Slov. Antropol., 24(1-2):1-15, 2021

DEGREE OF SIMILARITY OF CRANIAL DIMENSIONS IN CONNECTION WITH SEXUAL DIMORPHISM IN A DOCUMENTED SAMPLE OF EIGHT MEMBERS OF THE SPORCK AND SWÉERTS-SPORCK FAMILIES (BOHEMIA, 17TH – 20TH CENTURIES)

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Abstract: Analyses of osteological non-metric traits and frontal sinuses in the noble Sporck and Swéerts-Sporck families have already shown that the degree of similarity between individuals reflects their documented family relationships. The aim of this study was to verify whether these are also reflected by cranial dimensions, the variability of which, according to some previous studies, is also influenced by genetic factors. The sample comprises eight adult individuals from the 17th – 20th centuries, in whom 36 cranial dimensions were measured. To remove the possible effect of sexual dimorphism on the similarity of individuals, 26 indices of the evaluated dimensions were calculated, and all measured dimensions were adjusted to size. The degree of similarity between individuals was calculated based on all three datasets. In all cases, a positive relationship between the degree of relatedness and biodistance was evident, even in the unadjusted measured dimensions, despite their significant sexual dimorphism. In addition, there was a greater degree of similarity between biologically related compared to unrelated individuals in all three datasets. This suggests that genetics could affect craniometric traits regardless of sex, although the possible influence of other factors on the results is also discussed.

Key words: craniometry, genealogically documented sample, biological distance, inbreeding, sexual dimorphism, aristocracy

Introduction

Osteometry is one of the basic methods for processing and comparing osteological material in order to determine the characteristics of past populations (e.g. Šefčáková et al. 2011, Brewster et al. 2014, Allen and von Cramon-Taubadel 2017). The early 1960s, saw the first consideration of the potential of skeletal dimensions for determining the degree of similarity between individuals, in order to reveal their potential family relationships (Ullrich 1969, Bondioli et al. 1986), especially in skulls (Dudzik and Kolatorowitz 2016). This assumption was confirmed when several studies of genealogically documented osteological samples showed a positive relationship between the degree of relatedness and the degree of similarity of individuals based on cranial dimensions. The greatest degree of similarity was between close biological relatives, such as parents and children, or siblings, and similarity decreased with increasing generations (Strouhal 1992, Vlček 1997, Drozdová 2006). In addition, for many dimensions and their indices, the contribution of genetic factors to their variability was later demonstrated through the calculation of heritability (e.g. Sjøvold 1984, Carson 2006, Sherwood et al. 2008, Martínez-Abadías et al. 2009, Gavrus-Ion et al. 2017).

The mentioned studies dealing with the relationship between relatedness and similarity, however, were only focused on comparing individuals of the same sex – either because the study sample did not allow for anything else, because the aim of the research was to determine the similarity of the biologically related only in the male line, or because researchers were also aware that significant sexual dimorphism in cranial dimensions has been known for just as long (e.g. Giles and Elliot 1963, Holland 1986, Gapert et al. 2009, Toneva et al. 2020). On the other hand, it has been shown that using standardized size-adjusted data, individuals can be compared regardless their sex (Carson 2006, Martínez-Abadías et al. 2009, Cvrček et al. 2021). This provides greater opportunities for the analysis of family samples, e.g. in determining the degree of similarity between the spouses and between them and their offspring. This is already penetrating the field of historical anthropology and individual identification (Thurzo et al. 2002). However, it must be taken into account that this is only possible in some cases within genealogically documented samples. Like other osteological or dental features used to determine the degree of similarity between individuals (non-metric traits, frontal sinuses, developmental anomalies), craniometric traits cannot ordinarily be expected to have the potential to identify exact relationships and reconstruct pedigrees (e.g. Alt et al. 1995, Cameriere et al. 2008).

Although the need to understand basic genetics and the heritability of facial or cranial shape and size remains topical (Dudzik and Kolatorowitz 2016), there are only a small number of studies that have addressed it thus far (Stojanowski and Schillaci 2006). Therefore, the aim of this study is to expand knowledge about the relationship between biological relatedness and craniometric similarity using the united noble Sporck and Swéerts-Sporck families, and to answer the following questions: 1) Is the sexual dimorphism of individuals in cranial dimensions evident in the studied sample? 2) Is there a positive relationship between the degree of similarity and the degree of biological distance of individuals, based on unadjusted measured cranial dimensions, size-adjusted cranial dimensions, and indices? 3) Is there a greater degree of similarity in biologically related individuals than in unrelated individuals, based on unadjusted measured cranial dimensions, size-adjusted cranial dimensions, and indices?

