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Non-metric traits, physiological stress indicators and paleopathological lesion on human skeletal remains from an early modern cemetery in Wyszyński Street, Wrocław, Poland (15th–18th centuries AD)

Agnieszka Tomaszewska, Barbara Kwiatkowska

Department of Anthropology, Wroclaw University of Environmental and Life Sciences, Poland

Abstract: The anthropological analysis and assessment of the living conditions of historical populations should be comprehensive. Due to the scarcity of the well-preserved skeletal remains of a population buried at the cemetery in Wyszyński Street, Wrocław, each piece of information is particularly important in providing the complementary information about living and health conditions of late medieval and early modern inhabitants of Wrocław. This study aims to assess the living conditions of the late medieval and early modern Wrocław inhabitants. This aim was reached by analyzing the frequency of non-metrical cranial and postcranial traits, physiological stress indicators, and pathological lesions. The importance of these traits for population studies is also discussed. For 98 skeletons (22.4% male and 37.8% female) from a cemetery located in Wyszyński Street, (15th –18th centuries AD), the frequencies (p) of the following traits were analyzed: 38 non-metric cranial and 9 post-cranial traits, the morphological indicators of physiological stress (i.e. *cribra orbitalia* and enamel hypoplasia), caries and pathological lesions on bones. Among the non-metric cranial traits, only nine (23.7%) were not observed. The most frequent (from p= 0.30 to p=0.65) were *foramen parietale, incisura frontalis accesoria seu foramen frontale accesorius, foramen supraorbitale, M3 mandibulare, ossicula suturae lambdoideae,* and *foramen mastoideum extrasuturale*. Only three non-metric post-cranial traits were observed, but with low frequency (p=0.01 and 0.02). *Cribra orbitalia* was present in 37.0% of the skeletons while enamel hypoplasia was present in only 2.6%. Susceptibility to caries occurred in 68% of the cases while carries lesions occurred in 31.2%. Among pathological changes, the most frequent were degenerative changes (21.6%) and injuries (19.6%). Owing to the poorly preserved remains, the complete assessment of the living conditions of the population was difficult. The number of the observed traits would have probably increased, had the number of complete and well-preserved skeletons been higher. The results of the study suggest that the living conditions of the studied population were poor. It is hypothesized that the cemetery was a burial place for prisoners and victims of various epidemics that affected the city. But since the historical sources of this cemetery are scarce, it is hard to unequivocally state its purpose with certainty.

Key words: discrete traits, enamel hypoplasia, dental caries, cribra orbitalia, pathological lesions, early modern Wrocław inhabitants

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Introduction

The anthropological analysis and assessment of living conditions of the historical population should be conducted comprehensively. Due to the scarcity of the well-preserved skeletal remains such an investigation is impeded and each piece of information is particularly important in providing the information about living and health conditions of late medieval and early modern inhabitants of Wrocław. Despite preliminary investigations (Markowska 2007), concerning mainly metric traits, thus, to learn the living conditions of this historical population, we need to conduct a comprehensive anthropological analysis and living conditions assessment. This picture is created from non-metric traits, morphological indicators of the physiological stress of individuals, and pathological lesions. Non-metric (or discrete) traits are considered as a variant of the normal anatomy of the skeleton. Easy to score, they are often analyzed in anthropological research, where they are represented by the frequency of their presence in sample elements.

It has been suggested that non-metric traits have a genetic origin, and thus their within- and between-population variances should be observed (Berry and Berry 1967; Anderson 1989; Kaur et al. 2012; Khudaverdyan 2013). Only few studies have reported the heritability of non-metric traits (Cheverud and Buikstra 1981a, b; Sjøvold 1984) (however, see Rightmire 1972; Vitek 2012). Nevertheless, newest research has revealed non-metric traits proved to be a proxy for genetic markers (Evteev and Movsesian 2016). Since the genetic affinity of discrete traits has not been proven by others, any observed similarity of populations, even if very likely, should be treated with caution.

