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ORIGINAL ARTICLE

Age assessment in unaccompanied minors: assessing uniformity of protocols across Europe

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Abstract

Age assessment of migrants is crucial, particularly for unaccompanied foreign minors, a population facing legal, social, and humanitarian challenges. Despite existing guidelines, there is no unified protocol in Europe for age assessment.

The Forensic Anthropology Society of Europe (FASE) conducted a comprehensive questionnaire to understand age estimation practices in Europe. The questionnaire had sections focusing on the professional background of respondents, annual assessment numbers, requesting parties and reasons, types of examinations conducted (e.g., physical, radiological), followed protocols, age estimation methods, and questions on how age estimates are reported.

The questionnaire's findings reveal extensive engagement of the forensic community in age assessment in the living, emphasizing multidisciplinary approaches. However, there seems to be an incomplete appreciation of AGFAD guidelines. Commonalities exist in examination methodologies and imaging tests. However, discrepancies emerged among respondents regarding sexual maturity assessment and reporting assessment results. Given the increasing importance of age assessment, especially for migrant child protection, the study stresses the need for a unified protocol across European countries. This can only be achieved if EU Member States wholeheartedly embrace the fundamental principles outlined in EU Directives and conduct medical age assessments aligned with recognized standards such as the AGFAD guidelines.

Keywords Age estimation · Unaccompanied minors · Medical age assessment · Skeletal development · Dental development

Introduction

In 2021, according to the © United Nations Children's Fund (UNICEF) [1], over 165,500 refugees and migrants arrived in Europe through Greece, Italy, Bulgaria, Serbia, Bosnia and Herzegovina, and Montenegro. Of these, around 23,000 are estimated to be children. Due to the pandemic, there has been a decrease in arrivals in most European countries, but in the second half of 2020, the numbers started rising again [2], and today, arrivals of unaccompanied minors in southern Europe are once again soaring. According to Eurostat [3], in 2021, more than forty-four thousand asylum applicants were between 14 and 17 years.

Since many of these migrants arrive in Europe without documents, age assessment is required more and more frequently to ascertain whether they have attained the age of 18 years. Individuals under the age of 18 years are regarded as minors and are protected by international law. Additionally, judicial authorities are increasingly seeking age estimation to ascertain imputability, while the Juvenile Court specifically requests such assessments when the age of adopted minors is in question [4]. A recent report [5, 6] by the © United Nations Children's Fund (UNICEF), highlighted how in sub-Saharan Africa nearly 96 million children do not have their birth registered and around 118 million do not possess a birth certificate. It is estimated that in this region, by 2030 the total number of unregistered children will exceed 100 million. Similarly, in Asia and the Pacific, there are currently around 65 million unregistered children and 97 million without a birth certificate [7].

It is therefore evident that the age of migrants is one of the key variables that must be ascertained in order to integrate them into society, since it carries significant legal implications. Indeed, many benefits that unaccompanied

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minors receive, in place to provide them with support and protection, are usually inaccessible to adult migrants. For example, the internationally protected status of unaccompanied minors allows them to continue and complete their education until 18 years, have liberal access to healthcare, and receive special accommodation facilities, and entitles them to social welfare support [8]. Equally, it is important that juveniles are housed under safe conditions, including not being housed with adults.

Age estimation has sparked considerable debate, particularly in relation to migration and human trafficking. Various parties agree on the significance of age assessment and the need for procedural and legal safeguards [9–11]. Article 25 of EU Directive 2013/32/EU [12] plays a pivotal role in regulating the status of medical age assessment as a potential means of evidence gathering within administrative age assessment contexts, defining corresponding requirements within asylum procedures. Furthermore, EU Directive 2016/800 and EU Directive 2013/59/EURATOM regulate medical age assessment within asylum and criminal procedures, addressing the initiation of administrative age assessment procedures and the application of outcomes, as well as non-medical imaging exposures, including radiological age assessment [13, 14]. Though certain age assessment guidelines and recommendations exist [15–22], there is no universal, systematic protocol that has been adopted in Europe, regardless of the reason why age assessment is required. In the last decade a number of studies have investigated age estimation practices in Europe, highlighting the lack of a common approach to the issue across European countries [23, 24]. This lack of uniformity may have drastic implications on unaccompanied minors in question, since without a standardized systematic approach, conclusions estimating the final age could be contradictory in different countries, or even between institutions within a given country. Age estimation is a complex procedure that must prioritize the best interests of the child and rely on current evidence-based research. It should encompass a variety of methodological approaches and appropriate reference data to enable accurate comparisons, while also presenting estimation outcomes along with their associated error rates. Forensic practitioners, who have been actively contributing to scientific publications on age estimation, possess valuable insights that can aid in the development of scientifically robust age assessment protocols and frameworks, grounded in contemporary anthropological and medical knowledge [25]. European organizations such as *AGFAD* and the *Forensic Anthropology Society of Europe* (FASE) are committed to advancing the adoption of optimal approaches in forensic age assessment by supporting evidence-based research and the implementation of validated methodologies, as well as providing guidelines on age assessment in the living [15–20].