Material and methods

The analyzed sample comprises eight adult individuals (four males and four females, aged 39–81 years), numbered 1–8, from Church of the Holy Trinity, Kuks hospital (Hradec Králové region, Czech Republic), whose osteobiographical research began based on the need to restore their coffins:

1. General Johann Nepomuk, Count Sporck (6 January 1600 – 6 August 1679)
2. Eleonora Maria Catharine, Countess Sporck, née Fineck (10 February 1639 – 3 September 1674)
3. Francisca Elizabeth Apollonia, Countess Sporck, née Baroness (i.e. Freifrau) from Reist and Swéerts (11 January 1667 – 22 April 1726)
4. Cavalry Captain Joseph Philipp Friedrich Karl, Count Swéerts-Sporck, Baron (i.e. Freiherr) from Reist, Laaken and Blauenthurn (10 February 1809 – 12 November 1848)
5. Barbara, Countness from Rothkirch and Panthen, née Countess Swéerts-Sporck, Baroness from Reist, Laaken and Blauenthurn (9 February 1810 – 7 October 1873)
6. Joseph, Count Swéerts-Sporck, Baron from Reist, Laaken and Blauenthurn (7 July 1788 –11 February 1855)
7. Moritz Gustav, Count Swéerts-Sporck, Baron from Reist, Laaken and Blauenthurn (12 May 1821 – 21 November 1882)
8. Céline Pauline, Countess Swéerts-Sporck, Baroness from Reist, Laaken and Blauenthurn, née de Noblée (10 August 1832 – 13 July 1914)

The family tree shows the biological relationships of these individuals (Fig. 1). There is one consanguineous marriage in generation No. 3 of the sample: the mother of the groom and the father of the bride were siblings, and the father of the groom and the mother of the bride were half-siblings (Dobřenský z Dobřenic 1841 – 1919, Wurzbach 1880). Genealogical data came from the State Regional Archives in Zámrsk, Litoměřice, Prague, and Plzeň, as well as from the Prague City Archive, the National Museum Archive in Prague, the parish registers of Vienna, and the Central State Historical Archives of Ukraine-City of Lviv. In addition, the identities of the individuals were also confirmed by the inscribed plates found in their coffins. Finally, DNA and blood group analyses supported the documented relationships between the individuals (Mazura et al. 1997).

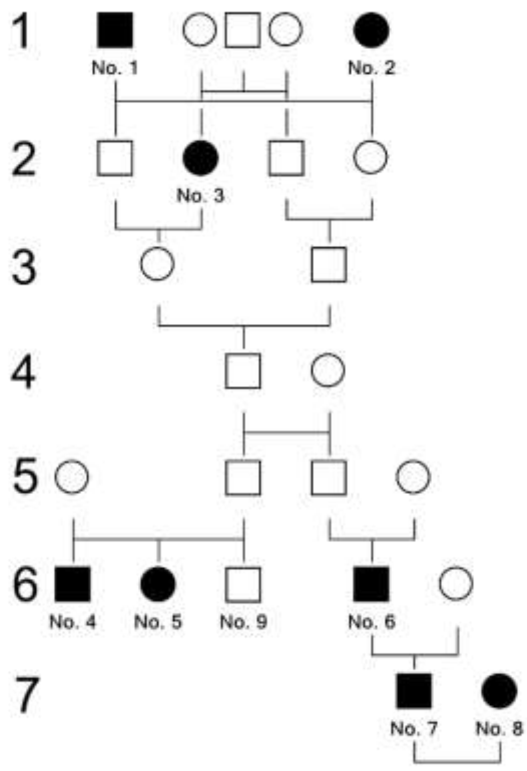

Figure 1: The family tree of the studied individuals from the noble Swéerts-Sporck family, according to Dobřenský z Dobřenic (1841 – 1919) and Wurzbach (1880).

Although the skeletal remains of juvenile Philipp Benitus, Count Swéerts-Sporck, Baron from Reist, Laaken and Blauenthurn (Feb. 9th 1810 – July 4th 1817; No. 9) have also been the subject of previous research (Cvrček et al. 2021), this individual was not included in this study due to poor preservation and especially the not completed development of his skeleton. Assessed individuals should at least have attained young adulthood (e.g. Carson 2006, Drozdová 2006).

A total of 36 cranial dimensions were measured in all individuals (Table 1) by the standard methodology according to Martin (Knussmann 1988). Due to atrophic changes in the maxilla caused by partial or complete intravital teeth loss in almost all individuals, this part of the skull was not included in the measurement (Sjøvold 1984, Carson 2006, Drozdová 2006). The measured dimensions were selected mainly based on their use in previous studies (e.g Šefčáková et al. 2011, Sjøvold 1984, Carson 2006). Because the sample includes both males and females, and sex differences in skull size are well known, whether these differences were also present in this case was also assessed, based on the set of all 36 evaluated dimensions. For this purpose, two approaches were used: 1) redundancy analysis (RDA) with a Monte Carlo permutation test with a significance level of $\alpha = 0.05$ that shows the degree of sexual dimorphism of the measured dimensions; 2) principal component analysis (PCA) that shows the proximity of individuals according to their sex based on the measured dimensions. Moreover, in order to eliminate the possible effect of size sexual dimorphism, 26 indices of the evaluated dimensions were calculated (Table 1), and all 36 measured dimensions were transformed by the geometric mean and logarithmization (Mosimann 1970, Rmoutilová et al. 2018, Cvrček et al. 2021).

Table 1: Evaluated cranial linear dimensions (N = 36) and indices of cranial linear dimensions (N = 26).