Due to their importance for genetic studies, non-metric traits in human skeletal remains from the early modern cemetery in Wyszyński Street in Wrocław, Poland may provide the complementary picture of the late medieval and early modern inhabitants of Wrocław. These traits may be especially useful because the skeletal remains are poorly preserved. Moreover, comparative studies on the non-metric traits of different populations from Wrocław may be informative, for instance, in research on migration in early modern Wrocław.

To conduct the comprehensive anthropological analysis and assessment of the living conditions of late medieval and early modern Wrocław inhabitants, the frequencies of various non-metrical cranial and postcranial traits in adult human skeletal remains from a cemetery dated to between the 15th and 18th centuries AD were analyzed. Physiological stress indicators and pathological lesions were also analyzed.

Material and Methods

The anthropological excavation preceding the construction of the Main Library of Wrocław University started in June 2003 and lasted four months. The excavation site was located near Ostrów Tumski, the oldest part of the city. The cemetery belonged to the St. Aegidius Church, which dates back to the thirteenth century.

However, there was no church within the area of the cemetery, an unusual situation in the medieval cemeteries in Wrocław. The cemetery located in Wyszyński Street is dated to between the 15th and 18th centuries AD, but it is impossible to identify the precise time because of, as mentioned before, the absence of a church in this cemetery. The

Table 1. Preservation conditions (Limisiewicz et al. 2003, modified)

Preservation condition	% of undamaged bones for each individual	n	%
Very good	90–100	1	0.3
Quite good	70–89	18	5.5
Good	50–69	18	5.5
Fragmentary	30–49	250	76.7
Bad	<20	7	2.1
Illegible	none of bones were complete	32	9.8
Total		326	100

cemetery does not even exist in the historical plans of the city (Limisiewicz et al. 2003).

In the cemetery, 328 graves but fewer skeletons were excavated because four graves were double and six graves had double numeration. Hence, 326 graves were verified. Because the cemetery is located in a humid area with frequent floodings, most skeletons (76.7%) were heavily fragmented (Table 1).

Most skeletons (65.6%) were buried with their heads pointed west (Limisiewicz et al. 2003).

A study sample consisted of 98 skeletons, selected for further conservation and analyses, and presently held at the Department of Human Biology, University of Wrocław, Poland. The previous analyses of these skeletons (Markowska 2007) included the analysis of the metric characteristic of male and female skulls and postcranial skeletons. In this particular study, the anthropological analysis and assessment of living conditions based on non-metric traits, physiological stress indicators and paleopathological lesion analysis is made.

The sex of the individuals was determined based on sexually dimorphic cranial traits, and also, if available, sexually dimorphic pelvic traits. The sex could not be determined for 39.8% of the skeletons; 22.4% of the skeletons were classified as male, and 37.8% were classified as female (Table 2).

Age at death was determined based on cranial suture obliteration, degenerative changes in the bones (Lovejoy et al. 1985; Brooks and Suchey 1990), and dental changes (Acsádi and Nemeskéri

Table 2. Age and sex proportions of the sample

Age	Sex							
	Male		Female		Undetermined sex		Total	
	n	%	n	%	n	%	n	%
	22	22.4	37	37.8	39	39.8	98	100.0
Infans I					3	7.7	3	3.1
Infans I/II					2	5.1	2	2.0
Infans II					2	5.1	2	2.0
Juvenis			2	5.4	3	7.7	5	5.1
Juvenis/Adultus			1	2.7			1	1.0
Adultus	9	40.9	20	54.1	11	28.2	40	40.8
Adultus/Maturus	5	22.7	1	2.7			6	6.1
Maturus	8	36.4	12	32.4			20	20.4
Maturus/Senilis								
Senilis			1	2.7			1	1.0
Undetermined					18	46.2	18	18.4
Total	22	100.0	37	100.0	39	100.0	98	100.0

1970; Workshop 1980; Steckel et al. 2006). The age at death was assessed for 81.6% of the individuals. Among the male skeletons, 40.9% were in *adultus* age (20–35 years) and 36.4% in *maturus* (35–50 years) classes of age. The female skeletons were mainly in *adultus* (54.1%) and *maturus* (32.4%) classes of age (Table 2).

