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Estimating age-at-death in burnt adult human remains using the Falys–Prangle method

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Abstract

Objectives: The Falys–Prangle-method assesses age-related morphological changes to the sternal clavicle end (SCE), enabling the observation of mature adults from the 5th decade onwards in unburnt human skeletal remains. The aim of this study is to investigate the applicability of the Falys–Prangle-method on burnt human remains.

Materials and methods: Fifty-two SCE of 40 cremated individuals (out of 86) from the William M. Bass collection of the Forensic Anthropology Center (Knoxville, Tennessee) of known age-at-death and sex are available for assessment. Surface topography, porosity, and osteophyte formation are evaluated, after which the calculated composite score is associated with the corresponding age range as described by Falys and Prangle. The method is also applied on an archaeological case study from Oudenburg, Belgium, dating to the Roman period.

Results: The assessed age ranges strongly agree with the true age ranges ($\alpha = 0.828$), suggesting the Falys–Prangle-method to be applicable on burnt human remains. The case study from Oudenburg yields markedly improved age-at-death estimates, significantly enhancing our understanding of the age distribution within this community.

Discussion: Information on age-at-death is key in the construction of biological profiles of past individuals. The mature adult is often invisible in the archaeological record since most macroscopic age estimation methods do not distinguish beyond 46+ years old. Our study stresses the usefulness of a large-scale application of the Falys–Prangle-method, which will increase the visibility of mature adults, especially in archaeological burnt human skeletal collections, where such information is, at present, extremely difficult to obtain.

KEYWORDS
biological profile, cremated remains, mature adult, morphological changes

1 | INTRODUCTION

Understanding past populations and reconstructing their behavior is an important aim in anthropological and archaeological research, including fields such as palaeodemography and palaeopathology. The fundamental elements for the construction of biological profiles include information on age-at-death, sex, stature, and pathological anomalies for each studied individual. This information is needed to reconstruct life stages and social roles in various communities from the past. Several methods exist to obtain this information, although most assess pathologies, age-related changes, and sex in unburnt human skeletal remains (Brooks & Suchey, 1990; Meindl & Lovejoy, 1985; Workshop of European Archaeologists (WEA), 1980). Clearly, burnt skeletal remains are more difficult to evaluate than unburnt remains, due to the heating process that often destroys important features needed for most of these analyses, and contributes to the fragmentary state of the remains. Over the last decade, several studies aimed to improve sexing (Cavazzuti et al., 2019; D. Gonçalves et al., 2011; Gonçalves et al., 2015) and aging methods (Absolonova et al., 2013; Gocha & Schutkowski, 2013; Oliveira-Santos et al., 2017) for burnt human remains. Still, at present, it remains particularly challenging to assess the age-at-death of cremated individuals, especially in adults.

Estimating age in nonadult cremated remains is undertaken by assessing dental development and eruption (Demirjian et al., 1973; Liversidge et al., 1998; Moorrees et al., 1963; Ubelaker, 1987) and stages of epiphyseal fusion (Black & Scheuer, 1996). Being protected by the jaw, tooth roots and unerupted tooth crowns are often preserved after the cremation process, enabling age assessment in nonadults. Age-estimation of unburnt adult individuals is performed by assessing changes to the pubic symphysis (Brooks & Suchey, 1990), sternal rib ends (İşcan et al., 1984, 1985), and the auricular surface (Buckberry & Chamberlain, 2002) and evaluating the degree of cranial suture closure (Meindl & Lovejoy, 1985). However, most macroscopic age estimation methods are not suited to estimate the age of older adults, and often the oldest age category is considered to be 46+ years (Falys & Lewis, 2011). In cremated remains, most elements needed for age estimation, such as the sternal rib ends, the pubic symphysis, and the auricular surface, are often deformed, fragmented or otherwise unobservable. This makes macroscopic age assessment of cremated adult remains extremely difficult and often only broad age categories, such as 18+ or 40+ years, can be assigned (Silva, 2015; Ulguim, 2015; Veselka & Lemmers, 2014).

