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RESEARCH

# Medieval migrations and the birth of modern British peoples: a craniometric approach

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**Abstract**

Craniometric characteristics have long been used to reconstruct among-group variation, potential migration routes and ancestral origins. This study presents results of the comparison of 946 individuals from 16 British medieval sites using craniometric analyses. The purpose is to determine: 1) if observable cranial variation exists among British medieval groups, 2) whether it can best be detected from neurocranial or facial measurements, and 3) the potential causes of these differences. The data were analyzed with multivariate statistical analyses. A selection of 18 variables recorded on each cranium was used for comparison among separately pooled males and females for each site. Principal component analysis was carried out on the mean measurements for these pooled samples to detect differences.

The results support findings from previous studies indicating a observable difference in measurements among British samples. Male and female samples follow the same grouping pattern, indicating the validity of the statistical analysis. Both neurocranial and facial measurements contribute to the variability of the groups analyzed.

The differences in craniometric measurements are likely determined by immigration from other European areas. Samples from British towns where migration occurred more frequently during and before the Middle Ages (i.e., Hythe, London and Scarborough) support this difference. These towns were major ports, and the movement of people was frequent, with various migrant groups selectively populating them (e.g., Scandinavian, Icelandic, Flemish, French). This is supported by correspondence of the results with historical and archaeological records.

**Keywords** craniometric analysis · biological distance · migration · Britain · Middle Ages

## Introduction

It has been shown that the main characteristics of an individual's cranial morphology are genetically transmitted directly through generations (Howells 1973; Sparks and Jantz 2002; Relethford 2004; Harvati and Weaver 2006). However, the influence of long-standing population migration also affects the variability of cranial morphology (Relethford 2004; Spradley and Jantz 2021). Both archaeological and biological data suggest there have been several population movements in Britain from continental Europe in the past. This hypothesis is confirmed by historical literature (Hunter and Ralston 1999; Gillingham and Griffiths 2000; Töpf et al. 2005), and is corroborated by research carried out in the first half of the 20$^{th}$ century (Little 1943; Stoessiger and Morant 1932).

Genetic and isotopic data also provide proof of human mobility, confirmed by extensive research to date (Oppenheimer 2006; Lazaridis et al. 2014; Pellegrini et al. 2016; Olalde et al. 2018; Pearson et al. 2019; Evans et al. 2022). Differences in Y-chromosomes among populations within the British Isles have been detected by several researchers. The results suggest different parts of the British Isles have diverse paternal histories (Capelli et al. 2003; Lall et al. 2021). For example, Scandinavian populations had an impact in both Scotland and the Northern Isles (Berry and Firth 1986), and substantial migration in the Early Bronze Age and Anglo-Saxon periods occurred in England (Weale et al. 2002; Hemer et al. 2013; Schiffels et al. 2016; Patterson et al. 2022).

The analysis of stable isotopes from different tissues is an effective method to gain insight on human mobility

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throughout the course of an individual's life. In fact, this analysis proved there was a movement of people from outside Britain, especially in ports, during medieval times (Kendall et al. 2013; Leggett 2021). If migrations can be proven through interdisciplinary methods, a significant correspondence should also be expected from the craniometric analysis.

Craniometric research is valuable for understanding population history as it allows measurement reproducibility (Howells 1973). Human migrations can have differing impacts on craniometric variation in regard to both genetic and environmental factors. Craniometric information can, therefore, be used to detect within and among group variation, migration routes and ancestral origins.

Migrations are essential for understanding the different components of a population. There are close linkages between population movements as a phenomenon and a significant number of other processes and behavioral patterns (Anthony 1990). However, British research involving craniometric data appears sporadically in recent scientific literature. Much of the research undertaken on British craniometric data analyzes Pre-Historic, Romano-British and Anglo-Saxon populations, to investigate whether the variation is a consequence of ancient migrations; there is a substantial lack of research performed on British medieval populations. Moreover, most of these studies are now dated (i.e., Little 1943; Tattersall 1968; Brothwell and Krzanowski 1974; Dawes and Magilton 1980).

The purpose of this study is to determine whether cranial morphological variation between British medieval populations exists, and the reasons contributing to these differences (i.e., a result of previous and contemporary population movements). Craniofacial morphology variability of 946 skulls from 16 British samples was analysed. Craniometric data were recorded in samples from five osteological collections and compared with previously published data.

To determine whether there are significant differences between samples, three main research questions are proposed: 1) Are there quantifiable differences in craniofacial morphology among British medieval samples? 2) If differences among these samples exist, can they be determined by neurocranial, facial measurements or both? 3) Would these differences likely be a result of the distinctive waves of migration occurred before and during the Middle Ages from various parts of Europe?

## Materials and Methods

### Skeletal samples

For the selection of samples the focus was to acquire data from material covering a large geographical region from North to South in Britain. However, due to the limited archaeological material available, the number of remains from Southern archaeological sites is greater than that of the Northern sites (Table 1 and Fig. 1).

This study involves analyses of 946 skulls in 16 British medieval samples from: Poulton (Cheshire), Linenhall (Chester), St Owen's church (Gloucester), St Saviour (London), Dominican Friary (London), St Mary Graces (London), East

**Table 1** Dating and number of individuals analyzed, where ?Males and ?Females indicate probable males and probable females

| Site | Period | Number of Males | Number of Females | Number of ?Males | Number of ?Females | Data collected/published by |
|---|---|---|---|---|---|---|
| Poulton | $14^{th}$-$16^{th}$ CE | 106 | 41 | 11 | 4 | Valoriani (this study) |
| Linenhall | $12^{th}$-$15^{th}$ CE | 7 | 3 | 0 | 0 | Valoriani (this study) |
| St Owen | $12^{th}$-$15^{th}$ CE | 48 | 25 | 3 | 3 | Valoriani (this study) |
| St Saviour | $11^{th}$-$16^{th}$ CE | 52 | 0 | 0 | 0 | WORD (2015) |
| Dominican Friary | $13^{th}$-$16^{th}$ CE | 3 | 0 | 0 | 4 | WORD (2015) |
| St Mary Graces | $14^{th}$-$16^{th}$ CE | 14 | 8 | 7 | 3 | WORD (2015) |
| East Smithfield | $14^{th}$ CE | 31 | 15 | 6 | 4 | WORD (2015) |
| St Mary Merton | $12^{th}$-$16^{th}$ CE | 59 | 4 | 10 | 1 | WORD (2015) |
| St Mary Spital | $12^{th}$-$16^{th}$ CE | 13 | 7 | 4 | 2 | WORD (2015) |
| St Nicholas Shambles | $11^{th}$-$12^{th}$ CE | 14 | 19 | 0 | 0 | WORD (2015) |
| Guildhall Yard | $11^{th}$-$14^{th}$ CE | 4 | 4 | 3 | 1 | WORD (2015) |
| St Gregory | $11^{th}$-$16^{th}$ CE | 45 | 22 | 3 | 4 | Valoriani (this study) |
| St Leonard | N/A | 75 | 34 | 37 | 53 | Stoessiger and Morant (1932) |
| Castle Hill | ?$12^{th}$-$16^{th}$ CE | 43 | 18 | 0 | 0 | Little (1943) |
| Guisborough | $12^{th}$-$16^{th}$ CE | 14 | 8 | 4 | 6 | Anderson (1994) |
| Ballumbie | $7^{th}$-$17^{th}$ CE | 22 | 9 | 4 | 2 | Valoriani (this study) |
| Total | | **550** | **217** | **92** | **87** | |

