ANTHROPOLOGICAL REVIEW

WYDAWNICTWO
UNIWERSYTETU
ŁÓDZKIEGO

ANTHROPOLOGICAL REVIEW

The Official Publication of
the Polish Anthropological Society

Volume 85/2022
Issue 3

PTA
POLSKIE TOWARZYSTWO ANTROPOLOGICZNE

WYDAWNICTWO
UNIWERSYTETU
ŁÓDZKIEGO
Łódź 2022

Published by Łódź University Press
Publisher's sheets 8,5; printing sheets 8.25
W.10815.22.0.C
ISSN 1898-6773
e-ISSN 2083-4594

Contents

Anthropological Review • Vol. 85(3), 1–18 (2022)

Anthropological Review
Available online at: https://doi.org/10.18778/1898-6773.85.3.01

Mandibular Canal and the Arrangement of the Neurovascular Bundle Exit Routes in Divergent Populations

Agnieszka Tomaszewska[1], Daniel Psonak[2], Joanna Rudzka[2]

[1] Department of Anthropology, Wroclaw University of Environmental and Life Sciences, Poland
[2] Department of Human Biology, Department of Biological Sciences, University of Wroclaw, Poland

Abstract: *Aim:* In face anatomy and surgery, variation in the presence, number, location, and size of the mental foramen is discussed. Knowledge of the location of the mental foramen canal, which may led due to the possibility of accidental injury of the neurovascular bundle passing through this canal may lead to anesthesia. This study aimed to present selected anatomical features of human mandibles, focusing on the morphology of the mandibular canal and its neurovascular bundle exit in populations with different socio-economic status.
Material and methods: Selected well preserved and unharmed human skulls (N= 169) (50.3% males, 49.7% females) from two populations (rural and outskirts) from Poland were used. Populations differed in socio-economic statuses.
Results: Obvious dimorphic differences in each analyzed population were stated and inter-population differences were observed as well. In an outskirt population sexual dimorphism was more evident. Those differences should be considered when approaching the mandibular canal during anesthetic, surgical and forensic procedures.
Discussion: The occurrence of the mental foramen is relatively constant, but location is variable, and thus, each individual may exhibit a different arrangement of bundle exits. Both the position and the direction of the exit of the neurovascular bundle were similar to other European population. However, differences in localization between those two investigated populations were observed. This may suggest that not only genetic but also environmental factors, such as living conditions and diet (which affects developmental stability), may influence the morphology of the mandibular features.

Key words: cranial openings, mental foramen, mandibular foramen, canal mandible.

Original article

Received: 23.09.2021; Revised: 11.05.2022; Accepted: 18.05.2022

Introduction

Knowledge of the localization of the craniofacial foramina is of importance, mainly for dental, surgical, anesthetic and cosmetic procedures concerning the human skull (Cutright et al. 2003). Among the variety of skull foramina, mental and mandibular foramina are of greatest interest in both clinical and diagnostic practices.

The human mandible is the largest, strongest, and lowest bone in the face. Its innervation is provided by inferior alveolar nerve, a branch of the mandibular division of trigeminal (CNV) nerve (*nervus trigeminus*), which may be impaired due to, e.g. an accidental injury during dental or surgical procedures. A lesion to CNV may lead to local anesthesia, i.e., half of the mandibular region in the case of branches of the inferior alveolar nerve division (Gray 1985), which is described in detail by Renton et al. (2010).

The functional complexity of the human mandible has contributed to its complex structure, in which foramina and canals responsible for communication between the spaces within the human skull can be distinguished. The mandibular foramen is located in the middle of the mandibular ramus, in the inner (medial) aspect of the mandible. The mental foramen is located lateral to the mental protuberance, usually inferior to the apices of the mandibular first and second premolars. The mental foramen allows entrance of the mental nerve and blood vessels into the mandibular canal (Valente et al. 2012; Łasinski 1993; Samantha and Kharb 2013). Through the mandibular canal runs the inferior alveolar nerve and inferior alveolar artery, which provides blood supply to the lower teeth, periodonts of the buccal side and chin and lower lip (Gray 1985; Drake et al. 2010).

Inter- populations and regional differences in size and location of the mental and mandibular foramina has been reported (Green 1987; Moiseiwitsch and Hill 1998; Nayarana and Prashanthi 2003; Hasan 2012; Shenoy et al. 2012). Thus, its position, size, and number need to be considered before preparing osteotomy and other surgical procedures in the foraminal area. Although different methods of measurements of the mandibular features have been reported, the traditional anthropometric measurements with sliding calipers are most often carried out. However, some research was conducted on roentgenographs. Therefore, we should be aware of small simplification of the obtained measurements, because the results are in 2 D space, and therefore, some of the curvilinear measurements may be simplified. Moreover, anatomical variations may impede observations of some mandibular features, such as the bifid or trifid mandibular canal (Mizbah et al. 2012; Miličević et al. 2021), which may not be detected in panoramic or periapical films (Dario 2002). Its occurrence depends on the assessment method (cone- beam computed tomography or panoramic radiographs) but for anthropological and archaeological field work purposes only macroscopic assessment is useable. Radiographic assessment of mental and mandibular foramina may be tentative. Jacobs et al. (2004) reported the mental foramen was detected on 94% of panoramic radiographs, but clear visibility was only attained in only 49% of the time. Similarly, Yosue and Brooks (1989) observed the mental foramen in 87.5% of the samples, but the foramina were clearly visible only in 64% of the samples. Therefore, computed tomography seems to be the best solution in visualizing the position of the foraminal area. According to Sonick et al. (1994), average linear errors for CT investigation is only 1.8% (compared to 24% for panoramic films and 14% for periapical films).

This study aims to compare selected anatomical features of human mandibles, focusing on the morphology of the mental and mandibular foramina. Since there have been reported inter-populations and regional differences in mandibular morphology, we used 2 populations with different socioeconomic statuses to determine whether environmental (geographical) conditions, e.g., life conditions and diet (which affects developmental stability) in diverse populations can influence the morphology of the mandibular features. This study makes also clinical suggestions to reduce inadvertent damage to the mental and inferior alveolar nerve during surgical procedures or dental approaches in the foraminal area.

Material and methods

The study used 169 adult skulls, held at the Department of Human Biology, University of Wroclaw, Poland. The adult age of the crania was confirmed based on the closure of sphenooccipital synchondrosis. The sex of the individuals was determined based on sexually dimorphic cranial features (Workshop 1980). None of the examined skulls showed signs of cranial deformations, malformations, or trauma.

For the analysis, a selection of 2 populations from the Middle-Western European region with different socioeconomic statuses, were used:

1. An example of the rural population sample from Sypniewo site (Maków County, Masovian Voivodeship, Poland) (X^{th} – $XIII^{th}$ centuries) (Sekutowski 2002; Biermann 2006). This sample consisted of 75 skulls 25 (33.0%) skulls which were classified as male and 50 (67.0%) as female.

2. An example of the outskirt population sample from Gródek upon the Bug River (Hrubieszów County, Lublin Voivodeship, Poland) (X^{th-} $XIII^{th}$ centuries) was examined (Belniak et al., 1961). The sample consisted of 94 skulls 60 (64.0%) classified as male and 34 (36.0%) as female.

Morphometric measurements were conducted using a MicroScribe G2L, a 3D contact scanner (www.e-microscribe.com). The measurements (Tab. 1, Fig. 1) were carried out according to Martin's instructions (Martin et al. 1988) and recorded to two decimal places of a millimeter. Each measurement was conducted twice and an average of 2 measurements was used for statistical analyses using Statistica 13.0 software (StatSoft 2016).

The mean, standard deviation (SD), and variation ranges (minimum-maximum) for each of the measurements were calculated. All variables had a normal distribution (Shapiro–Wilk test; p>0.05), mostly with homogeneous variances (Levene's test; $p>0.05$). For paired comparisons, the Student t-test was used (in cases where variances were not homogenous- with Cochran-Cox adjustment) or Wilcoxon test as an alternative. For unpaired comparisons, as an alternative, *the U*-Mann Whitney test was used. Pearson correlation coefficient (or Spearman for non- normal distribution of the features) was also calculated. The scale according to Stanisz (1998) was used to apply the strength of the correlation:

$0 < r < 0.1$	very weak correlation
$0.1 \leq r < 0.3$	weak correlation
$0.3 \leq r < 0.5$	average correlation
$0.5 \leq r < 0.7$	high correlation
$0.7 \leq r < 0.9$	very height correlation
$0.9 \leq r < 1$	almost complete correlation.

Table 1. Measurements taken in the study sample

Martin's et al. (1988) measurement number	Measurements	Description of measurements	Figure 1- measurement number
65	kdl-kdl	intercondylar breadth	1–1
65(1)	kr-kr	distance between coronoid processes	2–2
66	go-go	gonion- gonion distance	3–3
68	gn-go	gnathion- gonion distance	4–3
69	id-gn	infradentale- gnathion distance	4–5
69(2)	CHM2	mandibular corpus height below second molar	13
70	go-cm	mandibular ramus height gonion- caput mandibulae	
70(3)	MID	mandibular incisura depth	8
79	MA	mandibular angle	7
	kdl-kr	distance between condylar and coronoid processes	1–2
	pg- gn	pogonion- gnathion distance	6–4
	id- pg	infradentale- pogonion distance	5–6
	pg- ml	pogonion- formane mentale distance	6–9
	MinCH	minimal corpus height	10
	MaxCH	maximal corpus height	11
	MinMB	minimal mandibular breadth	
	MaxMB	maximal mandibular breadth	
	FMeB	mental foramen breadth	9
	FMaB	mandibular foramen breadth	12
	mb- ml	mandibular foramen and mental foramen distance (mandibular canal length)	

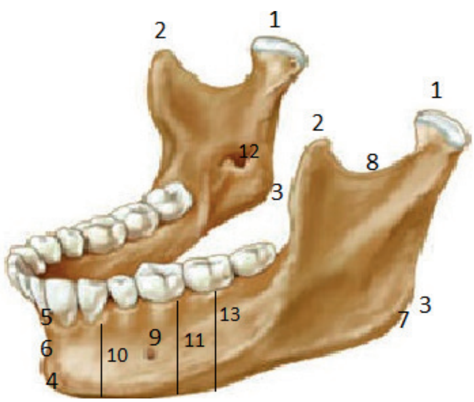

Fig. 1. Measurements taken in the study sample (numbers described in Table 1) (www.legacy.owensboro.kctcs.edu)

Sexual dimorphism was calculated using the formula, where:

$$SexDim = [(\bar{X}_m - \bar{X}_f) : \bar{X}_f] \times 100\%,$$

$\bar{X}_m$ – male mean, $\bar{X}_f$ – female mean.