The lack of information about the 5th decade and onwards in skeletal remains, burnt and unburnt, hinders interpretation of social roles of older adults in past populations. Falys and Prangle (2015) developed a method for distinguishing mature and older adults by using degenerative changes of the sternal clavicle end (SCE), enabling the identification of “elderly” individuals (i.e., 70+ years) in unburnt human remains. Blom et al. (2018) tested this method on a Dutch post-Medieval collection of known sex and age-at-death, and reported that the correct age category was assigned for 87% of the individuals. However, they found repeatability of the method to be problematic. In addition, the ranges of the age categories were still too broad (e.g., 56–75 years) to be more precise than other available macroscopic age estimation methods for unburnt remains. In the case of cremated remains, assigning even a broad age range is often impossible, and the age ranges proposed by Falys and Prangle (2015) would markedly improve the demographic information that can be obtained from burnt human remains.

The aim of this paper is to test the repeatability and reliability of the method of Falys and Prangle (2015) on cremated adult human remains. This is achieved by analyzing 86 cremated adult human remains of known age and sex from the Forensic Anthropology Center of the University of Tennessee, United States. Assessment of repeatability of the method is performed via the evaluation of intra-observer agreement of three different observers with varying levels of experience, while reliability is tested by assessing inter-observer agreement. If indeed the method proves to be reliable for burnt human remains, it will greatly contribute to our understanding of life stages from the 5th decade onwards in past populations that practiced cremation as a funerary rite.

2 | MATERIAL AND METHODS

A total of 86 burnt human remains were analyzed, of which 40 individuals had one or both SCEs (n = 52) available for inspection. The remains come from the Forensic Anthropology Center of Tennessee University in Knoxville, United States, and are part of the William M. Bass Donated Skeletal Collection that was obtained via the Body Donation Program. The collection includes burnt remains from modern males and females of European ancestry with ages ranging from 32 to 101 years.

The Falys–Prangle method assesses age-related morphological changes of the SCE. Three features are scored, (1) surface topography, (2) porosity, and (3) osteophyte formation, resulting in a composite score. Each composite score was assigned to an age stage with an attributed age range (see Table 1).

A total of five individuals had a documented age of <40 years, which would make them unsuitable for the Falys–Prangle method (Falys & Prangle, 2015). However, when studying individuals of unknown age-at-death, it is not possible to make that exclusion upfront. Therefore, these individuals were included in the analysis. All SCE were evaluated for completeness (expressed as >75%, 50–75%, 25–49%, and <25%), after which the three features as described by Falys and Prangle (2015) were assessed. Based on the composite score, the corresponding age range was assigned to each individual. If two SCE were available per individual, both sides were assessed separately. It was not always possible to side the SCE. Therefore, instead of assigning sides (left or right), both SCE from the same individual were labeled 1 and 2. This impaired the analysis of differences due to handedness, but it permitted assessment of the reliability of the composite score when the side of a single SCE was unknown. For the William M. Bass collection, age-at-death and sex is known. For the archaeological case study, sex could not be estimated. Therefore, the male and female age ranges were combined, resulting in slightly large ranges.

TABLE 1 Age stages, composite scores, and attributed age ranges for each sex (Falys & Prangle, 2015)

Age stage	Composite score	Age range males (years)	Composite score	Age range females (years)
I	3–5	42.5–55.1	3–5	42.2–56.4
II	6–7	46.1–64.3	6–8	52.6–76.4
III	8–9	56.1–75.3	9–10	62.1–81.9
IV	10–12	66.5–83.3	11–12	70.9–87.7
V	13–16	76.2–90.0	13–16	86.2–87.8

All cremations were analyzed by two observers with experience in osteoarchaeological analyses of cremated remains. The first observer, B, has extensive (8 years), while the second observer, M, has less experience (3 years). Both experienced observers assessed all observable SCE (n = 52) by evaluating the three degenerative features as described by Falys and Prangle (2015). To test the difficulty of the application of the method, a third observer, C, with no practical osteoarchaeological experience, assessed 25 randomly selected SCE. After this, a blind test was performed by randomly selecting 19 SCE which were re-assessed by all observers. Repeatability of the Falys–Prangle method was tested by comparing the estimated age range from the first to the second observation of each observer. Reliability of the method was evaluated by comparing all estimated age ranges (distinguishing between first and second observations) to the documented age ranges. Intra- and inter-observer errors were assessed by calculating Krippendorff's alpha, distinguishing between first and second observations, scores from both sides, and scores for females and males. Ideally, Krippendorff's alpha is ≥ 0.800, but an α between 0.800 and 0.670 still yields an acceptable level of agreement (Krippendorff, 2004). The correlation between the three features and the composite score with documented age was evaluated using Spearman's ranked correlation coefficient. Statistical significance was set at $p < 0.05$. All statistical tests were performed in SPSS 25. To calculate the Krippendorff's alpha, the KALPHA SPSS macro that was developed by Hayes (2005) was used.