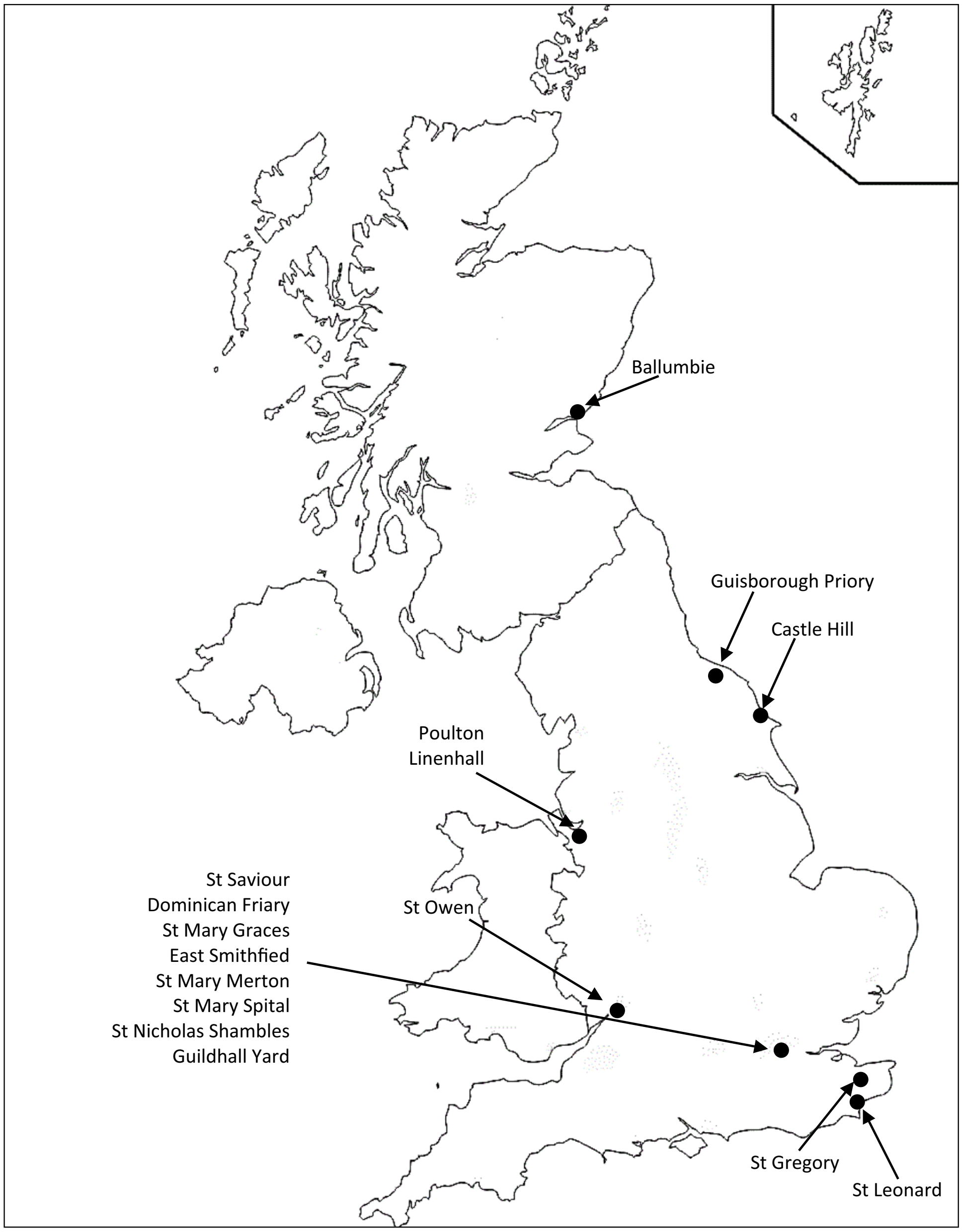


**Fig. 1** Location of the origin of the samples analyzed for this study

Smithfield (London), St Mary Merton (London), St Mary Spital (London), St Nicholas Shambles (London), Guildhall Yard (London), St Gregory (Canterbury), St Leonard (Hythe), Castle Hill (Scarborough), Guisborough priory (Guisborough) and Ballumbie (Dundee).

The nature of the populations represented is both rural (smaller communities based on an agricultural economy), and urban (larger cities with a major movement of people, attributed to an economy based more on trade). The craniometric data was acquired by the author for five of the samples, i.e., Poulton, a rural settlement in Cheshire (Emery 2000), Linenhall, a Greyfriars' burial site from Chester (Davenport 2018), St Owen's cemetery from Glocester's Southgate Street (Atkin 1990) (Fig. 2), St Gregory's Priory cemetery in Canterbury (Hicks and Hicks 2001), and Ballumbie parish, a rural site located three miles north of Dundee (Cachart and Hall 2014; Hall and Cachart 2005).

Data from the remaining 11 samples were pooled together for the statistical analysis. The rationale is that these peoples are thought to be closely related, in part because they are from the same geographical location. Apart from St Nicholas Shambles, which was analyzed and published by White and Dyson (1988), the data were acquired online via the Wellcome Osteological Research Database, made available by the Museum of London Archaeology (MOLA) (WORD 2015). Data for the Hythe crania, recorded and published by Stoessiger and Morant (1932), and those from the material recovered at Castle Hill (Scarborough), published by Little

**Fig. 2** Male skull from Sk 1468 from Southgate Street (Gloucester)

(1943), are from studies conducted in the early 20th century. The human remains from Guisborough were analysed and published by Anderson (1994).