Measurement	Measurement definition	Index	Index definition
M1	Maximum cranial length (g - op)	I1	M8:M1
M1c	Metopion-opisthocranion length (m - op)	I2	M17:M1
M2	Nasio-occipital length (g - i)	I3	M17:M8
M3	Glabello-lambda length (g - l)	I4	M20:M1
M5	Basion-nasion length (n - ba)	I5	M20:M8
M7	Foramen magnum length (ba - o)	I9	M17:M23
M8	Maximum cranial breadth (eu - eu)	I11	M11:M24
M9	Least frontal breadth (ft - ft)	I12	M9:M10
M10	Maximum frontal breadth (co - co)	I13	M9:M8
M11	Biauricular breadth (au - au)	I13a	M10:M8
M12	Biasterionic breadth (ast - ast)	I14	M12:M8
M13	Bimastoideal breadth (ms - ms)	I16	M27:M26
M16	Foramen magnum breadth (fol - fol)	I17	M28:M26
M17	Basion-bregma height (ba - b)	I18	M28:M27
M17a	Basion-apex height (ba - apx)	I19	M26:M25
M20	Auriculo-bregmatic height (b ⊥ po - po)	I20	M27:M25
M23	Horizontal circumference (g ∩ op ∩ g)	I21	M28:M25
M24	Transverzal arc (po ∩ b ∩ po)	I22	M29:M26
M25	Total sagittal arc (n ∩ o)	I24	M30:M27
M26	Frontal sagittal arc (n ∩ b)	I25	M31:M28
M27	Parietal sagittal arc (b ∩ l)	I29	M31:M12
M28	Occipital sagittal arc (l ∩ o)	I33	M16:M7
M29	Nasion-bregma chord (n - b)	I37	(1+8+17):3
M30	Bregma-lambda chord (b - l)	I42	M52:M51
M31	Lambda-opisthion chord (l - o)	I46	M50:M44
M43	Outer biorbital breadth (fmt - fmt)	I48	M54:M55
M43(1)	Inner biorbital breadth (fmo - fmo)		
M44	Biorbital breadth (ek - ek)		
M45	Bizygomatic breadth (zy - zy)		
M46	Bimalar breadth (zm - zm)		
M50	Anterior interorbital breadth (mf - mf)		
M51	Orbital breadth (mf - ek)		
M52	Orbital height (spa - sbk)		
M54	Nasal breadth (apt - apt)		
M55	Nasal height (n - ns)		
M57	Simotic chord		

Subsequently, the degree of similarity between individuals was calculated using the Pearson correlation coefficient based on three datasets: 1) the 36 unadjusted measured dimensions, 2) 26 indices of the unadjusted measured dimensions, and 3) the 36 standardized dimensions adjusted to size.

To graphically express the relationship between the degree of similarity between biologically related individuals and their biological distance, the logarithm of coefficients of their relationship (r), estimated using a tabular method (Falconer and Mackay 1996), was calculated, based on the method of VanRaden (1992). In this step, use of a logarithm (logR) entirely eliminates unrelated individuals, because their coefficient of relationship is always zero, and thus the logarithm is not defined. A graphical expression of the degree of similarity to the biological distance of individuals was created for all three of the datasets mentioned above. In the same way, boxplots were used to show the variability of the degree of similarity of biologically related and unrelated pairs in the sample, again for all three datasets. Statistical methods, however, were not applied in these approaches, due to the small number of individuals in the sample; their power would be low (Ellis 2010). The focus was therefore on graphical results (Cvrček et al. 2021).

Results

Due to the good preservation of the skulls of the evaluated individuals, all the selected dimensions could be measured, except for dimensions M13 (bimastoideal breadth) and M45 (bizygomatic breadth) in individual No. 1, and dimensions Nos. 17a (basion-apex height) and 57 (simotic chord) in individual No. 2 (Table 2). All the selected indices could be calculated for all individuals (Table 3).

Table 2: The values of measured dimensions of individuals Nos. 1–8, in parentheses after their number is their sex (M = male, F = female). Dimensions are in centimeters.

	Individuals							
Measurement	**1 (M)**	**2 (F)**	**3 (F)**	**4 (M)**	**5 (F)**	**6 (M)**	**7 (M)**	**8 (F)**
M1	188	171	177	182	167	188	181	173
M1c	185	168	177	179	164	183	178	174
M2	188	162	165	177	163	186	175	155
M3	174	163	173	174	156	185	176	170
M5	104	86	91	102	98	104	105	90
M7	35	40	34	34	32	38	38	34
M8	153	145	152	144	138	154	147	145
M9	94	93	89	92	92	99	103	88
M10	126	118	125	118	109	129	127	116
M11	132	122	115	112	114	123	130	118
M12	113	110	113	111	109	111	114	111
M13	-	97	93	107	94	104	107	97
M16	34	33	30	30	30	32	30	32
M17	130	111	118	123	118	130	139	122
M17a	131	-	117	124	117	131	141	124
M20	110	103	111	111	102	122	118	105
M23	533	503	522	514	480	542	521	502
M24	315	300	315	315	298	335	330	302
M25	364	345	355	359	325	369	361	350
M26	131	126	121	132	111	126	133	117
M27	113	110	121	116	105	133	120	120
M28	120	109	113	111	109	110	108	113
M29	112	110	113	114	97	113	116	104
M30	106	100	109	106	96	116	110	91
M31	96	86	85	90	92	94	93	110
M43	111	95	97	105	100	104	107	94

Table 2 continued								
M43(1)	104	85	91	93	93	97	102	86
M44	104	84	93	98	93	97	102	97
M45	-	120	126	125	120	127	135	120
M46	102	83	81	83	91	86	88	81
M50	23	19	17	19	20	21	21	19
M51	40	32	42	39	40	44	44	38
M52	38	32	40	38	33	39	35	34
M54	28	22	22	24	27	23	24	23
M55	55	47	54	44	50	56	50	48
M57	9	-	8	8	10	9	7	8

Table 3: The values of dimensionless indices of cranial dimensions of individuals Nos. 1–8, in parentheses after their number is their sex (M = male, F = female).