The significance level was taken at $p<0.05$ (Stanisz 1998; Field 2006).

Results

For the Sypniewo and Gródek upon the Bug River samples, for unpaired features, significant differences between those two investigated populations were found for 8 features. For the population from the Gródek upon Bug River all features had higher values than those in the Sypniewo population (except for *id-pg*, *go-cm*, and MA, although not significant) (Tab. 2).

Table 2. Differences between two analysed populations (bilateral features were averaged)

Features	Sypniewo			Gródek upon the Bug			Test Z	Test *t*	*Df*	*p*
	$\bar{X}$	SD	N	$\bar{X}$	SD	N				
go-go	95.8	7.1	38	100.5	7.4	41	2.68			**$p^3=0.001^*$**
pg-gn	14.0	1.8	73	15.7	2.1	91	5.37			**$p^3<0.001^*$**
id-gn	24.0	3.5	68	25.3	3.3	87		2.4	153	**$p^1<0.001^*$**
id-pg	9.9	2.8	68	9.9	2.4	87	3.36			$p^3= 0.920$
kdl-kdl	117.7	5.2	29	119.7	6.3	49	4.66			$p^3=0.110$
kr-kr	95.3	6.0	51	97.9	9.9	64	3.81			**$p^3<0.001^*$**
gn-go	79.1	4.5	55	81.7	7.0	86		3.04		**$p^2=0.002^*$**
pg-FMeB	23.9	2.6	74	24.4	4.0	92		0.38		$p^2=0.703$
CHM2	21.4	3.2	57	22.0	4.0	89		0.64		$p^2=0.526$
MINMH	18.2	4.5	57	19.9	5.1	91		1.06		$p^2=0.289$
MAXMH	22.3	5.5	57	24.4	5.9	91		1.04		$p^2=0.263$
kdl-kr	42.2	4.0	57	43.0	4.6	87		1.05		$p^2=0.292$
MID	12.1	1.4	55	12.5	1.9	84		2.37		**$p^2=0.018^*$**
MA	138.2	5.6	50	135.3	6.8	86		1.9		$p^2=0.058$
MinMB	11.1	1.4	75	12.0	1.5	94		1.28		$p^2=0.202$
MaxMB	14.6	1.6	75	15.4	1.6	94		2.38		**$p^2=0.017^*$**
mb-ml	56.7	3.8	73	59.0	4.0	88		1.55		$p^2=0.120$
FMeB	3.4	1.2	75	3.9	0.9	94		2.42		**$p^2=0.016^*$**
FMaB	2.7	0.6	74	3.5	1.7	92		0.05		$p^2=0.960$
go-cm	60.2	6.6	49	59.2	9.9	77		0.14		$p^2=0.889$

p^2- Wilcoxon's test, p^3- U-Manna Whitney's test

After controlling for sex, even more features were found to differ significantly. Sexual dimorphism for Sypniewo population was 7.0% and for Gródek upon the Bug River 7.5%. Descriptive statistics are presented in Tables 3 and 4 for Sypniewo and Gródek located along the Bug River respectively. Right and left side measurements were higher for males in both populations (except for FMaB in the Sypniewo sample) (Tab. 3 and 4). Comparisons of bilateral features has revealed significant differences in both sexes for few features, but only in the population from the Gródek upon the Bug River (Tab. 5). In contrast, in the Sypniewo sample, no significant differences between sides were observed.

When mandibular features were compared, a high correlation was also found between mandibular canal length (mb-ml) and mandibular foramen breath (FMaB) for males in population from Gródek upon the Bug River and Sypniewo. High correlation was also found between mandibular foramen breath (FMaB) and mental foramen breadth in males from the Sypniewo. A weak correlation was found between FMaB and FMeB for males from the Gródek upon the Bug River and for females from both populations for mental canal length and FMaB. No statistically significant correlation was found between mandibular canal length and FMeB in both populations (Tab. 6).

Table 3. Descriptive statistics for male and female skulls in the Sypniewo population [in mm]

Features	Body side	FEMALES				MALES				Test Z**	Test C*	*df*	*p*
		$\bar{X}$	SD	N	Ranges min-max	$\bar{X}$	SD	N	Ranges min-max				
go-go		94.1	7.4	22	85-114	98.2	6.3	16	90-107				
pg-gn		13.4	1.5	50	11-17	15.3	1.7	23	11-18	4.09			<0.01
id-gn		23.1	2.9	46	16-29	26.1	3.9	22	19-34		3.53	66	<0.01
id-pg		9.4	2.5	46	4-16	10.7	3.2	22	5-17				
kdl-kdl		115.2	3.8	18	110-125	121.9	4.7	11	112-129	3.12			<0.01
kr-kr		94.1	5.6	35	82-105	97.9	6.3	16	85-106		2.14	49	0.037
gn-go	right	77.5	3.7	30	70-86	80.9	4.2	21	74-89	2.99		49	<0.01
gn-go	left	78.0	4.3	24	70-86	80.9	5.5	19	72-90	2.00			0.045
pg-FMeB	right	23.6	1.8	49	19-29	25.3	1.5	24	23-29	3.73			<0.01
pg-FMeB	left	23.9	1.7	49	19-27	25.1	1.3	24	22-28	2.74			0.06
CHM2	right	20.7	3.1	37	15-26	23.0	3.6	19	16-31	2.41			0.016
CHM2	left	20.5	3.0	36	16-29	22.6	3.4	15	16-28				
MinMH	right	19.5	2.8	37	12-24	21.7	3.4	18	17-29	2.12			0.034
MinMH	left	19.1	2.1	36	15-24	21.8	2.6	12	17-25				
MaxMH	right	23.8	2.5	37	17-29	27.3	3.7	18	22-34	3.30			<0.001
MaxMH	left	23.9	2.8	36	19-31	26.4	4.1	12	20-34				<0.001
kdl-kr	right	41.2	3.3	29	35-48	43.2	4.7	16	36-50				
kdl-kr	left	41.7	3.7	28	34-49	43.5	4.4	14	37-50				
MID	right	12.0	1.4	26	10-15	12.8	1.5	15	10-15				
MID	left	11.9	1.2	27	10-14	12.4	1.8	14	9-15				
MA	right	138.0	5.2	23	129-147	138.6	6.5	18	130-152				
MA	left	138.2	5.0	18	130-147	138.4	6.9	14	128-153				
Min MB	right	10.8	1.4	49	8-14	11.9	1.4	25	10-14	2.71			0.007
MinMB	left	10.7	1.1	49	8-14	11.8	1.8	24	9-16				<0.001
MaxMB	right	14.4	1.8	49	10-17	14.7	1.5	25	11-18	2.73			0.006
MaxMB	left	14.5	1.7	49	10-18	15.1	1.6	24	12-19		5.69	68	0.001
Mb-ml	right	55.0	2.5	48	50-61	59.4	3.8	22	51-66		5.03	62	<0.001
Mb-ml	left	55.4	2.8	43	46-61	59.8	4.1	21	52-67				<0.001
FMeB	right	3.4	1.3	50	1-6	3.6	1.4	24	2-7				
FMeB	left	3.3	1.3	49	1-7	3.2	1.3	25	1-21				
FMaB	right	2.7	0.6	48	2-4	2.9	0.9	23	2-5				
FMaB	left	2.8	0.5	45	2-4	2.7	0.8	21	1-4				
go-cm	right	59.0	3.6	22	52-67	64.7	4.4	17	59-73		4.52	37	<0.001
go-cm	left	57.8	3.8	18	50-65	64.1	4.8	14	58-73		4.18	30	<0.001

*Test C- Cochran- Cox' adjustment; **Test z- U Mann- Whitney test

Table 4. Descriptive statistics for male and female skulls in the Gródek upon the Bug River population [in mm]