Among the analyzed skeletons, 80 had skulls, but 64 (80.0%) of these skulls were only fragmentarily preserved. Among the others partly preserved skulls, following states of skull preservation were found: 7.5% as *calotta,* 3.8% as *cranium,* 3.8% as *calvaria,* 2.5% as *calvarium,* 1.2% as *calvaria* and 1.2% as *calotta* with jawbone (Table 3).

To assess health and living conditions, the frequencies (*p*) of 38 non-metric cranial (Table 4) (according to Berry and Berry 1967) and 9 post-cranial (Table 5) (according to Finnegan 1978) traits were analyzed. The frequencies of the morphological indicators of physiological stress (i.e. *cribra orbitalia,* enamel hypoplasia (EH) and caries) and of pathological lesions on bones were also analyzed. The observations were made on the roof of both orbits to score the occurrence and severity of *cribra orbitalia* according to the seven-grade scale proposed by Hengen (1971).

Enamel hypoplasia (EH) is a tooth deficiency in which enamel is thin; it results from systemic disturbances (Goodman et al. 1980). Formed only during the apposition of enamel (till 7–8 years old), EH reflects health and living conditions at a young age. The incidence of enamel hypoplasia was assessed by counting changes in the preserved teeth of each individual's skull. This number was referenced to all skulls with preserved incisors and tusks in the jaw or mandible, the most sensitive teeth to hypoplasia (El-Najjar et al. 1978; Goodman et al. 1980; Yamamoto 1988; Goodman 1989, 1991; Goodman and Rose 1990; Reid and Dean 2006).

Caries (*caries dentes*) is caused mainly by organic acids which demineralize tooth structure. These acids are mainly products of bacterial fermentation (*Streptococcus mutans* and *Lactobacillus acidophilus*) (Jańczuk 1981; Einwag and Naujoks 1994; Dąbrowski and Gronkiewicz 1997; Borysewicz-Lewicka and Chłapowska 2006; Tomczyk 2012). Susceptibility to carries was calculated according to Borysewicz and Otocki (1975) as CD [%N(dc)] = N(dc)/N individuals with teeth, where N(dc) is the number of teeth with caries. The incidence of caries (%C) was calculated as (%C) = C/Z, where C is the number of teeth with caries and Z is the number of all investigated teeth.

Table 3. Preservation of the skulls

Skull's condition	Male		Female		Undetermined sex		Total	
	n	%	n	%	n	%	n	%
Cranium	–		1	1.2	2	2.5	3	3.8
Calvarium	–	–	1	1.2	1	1.2	2	2.5
Calvaria	–	–	1	1.2	2	2.5	3	3.8
Calvaria (+ mandibula)	–	–	1	1.2	–	–	1	1.2
Calotta	–	–	6	7.5	–	–	6	7.5
Calotta (+ mandibula)	1	1.2	–	–	–	–	1	1.2
Fragmentary	18	22.5	27	33.7	19	23.8	64	80.0
Total	19	23.7	37	46.2	24	30.0	80	100.0

Table 4. The occurrence of non- metric characteristic of the skull, defined according to Berry and Berry (1967)

