



Cranial secular change from the nineteenth to the twentieth century in modern German individuals compared to modern Euro-American individuals

Katharina Jellinghaus¹ · Katharina Hoeland² · Carolin Hachmann¹ · Andreas Prescher³ · Michael Bohnert¹ · Richard Jantz⁴

Received: 13 October 2017 / Accepted: 21 February 2018 / Published online: 22 March 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract

Studying secular changes on human skulls is a central issue in anthropological research, which is however insufficiently investigated for modern German populations. With our study, we focus on morphological cranial variations within Germans during the nineteenth and twentieth centuries. To study this, we recorded different facial landmarks from a cohort study of about 540 German individuals of different age and sex by calculating their cranial size, shape dimensions, and cranial module and cranial capacity to get information about variations occurring during the decades. According to this, measured variables for Germans and Americans, to which we compared our results, were maximum cranial length (glabella-occipital length), basion-bregma height (BBH), basion-nasion length (BNL), maximum cranial breadth (XCB), and cranial base breadth (AUB). Cranial size was calculated as the geometric mean of GOL, BBH, and XCB. Samples were organized into quarter century birth cohorts, with birth years ranging from 1800 to 1950. One-way ANOVA was used to test for variation among cohorts. Over the past 150 years, Americans and Germans showed significant parallel changes, but the American cranium remained relatively higher, with a longer cranial base, as well as narrower than the German cranium. Our results should also lead to the extension of the range of populations listed and investigated for Fordisc®, a forensic software to identify unknown individuals as from their skeletal remains or just parts of them. Fordisc cannot provide a satisfying identification of European individuals yet because the database is missing enough European reference samples.

Keywords Forensic anthropology · Secular change · Identification · Cranial secular change

Introduction

Historically cranial change was most intensively studied by paleoanthropologists interested in a time frame of thousands

or hundreds of thousands of years. Short-time-scale changes (100–200 years) have been sufficiently documented but there is little understanding of the mechanisms involved in the general nature of cranial changes. The decrease in skull size since the end of Pleistocene has been examined by Henneberg in 1988. He showed that the cranial capacity in Europeans has decreased about 9.9% in males and 17.4% in females from maximum in the Mesolithic to the nineteenth century. [1].

New and recent investigations on changes in cranial dimensions include lateral radiographs and compare crania of modern orthodontic patients to crania of individuals who were living in earlier centuries [2–4]. By evaluating changes in size and shape of skulls and jaws in British populations of 30 different skulls, Rock et al. recognized greater horizontal measurements in the base of the anterior cranial fossa and in the maxillary of modern skulls than in medieval skulls. Moreover, in twentieth century skulls, cranial vault measurements were

✉ Katharina Jellinghaus
katharina.jellinghaus@uni-wuerzburg.de

¹ Institute of Forensic Medicine, Julius-Maximilians-University, Versbacher Str. 3, 97078 Würzburg, Germany

² Department of Chemistry, University of Tennessee, Knoxville, TN 37996, USA

³ Institute of Molecular and Cellular Anatomy Medical Faculty, RWTH Aachen University, Wendlingweg 2, 52057 Aachen, Germany

⁴ Department of Anthropology, University of Tennessee, 250 South Stadium Hall, Knoxville, TN 37996-0720, USA

significantly higher, particularly in the anterior cranial fossa [4].

Secular trends in the facial skull cover the past 100–300 years [5]. Scientific work focused intensively on three-dimensional geometric morphometrics demonstrating a significant change in cranial morphology over a roughly 150-year period [6–8]. A study investigating craniofacial secular change in American Blacks and Whites showed that in the sagittal plane, most of the morphometric change is associated with a downward movement of the cranial base. Secular change in American crania is proximately related to a decrease in cranial base breadth and an increase in cranial capacity; these changes demonstrate ultimately a reflection of improved infant growth due to better health and nutrition [8]. Weisensee et al. showed that the patterns of secular change such as a decreased facial breadth and a more inferior placed cranial base are similar to observations in other populations in the USA, Japan, and Europe. Thus, a similar pattern of secular change occurred in genetically and geographically diverse populations experiencing modern environmental conditions [7]. Detailed analyses by Jantz et al. examined secular change in cranial morphology from the mid of the nineteenth century to the 1970s by using five craniofacial variables. As a result, Jantz et al. could represent remarkable changes in the size and shape of the cranial vault, since there was an increase in the vault height and the vault became longer and narrower, too. Overall, Jantz et al. stated that changes in shape are greater than changes in size of the cranial vault and that such characteristic variations must occur by early childhood [6]. While Weisensee and Jantz researched the pattern of secular change in the cranial morphology of US and Portuguese individuals in 2016, they determined that the morphometric cranial change in Portuguese has been considerably less than in Americans [9].