In this context, the *Forensic Anthropology Society of Europe* (FASE) prepared a comprehensive questionnaire that aimed at investigating how age assessment in the living is performed across Europe. The aim of this paper is thus to report on current age estimation practices in juveniles in Europe and based on this to provide suggestions on the way forward.

Materials and methods

In May 2020 the questionnaire was sent electronically across Europe to a number of institutions dealing with age assessments. The last replies to the questionnaires were received at the end of 2021. The first part of it aimed at collecting information on the type of professional and the academic/professional background of the person who fills out the questionnaire. Subsequent sections of the questionnaire were aimed at acquiring data on the number of age assessments carried out annually, as well as obtaining information on which parties request these evaluations and why. There were also a number of questions about the types of examinations carried out (e.g., physical examination, radiological examination), any protocols followed, the methods/classification used to estimate age, and the information provided to the alleged minor. The last part of the questionnaire investigates how age estimates are reported (e.g., age range, minimum age).

Data were analyzed by simple counts and percentages (please note that "n" refers to the number of participants who gave that answer). No attempts were made to statistically analyze differences between countries/regions due to small sample sizes. Graphic representations of findings were made where possible.

Results

Forty-six questionnaires were completed. Of these, 28 participants were male and 18 females (mean age $48 \pm 10{,}3$ years), representing thirteen countries (Belgium $n=1$, Denmark $n=1$, Finland $n=1$, France $n=16$, Germany $n=4$, Italy $n=5$, Norway $n=1$, Slovakia $n=1$, Spain $n=3$, Sweden $n=1$, Switzerland $n=3$, The Netherlands $n=1$, Turkey $n=8$). Turkey was included in the survey since it plays an important role in processing and regulating migrant traffic that enters the European continent. It was therefore deemed important, to include responses from Turkey.

The types of professional institution/organization of the participants are shown in Table 1.

With regard to the area of expertise of the participants, 71.7% work as forensic pathologists ($n=33$), followed by

Table 1 Institutions of the participants (please note: three participants indicated more than one institution)

University	University Hospital	Hospital	Local health unit	Forensic institute	Other
n	*n*	*n*	*n*	*n*	*n*
11	20	3	0	15	/

biological anthropologists (15.2%; $n=7$), forensic odontologists (10.9%; $n=5$), and radiologists (2.2%; $n=1$).

Forty out of 46 (87%) respondents (Table 2) reported to have been dealing with age estimation in the living for more than 5 years (41% for over a decade). Around half of them perform between 10 and 50 age assessments per year, whereas 28% (13/46) stated that they perform more than a hundred examinations per year. This latter group includes participants from France, Turkey, Switzerland, Norway, Sweden, Germany, and Italy.

With regard to the authorities that request age assessments, the most frequent were the Public Prosecutor's Office ($n=33$), followed by the Juvenile Court ($n=27$), the Ordinary Court ($n=22$), the Minor's Counsel ($n=9$) and private individuals ($n=6$). Six participants (Sweden, Norway, Denmark, The Netherlands, Finland, and Turkey) indicated that they were consulted by migration services (Danish Immigration Service; Immigration and Naturalisation Service; Immigration Authority; Migration Authority Sweden; The immigration Service) or civilian refugee associations.

The main reasons for the requests for age estimation were unaccompanied foreign minors ($n=38$), identifying criminal responsibility ($n=36$), missing birth records ($n=12$), and rectification of birth record in case of adoption ($n=5$). Other singular responses were sexual abuse cases ($n=1$), retirement ($n=1$), attending army ($n=2$), and marriage ($n=1$). It is thus interesting to note that there are many reasons other than the problem of unaccompanied minors where age estimation is of relevance.