The Falys–Prangle method was also applied to archaeologically cremated human remains from a mass grave retrieved from a cemetery dating to the Roman period from Oudenburg, Belgium, that contained the remains of at least five individuals. The five available SCE were assessed by observers B and M. The estimated age-at-death obtained via the Black-Scheuer method (Black & Scheuer, 1996) was compared to the age estimates obtained using the Falys–Prangle method (Falys & Prangle, 2015). Several fragments of auricular surfaces were used to compare age estimates (Buckberry & Chamberlain, 2002).

3 | RESULTS

3.1 | The William M. Bass donated skeletal collection

A total of 40 individuals (46.5%; 40/86) had SCE available for assessment, of which 12 had both sides present. Appendix 1 provides an overview of the scores for each feature and the composite scores of all observers per observation, and per individual with documented age-at-death and sex. Figure 1 shows two of the features—surface topography and porosity (both micro- and macroporosity)—on two SCE from the William M. Bass collection. Table 2 provides an overview of the reliability of the assessments of each observer per observation (1 and 2) expressed as Spearman's rho. More than half of the SCE were well preserved (>75% of the surface; n = 28), while 10 SCE had about 50% of the surface present. In seven cases, completeness of the SCE surface was between 25 and 49%, and 7 SCE had a surface completeness of less than 25%.

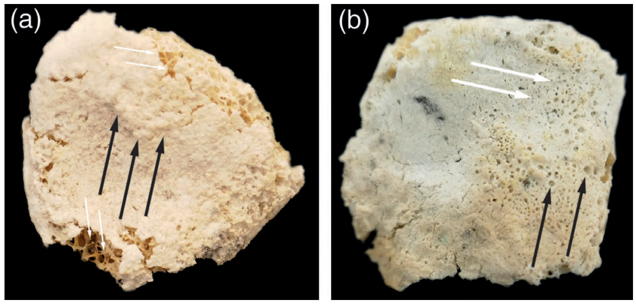

FIGURE 1 (a) Sternal clavicle end (SCE) showing formation of nodules (black arrows), note post-mortem porosity (white arrows), (b) SCE showing both micro- (white arrows) and macroporosity (black arrows)

Reasonable agreement existed between the age ranges of all first observations and the true age range, with α varying from 0.688 to 0.782. Only the first observer, B, showed an improvement in the second observation, yielding a α of 0.828, suggesting assessed age ranges to strongly agree with the true age ranges. The second observations of M and C, however, had a α of 0.606 and 0.515, respectively, implying poor agreement with the true age ranges. Both experienced observers, B and M, had an intra-observer agreement of α > 0.860, suggesting good repeatability. Unexperienced observer C presented an α of 0.600 for intra-observer agreement, implying poor repeatability. Inter-observer agreement was better for the second observations and yields α = 0.816, which suggested good reliability.

Individuals with two SCE available showed similar composite scores between the two sides. The α for the results of both sides of the three observers ranged from 0.834 to 0.923, suggesting that in the majority of cases (regardless of observer) both sides were scored similarly. In the first observations of B and M, the female scores were

TABLE 2 Repeatability and reliability using Krippendorffs's alpha

Agreement with documented age			
	Krippendorff's alpha (α)		Krippendorff's alpha (α)
B1	0.688	B2	0.828
M1	0.696	M2	0.606
C1	0.782	C2	0.514
Intra-observer agreement			
B1 versus B2			0.863
M1 versus M2			0.878
C1 versus C2			0.600
Inter-observer agreement			
B1 versus M1 versus C1			0.747
B2 versus M2 versus C2			0.816
Inter-side agreement			
Bs1 versus Bs2			0.834
Ms1 versus Ms2			0.923
Cs1 versus Cs2			0.862
Female/male agreement with true age range			
Female scores		**Male scores**	
B1	0.518	B1	0.714
M1	0.463	M1	0.818
C1	0.893	C1	0.656
B2	0.623	B2	0.937
M2	0.426	M2	0.818
C2	0.001	C2	0.586
Correlation with documented age[a]			
		Spearman's rho (ρ)	*p*-value
S		0.394	0.013
P		0.257	0.114
O		0.291	0.073
Composite score (S + P + O)		0.478	0.002
Composite score (S + P)		0.432	0.005
Composite score (S + O)		0.483	0.002
Composite a score (P + O)		0.373	0.018

Abbreviations: B1/2, observer B first or second observation; Bs1/2, observer B side 1 or 2; C1/2, observer C first or second observation; Cs1/2, observer C side 1 or 2; M1/2, observer M first or second observation; Ms1/2, observer M side 1 or 2; O, osteophyte formation; P, porosity; S, surface topography.