No	No. of trait according to Berry and Berry (1967)	Non-metric trait	N	n	*p*
1	2	*ossiculum fonticuli posterioris*	20	–	–
2	3	*ossicula suturae lambdoideae*	20	7	0.350
3	4	*foramen parietale*	20	10	0.500
4	5	*ossiculum fonticuli anterioris*	20	–	–
5	6	*sutura frontalis*	20	3	0.150
6	7	*ossicula suturae coronalis*	20	–	–
7	8	*ossiculum fonticuli anterolateralis*	20	–	–
8	10	*ossiculum incisurae parietalis*	20	–	–
9	11	*ossiculum fonticuli posterolateralis*	20	1	0.050
10	16	*canalis condylaris patens*	20	2	0.100
11	19	*canalis hypoglossi bipartitus*	20	1	0.050
12	21	*incisura spinosa*	20	–	–
13	22	*foramina palatina minora*	20	3	0.150
14	23	*torus palatinus*	20	1	0.050
15	26	*foramen supraorbitale*	20	8	0.400
16	27	*incisura frontalis accesoria seu foramen frontale accesorius*	20	13	0.650
17	30	*foramen supraorbitale accesorius*	20	2	0.100
18	55	*M3 maxillae*	81	6	0.074
19	56	*M3 mandibulare*	81	32	0.395
20		*foramen mastoideum extrasuturale*	20	6	0.300
21		*foramen occipitale*	20	4	0.200
22		*sutura supranasalis*	20	4	0.200
23		*foramen mentale*	20	4	0.200
24		*foramen maxillare*	20	4	0.200
25		*tuberculum zygomaxillare*	20	3	0.150
26		*foramen frontale*	20	3	0.150
27		*spina mentalis*	20	2	0.100
28		*foramen zygomaticofaciale*	20	2	0.100
29		*sulci frontales*	20	2	0.100
30		*processus paramastiodeus*	20	1	0.050
31		*foramina nasalia*	20	1	0.050
32		*foramen supraorbitale bipartius*	20	1	0.050
33		*processus zygoidale*	20	1	0.050
34		*sutura squamo- mastiodea*	20	1	0.050
35		*ossicula suturae sagittalis*	20	1	0.050
36	51	*torus mandibularis*	20	–	–
37	44	*os Incae*	20	–	–
38	36	*spina trochlearis*	20	–	–

N – number of skulls for which non-metric traits were examined; n – appearance of non-metric traits; p – frequency of non- metric traits.

Table 5. The frequency of occurrence of the non- metric characteristic of postcranial skeletal defined according to Finnegan (1978)

No	No. of trait according to Finnegan (1978)	Bone	Trait	N	n	*p*
1	2	femur	*facies Poirieri*	98	–	–
2	6	femur	*trochanter tertius*	98	1	0.010
3	7	tibia	*facies medialis conquiniscis*	98	–	–
4	8	tibia	*facies lateralis conquiniscis*	98	–	–
5	10	humerus	*foramen supracondylare*	98	2	0.020
6	17	patella	*incisura patellae*	98	–	–
7	18	patella	*fossa patellae*	98	–	–
8	21	calcaneus	*facies articularis medialis*	98	1	0.010
9	22	calcaneus	*continuatio lateralis trochleare*	98	–	–

Based on the classification of the pathological changes by Gladykowska-Rzeczycka (1976), pathological lesions were classified into developmental changes, injuries, infectious diseases (specific and non-specific), degenerative changes, metabolic diseases, endocrine diseases, and tumors. Because the remains were fragmentarily preserved, these traits were analyzed without distinguishing the sexes.

Results

Among all the analyzed 38 non-metric cranial traits, only nine (23.7%) were not observed (Table 4).

The most frequent non-metric traits (frequency from $p= 0.300$ to $p= 0.650$) were as follows:

– *foramen parietale,*
– *incisura frontalis accesoria seu foramen frontale accesorius,*
– *foramen supraorbitale,*
– *M3 mandibulare,*
– *ossicula suturae lambdoideae,*
– *foramen mastoideum extrasuturale.*

With the medium frequencies (from $p= 0.150$ to $p= 0.200$) appeared the following traits:

– *sutura frontalis,*
– *foramen occipitale,*
– *sutura supranasalis,*
– *foramen mentale,*
– *foramen maxillare,*
– *tuberculum zygomaxillare,*
– *foramen frontale,*
– *foramina palatina minora,*

The postcranial skeletal remains were analyzed according to Finnegan's (1978) description of non-metric cranial traits. Because the studied sample was poorly preserved, only three of the nine analyzed non-metric postcranial traits were observed, with low frequencies (p=0.010 and 0.020) (Table 5).