The most frequent geographical area of origin of the individuals undergoing age assessments was Sub-Saharan Africa ($n=33$) followed by North Africa ($n=25$), Middle East ($n=21$), Asia (other than the Middle East; $n=11$), Europe ($n=11$), and Central America ($n=1$). Age assessments of Africans were thus by far the most common.

Table 3 outlines practitioners involved in the process of age estimation in their institution. Forensic pathologists ($n=44$), radiologists ($n=38$), and dentists ($n=25$) are the most frequently involved practitioners, whereas biological anthropologists ($n=8$) and pediatricians ($n=6$) are employed in less than 20% of the cases. Half of the respondents reported that the team performing age assessment in their institution comprises less than three practitioners, usually a forensic practitioner and a radiologist. Ten percent of responses indicated a single practitioner. It is interesting to note that of the 25 dentists involved in age estimations, only 13 are reported as being working as forensic odontologists.

Thirty-nine out forty-six participants (85%) stated that they follow guidelines and/or protocols on age estimation in the living (Table 4). Almost 70% of participants ($n=31$) claim to follow the guidelines provided by the *Study Group on Forensic Age Diagnostic* (AGFAD) [15, 17–20], whereas only a few indicated that they follow the guidelines provided by *FASE* [16] ($n=6$) and the recommendation by the *European Asylum Support Office* [21] ($n=5$).

Participants were then asked if information about the age assessment process, results and possible consequences, are provided to the alleged minor (Table 5). Almost all the participants indicated that the alleged minor is informed that his age will be assessed through a medical procedure. Similarly, information on what the procedure consists of is provided in most of the cases. Around 80% of practitioners reported that the alleged minor is informed on the possible results of

Table 2 Years of experience on age estimation in the living and number of age assessments per year

Question: How long has your institution been carrying out age estimation on living individuals?				
< 1 year	*1–5 years*	*5–10 years*	*> 10 years*	*I don't know*
n	*n*	*n*	*n*	*n*
1	6	11	27	1
Question: How long have you been carrying out age estimation on living individuals?				
< 1 year	*1–5 years*	*5–10 years*	*> 10 years*	*I don't know*
n	*n*	*n*	*n*	*n*
0	6	20	20	0
Question: How many age assessments do you perform per year?				
< 10	*10–50*	*50–100*	*> 100*	*I don't know*
n	*n*	*n*	*n*	*n*
8	22	3	13	0

Table 3 Practitioners performing age assessment on living individuals. *13 out of 25 are forensic odontologists

Question: Which are the practitioners involved in the process of age estimation in your institution?	
Forensic pathologist	44
Radiologist	38
Dentist	25*
Anthropologist	8
Paediatrician	6
Intercultural mediator	5
Psychologist	3
Social worker	3
Psychiatrist	2
Auxologist	2

Table 4 Guidelines/protocols followed by participants (* national or regional protocols)

Question: Do you follow any guidelines/protocols?				
Yes	*No*	*It depends on the single case*	*I don't know*	
n	*n*	*n*	*n*	
39	2	3	2	
Question: Which guidelines/protocols do you follow?				
Study group on Forensic Age Diagnostic (AGFAD)	Forensic Anthropology Society of Europe (*FASE*)	*European Asylum Support Office (EASO)*	*Asylum Information Database (AIDA)*	*Others*
n	*n*	*n*	*n*	*n*
31	6	5	0	9*

Table 5 Information provided to the alleged minor prior to age assessment

Question: Is the alleged minor informed:			
	Yes	***No***	***I don't know/I don't remember***
	n	*n*	*n*
That his/her age will be determined through a medical procedure?	44	0	2
On what this procedure consists of?	43	1	2
About the possible results?	36	5	5
About the consequences that results could entail?	29	11	6
About the consequences of his refusal to undergo this procedure?	32	10	4
About the right to be heard on the reasons for his refusal?	27	10	9

the age assessment, whereas 70% declared that the minor is made aware of the consequences of refusal to undergo the procedure.

Forty-four out of forty-six respondents (96%) ask for the consent of the alleged minor, whereas the consent of the legal guardians is asked for by approximately two-thirds ($n=30$) of the participants. In most of the cases ($n=32$), a social interview is carried out (personal/familiar biography), whereas only eighteen participants stated that they assess the socio-economic level of the minor.