[a]Results are based on the scores of the first observation of observer B.

not in agreement with the true age ranges, while the male scores showed reasonable to strong agreement. The first observations of observer C demonstrated the opposite. A slight improvement of agreement for the female scores and a marked improvement of the male scores was visible in the second observations of B, while agreement of the second observations of C markedly decreased.

Figure 2 shows the relationship between the scores of each feature and the documented age. The scores of the first observation of B were used. "Surface topography" and "porosity" were relatively easy to score, while "osteophyte formation" was more problematic.

3.2 | Archaeological case study: Oudenburg

The cremation deposit from Oudenburg, Belgium, with a total weight of about 17 kg, contained the remains of at least five individuals based on the presence of unique skeletal elements, which were five right petrous parts. Nearly all fragments were fully calcined and the preservation of the bone material was good. Careful osteoarchaeological analysis of the remains yielded five SCE. Figure 3 shows the sternal ends of the five clavicles. Table 3 shows the age-at-death estimation using the Black-Scheuer method in the left column, while the right column shows the results for age-estimation using the Falys-and-Prangle method. The result of both observers, B and M, yielded the same age range. Although several skeletal fragments with female and male characteristics were observed, it was not possible to determine the sex of the clavicle ends. Therefore, the age range for males and females (as established by Falys & Prangle, 2015) was combined by taking the minimum and maximum of both age ranges (see Table 1), resulting in a slightly larger range. For example, for clavicle "E," the composite score is 10 which has an age range of 66.5–83.3 years for males and 62.1–81.9 years for females. Since the sex here was unknown, the age range associated to this SCE was 62.1–83.3 (Table 3). Several fragments of the auricular surface were retrieved and showed similar age ranges, varying from less than 25 years to 40+ years, supporting the assessed age ranges of the SCE.

4 | DISCUSSION

4.1 | Repeatability and reliability

All first observations suggested a positive correlation with documented age ranges, regardless of the observer (α > 0.688). The scores of observers M and C in the second observation showed a lower reliability (α = 0.606 and α = 0.515, respectively), implying repeatability of the scores was problematic, while observer B showed improvement (α = 0.828), suggesting good repeatability to be dependent on the level of osteoarchaeological experience which is consistent with other age estimation methods. Although the scores of M and C in the second observation showed a lower reliability, the differences in scores between the observers were smaller, resulting in an improvement of the inter-observer agreement in the second observation. Differences in repeatability and reliability of the scores may suggest that the description of the features needs to be clearer and less prone to subjectivity, for example, the difference between a nodule and slight osteophyte formation may be interpreted differently. Furthermore, thorough knowledge of osteoarchaeological methods and intensive

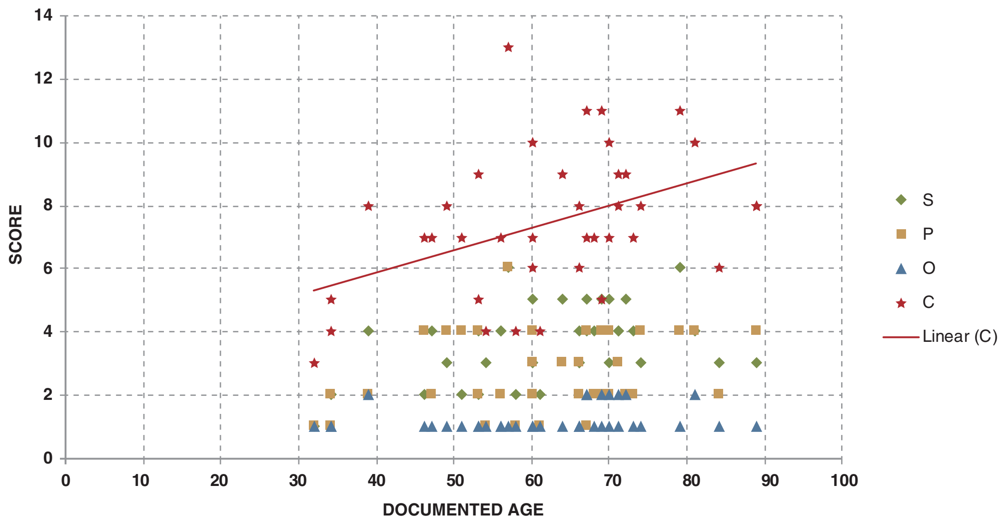

FIGURE 2 Score-age relationship between the three features. C, composite score; O, osteophyte formation; P, porosity; S, surface topography