Because of the poor preservation of the remains, all of the evidence presented in this section should be treated with speculation and caution. Since most of the skeletal elements were fragmentary preserved, we were unable to calculate the frequencies of the non-metric traits in the sample (see Table 1). Hence, we are aware of the weakness of our statements in this regard.

Cribra orbitalia was present in 37.0% of the skulls. Likely because the skulls were fragmentary preserved (Table 3), *cribra orbitalia* was observed only in the female skulls (41.2%) and in the skulls with undetermined sex (37.5%). All the

Table 6. Skeletal markers of physiological stress

Marker	Male		Female		Undetermined		All	
	n (N)	%	n (N)	%	n (N)	%	n (N)	%
Cribra orbitalia								
Occurrence, Yes			7 (17)	41.2	3 (8)	37.5	10 (27)	37.0
Severity								
0°	2 (2)	100	10 (17)	58.8	5 (8)	62.5	2 (27)	7.4
II°			2 (17)	11.8	5 (17)	29.4	17 (27)	63.0
IV°			5 (17)	29.4			5 (27)	29.4
Enamel hypoplasia								
Occurrence, Yes							2 (76)	2.6

skulls with undetermined sex (37.5% of the sample) had the second degree of *cribra orbitalia* severity. Only the female skulls had lesions of the fourth degree (29.4%). None of the skulls studied was affected by 1st, 3rd, 5th, or 7th grade of condition (Table 6).

Teeth were found in 76 individuals. Enamel hypolpasia (EH) was present only in two individuals, hence the low percentage of the EH occurrence (2.6%) (Table 6). This might result from many *ante-mortem* or *post-mortem* teeth lost.

Susceptibility to caries reached 68% (70.6% for the males and 60.0% for the females) of the sample, and caries lesions occurred in 31.2% of the cases (24.4% of male and 32.3% of female individuals) (Table 7).

Among pathological lesions, the most frequent were degenerative changes (21.6%) and injuries (19.6%). 13.7% of the lesions were caused by developmen-

Table 7. Dental caries

Characteristic	Male		Female		Undetermined		All	
	n (N)	%	n (N)	%	n (N)	%	n (N)	%
Susceptibility	12 (17)	70.6	18 (30)	60.0	21 (28)	75.0	51 (75)	68.0
Frequency	58 (238)	24.4	124 (384)	32.3	132 (385)	34.3	314 (1007)	31.2

Number of studied teeth given in parentheses.

Table 8. The frequency of occurrence of the pathological lesions in the studied sample

Pathological lesion	Male	Female	Undetermined	All
	n	n	n	n (%)
Developmental	1	5	1	7(13.7)
Metabolic		1	1	2(3.9)
Tumors	1	1	3	5(9.8)
Inflammatory				
specific		1	3	4(7.8)
non-specific	3	3	1	7(13.7)
Degenerations	1	7	3	11(21.6)
Injuries	5	3	2	10(19.6)
Endocrine	2	1	2	5(9.8)
All	12	22	16	51(100)

Phot. 1. Humerus-scapula fusion as an example of developmental change

Phot. 2. Spina bifida as an example of developmental change

Phot. 3. Suspected syphilitic change on tibias

Phot. 4. Non-specific inflammatory lesions on tibias

tal or inflammatory diseases (Table 8), among which the most interesting was humerus-scapula fusion or *spina bifida* (Photograph 1 and 2). Among inflammatory diseases, syphilitic changes were suspected (Photograph 3) and a few non-specific inflammatory lesions were found (Photograph 4).