Nearly 85% of respondents stated that a physical examination of the minor is performed (Table 6) during which stature and weight are assessed. Less than half of the participants (48%) indicated that sexual maturity according to Tanner stages [26] is evaluated. Eleven respondents from France stated that the evaluation of sexual maturity is forbidden in their country [27]. Of the 22 respondents who said they did not evaluate sexual maturation, seven (32%) stated that the result of the physical examination, including Tanner scores, is directly incorporated in the final age estimate, while fifteen (68%) stated that the Tanner stages are solely used to exclude serious growth defects. In addition, 12 respondents of those 22 respondents (54%) reported having encountered opposition from the alleged minor to the assessment of sexual maturity for reasons of modesty/religion.

More than half of the participants ($n=24$) do not refer to any growth curve, whereas eighteen stated that they follow the WHO Child Growth Standards [28], two the CDC Growth Charts [29] and two national growth standards.

Table 6 Statistics on what is assessed during physical examination

Question: Do you get the medical history of the alleged minor?		
Yes	*No*	
37	9	
Question: Is a physical examination performed?		
Yes	*No*	
39	7	
Question: If so, what do you evaluate?		
	Yes	***No***
Stature?	40	5
Weight?	40	5
Anthropometry (face)?	15	29
Anthropometry (body)?	19	26
Tanner stages (sexual maturity rating)?	22	24

More than 80% of respondents replied that an assessment by a mental health practitioner is not included in the age estimation procedure (Table 7).

Most participants found the use of ionizing radiation for age estimation in the living ethically acceptable. The majority also generally ask for recent test/x-rays/examinations before proceeding with the assessment in order to avoid unnecessary exposure to ionizing radiation (Table 8).

Table 7 Statistics on mental health evaluation

Question: Is an evaluation performed by a mental health practitioner?			
Yes	*No*	*I don't know*	
n	*n*	*n*	
6	35	5	
Question: If so, what is his/her training?			
Doctor/psychiatrist/neuropsychiatrist	*Psychologist/psychotherapist*		
n	*n*		
4	2		
Question: Does the mental health practitioner have a specific cross-cultural training?			
Yes	*No*	*I don't know*	
n	*n*	*n*	
2	3	1	
Question: Which areas are investigated?			
Cognitive area	*Emotional area*	*Symptomatology/diagnosis*	*Behavioural area*
n	*n*	*n*	*n*
6	5	5	4
Wechsler scale (WISC, WAIS, etc.; $n=3$); Raven's progressive matrices ($n=2$)	Emotion test ($n=3$); paper-and-pencil test ($n=1$); projective test ($n=1$)	Symptom rating scales ($n=4$)	e.g., CBL, ABCL ($n=2$)

Table 8 Questions regarding the use of ionising radiation for age estimation in the living

Question: Is the use of ionising radiation for age estimation in the living permitted by law in your country?			
Yes	*No*		
n	*n*		
42	4		
Question: Do you consider the use of ionising radiation for age estimation in the living ethically acceptable?			
Yes	*No*	*I don't know*	
n	*n*	*n*	
35	7	4	
Question: Do you always ask for recent tests/x-rays/examinations?			
Yes	*No*	*Sometimes*	*I don't know*
n	*n*	*n*	*n*
32	8	5	1
Question: Do you ensure that previous diagnostic imaging tests are not already available in order to avoid further exposure to ionising radiation?			
Yes	*No*	*Sometimes*	*I don't know*
n	*n*	*n*	*n*
24	14	6	2

X-rays of the left hand ($n=45$) and orthopanthomograms ($n=34$) are the imaging tests most commonly used by participants (Fig. 1), followed by a CT scan of the clavicle ($n=19$), X-ray of the clavicle ($n=10$), and X-ray of the pelvis ($n=8$). Intra-oral radiography of third molars ($n=2$), MRI of the clavicle ($n=2$), MRI of the knee ($n=2$), pelvic ultrasound ($n=1$), and X-ray of the elbow ($n=1$) are the less commonly used imaging tests.