Furthermore Proença et al. analyzed the three-dimensional (3D) changes in craniofacial morphology between identified Portuguese skulls from the eighteenth to the twentieth century and modern Portuguese individuals randomly selected from the armed forces. The results of this study showed a decrease in the anterior cranial base in skulls from each subsequent century. Moreover, the authors found a significant difference in the mean value of different craniofacial variables between males and females of the twenty-first century skulls [10]. In another study, Angel compared American skeletons dating from 1675 to 1879 with modern middle-class skeletons of white and black individuals. He found out a noticeable change skull morphology which was characterized by increase in head height, retraction of the face with increasing nose projection, and longer mastoids. White colonial individuals compared to modern showed a strong continuity where Blacks changed more [11].

Skull change of South African Negro males was also investigated by Cameron et al. in 1990. The researchers

arranged South African Negro male crania in 5-year birthdate cohorts, ranging from 1880–1884, 1890–1894, up to 1930–1934. Cameron et al. found that the cranial length exhibited a significant increase from 1890 to 1930. Over the same time period, Cameron et al. were also able to detect a statistically significant decline of cranial base height and the cranial base height index [12].

In their study on multivariate analyses of craniometric data in 2009, Ousley et al. supported the hypothesis that there are morphological differences between American Whites and Blacks. They confirmed significant geographic patterning in human variation with their data while also finding differences among groups within continents. Furthermore, Ousley et al. showed with their results that humans could be accurately classified into geographic origin using craniometrics even though there is overlap among groups; in detail, 74% of crania from 27 world populations from Howells could be accurately classified into their correct population [13].

It raises the questions of what has happened concerning cranial secular change elsewhere in Europe, Germany in particular, from the nineteenth to the twentieth century and if there is a possibility to differentiate between modern European—especially German—individuals using craniometrics, generating a valid method of identification in terms of forensic contexts.

The purpose of the present study is to extend the already existing findings regarding the general nature of cranial changes and specific mechanisms responsible for secular changes in modern German populations within the period from the nineteenth to the twentieth century. Central to this aim is a comparison of cranial morphology from modern Germans of the nineteenth to the twentieth century with Euro-Americans to further broaden the already existing Fordisc® data set. The ultimate goal is to evaluate the suitability of the German sample for the inclusion in Fordisc®, which still lacks an extensive modern German sample [14]. Our concrete expectations involve classifying German individuals as such next to other European individuals. Different investigations are in progress and show promising data for a valid discrimination of modern Europeans. The results of Fordisc used in forensic anthropology shall provide more than just a discrimination of European, Asian, and African origins in the future. But only when a valid database will be achieved, it can be proven how effective Fordisc will work for Europe.

Material and methods

With regard to our study samples, the term “Euro-Americans” refers to American citizens with known predominantly north-west European ancestry. Data from Euro-Americans were obtained from the Terry and Todd anatomical collections (nineteenth century), forensic cases, and the University of

Tennessee donated collection (twentieth century). Birth and death years were available for all individuals.

The term “German” indicates people with full German heritage and refers to information from museum records (nineteenth century), cemetery data (nineteenth and twentieth centuries), and positively identified forensic cases (twentieth century). Any other skulls not fitting the mentioned criteria were removed from the database. However, it cannot be guaranteed having a certain amount of unknown genetic admixture within the groups since the data have been collected postmortem.

A MicroScribe G2X digitizer with the program 3Skull was used for all cranial measurements in order to compute the measurements from the coordinates. All Euro-Americans were obtained from the American Forensic Data Bank (FDB). The German samples contained skulls from modern forensic cases in Munich, Mainz, Freiburg, Aachen, Tuebingen, Goettingen, and Cologne, from cemetery exhumations near Wuerzburg (Bavaria) and Inden (North Rhine Westphalia) and from the following collections: Helmer collection from the Centre for Anatomy and Human Identification in Dundee, Scotland; Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte (BGAEU), Anatomisches Institut der Charité Berlin, Institut für molekulare und zelluläre Anatomie Aachen; the Smithsonian Institution, National Museum of Natural History, Washington DC; and the Morton Collection, University of Pennsylvania Museum. Birth and death years and also sex were known from all German samples.