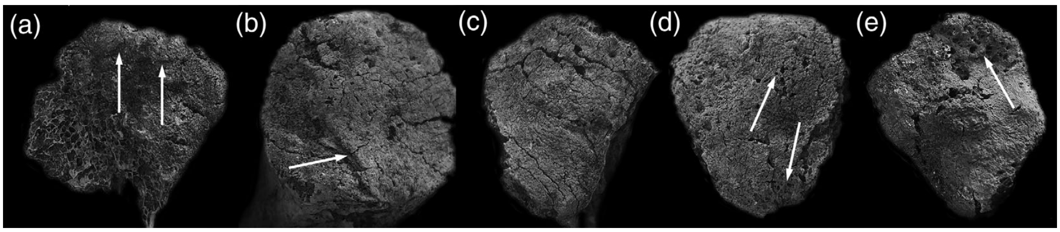

FIGURE 3 Five sternal clavicle end from Oudenburg mass grave displaying differences in age-at-death. (a) Note the visible grooves (see arrows), characteristic for unfused surfaces. (b) Note the fusing line of the medial ephiphysis (see arrow). (c) Surface is still smooth without ante-mortem porosity. (d) Surface has a more granular appearance with patches of ante-mortem porosity (see arrows). (e) Surface is coarse, shows undulation, and macroporosity (see arrow)

TABLE 3 Results for grave 53A from Oudenburg using different age-estimation methods

	Age-estimate using Black-Scheuer method	Age-estimate using Falys–Prangel method
Clavicle A	<25 years	<42 years
Clavicle B	22–30 years	<42 years
Clavicle C	>25 years	42.2–56.4 years
Clavicle D	>25 years	46.1–76.4 years
Clavicle E	>25 years	62.1–83.3 years

training in the use of the Falys–Prangle method is needed to obtain reliable results.

Factors such as activity and handedness may influence the changes in morphology of the SCE (Langley-Shirley & Jantz, 2010; Meijerman et al., 2007; Yood & Goldenberg, 1980). This may also result in differences in morphology between the left and right sides, as seems to have been the case in the 19th–20th-century Coimbra Collection in the study of Falys and Prangle (2015). However, the other three collections analyzed in their study (20th-century Haman-Todd Collection, 19th-20th-century Pretoria Bone Collection, and 18th–19th-century St. Bride's Documented Collection) did not present side-related score differences (Falys & Prangle, 2015). The relatively high agreement of scores between sides in this study (n = 12), ranging from α = 0.834 to α = 0.923 for different observers, implied there is no statistically significant difference in the reliability of the scores from either side regardless of the observer. This suggests the influence of handedness, activity, and other factors affecting the morphological appearance of the SCE to be minimal in the William M. Bass collection.

Two individuals, a female aged 89 years and a male aged 84 years, displayed large differences between estimated and documented age ranges. All observers estimated the age range of both individuals to be lower than the actual range, whereby age-at-death of the female was estimated to be between 52.6 and 76.4 years, and that of the male to be between 46.1 and 64.3 years. Although partial preservation of the SCE may influence age estimation, completeness of both SCE was ≥ 50% and lacked ante-mortem porosity and osteophyte formation, yielding a relatively low composite score. Although the influence of activity and handedness was suggested to have been minimal in the William M. Bass collection, a possible explanation for the underestimating of age in these two individuals may be attributed to activity or the lack thereof, affecting the changes in sternal end morphology. Another possibility is that handedness influenced the development of degenerative changes to the SCE in these individuals.

Only one SCE of each individual was available, which impaired the assessment of side-related differences in SCE morphology. Nevertheless, the influence of activity and handedness may be population and time period specific, and more research on the influence of these factors is needed to improve our understanding of the various degenerative changes in the SCE.