For the purpose of this study, males and females were analysed separately to avoid misclassification due to difference in measurements as a result of sexual dimorphism. The plots are also divided by sex and the samples were all given the name of each archaeological site.

## Selection of individuals and craniometric measurements

Before starting the data collection, a preservation assessment was carried out on the skeletal material. If post-mortem pressure or artificial modification changed a significant area of the skull, the individual would be excluded from the analysis (Howells 1973). Additionally, the skulls were required to have a minimum presence of at least the frontal bone, right and left parietals, right and left temporals and occipital (i.e., a full calvarium). The presence of these anatomical areas allowed the collection of the minimum number of measurements required for the analysis.

For sex estimation, standard cranial and postcranial indicators were used (Buikstra and Ubelaker 1994). For an optimal selection of adults, two age-at-death indicators were used: fusion of the spheno-occipital synchondrosis and ectocranial suture closure. Spheno-occipital synchondrosis is a reliable indicator of age as complete fusion occurs in females at approximately 16 years, and around of 18 years of age in males (Sahni et al. 1998; Schaefer et al. 2009; Shirley and Jantz 2011; Cunningham et al. 2016). Though ectocranial suture closure (Meindl and Lovejoy 1985) and its limitations have been extensively discussed in the literature, the methods have been adopted by the authors to exclude non-adult individuals.

**Table 2** Measurements used for data collection in this study and studies used for comparison

| Cranial Measurement | Martin and Saller Code | British Code |
|---|---|---|
| Maximum length of the neural skull | MS 1 | L |
| Cranial base length | MS 5 | LB |
| Maximum neurocranial breadth | MS 8 | B |
| Basion-bregma height | MS 17 | H’ |
| Nasion-bregma arch | MS 26 | $S_1$ |
| Parietal longitudinal arch | MS 27 | $S_2$ |
| Occipital arch | MS 28 | $S_3$ |
| Nasion-bregma chord | MS 29 | $S'_1$ |
| Bregma-lambda chord | MS 30 | $S'_2$ |
| Lambda-opisthion chord | MS 31 | $S'_3$ |
| Foramen magnum length | MS 7 | FL |
| Length of the face | MS 40 | GL |
| Maximum bimaxillary breadth of the midface | MS 46 | GB |
| Height of the upper face | MS 48 | G’H |
| Orbital breadth | MS 51 | $O'_1$ |
| Orbital height | MS 52 | $O'_2$ |
| Nasal breadth | MS 54 | NB |
| Nasal height | MS 55 | NH’L |

Standard osteometric data recording methods developed by Martin and Saller (1957) and Borrini (2022) were adopted. The total number of craniometric measurements that were collected by the first author (SV) on each cranium amounts to 45 variables, which were recorded for completeness of the information. Some of these variables are recorded spatially adjacent to one another, yielding analogous measurements.

For this reason, to allow an easier analysis of the data, a Pearson’s product-moment correlation test was carried out. The test allowed the selection of a set of measurements, excluding the values that had a correlation of $r > .500$ (Emerson 2015). The resulting dataset was then composed of 21 variables. The measurements were consequently checked for correspondence with those recorded by the other authors and reduced to 18 variables for improved data analysis (Table 2).

## Statistical methods

First, all individuals that were assigned unknown sex were removed from the database. Those assessed as “probable male” or “probable female” were included to maximize sample sizes. Second, missing value analysis was carried out to exclude individuals with >50% of the measurements missing. Finally, any individual that showed extremely low or high values in the statistical analysis was checked with the original data file for accuracy. If no inputting error could be identified, the individual was left in the dataset. The dataset resulting from the data preparation consisted of 670 individuals with less than 50% missing data.

Principal component analysis was carried out in IBM SPSS Statistics v24, where a set of factors (or PCs) were retained by the program to determine variability of the sample (Jolliffe 2002; Dytham 2011). SPSS Statistics v24 uses Kaiser's criterion (Kaiser 1960) to extract these factors, i.e., only the factors with Eigenvalues greater than 1 were retained. The factor scores were then used to produce three-dimensional scatterplots to visualize the results of the analysis.

## Results

The means resulting from each variable in the different samples were employed for the data analysis. The pooled samples were analysed independently to avoid misclassification because of sexual dimorphism. All samples analysed are outlined in Table 1 for the males; for the females Guisborough was not included due to a lack of facial measurements. This procedure allowed the determination of which variables had the most significance in discriminating between groups. After carrying out the PCA, the highest factor scores were retained to produce the scatterplots. Factor scores with loadings of 10% or more were chosen to produce the graphs.

### Males

In the analysis of males four principal components were extracted, which account for 88.1% of the total variance. For the scatterplot in Fig. 3 only the first three components were used, which explain 79.2% of the variation (PC 1 = 44.242%, PC 2 = 22.566% and PC 3 = 12.408%).

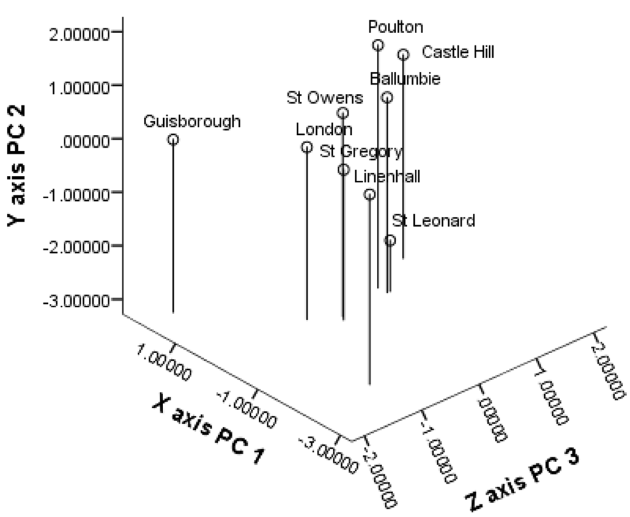


Fig. 3 Three-dimensional scatterplot showing PC1, PC2 and PC3 for the male samples

The component matrix in Table 3 shows the loadings for the different principal components. The variables that drive most of the variation in the first component are MS 48 (height of the upper face) with a value of .973 and MS 5 (cranial base length) with a value of .944. Fairly important are also the variables MS 55 (nasal height), MS 54 (nasal breadth) and MS 29 (nasion-bregma chord), with loadings not much dissimilar from the first two. On the second principal component, most of the difference between samples is determined by measurements MS 27 (parietal longitudinal arch) with a loading of .928, and MS 30 (bregma-lambda chord) showing loading of .873. The measurements with a fairly high influence on variability between samples are MS 1 (maximum length of the neural skull) and MS 31 (lambda-opisthion chord). On the third principal component, only two measurements seem to have a notable impact on variability between groups, i.e., MS 51 (orbital breadth) with a loading value of .824 and MS 40 (length of the face) with a value of -.742.