According to respondents (Table 9), the most commonly used atlas for estimating age based on skeletal maturity is the Greulich and Pyle [30] radiographic atlas ($n=40$). This is followed by the typology on the ossification of the medial end of the clavicle developed by Schmeling and colleagues [31] ($n=24$) and the third edition of the Tanner-Whitehouse method [32] ($n=11$). Eighteen participants reported using (also) other methods/typologies, such as Maturos ($n=2$) [33], Gök atlas ($n=1$) [34], Todd and D'Errico 1928 ($n=1$) [35], McKern and Stewart 1957 ($n=1$) [36], Jit and Kulkarni 1976 ($n=1$) [37], Owings and Suchey 1985 ($n=1$) [38], Ji et al. (1994) ($n=1$) [39], Kreitner et al. (1998) ($n=1$) [40], Schmeling et al. (2004) complementary typology by Kellinghaus et al. (2010a) ($n=2$) [41], Gilsanz and Ratib 2005 ($n=1$) [42], and Scheuer and Black 2000 ($n=1$) [43]. Others indicated using reference studies such as Schaefer and Black 2005 ($n=1$) [44], Schulz et al. (2005) based on Schmeling et al. (2004) typology ($n=1$) [45], Kellinghaus et al. (2010b) based on Schmeling et al. (2004) typology ($n=1$) [46], and Wittschieber et al. (2014) based on Kellinghaus et al. (2010a) complementary typology ($n=1$) [47].

With regard to dental development (Table 10), the classification developed by Demirjian and colleagues [48–50] is the most used ($n=33$), followed by the methods developed by Cameriere and colleagues [51, 52] ($n=5$ and $n=3$). Three participants apply the classification developed by Moorrees and colleagues [53] and its complementary typology by Liversidge [54], while two use the atlas developed by Ubelaker [55]. Five respondents mentioned using other studies: Demirjian reference study on Turkish population ($n=1$) [56]; Ruhstaller (2006) reference study based on Olze et al. (2010) classification (dissertation; $n=1$) [57]; Kahl and

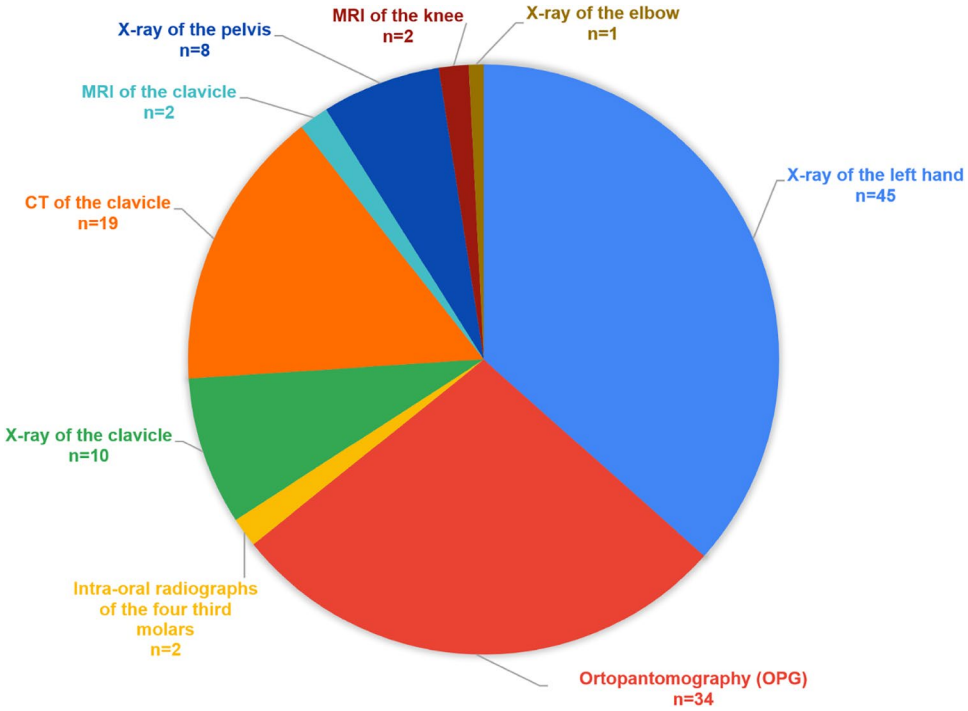

Fig. 1 Reported radiological methods uses (please note that the majority of respondents indicated more than one imaging test)

Table 9 Methods/atlases used for estimating age based on skeletal development (please note that ten participants indicated more than one method/atlas)