	Individuals							
Index	**1 (M)**	**2 (F)**	**3 (F)**	**4 (M)**	**5 (F)**	**6 (M)**	**7 (M)**	**8 (F)**
I1	81	85	86	79	83	82	81	84
I2	69	65	67	68	71	69	77	71
I3	85	77	78	85	86	84	95	84
I4	59	60	63	61	61	65	65	61
I5	72	71	73	77	74	79	80	72
I9	24	22	23	24	25	24	27	24
I11	42	41	37	36	38	37	39	39
I12	75	79	71	78	84	77	81	76
I13	61	64	59	64	67	64	70	61
I13a	82	81	82	82	79	84	86	80
I14	74	76	74	77	79	72	78	77
I16	86	87	100	88	95	106	90	103
I17	92	87	93	84	98	87	81	97
I18	106	99	93	96	104	83	90	94
I19	36	37	34	37	34	34	37	33
I20	31	32	34	32	32	36	33	34
I21	33	32	32	30	34	30	29	32
I22	86	87	93	86	87	90	87	89
I24	94	91	90	91	81	87	92	76
I25	80	79	75	81	84	86	86	97
I29	85	78	75	81	84	85	82	99
I33	97	83	88	88	94	84	79	94
I37	384	353	368	367	344	385	374	359
I42	88	100	95	86	83	89	80	90
I46	22	23	18	19	22	22	21	20
I48	51	47	41	55	54	41	48	48

RDA showed statistically significant differences in trait affinity between males and females in the unadjusted measured cranial dimensions (p-value = 0.038). However, the considerable variance of trait vectors along the second canonical (vertical) axis showed that dimensions are not only affected by sex, but also by other factors (Fig. 2). Measures Nos. 2 (nasio-occipital length), 9 (least frontal breadth), 17 (basion-bregma height), 43(1) (inner biorbital breadth) and 44 (biorbital breadth) appear to be the most affected by sex which is shown by the greatest proximity to the first canonical (horizontal) axis.