All samples were divided into seven 25-year birth cohorts, beginning with 1800 and ending with 1950. Table 1 shows sample sizes by birth year cohorts. These sample sizes are maximum; individual analyses are slightly lower due to missing data. The German sample was tested for variation among birth year cohorts using one-way analysis of variance, separately for each variable and each sex. Two-level analysis of variance was used to assess differences between Euro-Americans and Germans. Birth cohort and country of origin (America and Germany) were the applied factors. Discriminant function

analysis was conducted to determine whether Euro-Americans and Germans could be successfully classified. Statistical analyses were conducted using NCSS 10 Statistical Software (2015) and Fordisc3.1® [15].

Variables for our paper were limited to five vault measurements: glabello-occipital length (GOL), basion-bregma height (BBH), basion-nasion length (BNL), maximum cranial breadth (XCB), and biauricular breadth (AUB). These variables describe variation in length, height, and breadth of the cranial vault. Cranial size was computed as the geometric mean of GOL, BBH, and XCB. The sample size ranges are the minima and maxima over the six variables used. After a one-way ANOVA to test whether Germans exhibit significant variation among quarter century birth cohorts, a two-level ANOVA comparing Germans and Euro-Americans was performed. For interpreting, we compared the meaning of secular variation with birth cohort and country as factor variables.

Results

Table 2 shows the ANOVA results for German females and males. BBH and BNL show highly significant variation among birth cohorts in both sexes. GOL and AUB are not significant in sex, while XCB is significant only in males and size only in females. The results of the two-level ANOVA comparing Germans and Euro-Americans by birth cohorts are shown in Table 3. Almost all variables show significant variation among quarter century birth cohorts. Only AUB in males and XCB and AUB in females fail to reach statistical significance. Country of origin is uniformly significant for males, while in females, it is limited to BBH, XCB, and AUB. The interaction term tests whether Germans and Euro-Americans exhibit a similar pattern of secular change. All vault measurements in males except AUB are non-significant.

Figure 1 shows the plots for GOL, BBH, BNL, and XCB. GOL, BBH, and BNL show a common pattern of decrease from early to late nineteenth century; thereafter, they increase.

Table 1 Distribution of sample by groups and quarter century birth cohort. *EAF* Euro-American females, *EAM* Euro-American males, *GF* German females, *GM* German males

	EAF	EAM	GF	GM	Total
1800	0	8	5	13	26
1825	2	58	8	25	93
1850	14	57	23	57	151
1875	77	51	14	18	160
1900	125	134	75	74	408
1925	241	516	58	114	929
1950	242	350	13	43	648
Total	701	1174	196	344	2415

Table 2 *F* ratios and probabilities testing for variation among quarter century birth cohorts in Germans (*ndf* and *ddf* numerator and denominator degrees of freedom for *F* test)

	Males		Females	
	<i>F</i> (ndf, ddf)	<i>P</i>	<i>F</i> (ndf, ddf)	<i>P</i>
GOL	1.64 (6306)	0.1355	1.53 (6170)	0.1701
BBH	11.50 (6311)	<0.0001	7.41 (6173)	<0.0001
BNL	8.90 (6.318)	<0.0001	7.93 (6179)	<0.0001
XCB	3.39 (6314)	0.0030	0.56 (6171)	0.7614
AUB	1.74 (6323)	0.1122	1.06 (6179)	0.3918
Size	1.91 (6293)	0.0790	2.78 (6162)	0.0133

Table 3 Two-level ANOVA results comparing Germans and Americans by birth cohort

	Quarter century		Country		Interaction	
	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
Males						
GOL	6.73	<0.0001	44.88	<0.0001	1.22	0.2912
BBH	36.26	<0.0001	58.48	<0.0001	1.53	0.1646
BNL	23.45	<0.0001	25.70	<0.0001	0.78	0.5868
XCB	7.09	<0.0001	33.54	<0.0001	1.12	0.3466
AUB	1.65	0.1293	14.38	<0.0001	3.54	0.0018
Size	8.11	<0.0001	14.91	0.0001	0.77	0.5966
Females						
GOL	4.11	0.0011	2.09	0.1483	1.27	0.2726
BBH	23.79	<0.0001	13.44	0.0003	1.63	0.1484
BNL	17.59	<0.0001	1.00	0.3170	0.83	0.5309
XCB	1.85	0.1015	9.94	0.0017	0.67	0.6432
AUB	1.33	0.2482	18.54	<0.0001	2.77	0.0172
Size	7.97	<0.0001	0.75	0.3880	1.62	0.1525

XCB declines more or less regularly, although in German individuals, the change is more pronounced. While the change in Germans and Euro-Americans is more or less parallel, Euro-American crania can be described as longer, higher, and narrower and with a longer cranial base than German crania. These differences are mostly observed through the time period, but by the last cohort, Germans and Euro-Americans have converged to similar values for BNL and XCB. The pattern of change in females is broadly similar to males (Fig. 2), although in some cases it is more erratic, especially GOL and BBH. For GOL and XCB, Germans and Euro-Americans converge to common values in the last birth cohort. The generalization for males also applies to females; Germans have wider and lower crania than Euro-Americans and a shorter cranial base until the last birth cohort. Euro-American males also have larger crania than Germans, but females do not differ in size (graphs not shown).