Question: Which method/atlas do you use for estimating the age based on the skeletal development?	
Method/atlas	***n***
Greulich-Pyle (G&P) [30]	40
Tanner-Whitehouse, 2nd edition (TW2) [74]	7
Tanner-Whitehouse, 3rd edition (TW3) [32]	11
Schmeling (clavicle) [31]	24
Thiemann-Nitz [75]	9
FELS [76]	2
Other	18

Table 10 Methods/atlases used for estimating age based on dental development (please note that nine participants indicated more than one method/atlas)

Question: Which method/atlas do you use for estimating the age based on dental development?	
Method/atlas	***n***
Demirjian [48] – Mincer [49] – Willems [50]	33
Cameriere (European formula) [51]	5
Moorrees [53] – Liversidge [54]	3
Cameriere (third molar) [52]	3
Ubelaker [55]	2
Other [56–60]	5
N/A	6

Schwarze (1988) revision of dentition tables by Schour and Massler 1941 ($n=1$) [58]; Köheler et al. (1994) reference study on Belgian population ($n=1$) [59]; Olze et al. (2007) ($n=1$) [60]. Six participants do not use any dental typology.

More than half of the participants ($n=26$) indicated that the final report is written and signed by one practitioner only (*case manager*), but that the report is based on the technical opinions of other practitioners. Just under a third ($n=15$) stated that the report is jointly written and signed by all the involved practitioners. Four respondents stated that each practitioner presents their own report. One respondent claims to conduct age assessments alone.

Participants were then asked how they report the outcome of the assessment when asked to estimate an age threshold, i.e., whether an individual is under or over 18 years, and also how they report point age estimates if they are asked to give one (Table 11). In both cases, more than half of the respondents ($n=25$ and $n=26$, respectively) report the estimated age with standard deviation, whereas about a third ($n=16$ and $n=13$, respectively) provides a judgment on the consistency with the reported date of birth.

Large differences existed between the respondents when the results of the applied methods were discrepant (Table 12). Seventeen participants considered the assessment of skeletal development more reliable for the final age estimate, whereas twelve favored the assessment of dental development. Three respondents considered skeletal and dental development to be equally reliable while three others gave more importance to medical history and physical

Table 11 Reporting method of the result of the assessment

	n
Question: How is the result of the assessment reported when asked to determine whether the individual is under or over 18 years?	
Numerical probability	5
Non-numerical judgement	4
Estimated age	8
Estimated age with standard deviation	25
Judgement on the consistency with the reported date of birth	16
Minimum age	3
Question: How is the result of the assessment reported when asked for a point age estimate (e.g., rectification of birth record)?	
Estimated age	7
Estimated age with standard deviation	27
Judgement on the consistency with the reported date of birth	14
Minimum age	2
N/A	3

examination. Eleven participants provided other solutions to the issue: average of dental and skeletal development ($n=1$), the estimate with the lower age limit ($n=2$), the method that seems the most coherent when explaining it ($n=1$), it depends on the age range ($n=1$), it depends on the case ($n=1$), the assessment of the skeletal development and the psychological/psychiatric evaluation are considered equally reliable ($n=1$), final age cannot be estimated ($n=1$), not applicable (e.g., age assessment based solely on the skeletal development; $n=3$).

When asked how they integrate results when there is a discrepancy between the applied methods, over 40% ($n=21$) report the lowest age estimate, whereas around 20% ($n=10$) extend the age range. Another 20% ($n=9$) of respondents stated that there is no integration of the results and that they report only the age estimate deriving from the method considered the most reliable. Seven participants provided other solutions to this issue: highest minimum age ($n=1$), average of dental and skeletal development ($n=1$), Greulich and Pyle atlas result ($n=1$), the minimum age criteria according to AGFAD ($n=1$), the value of probability of being above or below 18 years, without mean or SD values ($n=1$), not applicable ($n=2$).

About 70% ($n=33$) of respondents search for data relating to the reference population of the individual. When asked what data they refer to if specific population data are not available, answers ranged from "geographically nearest population" ($n=7$), "European populations" ($n=5$), "Greulich and Pyle atlas" ($n=2$), to "Willems et al. (2001)" ($n=1$).

Finally, over 90% ($n=42$) of participants think that the procedures for age estimation in the living could be improved, mainly by obtaining more population data and by implementing non-ionizing techniques, such as MRI.