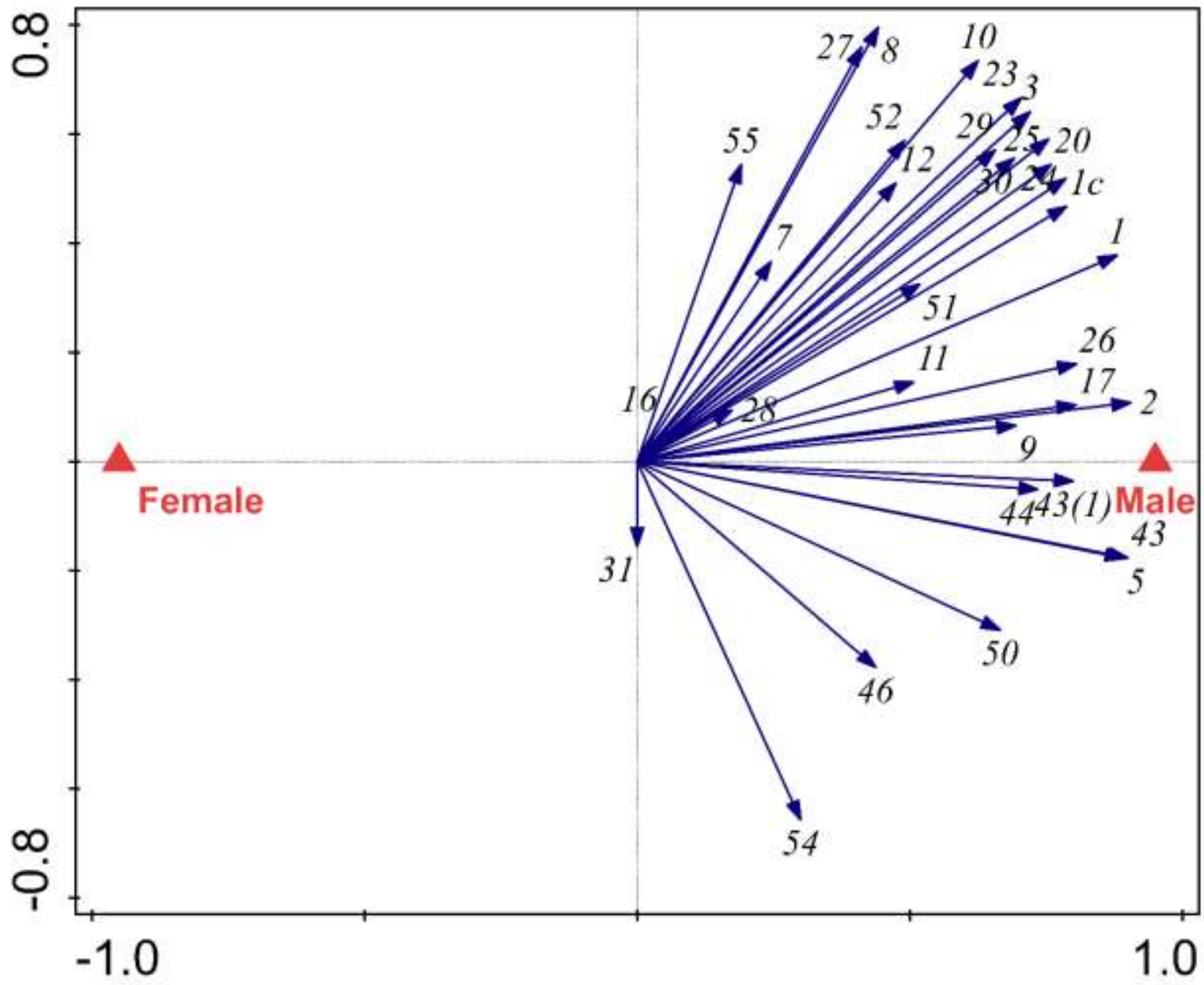

Figure 2: Plot of redundancy analysis (RDA) based on the 36 cranial dimensions of the eight evaluated individuals (Nos. 1–8) showing the sexual dimorphism of the individual measured dimensions.

PCA too showed clear differences between males and females in the unadjusted measured cranial dimensions (Fig. 3). At the same time, however, it also showed the closeness of male No. 6 and his son No. 7. These two individuals are relatively close to male No. 4 (the first cousin of male No. 6), while the most distant from them is male No. 1, the founder of the family, who is separated from them by 4 generations (Fig. 1). No clustering is evident between females, but on the other hand, this finding corresponds to the distances in males. Although female No. 5 is biologically related to females Nos. 2 and 3, they are separated by four and three generations, respectively. Other relationships between females are not based on biological kinship.

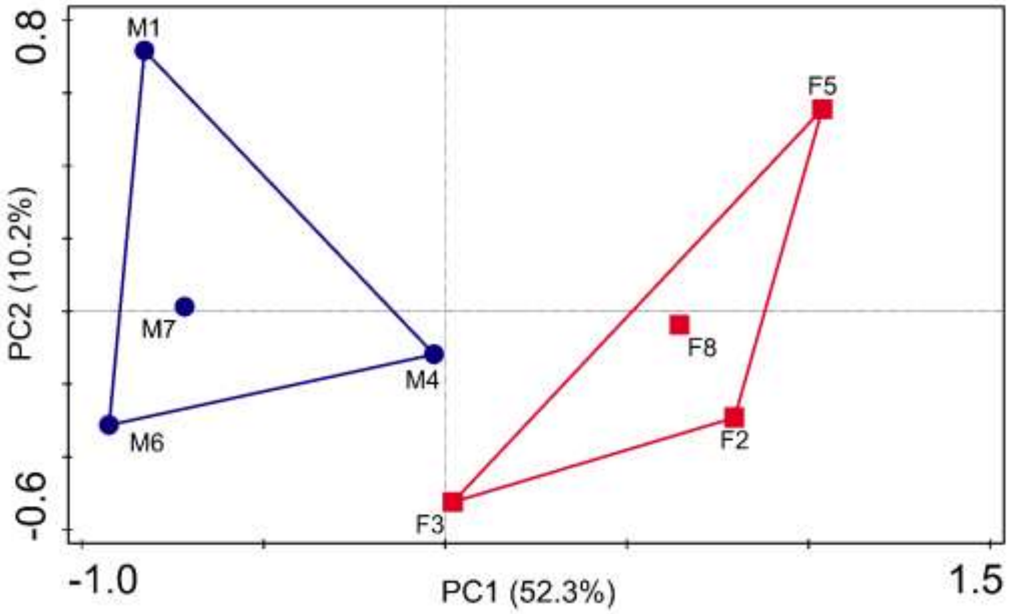

Figure 3: Principal component analysis (PCA) performed on 36 unadjusted measured cranial dimensions of the eight evaluated individuals (Nos. 1–8) showing their closeness according to their sex. F = female, M = male.

PCA based on size-adjusted cranial dimensions supports the documented relationships between individuals even more. While males, for whom there are no non-biological relationships, are very close, females, who are mostly biologically unrelated, are distant (Fig. 4). In males, the first cousins Nos. 4 and 6 are the closest in this case; male No. 7 (son of No. 6) is distant from them, and the founder of the family No. 1 is furthest from them.