The differences in reliability of the female and male scores did not show a consistent pattern. While in the first observation of observers B and M, the female scores did not agree with documented age ranges, the first observation of C was in strong agreement with the documented age ranges. The male scores of the first observations, showed reasonable to strong agreement with the true age ranges. Only the second observations of the most experienced observer, B, displayed improved agreement, and, based on these results, the estimated age ranges of either sex demonstrated a reasonable to strong agreement with the documented age ranges, suggesting the influence of sex on the reliability of age range estimations in this collection was minimal. Falys and Prangle (2015) also claim not to have observe sex-related differences in morphological changes to the SCE in the collections they used, although they did observe the female mean age to be greater for the same composite score that resulted in slightly different age ranges for males and females. Indeed, the influence of sex on changes in morphology is still poorly understood, and more research will enhance our knowledge of sex-related changes to the skeleton.

Five individuals (females aged 32, 34, and 39 years; males aged 32 and 34 years) had documented age <40 years, which would make the application of the Falys–Prangle method problematic. In the study of Falys and Prangle (2015), however, the number of individuals in the age group with the lowest composite score (3) is very small, and only one male individual and no female individual met that criterium. Clearly, more study of individuals with fused SCE with ages below 40 years are needed to improve the reliability of the lower end of the Falys–Prangle method. In the current study, two individuals (female and male) aged 32 years, presented fusing medial clavicular epiphyses suggesting their age range to be between 22 and 30 years (Langley-Shirley & Jantz, 2010). Figure 4 shows the fusing epiphysis of the 32-year-old male.

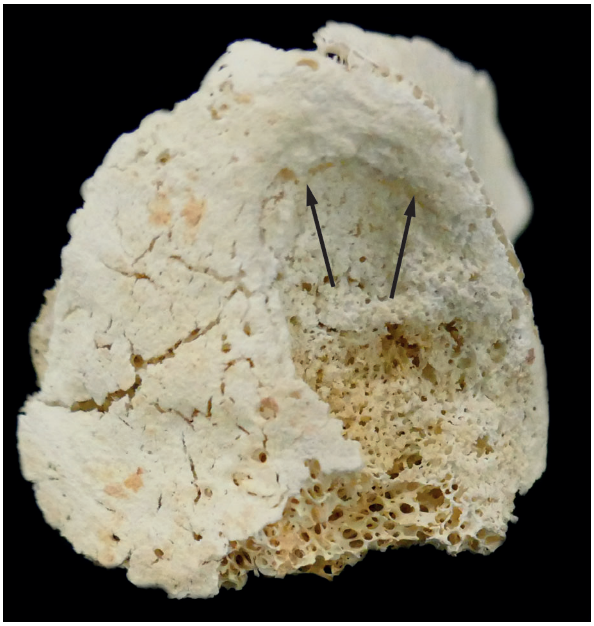

FIGURE 4 Sternal clavicle end of a male aged 32 years, black arrow points to the rim of the sternal epiphysis, note post-mortem damage to the opposite end of the arrow

Generally, the medial clavicle is expected to be fully fused between 22 and 30 years of age (Langley-Shirley & Jantz, 2010), but several factors, such as socioeconomic status and sex, may delay the fusing process (Meijerman et al., 2007). This may be the case in the two individuals aged 32 years from the William M. Bass collection, whereby the SCE are still in the process of fusing. The sternal epiphyses of the 34-year-old male and female were fully fused. Assessment of the SCE for the 32- and 34-year-olds, yielded a composite score of 3. Considering the single composite categories as constructed by Falys and Prangle (2015), the attributed age of the males would be 41 years, while for the female no age is available. Another option was to look at age ranges, whereby composite scores were combined to increase reliability of the result, such as composite scores 3–5, and so forth. (Falys & Prangle, 2015). Both 32- and 34-year-olds would fall into the group of composites scores 3–5, yielding an age range of 42.5 to 55.1 years for the male and 42.2 to 56.4 years for the female. Yet, 96.7% (29/30) of individuals assigned to this group of composite scores in the study by Falys and Prangle (2015) had a composite score of 4 or 5. This implies that the lower end of the age range (around 42 years) is too high, as younger individuals (with composite score 3) are lacking. Since the first stage of "surface topography" is described as a flat and smooth surface, whereby the epiphysis may be in the process of fusing (Falys & Prangle, 2015), a larger number of individuals younger than 42 years are expected to have a composite score of 3. Considering the scores of the 32- and 34-year-olds from the William M. Bass collection, the lower boundary of the age range of individuals with composite score 3 should be extended to include of 32 years. Therefore, we propose to expand the lower age limit of composite scores category 3–5 to enable inclusion of individuals younger than 40 years with fusing or fused medial clavicles.