In Fig. 3, the spatial distribution of samples can be observed. On the first principal component axis X, the samples cluster mainly based on their affinities for the facial and frontal areas. The only two samples that result as outliers are Linenhall and Guisborough. In fact, regarding facial height,

Table 3 Component loadings, eigenvalues, and variances for male British samples

| Measurement | Comp 1 | Comp 2 | Comp 3 | Comp 4 |
|---|---|---|---|---|
| MS 1 | .351 | .860 | .107 | .179 |
| MS 5 | .944 | -.154 | .052 | .204 |
| MS 8 | .786 | -.163 | .499 | .012 |
| MS 17 | .348 | -.583 | -.268 | -.073 |
| MS 26 | .912 | .267 | -.044 | .046 |
| MS 27 | -.242 | .928 | -.071 | -.070 |
| MS 28 | .062 | .497 | .270 | .760 |
| MS 29 | .941 | .225 | .003 | -.073 |
| MS 30 | -.193 | .873 | .289 | -.136 |
| MS 31 | -.163 | -.839 | .300 | .282 |
| MS 7 | .399 | -.072 | .460 | -.742 |
| MS 40 | -.219 | -.073 | -.742 | .129 |
| MS 46 | .843 | -.261 | .187 | .392 |
| MS 48 | .973 | -.129 | -.181 | .053 |
| MS 51 | -.269 | -.100 | .824 | .001 |
| MS 52 | .808 | .299 | -.311 | -.280 |
| MS 54 | .942 | -.123 | .053 | -.167 |
| MS 55 | .943 | .159 | -.192 | .073 |
| Eigenvalue | 7.964 | 4.062 | 2.233 | 1.602 |
| Variance (%) | 44.242 | 22.566 | 12.408 | 8.902 |
| Total Variance (%) | 44.242 | 66.807 | 79.216 | 88.118 |

Linenhall has the lowest measurement (63 mm), while Guisborough shows the highest (76.2 mm). The same can be said for cranial base length where, again, Linenhall yields the lowest value (95.3 mm) and Guisborough the highest (102.7 mm). This is also true with regard to dimensions of the nose and the nasion-bregma chord.

When analyzing the second principal component, the samples appear more scattered, and differences are mainly located on the neural skull. The samples that show most of the similarities are St Owen, Ballumbie, Linenhall and Castle Hill with a second cluster formed by London, Guisborough and Linenhall. St Gregory is slightly separated from this cluster, while the two extremes are occupied by St Leonard and Poulton. In fact, regarding both the measurements of the parietal longitudinal arch and the bregma-lambda chord, St Leonard shows the lowest values (122 mm and 108.9 mm) and Poulton the highest (127.7 mm and 114.3 mm).

Finally, the third principal component distinguishes between samples based on the orbital breadth and length of the face. For this comparison, samples form two different clusters: 1) St Leonard, Poulton, and Ballumbie, and 2) St Owen and St Gregory. London and Linenhall are somewhat distinct, while samples that differ the most for these traits are Guisborough and Castle Hill. Concerning orbital breadth, Guisborough yields the greatest measurement (42.5 mm) and Castle Hill the smallest (38 mm).

## Females

For analysis of the females, five principal components were extracted, accounting for 91% of the total variance. To generate the scatterplot in Fig. 4, the first three components were used, which account for 73.1% of the overall variation (PC 1 = 37.835%, PC 2 = 20.164% and PC 3 = 15.184%).

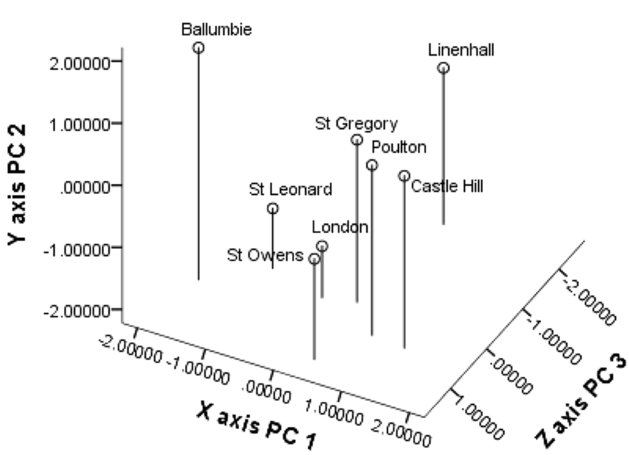


**Fig. 4** Three-dimensional scatterplot showing PC1, PC2 and PC3 for the female British samples

Table 4 shows the component matrix, with the loadings assigned to each variable used for this analysis. The variables with the largest loadings for the first principal component are MS 30 (bregma-lambda chord) with a value of .973 and MS 1 (maximum length of the neural skull) at .964. Significant impact is given by other variables, which are MS 27 (parietal longitudinal arch), MS 31 (lambda-opisthion chord), and MS 28 (occipital arch). The differences determined by the second component are related to the measurement MS 52 (orbital height) with a loading of .881. Relatively high values, but lower than the latter, are shown by the measurements MS 8 (maximum neurocranial breadth), MS 54 (nasal breadth), and MS 5 (cranial base length). Finally, the third principal component shows that the main differences are determined by MS 48 (height of the upper face), with a loading of .752, and MS 40 (length of the face), with a value of .745.