Features	Body side	FEMALES				MALES				Test Z**	Test C*	*df*	*p*
		$\bar{X}$	SD	N	Ranges min-max	$\bar{X}$	SD	N	Ranges min-max				
go-go		98.2	5.5	15	90-106	101.9	8.2	26	84-115				
pg-gn		15.1	1.8	33	11-18	16.1	2.2	58	11-22		2.29	89	0.024
id-gn		23.8	2.4	31	19-29	26.2	3.4	56	17-32		3.48	85	0.001
id-pg		8.8	2.3	31	5-14	10.5	2.3	56	5-17	3.10			0.002
kdl-kdl		116.3	4.3	21	106-126	122.3	6.5	28	106-133		3.66	47	0.001
kr-kr		94.7	13.3	26	34-108	100.1	6.0	38	85-111	2.15			0.032
gn-go	right	82.1	6.4	17	73-93	83.4	6.5	40	74-100	2.00			0.045
gn-go	left	79.8	6.0	28	73-99	82.5	5.8	40	71-96				
pg-FMeB	right	25.1	2.0	31	22-28	25.5	2.2	57	21-30				
pg-FMeB	left	25.3	1.9	32	21-29	25.6	2.2	57	23-31				
CHM2	right	21.3	2.8	29	15-27	22.9	3.3	51	15-29		2.42	82	0.018
CHM2	left	21.5	2.4	32	16-26	23.1	3.2	52	17-30				
MinMH	right	20.9	2.3	28	17-27	22.6	3.3	52	12-31		2.46	78	0.016
MinMH	left	21.6	2.1	31	18-26	22.1	3.0	54	12-27				
MaxMH	right	25.5	2.3	29	22-32	27.9	3.0	52	21-33	3.66			<0.001
MaxMH	left	25.7	2.5	30	22-33	27.3	2.8	54	22-33	2.51			0.012
kdl-kr	right	40.9	3.7	27	32-47	44.2	3.8	46	36-52	3.43			<0.001
kdl-kr	left	41.4	3.9	27	33-48	44.7	3.4	44	36-50	3.30			<0.001
MID	right	12.0	1.4	24	10-15	12.8	2.2	45	9-18				
MID	left	11.7	1.6	28	9-15	13.3	2.2	38	9-20	3.02			0.003
MA	right	137.5	6.5	17	126-150	134.0	8.0	40	106-145				
MA	left	136.5	7.2	29	123-150	135.5	7.0	39	119-151				
Min MB	right	11.2	1.1	33	9-14	12.6	1.5	58	9-16	4.41			0.003
MinMB	left	11.2	1.3	32	9-14	12.4	1.6	59	9-16	3.26			0.001
MaxMB	right	14.7	1.2	33	12-17	15.6	1.8	58	12-20	2.09			0.036
MaxMB	left	15.1	1.2	32	13-17	15.9	1.7	59	12-21	2.57			<0.010
Mb-ml	right	56.6	3.9	30	48-63	60.0	4.1	52	52-68	3.09			<0.001
Mb-ml	left	57.6	4.1	30	50-66	60.2	4.3	50	47-69		2.68	78	<0.001
FMeB	right	3.7	0.8	32	2-6	4.0	1.0	59	2-6				
FMeB	left	3.7	1.0	33	2-6	3.8	1.0	58	2-6				
FMaB	right	3.1	0.9	31	2-5	4.0	3.9	52	2-31				
FMaB	left	3.0	0.8	30	2-5	3.6	0.9	50	2-6	2.43			0.015
go-cm	right	59.3	3.3	16	52-63	64.5	6.4	34	48-87	2.94			<0.001
go-cm	left	59.8	4.4	25	50-66	63.9	4.7	34	54-74		3.36	57	0.001

*Test C- Cochran- Cox' test; **Test z- U Mann- Whitney test

Table 5. Bilateral features in males and females (those with significant differences only in population from the Gródek upon the Bug River

Features	Right side $\bar{X}$	SD	N	Left side $\bar{X}$		N	Test t	*Df*	*p*
				MALES					
gn-go	83.4	6.5	40	85.2	5.8	40	2.48		0.013[1]
MaxMH	27.8	2.9	52	27.3	2.8	54	2.00		0.046[1]
MID	12.8	2.2	45	13.3	2.2	38	2.63	29	*0.013*[2]
FMeB	4.0	1.0	59	3.8	1.0	58	1.97	87	*0.026*[2]
				FEMALES					
gn-go	82.1	6.4	17	79.8	6.0	28	2.22	25	*0.026*[1]
MinMH	20.9	2.3	28	21.6	2.1	31	2.17	25	*0.040*[2]
MA	137.5	6.5	17	136.5	7.2	29	2.13	25	*0.030*[1]
go-cm	61.4	4.2	16	62.2	4.2	25	2.09	25	*0.037*[1]

[1]- Wilcoxon' test; [2]- Student *t*-test

Table 6. Spearman's and Person's correlation coefficients for mandibular features in populations from Sypniewo and Gródek upon the Bug River

Cecha	MALES		FEMALES	
	mb-ml	FMeB	mb-ml	FMeB
		GRÓDEK UPPON BUG RIVER		
mb-ml	—	r_s=0,01	—	r_s=0,21
FMaB	r_s=0,57*	r=0,32*	r_s=0,36*	r=0,23
		SYPNIEWO		
mb-ml	—	r_s=0,21	—	r_s=-0,09
FMaB	r_s=0,50*	**r_s=0,55***	**r_s=0,37***	r_s=0,24

r_s- Spearman's correlation coefficient; r- Pearson's correlation coefficient; * **p≤0,05**

For male individuals from the Grodek upon the Bug River population statistically significant weak or moderate correlation was observed between *mb-ml* measurement and: *go-go, pg-gn, id-gn, gn-go, MinMB, MaxMB and MID* and for FMaB with *kdl-kr* and MA as well. In addition, a high correlation (0.6) was observed between FMaB and go-go (Tab. 6). For females, statistically significant and moderate correlation was found between mb-ml and MAxMB as well as between mb-bl and pg-FMaB and between FMaB and go-gndl-kr, MinMB and go-cm. High correlation (0.5) was fount between FMaB and MA measurements (Tab. 7 and 8). For males from a population from Sypniewo average correlation was found between mb-bl and kdl-kr. High correlation was also found between mb-bl and MID. For females, mb-ml was moderately correlated with gn-go and CHM2 (Tab. 7 and 8).

Table 7. Spearman's and Person's correlation coefficients for unpaired mandibular features in populations from Sypniewo and Gródek upon the Bug River

Site	Feature	go-go	pg-gn	id-gn	id-pg	kdl-kdl	kr-kr
GRODEK UPON BUG	**MALES**						
	mb-ml	r_s=0.19⋆	**r_s=0.41⋆**	**r_s=0.30⋆**	r=0.02	r=0.17	r=0.07
	FMaB	r_s=0.06	r_s =-0.03	r_s =0.01	r_s =0.01	r_s =0.05	r_s =-0.11
	FMeB	**r=0.6⋆**	r=0.11	r=0.22	r_s =-0.01	r=0.43	r_s =0.16
	FEMALES						
	mb-ml	r_s=0.23	r_s=-0.16	r_s=-0.26	r_s=0.04	r_s=-0.26	r_s=0.27
	FMaB	r=0.08	r=0.01	r=-0.36	r=-0.14	r=0.35	r_s=0.29
	FMeB	r=0.16	r=0.27	r=0.41	r_s=0.18	r=0.45	r_s=0.24
SYPNIEWO	**MALES**						
	mb-ml	r_s=0.08	r_s=-0.16	r_s=0.02	r_s=0.001	r_s=-0.24	r_s=-0.18
	FMaB	r=0.39	r_s=-0.10	r=-0.26	r=-0.29	r=0.36	r=-0.04
	FMeB	r_s=0.3	r_s=-0.02	r_s=-0.25	r_s=-0.23	r_s=0.33	r_s=0.38
	FEMALES						
	mb-ml	r_s=0.31	r_s=0.19	r_s=-0.13	r_s=-0.11	r_s=-0.03	r_s=0.07
	FMaB	r_s=-0.12	r_s=0.11	r_s=-0.22	r_s=-0.20	r_s=-0.28	r_s=0.09
	FMeB	r_s=-0.04	r_s=0.02	r=-0.08	r=-0.17	r_s=0.30	r_s=0.20

r_s - Spearmana correlation coefficient; r - Pearsona correlation coefficient; ⋆ **p≤0,05**

Table 8. Spearman's and Person's correlation coefficients for paired mandibular features in populations from Sypniewo and Gródek upon the Bug River

Site	Feature	gn-go	pg-FMaB	CHM2	MinCH	MaxCH	kdl-kr	MID	MA	MinMB	MaxMB	go-cm
GRODEK UPON BUG	**MALES**											
	mb-ml	**r_s=0.37⋆**	r_s =0.21	r_s =0.02	r_s =0.03	r_s =0.11	**r_s =0.58⋆**	**r_s =0.37⋆**	r_s =0.18	**r_s =0.48⋆**	**r_s =0.48⋆**	r_s =0.23
	FMaB	r_s =0.27	r_s =-0.01	r_s =0.01	r_s =-0.02	r_s =0.03	**r_s =0.47⋆**	r_s =0.22	**r_s =0.28⋆**	r_s =0.16	r_s =0.21	r_s =0.23
	FMeB	r_s =0.17	r_s =0.18	r_s =-0.01	r_s =0.17	r_s =0.22	r_s =-0.03	r_s =0.33	r_s =0.23	r_s =-0.07	r_s =-0.001	r_s =0.07
	FEMALES											
	mb-ml	r_s=-0.14	**r_s=0.45⋆**	r_s=0.24	r_s=0.22	r_s=0.25	r_s=0.18	r_s=0.10	r_s=-0.01	r_s=0.28	**r_s=0.36⋆**	r_s=-0.01
	FMaB	**r_s=0.35⋆**	r_s=0.34	r_s=0.12	r_s=0.31	r_s=0.32	**r_s=0.36⋆**	r_s=0.33	**r_s=0.50⋆**	**r_s=0.45⋆**	r_s=0.12	**r_s=0.47⋆**
	FMeB	r_s=0.06	r_s=0.28	r_s=0.21	r_s=0.20	r_s=0.30	r_s=0.10	r_s=0.18	r_s=0.06	r_s=0.18	r_s=0.04	r_s=0.10
SYPNIEWO	**MALES**											
	mb-ml	r_s=0.24	r_s=-0.21	r_s=0.32	r_s=0.17	r_s=0.08	**r_s=0.46⋆**	**r_s=0.53⋆**	r_s=0.24	r_s=0.21	r_s=0.25	r_s=0.35
	FMaB	r_s=0.33	r=-0.45	r=0.13	r=-0.20	r=-0.20	r_s=0.17	r=0.02	**r_s=0.48⋆**	r=-0.46	r_s=-0.15	r_s=0.22
	FMeB	r_s=0.01	r_s=-0.25	r_s=-0.26	r_s=-0.32	r_s=-0.33	r_s=-0.17	r_s=0.13	r_s=0.004	r_s=0.10	r_s=-0.02	r_s=-0.12
	FEMALES											
	mb-ml	**r_s=0.41⋆**	r_s=-0.02	**r_s=0.34⋆**	r_s=0.21	r_s=0.16	r_s=0.24	r_s=0.06	r_s=0.11	r_s=0.15	r_s=0.11	r_s=0.35
	FMaB	r_s=0.22	r_s=-0.26	r_s=0.28	r_s=0.15	r_s=0.17	r_s=0.13	r_s=-0.004	r_s=-0.11	r_s=-0.07	r_s=0.16	r_s=0.16
	FMeB	r_s=-0.13	r_s=-0.14	r_s=-0.07	r_s=-0.15	r_s=-0.10	r_s=-0.10	r_s=0.04	**r_s=-0.45⋆**	r_s=-0.13	r_s=0.08	r_s=-0.27