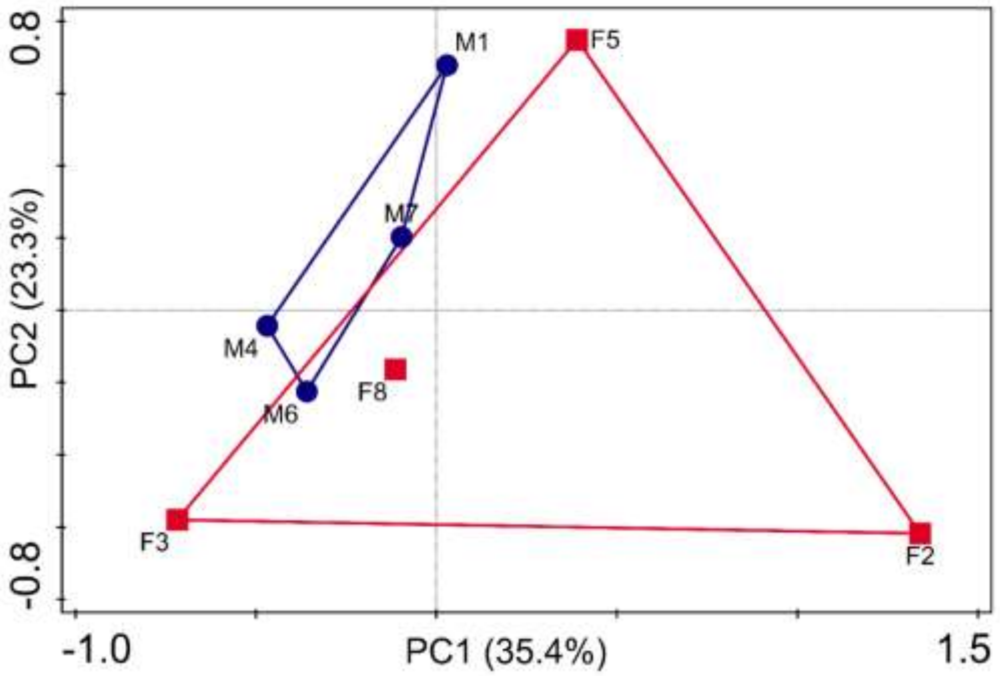

Figure 4: Principal component analysis (PCA) performed on 36 size-adjusted cranial dimensions of the eight evaluated individuals (Nos. 1–8) showing their closeness according to their sex. F = female, M = male.

Table 4 gives the resulting values for the degree of similarity between individuals based on unadjusted measured dimensions (section A), indices of unadjusted measured dimensions (section B), and standardized dimensions adjusted to size (section C). In all these variants, a positive relationship between the degree of similarity and the degree of relatedness of individuals is evident (Fig. 5). At the same time, however, it is shown that unadjusted measured dimensions and indices can reflect documented biological relationships more than standardized dimensions adjusted to size (coefficient of determination R2 = 0.11 and 0.11 versus 0.09). Although, in general, it is shown that the greater the similarity between individuals, the greater the degree of similarity between them, this is not absolutely valid. Although there is a high degree of similarity between close relatives, such as siblings or father and son (coefficients of relationship r = 0.5), the degree of similarity of some distant relatives is higher, for example between first male cousins (r = 0.125), great-great-grandparent/great-great-grandchild (r = 0.078125), the son of the first cousin/first cousin of the father (r = 0.06543), or great-great-great-grandparent/great-great-great-grandchild (r = 0.0625).

Finally, a comparison of the degree of similarity between biologically related and unrelated pairs in the sample showed that biologically related individuals have a higher median value of degree of similarity in all cases than unrelated pairs (Fig. 6).

Table 4: The degree of similarity of individuals Nos. 1–8 by cranial dimensions (sections A-C). M = male, F = female.

	Section A: Linear dimensions.							
	1 (M)	**2 (F)**	**3 (F)**	**4 (M)**	**5 (F)**	**6 (M)**	**7 (M)**	**8 (M)**
1 (M)	–	0.99811	0.99754	0.99844	0.99896	0.99755	0.99786	0.99693
2 (F)		–	0.99881	0.99830	0.99767	0.99796	0.99785	0.99765
3 (F)			–	0.99860	0.99770	0.99904	0.99794	0.99774
4 (M)				–	0.99826	0.99880	0.99877	0.99739
5 (F)					–	0.99801	0.99839	0.99757
6 (M)						–	0.99876	0.99717
7 (M)							–	0.99694
8 (F)								–
	Section B: Indices of linear dimensions.							
	1 (M)	2 (F)	3 (F)	4 (M)	5 (F)	6 (M)	7 (M)	8 (M)
1 (M)	–	0.99670	0.99546	0.99820	0.99600	0.99339	0.99400	0.99251
2 (F)		–	0.99740	0.99716	0.99444	0.99415	0.99315	0.99147
3 (F)			–	0.99588	0.99409	0.99664	0.99237	0.99274
4 (M)				–	0.99634	0.99604	0.99745	0.99291
5 (F)					–	0.99259	0.99263	0.99587
6 (M)						–	0.99641	0.99437
7 (M)							–	0.99008
8 (F)								–
	Section C: Adjusted linear dimensions.							
	1 (M)	2 (F)	3 (F)	4 (M)	5 (F)	6 (M)	7 (M)	8 (M)
1 (M)	–	0.99427	0.99530	0.99748	0.99824	0.99613	0.99653	0.99626
2 (F)		–	0.99338	0.99449	0.99249	0.99445	0.99438	0.99455
3 (F)			–	0.99702	0.99482	0.99834	0.99532	0.99575
4 (M)				–	0.99655	0.99770	0.99738	0.99655
5 (F)					–	0.99585	0.99503	0.99628
6 (M)						–	0.99725	0.99639
7 (M)							–	0.99553
8 (F)								–