Discussion

The *Forensic Anthropology Society of Europe* (FASE) formulated a questionnaire aiming at understanding how age assessment in the living is routinely performed in the various European institutions dealing with this issue. Forty-six questionnaires were completed by professionals (mainly forensic pathologists) from thirteen different countries: Belgium, Denmark, Finland, France, Germany, Italy, Norway, Slovakia, Spain, Sweden, Switzerland, The Netherlands, and Turkey. The general picture that emerged from this questionnaire is that even in the presence of standardized forensic literature, there is a lack of standardization, not only in

Table 12 Dealing with discrepancies between the results of the age assessment methods

	n
Question: If there is a discrepancy between the results of the applied methods, which one do you consider the most reliable for the final age estimate?	
Medical history and physical examination	3
Assessment of the skeletal development	17
Assessment of the dental development	12
Skeletal and dental development are considered equally reliable	3
Psychological/psychiatric evaluation	0
Other	11
Question: If there is a discrepancy between the results of the applied methods, how do you integrate the results?	
There is no integration of the results. We report only the age estimate deriving from the method considered the most reliable	9
Extension of the age range	10
Report of the lowest age estimate	19
Report of the highest age estimate	1
Other	7

terms of the specific individual methods used but also (and especially so) in the approaches followed to obtain a final age estimate.

Most of the participants have stated experience of five and more years, while more than 40% reported more than 10 years' experience with estimating age in the living. Approximately half of them carry out between 10 and 50 age assessments a year, while about 1 in 3 perform more than 100 assessments annually. The difference in the number of age assessments per year is very likely due to the different extent of the migration phenomenon in the various European countries and between small and large cities.

There seems to be a certain uniformity regarding which authorities generally request age assessments, mainly the Public Prosecutor's Office, the Juvenile Court and the Ordinary Court. In a few countries, such as Sweden and Denmark, requests come also from migration authorities. As expected, assessing the age of alleged unaccompanied foreign minors or the identification of criminal responsibility are the main reasons behind the requests for age assessment since, in both cases, age carries important legal implications and determine the future paths of these individuals [8]. However, several other motivations, such as adoption or missing birth records, were also reported, demonstrating the vast range of needs for reliable approaches.

In accordance with the main reports on migration [1, 2, 61], individuals undergoing age assessments in Europe are mainly from Sub-Saharan Africa, North Africa, and the Middle East. These areas are also those with the lowest rate of birth registrations in the world [5–7]. They are also, unfortunately, the regions of the world with lacking population-specific standards [62].

The practical guides proposed by the European Asylum Support Office [22] and the technical note by © United Nations Children's Fund [23] recommend a multidisciplinary holistic approach characterized by several steps: an interview with a social worker, followed by a psychological or neuropsychiatric evaluation, and an auxological examination performed by a pediatrician. Medical procedures, such as radiological examination should come last, favoring those methods considered less intrusive for the minor; this despite the fact that scientific literature provides a plethora of data on skeletal and dental maturation in different populations all around the world. With regard to the questionnaire, half of the participants claimed that the age assessment is carried out by less than three different practitioners (generally forensic pathologists and radiologists). Nonetheless, in a number of institutions age assessments are performed by a team including also forensic odontologists, biological anthropologists, pediatricians, psychologists, and social workers. However, according to the participants, social science professionals appear to be generally not engaged in age assessment procedures (less than 20%). This may be related to the fact that an age estimation based on a psychological evaluation and/or an interview does not provide a validated margin of error, which is required by most judicial and administrative agencies [11, 15, 63]. Moreover, assessing mental maturity may be extremely challenging in individuals with different cultural or educational backgrounds [15].

Over two-thirds of the respondents claim to follow the guidelines provided by the *Study Group on Forensic Age Diagnostics* (*AGFAD*) [15, 17–20] which recommends a three-step procedure consisting of a physical examination (anthropometric data, assessment of sexual maturation and identification of potential age-relevant developmental disorders), an assessment of the dental status (including radiographs), and an X-ray examination of the left hand. If the bones of the hand and wrist have completed their development, radiographic examination of the sternal end of the clavicle should be carried out. However, as will be discussed below, there seem to be an incomplete appreciation of AGFAD recommendations. Only five participants stated to follow the multidisciplinary holistic approach recommended by the *European Asylum Support Office* (*EASO*) [21], whereas nine use specific national or regional protocols.