It is important to address the forensic implications of the findings reported above: Germans and Euro-Americans with twentieth century birth years (the last three quarter century cohorts) were imported into Fordisc 3.1®. Table 4 shows the classification results by group and sex. It is immediately apparent that Germans are not classified as correctly as Euro-Americans. The misclassification involves both groups and sexes. If sex is ignored, then 377 (24.4%) Euro-Americans are misclassified as Germans, while 102 (33.0%) Germans are misclassified as Euro-Americans, a difference of almost 9%. For sex, 236 (15.3%) Euro-Americans are misclassified, while 65 (21.0%) Germans are misclassified, a difference slightly greater than 5%. The reasons for this classification pattern can be discerned by examining the distance between groups and sexes. The Mahalanobis distances (*D*) are plotted

in Fig. 3. The lengths of the lines connecting groups and sexes are the distances, and the number adjacent to each line gives the Mahalanobis distance. It shows that Germans are less dimorphic than Euro-Americans (1.51 vs 1.99) and that the female group differences are less than the male group differences (1.00 vs. 1.31).

Discussion

Our results show that there have been significant changes in the cranial shape from the nineteenth to the mid-twentieth century in both Germans and Euro-Americans. In both groups, the cranium becomes longer, higher, and narrower, with a longer cranial base. However, throughout this period of time, German-American differences are for the most part maintained. In general, almost throughout the entire period of time, we found that the Euro-American cranium is higher with a longer cranial base and narrower both for males and females in comparison to Germans.

Several authors such as Boas (1911), Hulse (1964), and Jantz and Jantz (2016) have suggested that exogamy (outbreeding) may play a role in cranial change [2, 16, 17]. Thus Boas (1911) called attention to the influence of the breakdown of former ethnic marriage barriers as a potential cause of the changes in descendants of immigrants [16]. Hulse (1964) showed how outbreeding caused significant changes in body morphology. Interestingly, Hulse also found these changes to occur in the cranial morphing over time [17]. Euro-Americans have experienced extensive breakdown of genetic barriers that existed and still exist in their European ancestors. Barbuijani and colleagues showed in 1991 that in Europe, language is a barrier to gene flow, meaning people tend to marry within their language group [18]. In a further investigation on genetic variation in Europeans, Novembre et al. could show in 2008 that despite low average levels of genetic differentiation among Europeans, there is a close relationship between genetic and geographic distances. The results of the study illustrated that a geographical map of Europe arises as an efficient two-dimensional summary of genetic variation in Europeans [19]. In the USA by contrast, a breakdown of ethnic intermarriages could be demonstrated, where language barriers have mostly been removed [20]. Germans, while not immune to effects of breakdown of inbreeding, presumably have had a more closed gene pool than Euro-Americans. Yet, Germans appear to have experienced cranial change more or less comparable to Euro-Americans, suggesting that breakdown of inbreeding may not play a substantial role.

The quality of life has substantially changed for both populations—Germans and Euro-Americans—and this may have effected on the variation in the cranial shape, too. So far, specific mechanisms leading to these cranial alterations have