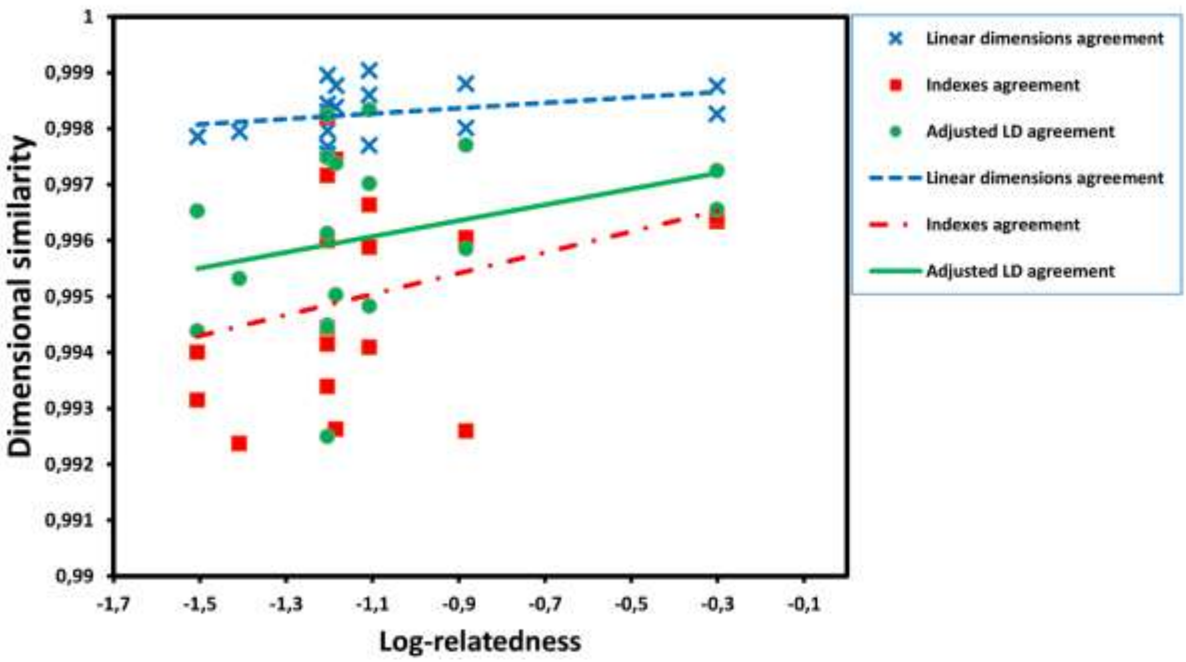

Figure 5: Relationship of the dimensional similarity between biologically related pairs (N = 18 pairs) in the noble Swéerts-Sporck family based on 36 cranial dimensions (y-axis) by log-relatedness of individuals (x-axis). The lines represent regression lines. Note: log-relatedness disregards biologically unrelated pairs.

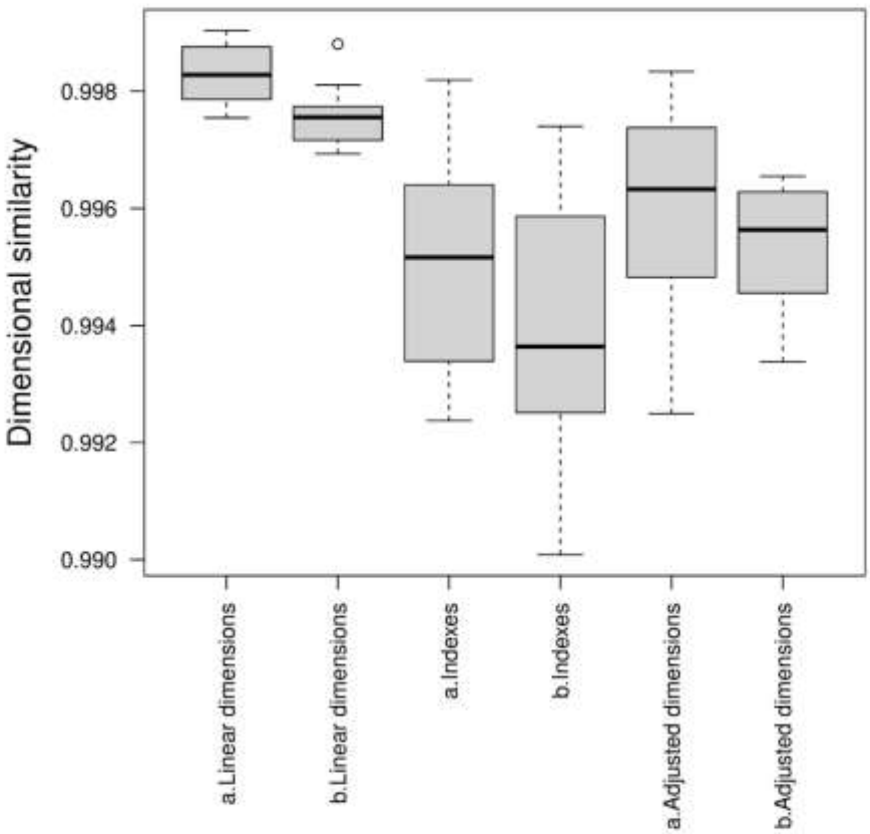

Figure 6: The degree of similarity and its variability between biologically related (a, N = 18 pairs) and unrelated (b, N = 10 pairs) individuals from the noble Swéerts-Sporck family based on 36 unadjusted measured cranial dimensions, their 26 indices, and 36 size-adjusted cranial dimensions.