A physical examination is routinely performed by about 85% of laboratories, although the sexual maturity according to Tanner stages [26] is assessed by less than 50%. Though Tanner stages are not meant to be used for age estimation, they represent a useful tool for ascertaining potential age-relevant developmental disorders which could influence skeletal age. Nonetheless, organizations, such as the *European Asylum Support Office*, find the examination of sexual maturation unacceptable, considering it potentially traumatic for children who may have been abused in their country of origin or during migration. In this regard, it is relevant that 11 respondents stated that evaluation of sexual maturity is forbidden in their country and this practice is severely discouraged.

Even though stature and weight are routinely recorded, more than half of the participants do not refer to any growth curve, while some follow the WHO Child Growth Standards [28]. Just like Tanner stages, growth curves are not validated to estimate the biological age of an individual; however, they allow for global inferences on nutritional status and help exclude serious growth retardation, which could affect age estimation. Growth curves should only be used for this purpose.

The use of ionizing radiation for age estimation in the living is considered ethically acceptable by most of participants. Although international organizations [21, 22] suggest that (ionizing) radiological examination should be used as a last resort, scientific literature agrees that the dose of radiation exposure related to the age assessment procedures is extremely low. It has been calculated, in fact, that each

are the most commonly used ways to report the results of the age assessment, several practitioners indicated that they also use numerical probability, non-numerical judgment, estimated age without standard deviation, and minimum age. This was in a way predictable given the current lack of international standards and guidelines on how to report the statistical information derived from the age assessment. The combination of results from various age estimation methods is statistically complex, and there appears to be a strong need for education and research in this field. However, it should be noted that, in compliance with EU Directives, the medical age assessment is not tasked with seeking an "estimation" or "assessment" of the precise chronological age during asylum and criminal proceedings. Instead, the emphasis is on the exclusion of age minority beyond reasonable doubt before an individual is designated as an adult, with the aim of safeguarding "the best interests of the child". Consequently, the primary goal should be the "minimum age" assessment [17, 20].

Similarly, there was a lack of uniformity among respondents on which exam they consider the most reliable for the final age estimate in case of a discrepancy between methods (e.g., skeletal vs dental). In such cases, most of the respondents either report the lowest age estimate or extend the age range. Both choices are more lenient toward the alleged minor. However, discrepancies in results are generally uncommon, and may occasionally arise from errors in stage determination or reliance on inadequate reference studies. When these discrepancies actually exist, it is essential to conduct thorough research to identify the underlying causes, such as diseases or socioeconomic factors.

In addition, another issue regarding age estimates concerns the use of population data related to the skeletal and dental methods. Indeed, around two-thirds of respondents search for population-specific reference data suitable to the alleged minor. However, a recent review [62] highlighted how, for many countries especially in Africa and Asia, there is a lack of such population data. There is still no consensus among researchers as to whether the rate of skeletal and dental maturity differs substantially among different populations, but the lack of data does not simplify questions about the biological age of an individual. It may be noted that the data on skeletal age for different populations usually underestimate the chronological age in most of populations studied, which would favor the minor [72, 73].

The main limitations of this study concern the disparity in the number of participants among different countries, and the fact that the results of the questionnaire probably cannot be representative of all the entities dealing with age estimation in the living. However, it does provide an idea of the large differences and discrepancies in age assessment practice across Europe. This finding indicates that there is a pertinent need for national and international standards for age estimation in the living and for training of the professionals involved with this often-sensitive topic.

Conclusion

The results of this questionnaire showed that the forensic community is heavily involved in age assessment in the living. Overall, commonalities were found in the multi-disciplinarity of the examinations, which should be the norm, and the types of imaging tests. However, while the majority of participants claim adherence to the AGFAD guidelines, their responses regarding the types of examinations conducted and the methods employed reveals that these guidelines are only partially implemented. Moreover, there are several points of discordance between responders, such as on the evaluation of sexual maturity, and how results of the assessments are reported. In addition, some inconsistencies were noted, such as low number of dentists involved in the age assessments despite the widespread use of orthopantomography. In light of the increasing extent of migration, it is necessary to establish a unified protocol in Europe for age assessment. However, this can only thrive if the administrations of EU member states fully apply the corresponding basic principles of EU Directives and medical age assessment are truly carried out according to the acknowledged state-of-the-art in the field (e.g., AGFAD guidelines).

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Declarations

Consent to participate All participants have provided their consent to participate to the study.

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