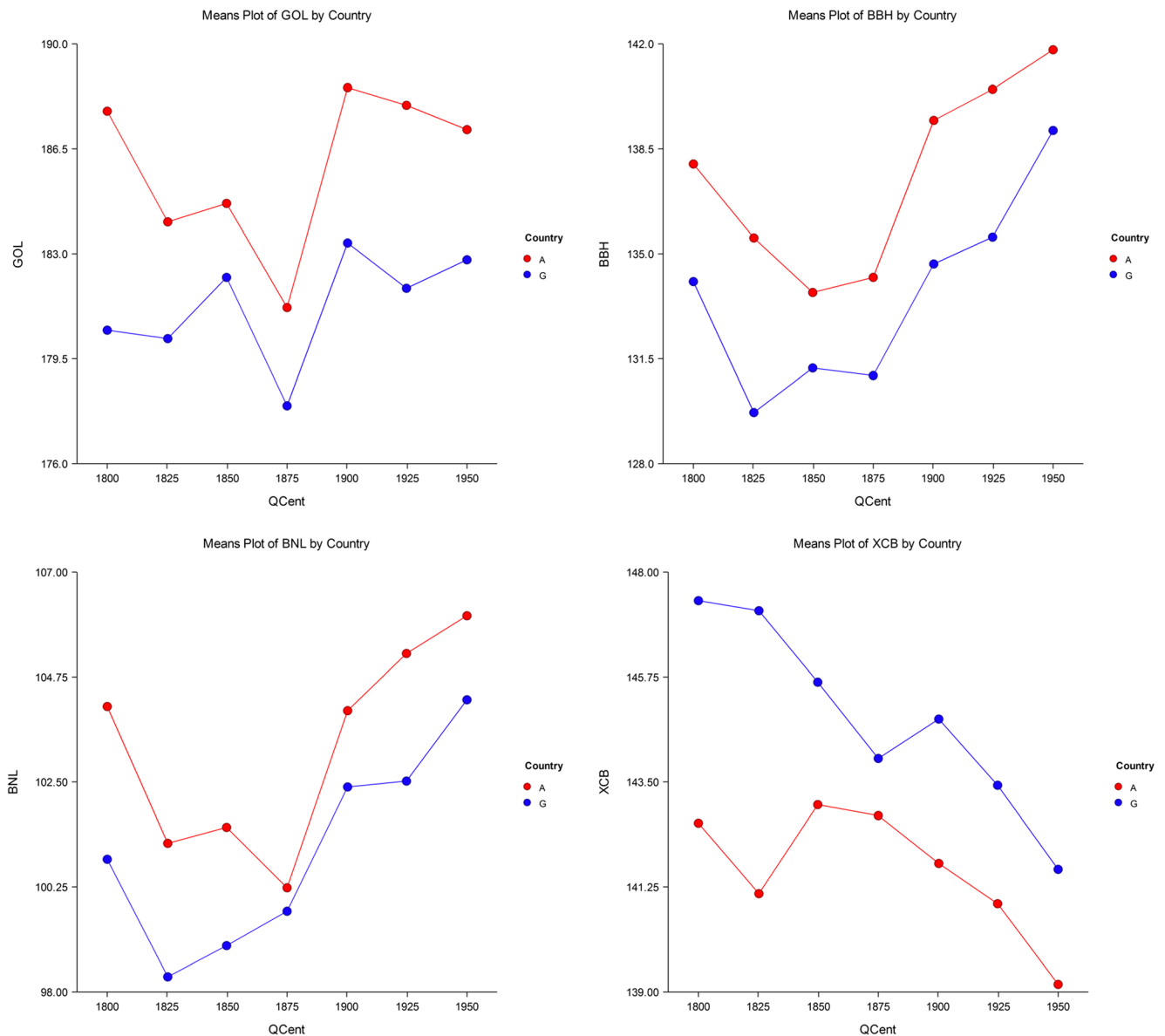


Fig. 1 Plots showing secular changes in German and American males for four cranial vault measurements differentiated by country. Yaxis measurements are in mm

not been found; however, they likely result from modified growth patterns due to an increase in wealth, health, and better nutrition habits as well as less physical work and decreases in mortality and morbidity [2].

Another aspect determining the varieties of changes is the quality of life; infant mortality is often used as an indicator for that. Malina et al. showed that next to remarkable secular changes in height, long bone length, and cranial morphology in the American population, there had been a decline in infant and childhood mortalities [21]. Schmidt et al. could demonstrate similar results for European populations; they found a strong relation between secular increase in height and decrease in postneonatal mortality [22]. Jantz and Jantz could demonstrate in another study on American populations that infant mortality had a very high correlation with cranial

variables. They indicated that infant and postneonatal mortalities would reflect general quality of life, including health and nutritional factors which influence growth. What still remained unclear in this and in another study of Jantz and Jantz was the extent to which infant and postneonatal mortalities interact with growth potential. As an explanation for the observed development that many infants and children survive today who would not have had been born in the last century, Jantz and Jantz see changes in the gene pool in the last century, visible in the extent to which genetic differences in growth potential exist between survivors and nonsurvivors [2, 6].