The spatial relations between samples is presented in Fig. 4. It was not possible to include Guisborough in the analysis, as the female sample did not have a complete set of measurements. The differences in the first component seem to distinguish most by neurocranial measurements. A cluster is formed by Poulton, Linenhall, St Owen and St Gregory. London is located slightly on the side of this group, while St Leonard is plotted in a more isolated location. The two most divergent samples are Ballumbie and Castle Hill. The first

**Table 4** Component loadings, eigenvalues, and variances for female British samples

| Measurement | Comp 1 | Comp 2 | Comp 3 | Comp 4 | Comp 5 |
|---|---|---|---|---|---|
| MS 1 | .964 | .181 | .088 | .122 | -.011 |
| MS 5 | .599 | -.658 | .372 | -.072 | .246 |
| MS 8 | -.183 | .694 | -.353 | .058 | .568 |
| MS 17 | .671 | -.510 | .033 | -.106 | .471 |
| MS 26 | .810 | .296 | -.305 | .070 | .311 |
| MS 27 | .957 | .037 | .108 | .188 | .163 |
| MS 28 | .850 | .281 | -.232 | .080 | -.307 |
| MS 29 | .789 | .290 | .217 | -.356 | .143 |
| MS 30 | .973 | .073 | -.084 | -.007 | .003 |
| MS 31 | .875 | -.098 | -.115 | -.017 | -.133 |
| MS 7 | -.217 | .057 | .652 | -.643 | .245 |
| MS 40 | .123 | -.572 | .745 | .217 | .001 |
| MS 46 | -.196 | -.413 | -.633 | .310 | .391 |
| MS 48 | -.112 | .378 | .752 | .241 | .157 |
| MS 51 | .254 | .266 | -.226 | -.530 | -.196 |
| MS 52 | .185 | .881 | .204 | -.153 | -.255 |
| MS 54 | -.426 | .671 | .154 | .018 | .549 |
| MS 55 | .128 | .462 | .417 | .756 | -.129 |
| Eigenvalue | 6.810 | 3.630 | 2.733 | 1.699 | 1.520 |
| Variance (%) | 37.835 | 20.164 | 15.184 | 9.440 | 8.445 |
| Total Variance (%) | 37.835 | 57.999 | 73.183 | 82.623 | 91.068 |

sample shows for both the bregma-lambda chord and the maximum length of the neural skull the lowest measurements (104 mm and 170.8 mm). On the other hand, Castle Hill showed the greatest measurements (113.4 mm and 180.7 mm).

The second component discriminates between female samples mainly by orbital height. The scatterplot shows the main cluster of Linenhall, St Gregory, Poulton, and Castle Hill. On the side is St Owen, with slightly lower values, while the samples at the greatest distance are St Leonard and London on one side, and Ballumbie on the opposite. However, regarding orbital height, Ballumbie does not have the greatest measurement (35.5 mm); this is shown by Castle Hill instead (35.8 mm). On the opposite side, London has the smallest mean (32.2 mm), which is near the value of St Leonard (32.6 mm). Analyzing maximum neurocranial breadth, Ballumbie does not report the highest mean value (142.9 mm). The highest is Poulton (143.2 mm). In this case, London and St Leonard are analogous, as they report an equivalent value (139.9 mm), but not the smallest, which is found in Poulton (138.2 mm). Conversely, Ballumbie and London represent opposites based on nasal breadth, where the first sample evidences the highest value (24.4 mm), while the second reports the lowest (23.4 mm).

Differences between groups on the third component are mainly driven by height of the upper face. Two clusters can be distinguished on the scatterplot. The first is formed by Castle Hill, Poulton and Ballumbie, while the second is formed by a looser association between London, St Gregory, and St Leonard. The most divergent samples are Linenhall and St Owen. Linenhall reported the lowest measurement in height of the upper face (63.5 mm), while St Owen expressed the greatest (67.6 mm). Similarly, regarding the length of the face, Linenhall expressed the lowest (86.5 mm), while the highest measurement is reported by St Owen (94 mm).

## Discussion

In answer to the first research question, there is a quantifiable difference in craniofacial morphology among the British medieval samples. They do not cluster based on spatial proximity, which is not unexpected given that this analysis is restricted geographically. Such variation would occur when there is a bioclimatic effect on the populations that leads to adaptation with different anthropometric distributions (Beals et al. 1984). Furthermore, the samples are not temporally distinct, as all date from the Middle Ages. However, discrimination could be a consequence of immigration of peoples outside Britain. The samples from cemeteries in towns with a historical record of resident immigrants are identified as outliers, i.e., Hythe, Scarborough, and London.

The second research question was proposed to understand what measurements drive the difference among British samples, and the results suggest they are detected by both facial and neurocranial dimensions. On the first principal component, male samples differ mainly in the face (e.g. nasal height, height of upper face, and cranial base length). On the second component, large loadings are associated with the neurocranium (e.g. bregma-lambda chord and parietal longitudinal arch). There is, however, a discrepancy in the female sample analysis that shows major discrimination based on the neurocranial measurements (e.g. bregma-lambda chord, parietal longitudinal arch, lambda-opisthion chord and occipital arch). The second principal component is associated with orbital height instead.

Previous studies proved a temporal trend leading to microevolutionary change over time in Britain (Mays 2000). The degree of variation between Neolithic and Bronze Age is reasonably high (Brothwell 2014). According to the author, further discrepancies among Anglo-Saxon and medieval peoples cannot be explained in terms of rapid microevolution. Brothwell and Krzanowski (1974) underlined differences between early Neolithic and Beaker/Food Vessel samples, suggesting a significant change in population composition. Two further medieval groups (brachycephalic in contrast with previous dolichocephalic samples) were compared. A different vault morphology from previous indigenous populations is evident, indicating further separation between Saxons and medieval samples. The theory is also supported by Tattersall (1968) and Goose (1981).

The comparison among British samples suggests homogeneity in craniofacial morphology during the Middle Ages. However, some groups present few dissimilarities, such as Guisborough. The archaeological and historical records do not mention any occurrence of migration during this time, neither the presence of Viking or Roman settlements in the previous periods. The discrepancy among craniometric data could be due to the small number of individuals (18 males and 14 females). In addition, females from this sample lack most of facial measurements, which is why they were excluded from analysis. The same can be said for Linenhall (males n=7, females n=3).

Another sample with evident dissimilarities is Scarborough, consistent with the findings of Tattersall (1968) and Little (1943). The latter author describes the cranial series as “aberrant” (1943: 33) and underlines how it cannot belong to any populations inhabiting the British Isles since Mesolithic times. Brothwell and Krzanowski (1974) reiterate these results. Several hypotheses are proposed. Little (1943) reports that Scarborough was a base for Vikings, who probably occupied the site until the 11$^{th}$ century, and the town was the only known settlement of Icelanders in England. By late 13$^{th}$ century, eastern ports were reached by a significant number of foreign sailors. They were mainly arriving from Flanders, northern France, Germany, Denmark and Norway. Scarborough was indeed the busiest port and hosted 235 naval landings during 1305 alone. It is estimated that approximately 4500 non-British fishermen were visiting Yorkshire fishing grounds each year. Furthermore, these ports had commercial links with Iceland. The demand for dried cod and stockfish encouraged British fishers to exploit Icelandic fisheries (Kowaleski 2003, 2007).