The 39-year-old female had fused medial clavicles and yielded a composite score of 6, giving her an age range of 52.6–76.4 years. Her age was overestimated based on the degenerative changes of the SCE. It is possible that activity or handedness influenced the morphological appearance of the SCE, causing the degenerative features to be more advanced than what would have been expected at her age, further stressing the need for additional research on the influence of these factors.

Although more study is needed on several aspects of the method, such as the potential influence of handedness, activity, and sex on the observed changes in the SCE, and possibly improvement of the description, the age estimations of this study showed a strong correlation with documented age. Although the cremation process affects the shape and structure of bone (Gonçalves et al., 2011), the features used in the Falys–Prangle method will not markedly change due to the heat, as shown in Figure 1. This implies the Falys–Prangle method to be applicable to burnt human remains, which significantly aids in detecting the older adults in cremation deposits from archeological and perhaps even forensic contexts.

4.2 | Scoring features

This study corroborated with the findings of Blom et al. (2018), stating "surface topography" to be the feature with the highest positive correlation with documented age that is used in the Falys–Prangle method (ρ = 0.394). Scoring this feature is relatively easy, since partial preservation of the surface still enables the assessment of "surface topography." The relatively low positive correlation of "porosity" and documented age in this study was not statistically significant (ρ = 0.257, p = 0.114), which was also observed in the study by Blom et al. (2018). Although it is widely acknowledged that porosity increases with age (Dequeker, 1975; Nelson & Weiss, 1999), its development and morphology are still poorly understood. Falys and Prangle (2015) stated microporosity to be followed by macroporosity, suggesting macroporosity to appear at a later stage, and to be linked with older age. However, Blom et al. (2018) observed cases with macro- but without microporosity, implying the relationship between these two types of porosity to be more complex than initially suggested by Falys and Prangle (2015). Furthermore, the distinction of ante- and post-mortem porosity in cremated remains may be challenging, and partial preservation of the SCE may hinder "porosity" evaluation. Indeed, "porosity" is scored by considering the percentage of the surface affected by micro- and/or macroporosity ranging from < 50% to ≥ 50% (Falys & Prangle, 2015) and poor preservation of the surface hinders the assessment of this percentage.

The feature "osteophyte formation" showed a stronger positive correlation with documented age (ρ = 0.291, p = 0.073) than "porosity" (ρ = 0.257, p = 0.114), but it failed to meet statistical significance. Observing osteophyte formation in cremated remains proved to be difficult. Although half of the SCE surfaces was nearly complete (>75%), osteophytes tend to break off easily, leading to a lower composite score and possibly an underestimation of age. Falys and Prangle (2015) noted the relationship between aging and osteophyte formation to be tentative and suggested this feature to be removed from the method. It is interesting, however, that in this study, "osteophyte formation", although problematic to score, yielded a stronger positive correlation than "porosity," which may suggest "osteophyte formation" to be a useful feature in the end.

Leaving the score for "osteophyte formation (O)" out, the scores for "surface topography (S)" and "porosity (P)" would yield a lower positive correlation (ρ = 0.432, p = 0.005) than the composite score consisting of all three features (ρ = 0.478, p = 0.002). Interestingly, if only the scores of the features S and O were considered, the resulting composite score yielded a statistically significant higher positive correlation (ρ = 0.483, p = 0.002) with documented age than the composite score consisting of all three features (ρ = 0.478, p = 0.002). Clearly, more research of the relationship between all three features and age is needed to determine the usefulness of each feature. Still, at his stage, we recommend to keep using all three features.

4.3 | Archaeological case study

SCE are not very robust and are less likely to survive the heating process than diaphyseal or cranial fragments. Retrieval of this skeletal element in archaeological collections varies between different time periods and depends on the completeness of the cremated remains and the combustion degree. The Roman collection of Bemmel, the Netherlands, contained 65 well preserved cremation deposits, whereby no SCE was retrieved (Veselka, 2018), while the Early Bronze Age collection of Leuze-en-Hainaut, Belgium, consisted of four cremations that yielded one SCE (Veselka, 2019), and the Middle Neolithic mass grave with a minimum number of 40 individuals from Stein, the Netherlands, had seven SCE (Veselka, 2017). Although SCE may not be observable in all cremation collections, the Falys–Prangle method increases the visibility of mature and older adults in cremated remains when SCE are present.