Discussion

Occurrence of the mental foramen is relatively constant, however, the location is variable. Thus, each individual may exhibit a different arrangement of the neurovascular bundle exit. The position and the direction of the exit of the neurovascular bundle were similar to other European populations (Tab. 9, 10). However, differences in localization between the two investigated populations were observed. Thus, it could suggest that not only genetic but also environmental (geographical) factors, such as living conditions (e.g., diet, which may affect developmental stability), may influence the morphology of the mandibular features.

The literature review revealed a broad variety of features characterized by the human mandible (Tab. 9) which may result from both different environmental conditions (e.g., different food accessibility) as well as nutrition culture. In poorer populations, for instance, a scarcity of food may result in the incorrect realization of the bone growth path. Moreover, nutrition culture, such as consistency and type of food, may result in differences in chewing intensity and, therefore, different sizes of the mandible (Raadsheer et al. 1999; Golusik et al. 2005). A secular trend observed in populations from different time ranges is also an important factor influencing the mandible's features.

Table 9. Comparison of studies concerning the morphometry of the mandibular features according to sexes [in mm]

Author, year of publication	N	Population, time ranges	Sex	Features (mean± SD)					
				go-go	id-gn	gn-go	kdl-kdl	MA	go-cm
This study, 2020	50	Poland (Sypniewo), XI-XII^th^	Female	94.1±7.4	23.1±2.9	77.6±3.8	115.2±3.8	138.2±5.3	58.2±3.7
	25		Male	98.2±6.3	26.1±3.9	81.2±4.7	121.9±4.7	138.5±6.1	64.6±4.3
	75		TOTAL	95.8±7.1	24.0±3.5	79.1V4.5	117.7±5.2		
This study, 2020	34	Poland (Gródek upon Bug), XIII-XVI^th^	Female	98.2±5.5	23.8±2.4	80.7±6.4	116.3±4.3	136.2±6.8	59.6±4.0
	60		Male	101.9±8.2	26.2±3.4	82.2±7.4	122.3±6.5	134.8±6.8	64.6±6.0
	94		TOTAL	100.5±7.4	25.3±3.3	81.7±7.0	119.7±6.3		
Mays, 2014	15	Nederland, XIX^th^	Female	91.1±7.5		69.7±.3.3	113.1±6.3	134.0±8.3	
	17		Male	99.9±6.8		76.3±7.6	116.9±6.9	126.9±8.7	
	15	England, X-XIX^th^	Female	96.2±7.1		70.5±6.1	116.7±7.7	126.4±6.4	
	17		Male	105.1±7.1		76.2±4.7	124.2±5.7	122.6±9.0	
Purmal et al., 2013	46	Malaisia, XX^th^	Female	103.9±5.4					
	44		Male	106.7±7.8					
	34		TOTAL	105.2±6.7					
		China, XX^th^	Female	105.3±6.5					
			Male	108.2±7.5					
	30		TOTAL	106.7±7.1					
		India, XX^th^	Female	98.7±8.4					
			Male	111.1±10.0					
	26		TOTAL	104.9±11.0					
Simalcsik et al., 2012	299	Romania, XVI-XVIII^th^	Female	94.1±7.3	28.6±3.0	66.1±5.1	112.8±7.2		60.2±4.8
	259		Male	104.8±9.0	32.4±3.0	69.1±4.8	123.9±8.4		64.9±5.0
Ongkana et al., 2009	102	Thailand, XX^th^	Female		28.2±6.5	79.2±4.6	116.1±5.9		62.6±5.6
			Male		28.3±6.1	83.2±5.2	123.8±6.3		68.1±4.4

Author, year of publication	N	Population, time ranges	Sex	Features (mean± SD)					
				go-go	id-gn	gn-go	kdl-kdl	MA	go-cm
Golusik et al. 2005	16	Poland (Złota), II-III$^{th\ BC}$	Female	94.1±4.6	30.4±5.0	80.0±3.8	113.9±5.6		
	69		Male	99.9±8.4	34.1±3.1	84.6±4.5	118.2±6.9		
	85		TOTAL	97.00	32.0	82.5	116.0		
	24	Poland (Milicz), XII-XIIIth	Female	93.4±4.9	30.9±2.2	83.4±5.1	112.8±8.3		
	22		Male	100.3±7.5	31.8±3.3	86.1±7.0	118.5±7.7		
	47		TOTAL	97.0	31.5	84.5	115.5		
	104	Poland (Gródek upon Bug), XIII-XVIIth	Female	94.6±6.4	27.0±2.7	77.0±4.8	116.2±6.0		
	160		Male	101.5±7.3	30.3±3.0	81.2±4.8	121.7±7.1		
	264		TOTAL	98.0	28.5	79.0	119.0		
	28	Poland (Warsaw), XXth	Female	94.6±6.6	27.5±3.2	77.0±4.3	110.1±6.6		
	70		Male	98.0±7.7	30.3±3.4	83.0±5.0	116.3±6.1		
	98		TOTAL	96.5	29.0	80.0	114.0		
Fabian and Mpembeni, 2002	25	Tanzania Bantu, ??	Female				77.0±3.9		
	25		Male				80.6±3.8		
Puisorua et al., 2006	91	Europe, Near East, Asia, Africa, ??	Female			91.0±3.6[1]			
			Male			114.1±38.9[1]			
			Female			89.0±1.8[2]			
			Male			110.0±3.6[2]			
			Female			95.0±1.67[3]			
			Male			119.0±29.9[3]			
		Zimbabwe, ??	Female			91.0±3.6		128.0	
			Male			114.0±38.9		123.0	
		Nigeria, ??	Female						
			Male						
			TOTAL					118.8	
		Turkey, ??	Female						
			Male						
			TOTAL					120.2	
		USA, ??	Female					126.5	
			Male					127.8	
		Spain, ??	Female						
			Male						
			TOTAL					118.1	
		China, ??	Female						
			Male						
			TOTAL					121.2	
		Romania, ??	Female					125.0±1.2	
			Male					119.0±1.1	

Legend: ??- data unavailable, [1]- full dentition; [2]- uncomplete dentition; [3]- no dentition

In this study, differences between sexes were found in both analyzed populations. However, for the population from Sypniewo (which is considered as rural population), we found fewer features that exhibited significant sex differences. When the sex of the individuals was controlled for the population from Gródek upon the Bug River, sexual dimorphism was observed in even more features and was slightly higher (7.5%) (Tab. 3 and 4). When sexual dimorphism was lower, living conditions, and thus, socioeconomic status of the population, are considered worse. Sexual dimorphism of the human body is well established. It may be the result of the environmental factors and lifestyle; sexual dimorphism may also be the result of genetic factors (Galdames et al. 2008; Mays 2014). Moreover, disorders of the endocrine system may also result in sex differences in the morphology of the human mandible (Piontek 1999) and greater masticatory forces may result in sexual dimorphism of the mandible. In general, there is less sexual dimorphism in body size in populations with poorer socio-economic status and living in unfavorable environmental conditions (Wells 2012; Tomaszewska et al. 2015). This conclusion may be also related to diet and eating habits. Our results support previous studies, which contend that worse environmental conditions may influence cranial morphology and, ultimately, disrupt an individual's skeletal development (Gilligan and Bulbeck 2007; Harvati and Weaver 2006; Pearson 2000; Perez et al. 2007; Wells 2012).