Different theories were suggested for the interpretation of Scarborough's place name. Whaley (2010) offers different options for the name, proposing Icelandic and Old Norse toponym's origins. The Nordic form is *Skarðaborg* in both languages, and originates from the word *Skarð*, meaning "gap, cleft", together with *borg*, which probably means "fortification". Different options are proposed for the first part of the name, which indicates an anthroponym or the landscape surrounding the town. In the first case, it could refer to *Skarði*, a fore- or nickname from the early Nordic world. The second option could originate from the word *skarð*, a topographical etymology linked to the landscape features of the area (Field 1980; Room 1988).

A difference is also detected between Guisborough and Castle Hill. Although the two towns are geographically close, one is coastal and the other is a rural town. As Anderson (1994) suggests, Guisborough could represent a closed breeding group. The dissimilarity could be a consequence of a major influx of people in Scarborough's port. Another explanation could be offered by the different background and origin of the towns. The possible presence of a Nordic settlement in Scarborough before the Middle Ages could have brought some variation in this group's cranial measurements.

As the national center for government and trading, London attracted people from all over Britain and Europe. It had different communities of foreigners, such as Italian merchants from Lucca known for silk trade (Lambert 2018), and others beyond Europe, such as Muslims from North Africa and the Middle East, and Jewish groups (Ormrod et al. 2018). Resident immigrants formed at least 6% of the population (Bolton 1998) and according to Lutkin (2016), between the years 1336 and 1584, 17,376 foreign residents can be identified, most of which were men. In London's suburbs, another 6725 foreigners were reported in Southwark and Middlesex. The largest identified group was "Teutonic", followed by Italians, French, Greek, Irish, Icelanders, Portuguese, and Danish. Teutonics were highly specialized artisans, such as weavers, cobblers, cordwainers, cappers, hat makers, goldsmiths, tailors, and beer brewers. Italian merchants and clerks were using the city as a trading outpost. French immigrants were reported as predominantly occupying servant roles. Most foreigners might have used London as first point of entry and moved to other areas of the country to seek employment (Lutkin 2016). Based on the record of alien subsidies and information of the time, the foreign community did not remain a closed group. Though numerous immigrants relocated with their nuclear family, evidence suggests that many married into the local community (Lutkin 2016).

The sample that most differs from the others is St Leonard, Hythe. The results demonstrate a clear separation from the main cluster. This relationship is consistent with Stoessiger and Morant (1932) findings, who also report that Hythe is widely removed from other series, with the shortest cranial length and narrowest orbits. Tattersall (1968) found that Hythe differs from other British samples at the 95% level of probability for the same indices and measurements.

Several authors (Parsons 1908; Stoessiger and Morant 1932; Wrathmell 2012) agree that this variability reflects a presence of people from Continental Europe. The singularity of this group could not be linked to a battle, as there are no evident signs of skeletal trauma. The authors believe Hythe may be considered "alien" as it cannot represent the population of the country at any time. A similarity with the Spitafields collection is proposed, which also resembles Italian crania, supposing that Hythe could represent Roman marine and auxiliaries' direct descendants who were historically stationed in the area (Stoessiger and Morant 1932; Wrathmell 2012). However, many Frenchmen resided in the region, who reached 58% of people with known nationality among outsiders (Ormrod et al. 2018) and people with a Flemish or Walloon origin. The influx could be a result of the town's importance as one of the Cinque Ports. The major towns, especially on the southern coast, were attractive to immigrants (Ormrod et al. 2018). In the 14th century, King Edward III encouraged skilled workers to move to East Anglia's and Kent's historic centers of woollen cloth production. The latter, together with Sussex, Hampshire, Surrey and Middlesex report the highest concentration of immigrants in the country. The Cinque Ports and London covered 41.2% of the national figure for taxpayers (Edwards 2002; Ormrod et al. 2018). The arrival of foreigners in Hythe could have therefore contributed to the variation detected by craniometric analysis.

Even though St Gregory and Hythe are located in the same region, they do not resemble each other as expected. Canterbury is not a port, and evidence suggests the influx of foreigners occurred later, during the 16th and 17th centuries (Edwards 2002).

The scatterplots show that both British and Hythe's sexes exhibit differences; however, the difference is more strongly displayed by male groups. The dissimilarity could thus be explained with a significant influx of men from Continental Europe, reflecting that the town was a major medieval port, and sailors were mainly men. The same can be said for the arrival of skilled artisans. The movement of the workforce would have been mainly made up of males, followed by women as part of the family unit. As reported by Kowaleski (2007), labor shortages raised a demand for sailors, and foreign men were recruited for ship crews. English kings employed foreign ships to transport troops and supplies for the Crown. Crews comprised Flemish, Dutch, Irish, Prussians, Portuguese, Spanish and Italians. Some sailors remained in the ports for extended periods and often contributed to the local economy, before returning home. However, others chose to stay, especially in the port towns (as confirmed by the alien subsidies).

Finally, St Owen, St Gregory, Poulton and Ballumbie cluster together. The last two represent rural locations, in which the populations probably led similar, agricultural lifestyles. In contrast, Gloucester and Canterbury are urban contexts, and therefore more open to the movement of people. Canterbury most likely experienced a later influx of pilgrims, and it is likely that the sample is part of a cemetery that was used predating this influx. Gloucester was known for its importance as an administrative and trading center, but its prominence was likely obfuscated by the nearby port of Bristol. According to Kowaleski (2007), Bristol witnessed abundant immigration, while Gloucester attracted more people from the surrounding countryside.

Overall, it could be that the samples from cities that witnessed waves of immigration immediately before and during the Middle Ages tend to differ most from ones considered more isolated. It is therefore important to underline how variation in craniometric measurements supports the impact that immigration had on population history and human variability, addressing answer the third research question noted above.

## Conclusion

This study demonstrates that British medieval population samples show significant variability in morphology and dimension of the skull. Dissimilarities among males are driven mainly by facial measurements on the first principal component, while on the second component discrimination is based on neurocranial measurements. In contrast, the female sample is primarily discriminated by neurocranial measurements. These differences led to the identification of a few outlier samples: Scarborough, London, and Hythe. The reason could be linked to foreign individuals migrating from outside Britain. The results are consistent with historical records of immigrants arriving and living in these urban sites. Scarborough was one of Britain's main eastern ports in the Middle Ages, with immigrants arriving from Iceland, Flanders, northern France, Germany, Denmark and Norway (Kowaleski 2003, 2007). Its Nordic origins are also reflected in the name-place *Skarðaborg* (Whaley 2010).