Discussion

Easy to identify and score, discrete traits can be very useful in anthropological research (Kaur et al. 2012), particularly on badly preserved skeletal material. Non-metric traits may reflect genetic differences between populations and can be used to compare them, thus being useful in biological distance analysis (Wood-Jones 1931; Berry and Berry 1967), hence analyzes of those traits might be helpful in populational comparisons of fragmentary preserved skeletal. In the population studied, however, the preservation was too poor, even for analyzing non-metric traits.

Since discrete traits permit measuring biological distances between past populations, analyzing such traits remains an important approach to trace genetic relationships among ancient populations. Strongly population-specific, discrete traits may vary a lot from population to population – even in skeletons coming from the same period, for which one could expect similarities rather than dissimilarities. Thus the differences in the incidences of variants for populations being compared certainly reflect genetical differences between the populations. One should also be aware that the usefulness of this approach may be reduced by the possibility of imposition by environmental factors on them during development. The term epigenetic as these variants are called, implies imposition of phenotypic continuity during development rather than at zygote formation (Kaur et al. 2012). It is possible that non-metric traits may occur because of adverse environmental factors during development. For instance, ambient temperature affects the frequencies with which some non-metric traits occur (Tomaszewska et al. 2012; Tomaszewska and Zelazniewicz 2014). The anthropological analyses of the human skeletal remains from the cemetery in Wyszyński Street in Wrocław revealed that the frequencies with which a few non-metric traits of male and female skulls occurred were similar to the frequencies with which the same traits of skulls occurred in the skeletal material from other cemeteries from Wrocław (Kwiatkowska 2005). Since in the present study the remains were poorly preserved, non-metric traits were analyzed for the male and female skeletons together. In previous research, however, sex differences were shown in only few non-metric traits (Berry 1975). Thus, it seems that sex differences in the frequency of occurrence of non-metric traits in human crania are not generally consistent, and so the sex determination of remains is not crucial.

The morphological indicators of physiological stress are non-specific and may result from negative physiological and environmental stimuli. For their ease of observation, universality for anthropological purposes, and causal factors, the most reliable indicators are *cribra orbitalia*, enamel hypoplasia, and dental caries. The relatively high frequency of degenerative changes observed in the population studied might result from a workload and high physical activity, a likely consequence of lower socioeconomic status of the population. The number of pathological lesions and stress indicators would probably have been higher, had the number of complete and well-preserved skeletons been higher.

Conclusion

Non-metric traits, morphological markers of physiological stress, and pathological lesions can provide information about the living and health conditions of late medieval and early modern inhabitants of Wrocław. So far, due to a lack of skeletal material, this specific transitional period has not been investigated. The living conditions of the population are difficult to analyze because the skeletal remains are poorly preserved. The results of the previous analysis of metric traits (Markowska 2007) and the results of the present analysis of non-metric traits, pathologies, and indicators of physiological stress suggest that the living conditions of the studied population were poor. The atypical localization of the cemetery on a frequently flooded area together with the relatively high occurrence of physiological stress indicators and pathological lesions may also suggest that it was an uncommon type of cemetery. This might have been a burial place for prisoners and victims of various epidemics that affected the city (Gilewska-Dubis 2000). For the scarcity of historical sources—the cemetery can-not be found in any historical plan or map of the city—it is hard to state the purpose of the cemetery with certainty.

We should be aware, however, that the conclusions about stress indicators and pathologies should be treated with caution because the state of preservation of the skeletons is likely to affect the number of observed traits: the more complete and well-preserved the skeletons, the greater the number of stress indicators and pathologies that could be observed.

Authors' contributions

AT conceived the paper, collected data, performed statistical computations and drafted the manuscript. BK was project supervisor, co-edited the final version of the manuscript. Both authors carefully read and accepted the final version of the manuscript.

Conflict of interest

The authors declare that the paper is without any conflict of interest and has not been published elsewhere.

Corresponding author

Agnieszka Tomaszewska, Department of Anthropology, Wrocław University of Environmental and Life Sciences, Kożuchowska 5, 50-631 Wrocław, Poland
e-mail: agnieszka.tomaszewska@upwr.edu.pl

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