Table 10. Comparison of studies concerning the morphometry of the mandibular features according to body side [in mm]

Author, year of publication	N	Population, time ranges	Body side	Feature				
				go-cm	MA	FMeB	FMaB	Mb-ml
This study, 2020	75	Poland (Sypniewo), XI-XIITh	Right	61.5±4.9	138.3±5.7	3.5±1.3	2.7±0.7	56.4±3.6
			Left	60.6±5.2	138.3±5.8	3.3±1.3	2.6±0.8	56.8±3.9
This study, 2020	94	Poland (Gródek upon Bug), XIII-XVIth	Right	62.8±6.1	135.0±7.7	3.9±0.9	3.7±3.1	58.8±4.3
			Left	62.1±5.0	135.9±7.1	3.8±1.0	3.4±0.9	59.2±4.4
Shenoy et al., 2012	50	India, ??	Right		124.4±6.0			
			Left		124.1±6.2			
Ennes and Monteiro de Medeiros, 2009	99	Brazil, ??	Right		131.8±8.5[1]			
			Left		131.2±8.2[1]			
			Right		125.6±7.8[2]			
			Left		125.7±9.2[2]			
			Right		126.5±7.8[3]			
			Left		125.7±9.2[3]			
Prośba-Mackiewicz et al., 2005	40	Poland, ??	Right	64.0±4.8[4]				
			Left	63.5±4.8[4]				
Oguz and Bozkir, 2002[7]	34	Turkey, ??	Right	65.6±5.0	120.2±4.7			
			Left	64.6±4.2	120.2±3.6			
Rai et al., 2014	40	India, ??	Right			2.6±0.9		
			Left			2.6±0.9		
Hoque et al., 2013	185	Bangladesh, ??	Right			2.6±0.7		
			Left			2.5±0.5		
Agarwal and Gupta, 2011	100	India, ??	Right			3.3		
			Left			3.3		
Junior et al., 2010	50	Brasil, XXth	Right					52.8
			Left					51.6
Singh and Srivastar, 2010	100	Turkey, ??	Right			2.8		
			Left			2.6		
Ilayperuma et al., 2009	51	Sri Lanka, ??	Right			3.3±0.9		
			Left			3.4±0.8		
Oliveira Junior et al., 2009	80	Brasil, ??	Right			2.4±0.6		
			Left			2.4±0.6		
Wychowański et al., 2008.	100	contemporary	Right			3.7±1.0	3.2±0.6	
			Left			3.8±1.0	3.4±0.6	
			Right			3.3±0.7	3.5±0.5	
			Left			3.8±1.1	3.3±0.4	

Author, year of publication	N	Population, time ranges	Body side	Feature				
				go-cm	MA	FMeB	FMaB	Mb-ml
Igbigbi and Lebona, 2005	70	Malawi- ??	Right Left			2.4±0.2 2.7±0.2		
Prośba-Mackiewicz et al., 2005	40	??	Right Left Right Left			2.7±1.0[1] 2.8±1.0[1] 2.9±1.1[4] 2.8±1.0[4]	3.9±0.9[1] 4.0±0.9[1] 4.1±1.8[2] 4.2±1.7[2]	
Goudot, 2002	1	France* - paleolith	Right Left			4.5 4.5		
Goudot, 1999	1	France*- 60000-45000	Right Left			6.0 6.0	5.0 5.0	
Phillips et al., 1992	75	??	Right+ Left			2.9		

Legend: [1] – no dentition; [2] mandibles with 1 to 10 teeth; [3] mandibles with 11 to 16 teeth; [4] partial lack of dentition; * Neanderthal's mandible.

Foraminal area of the mandible is considered as an important region relevant to anatomy, surgery, anthropology and forensic medicine. The position of the mental and mandibular foramina has been reported to vary in populations from different geographical regions. Currently, to our knowledge, there have not been any investigations concerning the position and morphology of these foramina in populations with divergent socio-economic statuses (SES). The SES may influence lifestyle and some behavioral habits regarding food consumption, consumed food type as well as breastfeeding. Developmental stability may also influence dental eruption, and this may possibly influence the position of the mental foramen. Positional change of mental foramen is a combination of osseous growth in the region combined with a mesial drift of the dental anlage. Williams and Krovitz (2004) stated that the mental foramen migrates posteriorly during ontogeny and found that the mental foramen forms prenatally under the anticipated anterior root of the developing first deciduous molar. Williams and Krovitz (2004) also asserted that this position is maintained at birth and remains mostly stable during the deciduous eruption. During the eruption of the second molar, the mental foramen generally migrates to a position inferior or to the second premolar (Hasan 2012; Narayana and Prashanthi 2003).

Possible limitations of this study may result from the anatomical variation in the mandibular area especially given that we did not analyze additional/ accessory mandibular and mental foramina in order to show only variation in mental/mandibular foramina and mandibular canal. If a large accessory mental foramen exists, that could make a regular mental foramen smaller than the foramen on contralateral side (if the contralateral side does not have the accessory mental foramen) (Iwanga et al. 2016). We are also aware that in cone-beam computed tomography different aspects of mandibular canal may occur (i.e. bifid or trifid mandibular canal (Naitoh et al. 2007). Bifid mandibular canal exhibits a variety of incidence, ranging from 0,08 to 65% (Mizbah et al. 2012; Miličević et al. 2021), which may not be seen in panoramic or periapical films (Dario 2002). Its occurrence depends on the assessment method (cone-beam computed tomography or panoramic radiographs) but for anthropological and archaeological field works purposes only macroscopic assessment is useable. Hence, this research is based on macroscopic observations and dedicated for field works/ excavations macroscopic examinations, where sophisticated methods are not possible to conduct. As such, this study aimed to facilitate conclusions based on macroscopic observations although for clinical studies this method could not be sufficient. Nevertheless, the results of our study should be considered when sudden and unplanned interventions in this region are conducted.

Conclusion

The results derived from different studies (please see Tab. 9 and 10 for details) may be flawed due to the application of different methods (Hasan 2012). In addition, the observed differences between right and left sides of the mandible may result from chewing habits (unilateral) (Sójka, Hędzelek 2011). Literature reviews revealed that although studies on the morphology and morphometry of mental and mandible foramina are common, research specifically focused on the distances between these foramina and morphology of the mandible canal are rather rare (Tab. 10). In this study we argue that such (methodological) differences should be considered when approaching to the mandibular canal during anesthetic, surgical and forensic procedures.

Conflict of interests

The authors declared no conflicts of interests

Authors' contribution

JR collected the data and performed statistical computations.

DP was project supervisor, co- edited the final version of the manuscript.

AT conceived the paper, performed statistical computations, drafted the manuscript and co- edited the final version of the manuscript.

All authors carefully read and accepted the final version of the manuscript.

Corresponding author

Agnieszka Tomaszewska, Department of Anthropology, Wroclaw University of Environmental and Life Sciences, Poland; e- mail: agnieszka.tomaszewska@upwr.edu.pl

Financial support: This work was supported by the Wrocław University of Environmental and Life Sciences (Poland) as the Ph.D. research program "Innowacyjny Naukowiec", no. N060/0005/21.

References

Agarwal DR, Gupta SB. 2011. Morphometric Analysis of Mental Foramen in Human Mandibles of South Gujarat. People's Journal of Scientific Research 4(1):15–18.

Belniak T, Krupiński T, Magnuszewicz M, Rauhut J, Szczotkowa Z. 1961. Cmentarzysko w Gródku nad Bugiem (XIII–XVII w.). Mat. Pr. Antrop. 50.

Bierman F. 2006. Sypniewo. Ein fruhmittelalterlicher Burg-Siedlungskomplex in Nordmasowien. Befunde, funde und kulturhistorische bewertung, teil 1. Archeologia Mazowsza i Podlasia. Studia i materiały. T. 4. Red. serii: W. Szymański. Instytut Archeologii i Etnologii PAN, Warszawa.

Cutright B, Quillopa N, Schubert W. 2003. An anthropometric analysis of the key foramina for maxillofacial surgery. Journal of Oral and Maxillofacial Surgery 61(3):354–357.

Dario LJ. 2002. Implant placement above a bifurcated man-dibular canal: A case report. Implant. Dent. 11:258–261.

Drake RL, Vogl AW, Mitchell AWM. 2010. Gray's Anatomy for Students. Churchill Livingstone 1142–1144.

Ennes JP, Monteiro de Medeiros R. 2009. Localization of Mandibular Foramen and Clinical Implications. Int. J. Morphol. 27(4):1305–1311.

Fabian FM, Mpembeni R. 2002. Sexual dimorphism in the mandibles of homogenius black population of Tanzania. Tanzania Journal of Science. 28(2):47–54.

Field A. 2006. Discovering statistics using SPSS. 3rd edition, Sage Publications Ltd., London.

Galdames ICS, Matamala DAZ, Smith RL. 2008. Evaluating Accuracy and Precision in Morphologic Traits for Sexual Dimorphism in Malnutrition Human Skull: a Comparative Study. Int. J. Morphol. 26(4): 877–881.

Gilligan I, Bulbeck D. 2007. Environment and morphology in Australian Aborigines: a re – analysis of the Birdsell database. Am. J. Phys. Anthropol. 134:75–91.

Golusik K, Sarul M, Rzeszut Ł, Matthews-Brzozowska T. 2005. Żuchwa ludzka w procesie ewolucji. Dent. Med. Probl. 42(1):103–109.

Goudot P. 1999. The mandibular canal of a Neanderthal: the La Chapelle-aux-Saints man anatomical-radiological study. J. Craniomaxillofac Surg. 27:134–139.

Goudot P. 2002. The mandibular canal of the "Old Man" of Cro-Magnon: anatomical-radiological study. J. Craniomaxillofac Surg. 30:213–218.

Gray H. 1985. Anatomy of the Human Body. Philadelphia : Lea & Febiger, United States 106–109.

Green RM. 1987. The position of the mental foramen: a comparison between the southern (Hong Kong) Chinese and other ethnic and racial groups. Oral. Surg. Oral Med. Oral Pathol. 63:281–290.

Harvati K, Weaver TD. 2006. Human cranial anatomy and the differential preservation of population history and climate signatures. Anat. Rec., Part A Discov. Mol. Cell. Evol. Biol. 288 A (12):1225–1233.

Hasan T. 2012. Mental Foramen Morphology: a must know in clinical dentistry. Journal of the Pakistan Dental Association 21(3):168–173.

Hoque M, Ara S, Begum S, Kamal M, Momen M. 2013. Study of Number, Shape, Size and Position of Mental Foramen in Bangladeshi Dry Adult Human Mandible. Bangladesh Journal of Anatomy 11(1):7–10.