Another outlier, London, was the national center for government and trading, which attracted a considerable number of foreign peoples identified as "Teutonic", followed by Italians, French, Greek, Irish, Icelanders, Portuguese, and Danish (Lutkin 2016). The number of immigrants living and working in the city is confirmed by the records of alien subsidies and historical information from the time.

Hythe, one of the Cinque Ports, demonstrates results as far removed from the others. The presence of immigrant communities and influence on the local population is supported by several authors (Stoessiger and Morant 1932; Tattersall 1968; Ormrod et al. 2018). In fact, in the town were many French and peoples of Flemish or Walloon origin.

The authors believe that the present research demonstrates the utility of craniometric analysis as a modern and reliable approach in reconstructing ancient population history. Craniometry can be carried out in conjunction with other disciplines (e.g., genetic, history, linguistics, archaeology) but can also be undertaken without other evidence. Furthermore, the study demonstrates that modern Britain is the result of the positive impact immigrants had in building contemporary the country as a multicultural and biologically complex entity.

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**Authors' contribution** Satu Valoriani: Investigation, Data collection & Analysis, Writing - original draft, Funding acquisition.

Joel D. Irish: Methodology, Review & editing.

Megan King: Review & editing original draft.

Matteo Borrini: Conceptualization, Methodology, Writing - review & editing

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## Declarations

**Conflict of interest** none.



## References

Anderson S (1994) The human remains from Gisborough priory, Cleveland 1985-86. Ancient Monuments Lab Rep 47/94. Unpublished

Anthony DW (1990) Migration in archeology: the baby and the bathwater. Am Anthropol 92(4):895–914

Atkin M (1990) Excavations in Gloucester 1989: an interim report. Glevensis Gloucester District Archaeol Res Group Rev 24:2–13
Beals KL, Smith CL, Dodd SM, Angel JL, Armstrong E, Blumenberg B, Girgis FG, Turkel S, Gibson KR, Henneberg M, Menk R, Morimoto I, Sokal RR, Trinkaus E (1984) Brain size, cranial morphology, climate, and time machines [and comments and reply]. Curr Anthropol 25(3):301–330
Berry RJ, Firth HN (eds) (1986) The people of Orkney, vol 4. The Orkney Press Ltd., St. Ola, Kirkwall
Bolton J (1998) The alien communities of London in the fifteenth century: the subsidy rolls of 1440 and 1483-4. Donington: Paul Watkins
Borrini M (2022) Overcoming the chaotic numerology of osteometry. A proposal for a univocal numeric coding system for osteometric measurements of the human skeleton. Archivio per l'Antropologia e la Etnologia 152:17–31
Brothwell D, Krzanowski W (1974) Evidence of biological differences between early British populations from Neolithic to Medieval times, as revealed by eleven commonly available cranial vault measurements. J Archaeol Sci 1(3):249–260
Brothwell DR (2014) The biology of early British populations. In: O'Donnabhain B, Lozada M (eds) Archaeological human remains: global perspectives. Springer, Heidelberg, pp 65–84
Buikstra JE, Ubelaker DH (1994) Standards for data collection from human skeletal remains. Arkansas Archaeol Surv Res 44:206
Cachart R, Hall D (2014) Early Christian Long cists at Pitkerro, Drumsturdy Road, Dundee and Market Knowe. Longforgan Tayside and Fife Archaeol J 19(20):49–60
Capelli C, Redhead N, Abernethy JK, Gratrix F, Wilson JF, Moen T, Hervig T, Richards M, Stumpf MP, Underhill PA, Bradshaw P (2003) AY chromosome census of the British Isles. Curr Biol 13(11):979–984
Cunningham C, Scheuer L, Black S (2016) Developmental juvenile osteology. Academic Press
Davenport CAL (2018) Combining forensic anthropological and geological approaches to investigate the preservation of human remains in British archaeological populations and their effects on palaeodemography. Doctoral thesis, Liverpool, Liverpool John Moores University
Dawes JD, Magilton JR (1980) The cemetery of St Helen-on-the-walls, Aldwark. The archaeology of York. The Medieval Cemeteries, vol 12. Council for British Archaeology
Dytham C (2011) Choosing and using statistics: a biologist's guide, 3rd edn. Wiley-Blackwell, West Sussex, England
Edwards E (2002) Interpretations of the influence of the immigrant population in Kent in the sixteenth and seventeenth centuries. Archaeol Cantiana 122:275–292
Emerson RW (2015) Causation and Pearson's correlation coefficient. J Vis Impair Blindness 109(3):242–244
Emery MM (2000) The Poulton Chronicles: Tales from a Medieval Chapel. Poulton Archaeology Press, Williamsburgh, Virginia
Evans JA, Pashley V, Mee K, Wagner D, Parker Pearson M, Fremondeau D, Albarella U, Madgwick R (2022) Applying lead (Pb) isotopes to explore mobility in humans and animals. PLoS One 17(10):e0274831
Field J (1980) Place-names of Great Britain and Ireland. Reprint Edition, Exeter. David & Charles Publishers
Gillingham J, Griffiths RA (2000) Medieval Britain: a very short introduction. Oxford University Press, Oxford
Goose DH (1981) Changes in human face breadth since the Mediaeval period in Britain. Arch Oral Biol 26(9):757–758
Hall D, Cachart R (2005) Ballumbie Church (Murroes parish), long cist emetery; medieval church and graveyard. Discov Excavation Scotl 6:21
Harvati K, Weaver TD (2006) Human cranial anatomy and the differential preservation of population history and climate signatures. The Anatom Record Part A: Discov Mol Cell EvolBiology: An Official Publication of the American Association of Anatomists 288(12):1225–1233
Hemer KA, Evans JA, Chenery CA, Lamb AL (2013) Evidence of early medieval trade and migration between Wales and the Mediterranean Sea region. J Archaeol Sci 40(5):2352–2359
Hicks M, Hicks A (2001) St Gregory's Priory, Northgate, Canterbury: Excavations 1988-1991, vol 2. Canterbury Archaeological Trust LTD, Canterbury
Howells WW (1973) Cranial variation in man. A study by multivariate analysis of patterns of difference. Among recent human populations. Papers Peabody Museum Archaeol Ethnol 67:1–259
Hunter J, Ralston I (eds) (1999) The archaeology of Britain. Routledge, London
Jolliffe IT (2002) Principal component analysis. 2nd Ed. Springer, New York
Kaiser HF (1960) The application of electronic computers to factor analysis. Educ Psychol Meas 20(1):141–151
Kendall EJ, Montgomery J, Evans JA, Stantis C, Mueller V (2013) Mobility, mortality, and the middle ages: Identification of migrant individuals in a 14th century black death cemetery population. Am J Phys Anthropol 150(2):210–222
Kowaleski M (2003) The commercialization of the sea fisheries in medieval England and Wales. Int J Maritime Hist 15(2):177–231
Kowaleski M (2007) "Alien" Encounters in the Maritime World of Medieval England. Mediev Encount 13(1):96
Lall GM, Lamarseau MHD, Wetton JH, Batini C, Hallast P, Huszar TI, Zadik D, Aase S, Baker T, Balaresque P, Bodmer W, Børglum AD, de Knijff P, Dunn H, Harding SE, Løvvik H, Dupuy BM, Pamjav H, Tillmar AO et al (2021) Subdividing Y-chromosome haplogroup R1a1 reveals Norse Viking dispersal lineages in Britain. Eur J Hum Genet 29(3):512–523
Lambert B (2018) 'Nostri Fratelli da Londra': the Lucchese community in late Medieval England. In: Fulton H, Campopiano M (eds) Anglo-Italian cultural relations in the later Middle ages. York Medieval Press, York, pp 87–102
Lazaridis I, Patterson N, Mittnik A, Renaud G, Mallick S, Kirsanow K, Sudmant PH, Schraiber JG, Castellano S, Lipson M, Berger B, Economou C, Bollongino R, Fu Q, Bos KI, Nordenfelt S, Li H, de Filippo C, Prüfer K et al (2014) Ancient human genomes suggest three ancestral populations for present-day Europeans. Nature 513(7518):409–413. https://doi.org/10.1038/nature13673
Leggett S (2021) Migration and cultural integration in the early medieval cemetery of Finglesham, Kent, through stable isotopes. Archaeol Anthropol Sci 13(10):1–24
Little KL (1943) A study of a series of human skulls from Castle Hill. Scarborough Biometrika 33(1):25–35
Lutkin J (2016) Settled or fleeting? London's medieval immigrant community revisited. Medieval merchants and money: essays in honour of James L. Bolton. Institute of Historical Research, London, pp 137–155
Martin R, Saller K (1957) Lehrbuch der Anthropologie, I. Stuttgart: Gustav Fischer
Mays S (2000) Biodistance studies using craniometric variation in British archaeological skeletal material. In: Cox M, Mays S (eds) Human osteology in archaeology and forensic science. Greenwich Medical Media, London
Meindl RS, Lovejoy CO (1985) Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. Am J Phys Anthropol 68(1):57–66
Olalde I, Brace S, Allentoft ME, Armit I, Kristiansen K, Booth T, Rohland N, Mallick S, Szécsényi-Nagy A, Mittnik A, Altena E, Lipson M, Lazaridis I, Harper TK, Patterson N, Broomandkhoshbacht N, Diekmann Y, Faltyskova Z, Fernandes D et al (2018) The Beaker phenomenon and the genomic transformation of northwest Europe. Nature 555:190–196. https://doi.org/10.1038/nature25738