Further results show that under the right circumstances, cranial change similar to that seen in Euro-Americans can also be seen elsewhere. Cranial change has also been seen in Portugal but appears to be less pronounced in America [7,

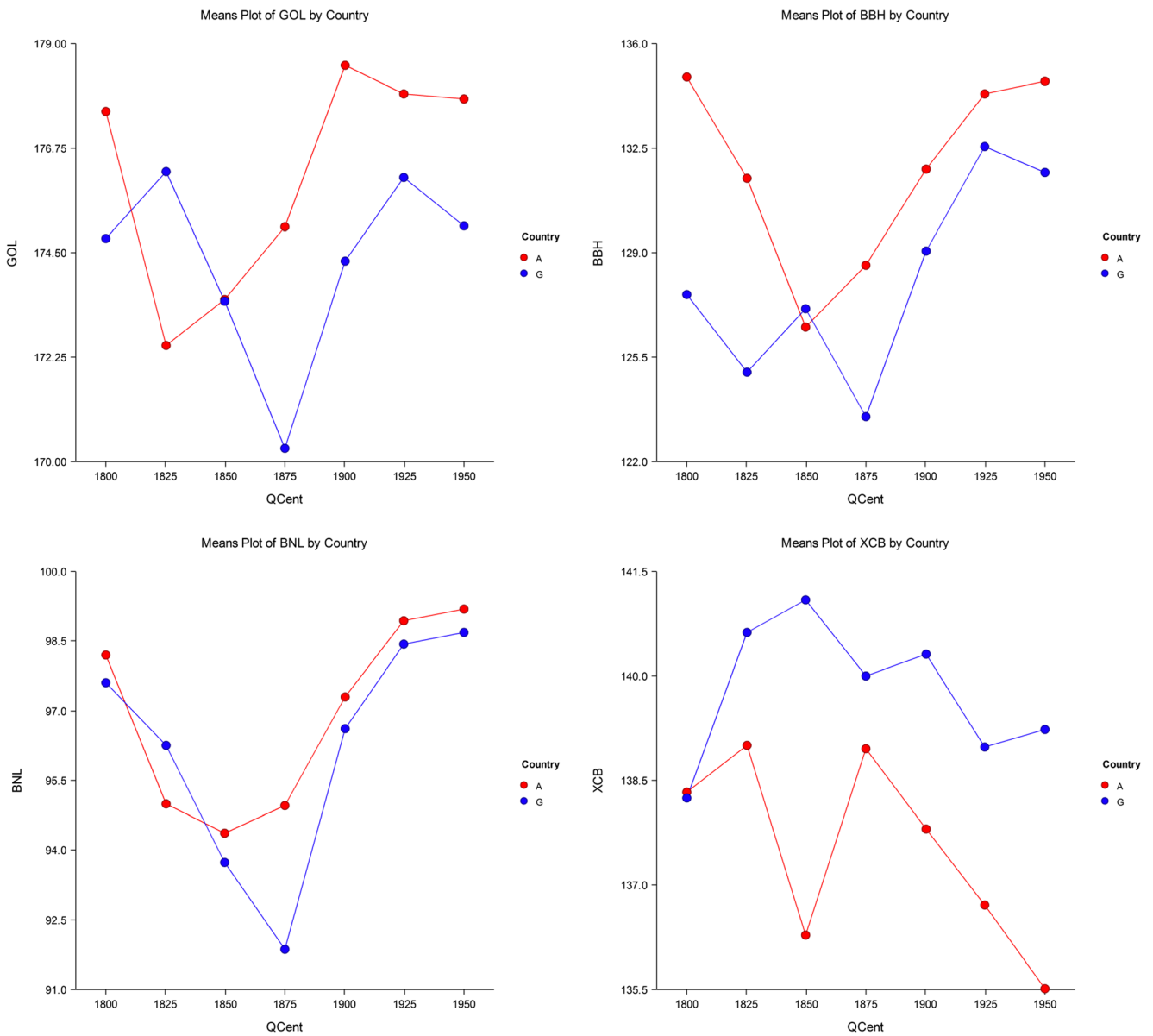


Fig. 2 Plots showing secular changes in German and American females for four cranial vault measurements differentiated by country. Yaxis measurements are in mm