Discussion

Similarly, to the previous analysis of osteological non-metric traits and frontal sinuses in this family sample (Velemínský and Dobisíková 2005, Cvrček et al. 2021), the results of this study confirm that craniometric traits may reflect documented relationships between individuals (Strouhal 1992, Vlček 1997, Drozdová 2006), and thus a contribution of genetic factors to craniometric trait variability is present (Sjøvold 1984, Carson 2006, Sherwood et al. 2008, Martínez-Abadías et al. 2009). This is evident both on the basis of size-adjusted cranial dimensions and indices of unadjusted measured cranial dimensions, in which the effect of sexual dimorphism was removed. But it is apparent also on the basis of unadjusted measured cranial dimensions, although sexual dimorphism was evident among individuals based on these data. Even the coefficient of determination values of the linear models of individual variables showed, albeit with small differences, that the similarity of individuals calculated on the basis of unadjusted measured dimensions and their indices reflects their relationships slightly better than the similarity calculated on the basis of size-adjusted dimensions. This is despite the fact that, according to the graphic results, the size-adjusted dimensions may appear to reflect family relationships better than the unadjusted measured dimensions. Although it might be expected that significant sexual dimorphism of the unadjusted measured dimensions could negatively affect the similarity of individuals (e.g. Thurzo et al. 2002, Carson 2006, Sherwood et al. 2008), as indicated by the results of RDA analysis, the size of the cranial dimensions need not be affected only by sex, but also by other factors, including genetic ones, as the final results show.

This finding points to a possible link with an earlier analysis of the frontal sinus dimensions in the Sporck and Swéerts-Sporck families (Cvrček et al. 2021). These were evaluated for total surface and volume, and maximum height and width; the sexual dimorphism of individuals according to the sinuses was not as pronounced in their case as in the cranial dimensions in this study. For the unadjusted dimensions, a positive correlation between similarity and biological relatedness was apparent. On the other hand, no positive correlation was apparent for most of the standardized data: only total volume showed a very weak indication of a positive trend, but this was weaker than in the original values. This suggested that genetics do affect the dimensions of the frontal sinuses, regardless of sex, although there are sex differences evident within different populations in randomly selected unrelated individuals (e.g. Motawei et al. 2016, Choi et al. 2018, Čechová et al. 2019). This could also apply to cranial dimensions. However, the result of the frontal sinuses analysis could be influenced by the number of individuals, which was even smaller than in this study, and by the number of the evaluated dimensions, which was also small. Compared to this study, the difference in the correlation between similarity and relatedness based on unadjusted and size-adjusted cranial dimensions is not so clear.

However, it appears that genetic factors may not be the only ones that have the effect of reducing sexual dimorphism in skull dimensions. Changes may, for example, occur due to a secular trend over decades or even centuries (e.g. Sjøvold 1995, Carson 2006), or as some studies have shown, increasing age can lead to decreased sexual dimorphism (e.g. Musilová et al. 2016, Velemínská et al. 2021). It must therefore be accepted that these aspects may also affect the results of this study, given the time scale of the sample and its age structure. It is also impossible to rule out the possible influence of increased consanguinity on the variability of craniometric traits as animal models showed (Kobryńczuk 1985), due to the documented consanguineous marriage in the third generation of the sample. On the other hand, the specific effects of inbreeding cannot be demonstrated precisely in this family (Cvrček et al. 2021), because the sample includes a small number of individuals, and in addition, there is a distance of several generations between some of them. In order to recognize these, it would be necessary to have the remains of other family members that were not available for this study, and a suitable comparison sample including both individuals with increased consanguinity and individuals with normal family relationships (Cvrček et al. 2020). To the best of our knowledge, no study has yet addressed the possible effect of inbreeding on cranial dimensions in genealogically documented samples. In this time, therefore, it is not even possible to rely on comparable results.

In any case, the tenet that the cranium as a phenotype reflects underlying genotypic patterning is well supported, but not the linear translation between genotype to phenotype. The complexity of this association often exceeds the estimation methods available to adequately describe the relationship between genetics and morphology (Dudzik and Kolatorowitz 2016). The use of craniometric variables to identify genetic relationships requires an estimation of heritability (Relethford 2007); unfortunately, a calculation of the contribution of the genetic component to the variability of the measured dimensions could not be made in this case. This is because firstly, the number of individuals in the sample is small (Gavrus-Ion et al. 2017, Formoso-Rafferty et al. 2017), and secondly because the sample includes only two pairs of the first-degree relatives (parents and children, siblings, or monozygotic and dizygotic twins), between whom heritability is usually calculated (e.g. Dahlberg 1926, Sharma 1991, Carson 2006). To verify the above findings and calculate the heritability of cranial dimensions, research on a larger sample than shown in this study would be also required.

Conclusions

This study showed that the cranial dimensions reflect the documented family relationships, both for unadjusted dimensions despite their significant sexual dimorphism, and for indices of these dimensions and size-adjusted dimensions. At the same time, all three datasets showed a difference between biologically related and unrelated individuals. These findings are consistent with the results of previous studies that analyzed non-metric osteological traits and frontal sinuses in the same sample. However, due to the existence of factors other than sexual dimorphism that may affect the variability of craniometric traits, such as secular trend, aging, or increased consanguinity, and the small number of individuals in the sample, it is necessary to focus on research into larger samples with genealogical documentation where calculation of the heritability of evaluated dimensions is possible.

Acknowledgments

The research was supported by Grant Agency of the Charles University (Grant Number: GAUK 1276217) and Ministry of Culture of the Czech Republic (DKRVO 2019–2023/7.I.c, 00023272). The authors would like to thank František Fortin (the Czech Genealogy and Heraldry Society in Prague), Milena Běličová (National Museum Archive, Prague) and Petr Mareš (National Archives, Prague, Czech Republic) for their help with the genealogical research, and Luboš Vostrý (Czech University of Life Sciences Prague) for help with calculating the coefficients of relationships. They would also like to thank Alastair Millar for linguistic review, and to two reviewers for their useful comments that have contributed to improving the text.

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