Oppenheimer S (2006) The Origins of the British. Constable and Robinson, London
Ormrod M, Lambert B, Mackman J (2018) Immigrant England, 1300–1550. Manchester University Press, Manchester
Parsons FG (1908) Report on the Hythe crania. J R Anthropol Inst G B Irel 38:419–450
Patterson N, Isakov M, Booth T et al (2022) Large-scale migration into Britain during the Middle to Late Bronze Age. Nature 601:588–594
Pearson MP, Sheridan JA, Jay M, Chamberlain A, Richards MP, Evans J (2019) The Beaker People: Isotopes, mobility and diet in prehistoric Britain. Prehistoric Society Research Paper, 7. Oxbow, Oxford
Pellegrini M, Pouncett J, Jay M, Pearson MP, Richards MP (2016) Tooth enamel oxygen "isoscapes" show a high degree of human mobility in prehistoric Britain. Sci Rep 6:34986. https://doi.org/10.1038/srep34986
Relethford JH (2004) Boas and beyond: migration and craniometric variation. Am J Hum Biol 16(4):379–386
Room A (1988) Dictionary of Place-names in the British Isles. Bloomsbury, London
Sahni D, Jit I, Suri S (1998) Time of fusion of the basisphenoid with the basilar part of the occipital bone in northwest Indian subjects. Forensic Sci Int 98(1-2):41–45
Schaefer M, Black SM, Scheuer L (2009) Juvenile osteology: a laboratory and field manual. Elsevier, Academic Press, London
Schiffels S, Haak W, Paajanen P, Llamas B, Popescu E, Loe L, Clarke R, Lyons A, Mortimer R, Sayer D, Tyler-Smith C, Cooper A, Durbin R (2016) Iron age and Anglo-Saxon genomes from East England reveal British migration history. Nat Commun 7(1):1–9
Shirley NR, Jantz RL (2011) Spheno-occipital synchondrosis fusion in modern Americans. J Forensic Sci 56(3):580–585
Sparks CS, Jantz RL (2002) A reassessment of human cranial plasticity: Boas revisited. Proc Natl Acad Sci 99(23):14636–14639
Spradley K, Jantz R (2021) What are we really estimating in forensic anthropological practice, population affinity or ancestry? Forensic Anthropol 4(4):309–318
Stoessiger BN, Morant GM (1932) A study of the crania in the vaulted ambulatory of Saint Leonard's church, Hythe. Biometrika 24:135–202
Tattersall I (1968) Multivariate analysis of some medieval British cranial series. Man 3(2):284–292
Töpf AL, Gilbert MTP, Dumbacher JP, Hoelzel AR (2005) Tracing the phylogeography of human populations in Britain based on 4th–11th century mtDNA genotypes. Mol Biol Evol 23(1):152–161
Weale ME, Weiss DA, Jager RF, Bradman N, Thomas MG (2002) Y chromosome evidence for Anglo-Saxon mass migration. Mol Biol Evol 19(7):1008–1021
Whaley D (2010) Scarborough revisited. Nomina 33:87–100
White WJ, Dyson T (1988) Skeletal remains from the cemetery of St. In: Nicholas shambles, City of London, vol 9. London & Middlesex Archaeological Society, London
WORD database, Museum of London. Accessed (19/03/2015) https://www.museumoflondon.org.uk/collections/other-collection-databases-and-libraries/centre-human-bioarchaeology/osteological-database
Wrathmell S (ed) (2012) A history of Wharram Percy and its neighbours. York University Archaeological Publications, York, p 15