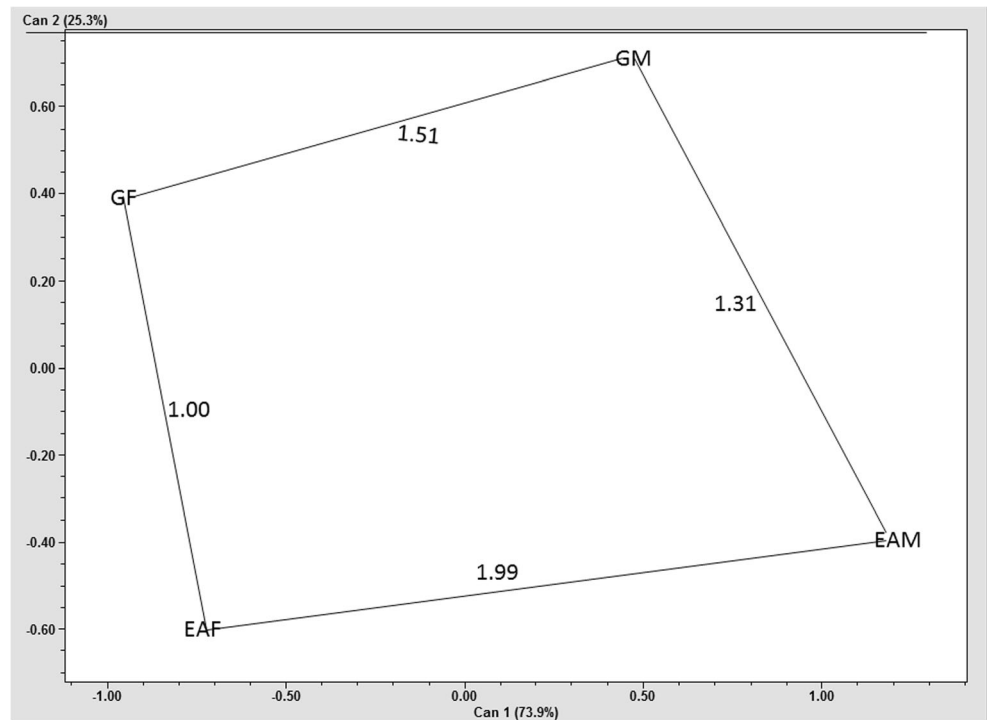
9]. One might expect that two world wars during the twentieth century would have had a negative impact on German quality of life; however, this is not visible while looking at this as a main factor influencing cranial change. In the late nineteenth

century, levels of infant mortality were still extremely high and ranging from around 250 per 1000 live births in Germany. At the turn of the century, infant mortality began to fall so that by 1950, most national infant mortality rates

Table 4 Fordisc 3.1 classification table using five vault variables. AF Euro-American females, AM Euro-American males, GF German females, GM German males

From group	Total number	Into group (counts)				
		AF	AM	GF	GM	Correct (%)
AF	585	358	64	122	41	61.2
AM	961	99	648	32	182	67.4
GF	120	34	3	64	19	53.3
GM	189	16	49	27	97	51.3
Total correct	1167 out of 1855 (62.9%) cross-validated					

Fig. 3 Canonical variate plot of Mahalanobis distances (D) between groups and sexes. Lengths of lines correspond to distances and numbers adjacent to lines give the distance



ranged between 20 and 80 per 1000 live births in Germany. The vital registration series suggests that the significant reduction in infant mortality was achieved through the increased number of women choosing breastfeeding for their children as a result of the deprivation during the First World War years [23, 24]. As a result, it can be clearly seen that secular change continued through the birth cohorts of the war years.

Our results furthermore shed some light on Ramsthaler et al.'s findings concerning inability of Fordisc® to classify Germans correctly by sex. Ramsthaler et al. performed a study in which they determined the accuracy of sex determination of 98 skulls from recent forensic cases of known age, sex, and Caucasian ancestry from cranium collections in Frankfurt and Mainz (Germany) by using the statistical software solution Fordisc® [25]. The results of our working group show that Germans differ systematically from Euro-Americans, and, more importantly, Germans appear to be less sexually dimorphic than Americans, resulting in greater misclassification rates in Fordisc [16, 23].

Our results conclusively demonstrated significant changes over the past 150 years, whereas Euro-American crania are relatively higher, larger with longer cranial bases, and narrower than German crania. Our study investigated the effect of the already existing findings regarding the general nature of cranial changes and specific mechanisms responsible for secular changes for modern German population within the period from the nineteenth to the twentieth century. We compared our results with existing values of modern American populations within the period from the nineteenth to the twentieth century. Our data for modern German populations

expand the already existing European sample for Fordisc®, which will further improve classification rates, e.g., concerning sex and ancestry. Knowledge about modern cranial morphology in Germans will also help in the general understanding of cranial changes from the past to the present in German individuals and the role of environmental factors.

