters and *a priori* age distribution. This method allows to construct the *a posteriori* distribution of age, conditioned to a determined value of the maturity index. Therefore, the *a posteriori* distribution was used to determine the probability of having a specific age or older for a new individual with unknown age, given a value of I_{3M}. The mode of this distribution was used as point estimate.

The SNBC model performance was evaluated using Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) as accuracy measures, and the slope (β_{ERR}) of the regression of the estimated age error to chronological age and the Inter-Quartile Range of error distribution (IQR_{ERR}) as precision measures.

Results

Forced migrants (test sample) had median age of 18 years old (1° - 3° quartiles: 17 - 20 years), median I_{3M} of 0.05 (1° - 3° quartiles: 0 - 0.2 years) and 14 (31%) of them had a complete development of the third molar (I_{3M} = 0). No significant differences between forced migrants and the training sample were found in terms of age, I_{3M} and for the complete development of the third molar.

Parameters of the age estimation model using the training sample are reported in the Table. The estimated breakpoint was 18.6 years, indicating that in the training sample the tooth maturity velocity decreased in the proximity of this age. The maturity index (I_{3M}) significantly decreased from 2.3 to 0.07 for increasing age up to the breakpoint ($\beta_1+\beta_2 \cdot \psi$). Subsequently, it significantly decreased by 0.017 ($\beta_2 + \beta_3$) for each year.

Increasing of age above the breakpoint corresponds to changes in I_{3M} tending toward zero, a complete tooth maturation.

In addition, the probability of being younger or older than a specific age, given the I_{3M} value can be estimated from the model. For example, the probability of being 18 years old or older conditioned to the I_{3M} values of 0.001, 0.15 and 0.3 decreased from 0.89 to 0.75 and 0.52, respectively.

Most of the accuracy and precision measures were substantially comparable across the two samples ($MAE_{training}$= 1.48, MAE_{test}= 1.57; $RMSE_{training}$= 1.93, $RMSE_{test}$= 2.09). The method showed a significant positive systematic bias in estimating residuals on the observed age in both samples ($\beta_{ERR\text{-}training}$= 0.10, p= 0.004, $\beta_{ERR\text{-}test}$= 0.30, p= 0.005).

Conclusions

The proposed Bayesian Calibration method with a Normal density (SNBC), with continuous independent predictor, the third molar as a maturity index, is a valid method to estimate age in forced migrant populations. The use of the Bayesian approach gives the possibility to estimate beside the age, the relative probability, thus, giving additional useful information during the decision of age assessment. In addition, the proposed model allows to introduce *a priori* information on age distribution of a particular population of interest that, if available, it will contribute to provide better estimates.

Bibliography

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Table Estimate of SNBC model parameters in the training sample

Parameter	Estimate	95% CI
β_1	2.30	1.975; 2.625
β_2	-0.12	-0.136; -0.092
β_3	0.103	0.102; 0.104
ψ	18.62	17.99; 19.24

95%CI: 95% Confidence Interval