Igbigbi PS, Lebona S. 2005. The position and dimensions of the mental foramen in adult Malawian mandibles. WAJM 24(3):184–189.

Ilayperuma I, Nanayakkara G, Palahepitiya N. 2009. Morphometric Analysis of the Mental Foramen in Adult Sri Lankan Mandibles. International Journal of Morphology 27(4):1019–1024.

Iwanaga J, Watanabe K, Saga T, Tabira Y, Kitashima S, Kusukawa J, Yamaki K. 2016. Accessory mental foramina and nerves: Application to periodontal, periapical, and implant surgery. Clinical Anatomy 29(4):493–501. https://doi.org/10.1002/ca.22635

Jacobs R, Mraiwa N, Van Steenberghe D, Sanderink G, Quirynen M. 2004. Appearance of the mandibular incisivecanal on panoramic radiographs. Surg Radiol Anat 26:329–333.

Junior ROM, Santos Saud AD, Rodrigues Fonseca D, De-Ary-Pires B, Ary Pires-Neto M, De Ary-Pires R. 2010. Morphometrical analysis of the human mandibular canal: a CT investigation. Surgical and Radiologic Anatomy 33:345–352.

Łasiński W. 1993. Anatomia głowy dla stomatologów. Państwowy Zakład Wydawnictw Lekarskich, Warszawa 26–30.

Martin R, Saller F, Knussman R. 1988. Antropologie In: Handbuch der vergleichenden Biologie des Menschen, Gustav Fischer Verlag, Stuttgart, New York.

Mays S. 2014. Mandibular morphology in two archaeologicalhuman skeletal samples from northwest Europewith different masticatory regimes. HOMO – Journal of Comparative Human Biology 25378:1–13.

Miličević A, Salarić I, Đanić P, Miličević H, Macan K, Orihovac Ž, Zajc I, Brajdić D, Macan D. 2021. Anatomical Variations of the Bifid Mandibular Canal on Panoramic Radiographs in Citizens from Zagreb, Croatia. Acta Stomatologica Croatica 55(3):248–255. https://doi.org/10.15644/asc55/3/2

Mizbah K, Gerlach N, Maal TJ, Bergé SJ, Meijer GJ. 2012. The clinical relevance of bifid and trifid mandibular canals. Oral Maxillofacial Surgery 16(1):147–151. https://doi.org/10.1007/s10006-011-0278-5

Moiseiwitsch JRD, Hill C. 1998. Position of the mental foramen in a North American, white population. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology 1, 85:457–460.

Naitoh M, Hiraiwa Y, Aimiya H, Ariji E. 2009. Observation of bifid mandibular canal using cone-beam computerized tomography. International J Journal of Oral and Maxillofacial Implants 24:155–159.

Narayana K, Prashanthi N. 2003. Incidence of large accessory mandibular foramen in human mandibles. European Journal of Anatomy 7(3):139–141.

Oguz O, Bozkir MG. 2002. Evaluation of Location of Mandibular and Mental Foramina in Dry, Young, Adult Human. West Indian Medical Journal 51(1):14–16.

Oliveira Junior EM, Araújo ALD, Da Silva CMF, Sousa-Rodrigues CF, Lima FJC. 2009. Morphological and Morphometric Study of the Mental Foramen on the M-CP-18 Jiachenjiang Point. International Journal of Morphology 27(1):231–238, https://doi.org/10.4067/S0717-95022009000100039

Ongkana N, Sudwan P. 2009. Gender difference in Thai mandibles using metric analysis. Chiang Mai,Medical Journal 48(2):43–48.

Pearson OM. 2000. Activity, climate, and postcranial robusticity: implications for modern human origins and scenarios of adaptive change. Current Anthropology 41(4):569–607.

Perez SI, Bernal V, Gonzalez PN. 2007. Morphological differentiation of aboriginal human populations from Tierra del Fuego (Patagonia): implications for South American peopling. *American Journal of Physical Anthropology* 133:1067–1079.

Phillips JL,Weller RN, Kulild JC. 1992. The Mental Foramen: Part III. Size and Position on Panoramic Radiographs. Journal of Endodontics 18(8):383–386.

Piontek J. 1999. Biologia populacji pradziejowych. Wydawnictwo Naukowe Uniwersytetu im. Adama Mickiewicza w Poznaniu, Poznań.

Prośba-Mackiewicz M, Mackiewicz J, Grzybiak M, Hreczecha J, Skwarek M. 2005. Zastosowanie badań morfometrycznych do oceny ważnych klinicznie parametrów morfologicznych żuchwy. Czasopismo Stomatologiczne LVIII, 2:116–123.

Puisorua M, Fornab N, Fatub AM, Fatub R, Fatua C. 2006. Analysis of mandibular variability in humans of different geographic areas. Annals of Anatomy 188:547–554.

Purmal K, Alam MK, Moganadass D, Zakariat NN, Cheong NW. 2013. The application and correlation of Pont's Index to the facial framework of three main ethnic groups in Malaysia. Australian Orthodontic Journal Volume 29(1): 34–42.

Raadsheer MC, Van Eijdet TMGJ, Van Ginkel FC, Prahl-Andersen B. 1999. Contribution of jaw muscle size and craniofacial morphology to human bite force magnitude. Journal of Dental Research 78:31–42.

Rai R, Shrestha S, Jha S. 2014. Mental foramen: a morphological and morphometrical study. International Journal of Healthcare and Biomedical Research 2(4):144–150.

Renton T, Adey-Viscuso D, Meechan J. et al. 2010. Trigeminal nerve injuries in relation to the local anaesthesia in mandibular injections. British Dental Journal 209, E15 https://doi.org/10.1038/sj.bdj.2010.978

Samanta PP, Kharb P. 2013. Morphometric analysis of mandibular foramen and incidence of accessory mandibular foramina in adult human mandibles of an Indian Population. Revista Argentina de Anatomia 5(2):60–66.

Sekutowski M. 2002. Wybrane cechy niemetryczne kości kończyny dolnej a przypuszczalny tryb życia średniowiecznych populacji z Sypniewa i Wrocławia (praca magisterska obroniona w Katedra Antropologii. Wrocław: Uniwersytet Wrocławski).

Shenoy V, Vijayalakshmi S, Saraswathi P. 2012. Osteometric Analysis of the Mandibular Foramen in Dry Human Mandibles. Journal of Clinical and Diagnostic Research 6(4):557–560.

Simalcsik A, Groza VM, Simalcsik RD, Miu G. 2012. The Medieval Nectropolis (16^{th}–18th centuries) of 'Sfantul Nicolae-Ciurchi' Church from Iasi city (Romania): Anthropologic data. Biologie animală LVIII:183–194.

Singh R, Srivastav AK. 2011. Evaluation of position, shape, size and incidence of mental foramen and accessory mental foramen in Indian adult human skulls. Int. J. Experim. Clinical Anat. 5:23–29.

Sójka A, Hędzelek W, 2011. Ocena różnych rodzajów asymetrii w narządzie żucia na podstawie badania klinicznego i instrumentalnego. Protet. Stomatol. LXI(1):28–36.

Sonick M, Abrahams J, Faiella R. 1994. A comparison of the accuracy of periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. Int. J. Oral. Maxillofac. Implants. 9:455–460.

Stanisz A. 1998. Przystępny kurs statystyki w oparciu o program STATISTICA PL na przykładach z medycyny. Kraków: StatSoft Polska.

Tomaszewska A, Kwiatkowska B, Jankauskas R. 2015. Is the area of the orbital opening in humans related to climate? Am. J. Hum. Biol. 27(6):845–850. https://doi.org/10.1002/ajhb.22735. Epub 2015 May 7.

Valente VB, Arita WM, Gonçalves PCG, Campos JADB, de Oliveira Capot TS. 2012. Location of the Mandibular Foramen According to the Amount of Dental Alveoli. Int. J. Morphol. 30(1):77–81.

Wells JCK. 2012. Sexual dimorphism in body composition across human populations: associations with climate and proxies for short – and long – term energy supply. Am. J. Hum. Biol. 24(4):411–419.

Wiliams FL, Krovitz GE. 2004. Ontogenetic migration of the mental foramen in Neandertals and modern humans. J. Hum. Evol. 47(4):199–219.

Workshop of European Anthropologists. 1980. Recommendations for sex and age diagnoses of skeletons. J. Hum. Evol. 9:517–549.

Wychowański P, Nieckula P, Panek M, Kalinowski E, Borkowska U, Wojtowicz A. 2008. Próba oceny położenia otworu żuchwowego i bródkowego na podstawie analizy cyfrowych zdjęć pantomograficznych. Dent Med. Probl. 45(1):21–28.

Yosue T, Brooks SL. 1989. The appearance of mental foramina on panoramic and periapical radiographs. II. Experimental evaluation. Oral Surg Oral Med Oral Pathol. 68(4):488–492. https://doi.org/10.1016/0030-4220(89)90151-5

Anthropological Review • Vol. 85(3), 19–30 (2022)

Anthropological Review

Available online at: https://doi.org/10.18778/1898-6773.85.3.02

POLSKIE TOWARZYSTWO ANTROPOLOGICZNE

Diversity of change in body mass index and skinfold thickness between different study courses within four years of study among the male students in a university in Poland

Gabriel Bobula[1], Wojciech Czarny[1], Zofia Ignasiak[2], Raja Chakraborty[3], Slawomir Kozieł[4]

[1] University of Rzeszow, Rzeszow, Poland
[2] Faculty of Physical Education, University School of Physical Education in Wroclaw, Wroclaw, Poland
[3] Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal, India
[4] Department of Anthropology, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wrocław, Poland

Abstract: *Objective*: This study examined whether there were significant changes (expectedly increase) in BMI (Body Mass Index), and relative subcutaneous body fat during the four years of study in a university and compared these changes between the students of different courses, viz., Computer science, Law and administration, Humanities and Physical education.