Acknowledgements The authors would like to acknowledge and thank Dr. Michael Francken, Prof. Prescher, Dr. Karl-Heinz Schiwy-Bochat, Prof. Matthias Graw, Dr. Stephanie Holley, Dr. Birgit Großkopf, Thomas Struchholz, Helmuth Schlereth, Thomas and Kevin Volk, Prof. Thomas Riepert, David Hunt, PhD, Douglas Owsley, PhD, Prof. Ursula Wittwer-Backofen, Katrin Koel-Abt, PhD, and Barbara Teßmann for providing the skull material and furthermore Laura Manthey, Sajid Matin, and Jana Geiger for data collection and making thus our investigations possible.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Henneberg M (1988) Decrease of human skull size in the Holocene. *Hum Biol* 60:395–405
2. Jantz RL, Jantz LM (2016) The remarkable change in Euro-American cranial shape and size. *Hum Biol* 88(1):56–64

3. Jonke E, Prossinger H, Bookstein FL, Schaefer K, Bernhard M, Freudenthaler JW (2008) Secular trends in the European male facial skull from the Migration Period to the present: a cephalometric study. *Eur J Orthod* 30(6):614–620
4. Rock WP, Sabieha AM, Evans RIW (2006) A cephalometric comparison of skulls from the fourteenth, sixteenth and twentieth centuries. *Br Dent J* 200(1):33–37
5. Floyd R, Fogel RW, Harris B, Hong SC (2011) *The changing body: health, nutrition, and human development in the western world since 1700*. Cambridge University Press, New York
6. Jantz RL, Meadows Jantz L (2000) Secular change in craniofacial morphology. *Am J Hum Biol* 12:327–338
7. Weisensee KE, Jantz RL (2011) Secular changes in craniofacial morphology of the Portuguese using geometric morphometrics. *Am J Phys Anthropol* 145:548–559
8. Wescott DJ, Jantz RL (2005) Assessing craniofacial secular change in American blacks and whites using geometric morphometry. In: Slice DE (ed) *Modern morphometrics in physical anthropology*. Kluwer/Plenum, New York, pp 231–245
9. Weisensee KE, Jantz RL (2016) An examination of the differential effects of the modern epidemiological transition on cranial morphology in the United States and Portugal. *Hum Biol* 88(1):30–37
10. Proença HHFA, Slavicek R, Cunha E, Sato S (2014) A 3D computerized tomography study of changes in craniofacial morphology of Portuguese skulls from the eighteenth century to the present. *Int J Stomatol Occlusion Med* 7(2):33–45
11. Angel JL (1976) Colonial to modern skeletal change in the USA. *Am J Phys Anthropol* 45(3):723–735
12. Cameron N, Tobias PV, Fraser WJ, Nagdee M (1990) Search for secular trends in calvarial diameters, cranial base height, indices, and capacity in South African Negro crania. *Am J Hum Biol* 2(1):53–61
13. Ousley SD, Jantz RL, Freid D (2009) Understanding race and human variation: why forensic anthropologists are good at identifying race. *Am J Phys Anthropol* 139(1):68–76
14. Manthey L, Jantz RL, Bohnert M, Jellinghaus K (2016) Secular change of sexually dimorphic cranial variables in Euro-Americans and Germans. *Int J Legal Med* 131(4):1113–1118
15. Jantz RL, Ousley SD (2005) *Fordisc*, version 3.1. Knoxville, TN: University of Tennessee
16. Boas F (1911) *Changes in bodily form of descendants of immigrants (final report)*. Reports of the Immigration Commission 38. Government Printing Office, Washington, DC
17. Hulse FS (1964) Exogamy and heterosis. *Yearb Phys Anthropol* 9: 240–257
18. Barbujani G, Sokal RR (1991) Zones of sharp genetic change in Europe are also linguistic boundaries. *PNAS* 87:1816–1819
19. Novembre J, Johnson T, Bryc K, Kutalik Z, Boyko AR, Auton A, Indap A, King KS, Bergmann S, Nelson MR, Stephens M, Bustamante CD (2008) Genes mirror geography within Europe. *Nature* 456(7218):98–101
20. Alba RD, Golden RM (1986) Patterns of ethnic intermarriage in the United States. *Soc Forces* 65:202–223
21. Malina RM (1979) Secular changes in size and maturity: causes and effects. *Monogr Soc Res Child Dev* 179:59–120
22. Schmidt IM, Jorgensen MH, Michaelsen KF (1995) Height of conscripts in Europe: is postneonatal mortality a predictor? *Ann Hum Biol* 22:57–67
23. Jantz RL (2004) The meaning and consequences of morphological variation. In *Understanding race and human variation conference, “race and human variation: setting an agenda for future research and education.”* Alexandria, VA: September, pp 12–14
24. Corsini CA, Viazzo PP (1997) Introduction: Recent advances and some open question in the long-term study of infant and child mortality. In: *The decline of infant and child mortality: The European Experience: 1750–1990*. Kluwer Law International, The Hague, The Netherlands, pp xiii–xxxi
25. Ramsthaler F, Kreutz K, Verhoff MA (2007) Accuracy of metric sex analysis of skeletal remains using *Fordisc* based on a recent skull collection. *Int J Legal Med* 121(6):477–482