A good example was grave 53A from Oudenburg, Belgium. A minimum of five individuals were buried together, based on the number of right petrous parts, and five SCE were retrieved. The surfaces of the SCE were relatively complete enabling age assessment (see Figure 2). As shown in Table 3, the difference in age-estimations is striking. Without the Falys–Prangle method, three of the five clavicles would not have provided a narrower age range than 25+ years, while the right column shows the marked difference in age ranges for all SCE. Even if the age ranges have a relatively large overlap, making this method less suitable for detecting older adults in unburnt remains, it showed a significant improvement compared to the Black–Sheuer method for cremated remains. Considering that in most cases age estimation in cremated remains results in broad age categories (e.g., 18+ or 25+ years), the method of Falys and Prangle (2015) significantly improves the number of individuals with a narrower age estimate, and contributes to detecting the "invisible" mature and older adults in past populations that practiced the burial ritual of cremation.

The SCE may not be present in every cremation, as is often the case with other skeletal elements required for sex or age estimations, but adding another age estimation method will further increase the number of cremated individuals for which an age estimation is possible. In archaeological cremation deposits, it is not always possible to assess sex, which results in slightly broader age ranges. However, the age estimate based on the SCE will still provide a narrower age range than without this method, improving our understanding of age-related burial patterns in archaeological assemblages. This method may also aid in the identification process of fire victims in forensic cases by narrowing down the age ranges, although improvement of the method is needed to further improve reliability.

5 | CONCLUSION

The Falys–Prangle method using age-related changes in morphology of the SCE, was tested on 52 SCE of 40 individuals of known sex and age-at-death. Repeatability proved to be problematic for less experienced and untrained observers, and reliability also was dependent on the level of experience. Clearly, osteoarchaeological training and experience with the method improved repeatability and reliability, but perhaps the current description of the features needs improvement to minimize subjectivity. This study observed a strong positive correlation between the age estimations using the Falys–Prangle method and the documented age, suggesting the method to be applicable to burnt human remains.

Both “porosity” and “osteophyte formation” presented lower positive correlations with documented age than “surface topography”, corroborating with the findings of Blom et al. (2018) and Falys and Prangle (2015). Interestingly, “osteophyte formation” in our study yielded a slightly stronger positive correlation with documented age than “porosity”, although this result failed to meet statistical significance. In addition, the composite score consisting of just “surface topography” and “osteophyte formation” scores yielded a slightly higher positive correlation with documented age than the composite score consisting of all features. More research on the relationship of the separate features with age is needed to improve the reliability of the method.

The case study of Roman Oudenburg has shown the marked contribution of the Falys–Prangle method for the age estimation in cremated remains, when SCE are available. The difference in age-estimation results with the Falys-and-Prangle method as opposed to the other available macroscopic methods for SCE was striking. Although it is not always possible to estimate sex, the slightly larger age range that resulted from combining male and female age ranges (see Table 1), still distinguished the mature and older age categories in cremated remains. A large-scale application of this age-estimation method will drastically increase information on the “invisible” older adults in populations that practiced cremation as a funerary rite.

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AUTHOR CONTRIBUTIONS

Barbara Veselka: Conceptualization; data curation; formal analysis; investigation; methodology; resources; software; validation; writing-original draft; writing-review and editing. **Marta Hlad:** Conceptualization; data curation; formal analysis; investigation; methodology; resources; software; validation; writing-original draft; writing-review and editing. **Dawnie Wolfe Steadman:** Methodology; resources; writing-original draft. **Henrica Annaert:** Writing-review and editing. **Mathieu Boudin:** Writing-review and editing; funding acquisition. **Giacomo Capuzzo:** Writing-review and editing. **Sarah Dalle:** Writing-review and editing. **Ioannis Kontopoulos:** Writing-review and editing. **Guy De Mulder:** Writing-review and editing; funding acquisition. **Charlotte Sabaux:** Writing-review and editing. **Kevin Salesse:** Writing-review and editing. **Amanda Sengeløv:** Writing-review and editing. **Elisavet Stamataki:** Writing-review and editing. **Martine Vercauteren:** Writing-review and editing; funding acquisition. **Dries Tys:** Writing-review and editing; funding acquisition. **Christophe Snoeck:** Conceptualization; data curation; formal analysis; funding acquisition; validation; writing-original draft; writing-review and editing; funding acquisition.

CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the supporting information of this article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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