Design: This was a prospective follow up study with measurements at two time points with gap of four years. Body mass index, Triceps, subscapular, mid-axillary, abdominal, supra-illiac and medial-calf skinfold thicknesses were measured at two points of time, just after entrance to university and again after completion of four years. Student's T-test, one-way ANOVA, and repeated measures ANNOVA (two-way) were employed to assess significance of differences in anthropometric measures between groups of students.

Setting: The study was conducted at the University of Rzeszów, Poland.

Participants: 191 young men university students aged approximately 19.5 years and 24.0 years, at the beginning and after four years, respectively, during this study.

Results: Students of all courses underwent increments in BMI, absolute- and relative skinfold thicknesses, except that the students of physical education course did not show change in skinfold thicknesses relative to BMI.

Conclusions: It has been concluded that the change in the adiposity profile during the years of study at university varied according to the course types. Further, detailed studies on the nature and cause of such variation occurring between course types may lead to better understanding etiology of overweight and obesity before entering to adult life.

Key words: BMI, body fat, freshmen, skinfold, lifestyle.

Original article

Received: 06.07.2022; Revised: 12.08.2022; Accepted: 15.08.2022

Introduction

Currently, obesity is unequivocally considered as a major global health challenge. It is not only a definite risk factor for a large number of chronic diseases but also obesity is currently regarded as a disease itself. According to the 2015 estimate, high body mass index contributed to about four million deaths globally representing 7.1% of the all cause deaths (Kushner and Kahan 2018). According to the recent statistics of The World Health Organisation, more than 1.9 billion adults, 18 years and older, were overweight while over 650 million were obese in 2016 (WHO 2016). The nationwide European Health Interview Survey (EHIS) survey in 2014 indicated that in Poland over 62% of men and nearly 46% of women were overweight (Augustynowicz et al. 2019). The occurrence of obesity and overweight is indicated by an increase in body mass index (BMI), body fat percent, waist circumference etc. Although genetic predispositions have been suggested to contribute to both obesity and overweight, human behaviour and lifestyle factors, such as physical activity (Must and Tybor 2005), and/or dietary habits (Vadiveloo et al. 2015) have also been found to influence its clinical manifestation (Yang et al. 2020).

The behaviour patterns of individuals are determined within specific cultural context while diverse choices and actions which, in turn, form a relatively stable trajectory over the life course of an individual (Wethington 2005). Human life has different transitional points at which this trajectory could be perturbed when the individuals try to build up certain strategies to adapt with the changing situations. Such transitions might occur during shifting educational levels and are generally accompanied with changes in structure and composition of peer group, altered work schedules and leisure-time activities, and finally, a cumulative effect of all these changes leads to alterations in health behaviors (Wethington 2005). Such transitions take place among young adults when they enter college after high school education. This involves several behavioral adaptations that have evolved to cope with the new conditions of life (Cluskey and Grobe 2009) and the individuals commence to adopt lifestyle and habitual behaviours that are likely to sustain through adulthood (Morseth et al. 2011; Gunes et al. 2012). It has been suggested that these lifestyle habits might lead to weight and fat gain contributing to a long-term negative health consequences (Johnson and Annesim 2018; Sun et al. 2019).

It is well documented that the transition from high school to college/university is a critical period for weight gain, a phenomenon that is popularly known 'Freshmen 15' (Anderson et al. 2003; Butler et al. 2004; Levitsky et al. 2004; Hoffman et al. 2006; Morrow 2006; Delinsky and Wilson 2008; Economos et al. 2008; Pliner and Saunders 2008; Racette et al. 2008), although a few suggested that such a concept of college weight gain was a paradigm based more on myth than scientific facts (Hodge et al. 1993; Graham and Jones 2002). Nevertheless, a number of studies have shown that late adolescence and early adulthood was indeed a critical time for a considerable weight gain (Papadaki et al. 2007; Vella-Zarb and Elgar 2009; Takomana and Kalimbira 2012).

In one study, male students were found to have put on weight, on average, 3.0 kg along with increases in other associated anthropometric dimensions (Pullman et al. 2009). In other studies, a weight gain, ranging from 1.3 to 3.3 kg, were reported among a large proportions of students during the early terms or first year at college (Anderson et al. 2003; Butler et al. 2004; Levitsky et al. 2004; Hoffman et al. 2006; Morrow 2006; Delinsky and Wilson 2008; Economos et al. 2008; Pliner and Saunders 2008). Yet another study reported that, following enrollment to college, more than 25% of students gained about 2.3 kg body weight within the first two months. Most of these studies found that weight gain was higher among males than females (Cluskey and Grobe 2009; Deforche et al. 2015). For instance, Deforche et al. (2015) reported that although students gained, on average, 2.7 kg of weight, a greater increase was observed in boys.

Although, college/university-student weight gain has been well-documented, hitherto, little is known regarding whether such changes in weight and other body dimensions, differ between different disciplines or study courses during the first months of transition to college/university life. Moreover, although most of the previous studies have considered the gain in body weight as the indicator of shift towards overweight and obesity, only a few took account of other measurements, such as, waist circumference and skinfold thickness (Pullman et al. 2009). Therefore, the aim of the present study was to estimate the obesity indicators, such as BMI, waist circumference and skinfold thickness at the beginning and the end of the first semester in among the male students in a university in Poland. Specifically, the study objective was to investigate whether there were significant changes (expected increase) in those measures during the four years of university life. In addition, the other aim of this study was to compare such changes between the students of different courses, viz., Computer science, Law and administration, Humanities and physical education, as well as to determine whether there was any effect of the type of study course on such changes.

Materials and Method

Study design and the participants

This study used a repeated measures design, undertaken at two points of time, at the beginning of course by a batch of pupils and after four years of study at the University of Rzeszów, a city in South-Eastern Poland with a population of 184,000. Study participants were 191 young males aged approximately 19.5 years and 24 years, at the beginning and after four years, respectively, within the time frame of this study. Participants were enrolled for this study from four different courses, viz., Computer science (N=22; 11.5%), Law and Administration (N=44; 23.1%), Humanities (N=61; 31.9%) and Physical Education (N=64; 33.5%), at the University of Rzeszów, Poland.

All study participants were healthy without any illness or infirmity symptoms reported during, or at least one month before the study commenced. No participants were physically challenged in any way. Informed consent was obtained from each participant before enrolment for the study. Necessary permissions from the concerned university authority were also procured before commencement of the study. Ethical protocols of conducting study on human subjects were followed according to the Helsinki declaration guidelines (Goodyear et al. 2007). All the participants that had entered the particular courses at the Rzeszów University in 2013 were included in the study. After 4 years of study, the same students underwent repeated measure procedures using the same protocol and by the same person (G.B.).

Anthropometry

One of the authors (GB), being a trained anthropometrist, took a battery of anthropometric measurements that included a total of 27 length, breadth, thickness and circumference measurements. However, for the purpose of the present study, only height, weight and six skinfold thicknesses were included in the analysis. Height and weight were measured following the standard protocol (Weiner and Lourie 1981) using standard anthropometer (GPS, Switzerland) and a standardised weight scale, respectively. Triceps, subscapular, mid-axillary, abdominal, supra-iliac and medial-calf skinfold thicknesses were measured by the Harpenden skinfold calliper on the left side of each participant. The skinfold measurement gave an estimated amount of subcutaneous fat deposition. BMI was calculated using standard formula (body weight in kg/ height in meter, squared).

Since it was not known that how much change in BMI values should be attributed to changes in subcutaneous body fat, the ratio of the sum of skinfolds-to-BMI was calculated as a standardised measure of body fatness. Higher values of the ratio indicated higher contribution of subcutaneous fat to BMI. For instance, in two persons with similar value of BMI, the ratio shows a different proportion of subcutaneous fat to body mass. Also changes in ratios reflect a change in proportions of subcutaneous fat and other component of body mass.

Statistics

Descriptive statistics of mean and standard deviation (SD) were calculated for all measurements. Student T-test for dependent samples was performed in order to assess differences between two successive measurements between four years. One way ANOVA was utilised to test the significance of differences in anthropometric measures between different study disciplines. Repeated measures ANOVA was used to test whether there is a significant difference in measures between the two time points at which measurements were taken. Post hoc comparisons were done based on Tukey HSD tests. All calculations were performed by using Statistica 13.1 software.

Results

The mean ages of the participants were 19.7 (SD = 0.61) and 24.2 (SD = 0.61) years, at the beginning and after four years of studies, respectively. The means and SD values of BMI, sum of four skinfold (SSF) thickness and SSF-to-BMI ratio at the beginning (t_1) and after 4 years at the university (t_2) in each study course, separately, are described in Table 1. It also shows the differences between the mean values at two points of time (t_2-t_1) of measurement of students, for each course separately. In all student groups, BMI showed significant differences between two measurements in each group (for each group, $p<0.01$) and among groups at each time of measurements (at t_1, $F=8.57$, $p<0.001$; at t_2, $F=15.03$, $p<0.001$). However, the groups differed significantly between themselves in the mean amount of BMI differences occurred after four years of studies ($F=4.32$, $p<0.01$).

Table 1. Means and SDs of BMI, SSF SSF-to-BMI ratio at the beginning (t_1) and after four years (t_2) each study course and of the differences between the two occasions (t_2-t_1)

Study courses	BMI t_1		BMI t_2		BMI (t_2-t_1)	
	Mean	SD	Mean	SD	Mean	SD
Physical education (N=64)	20.11	3.91	21.89	3.29	1.77*	2.29
Law and administration (N=44)	22.21	3.49	24.37	3.23	2.16*	1.82
Humanities (N=61)	22.78	3.30	25.44	2.93	2.66*	2.30
Computer Science (N=22)	23.36	1.70	24.19	1.90	0.83*	0.93
	F=8.57; p<0.001		F=15.03; p<0.001		F=4.32; p<0.01	
All students (N= 191)	21.82	3.63	23.86	3.36	2.03	2.14
	SSF t_1		**SSF** t_2		**SSF** (t_2-t_1)	
Physical education (N=64)	8.26	2.60	9.01	2.61	0.75*	1.32
Law and administration (N=44)	7.21	2.91	9.98	2.82	2.76*	2.15
Humanity (N=61)	7.77	3.29	9.83	2.87	2.06**	2.35
Computer science (N=22)	8.44	3.10	9.48	2.70	1.04*	1.62
	F=1.38; n.s.		F=1.37; n.s.		F=11.14; p<0.001	
All students (N= 191)	7.88	2.97	9.55	2.76	1.67	2.08
	SSF-to-BMI Ratio t_1		**SSF-to BMI Ratio** t_2		**SSF-to BMI Ratio** (t_2-t_1)	
Physical education (N=64)	0.42	0.13	0.42	0.12	-0.003	0.05
Law and administration (N=44)	0.32	0.08	0.41	0.09	0.089*	0.07
Humanity (N=61)	0.33	0.11	0.38	0.09	0.051***	0.08
Computer science (N=22)	0.36	0.14	0.39	0.12	0.031*	0.06
	F=9.03; p<0.001		F=1.13; n.s.		F=18.03; p<0.001	
All students (N= 191)	0.36	0.12	0.40	0.11	0.04	0.07

*p<0.001; **p<0.01;***p<0.05 – for t-tests to assess differences between t_1 and t_2 within each study course; F-values are for one-way ANOVA to assess differences between study courses on t_1 and t_2 and for the mean differences between t_1 and t_2.

In case of SSF, all groups showed significant differences ($p<0.01$ to $p<0.001$ for t-tests) within the four years of study period, but there were no significant within group differences either at the beginning or after four years of studies. The groups, however, differed significantly between themselves, with respect to the mean difference in SSF between the two points of measurements ($F=11.14$, $p<0.001$).

Regarding the SSF-to-BMI ratio, nearly all groups, showed significant increases in their mean subcutaneous fat relative to BMI values ($p<0.05$ to $p<0.01$ for t-tests), except for the students of physical education students, who did not show any increase in this ratio at the second point of time of measurements. The four groups differed significantly between them in SSF-to-BMI at the beginning of study ($F=9.03$, $p<0.001$). However, the second point of measurement after 4 years, group differences were not significant ($F=1.13$, p=n.s.).

The results of the two-way analyses of variance with repeated measures for the three variables (dependent), namely, BMI, SSF and SSF-to-BMI ratio, respectively, are presented in Table 2. In each analysis, course type and point of times (t_2 ort$_1$), were the two factors. Students form different study courses exhibited significantly different BMI at the beginning, and after 4 years of study, which indicates that all students increased their BMI within 4 years, however in varying degrees. For SSF, however, students did not differ between study courses. However, all significantly increased their amount of subcutaneous fat, but again, in varying degrees. Very similar result was observed for SSF-to-BMI ratio except that course of study significantly differentiated the proportion of subcutaneous fat relative to BMI values.

Changes in all measurements within each group are shown in Figure 1. Compared to other groups students of physical education had the lowest BMI, during both periods of measurements. They showed an increase in subcutaneous fat and BMI almost equally (post hoc, for BMI $p<0.001$, and for sum fat $p<0.05$), and therefore, had no significant changes in SSF-to-BMI ratio. Students of other 3 courses had significantly higher BMI than those of physical education course both at the beginning (post hoc for Low and administration $p<0.05$, for Humanities $p<0.001$, and for Computer sciences $p<0.01$), and after four years, except for Computer sciences (pot hoc for Low and Administration $p<0.01$, for Humanities $p<0.001$). In addition, among these students a significant increase in both BMI (post hoc for Low and administration $p<0.001$, for Humanities $p<0.001$) and amount of subcutaneous fat (post hoc for law and administration $p<0.001$, for Humanities $p<0.001$) was observed, except for Computer sciences. This was evident especially among the students of law and administration and humanities, although the increments were not equal. The students of these courses significantly accumulated more subcutaneous fat than other body tissue, resulting in a significant increase in the proportion of the subcutaneous fat in relation to BMI values (post hoc for law and administration $p<0.001$, for Humanities $p<0.001$).

Table 2. Results of two-way ANOVA for repeated measurements for BMI, SSF and SSF-to-BMI ratio

	BMI			SSF			SSF-to-BMI ratio		
	F	p <	Eta^2	F	p <	Eta^2	F	p <	Eta^2
Course	12.18	0.001	0.163	0.13	n.s.	0.002	4.22	0.01	0.063
Repeated	127.00	0.001	0.404	117.77	0.001	0.386	64.73	0.001	0.257
Interaction	4.69	0.01	0.070	11.14	0.001	0.152	18.03	0.001	0.224

Fig. 1. a)

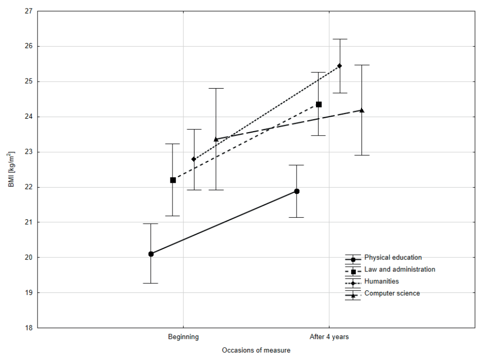

Fig. 1. b)

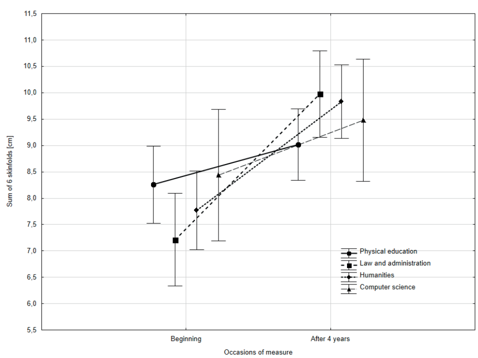

Fig. 1. c)

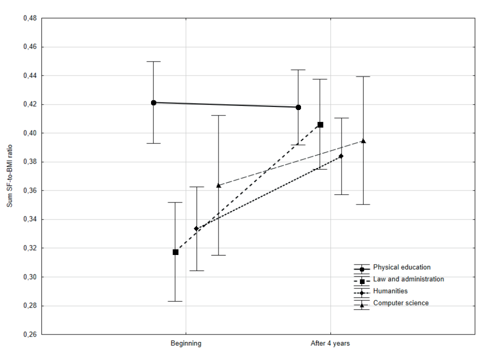

Figure 1. Changes of means in BMI (a), SSF (b) and SSF-to-BMI ratio (c) within each study course measured at two occasions

Discussion

Transition to higher education has been associated with weight gain among students as well as adverse changes in health behaviours (Deforche et al. 2015). At the outset, the present study showed that students increased their BMI and subcutaneous body fat significantly in all four disciplines in a span of four years after entering the university. The increase of BMI was the highest in humanities, followed by law, physical education and computer science, respectively. The increase in SSF was similar to BMI, except that the Law students gained more SSF than those of humanities, and the students of physical education gained the least amount of SFF. Interestingly, when the proportion of this subcutaneous fat relative to BMI was estimated, the three groups showed an increase while students of physical education showed a decrease.

Several previous studies have reported dietary, attitudinal and lifestyle changes among students during the first phase after entering into higher educational institutions. A study demonstrated that during the first year of study at university, both male and female students underwent unfavorable changes in nutrition profile, body weight and composition. The males, in fact, showed more adverse changes compared to females. Body weight, fat, BMI, waist circumference and waist-hip ratio significantly increased and for all of these dimensions, males showed significantly higher gains than females (Beaudry et al. 2019). Many earlier studies have demonstrated that a diet quality in both males and females decreased over the course of first-year of university study (Breslow et al. 2006; Gorgulho et al. 2012; Takomana nd Kalimbira 2012;

Deforche et al. 2015). Increased alcohol intake was also reported in several other studies over the first year at university in both male and female students indicating a decline in overall quality of diet (Butler et al. 2004; Breslow et al. 2006; Deliens et al. 2014; Deforche et al. 2015). In some studies, the males clearly displayed more adverse and lower quality eating patterns than females (Beaudry et al. 2019; Keller et al. 2008). In a study conducted on 108 male students in Canada made a detailed observation on the anthropometric, nutritional and behavioural changes occurred during the first year at university (Pullman et al. 2009). The study revealed a significant weight gain, of 3.0 kg, on an average, accompanied by significant increases in BMI, body fat, waist circumference, hip circumference, and waist-hip ratio. However, there was no significant change in the energy and nutrient intake, as such. Instead, it was found that intentions related to the maintenance of body mass had influenced the final body mass. Moreover, the pattern and nature of aerobic physical activities significantly changed, time spent for study and sitting before computer increased significantly while hours of sleep decreased. Consumption of alcoholic drinks and frequency of binge drinking significantly increased over the period of the study (Pullman et al. 2009). The participants of the present study underwent a possible set of changes regarding choice, attitude and habits that might have brought about change in body adiposity. Although the present study did not take into account changes in dietary patterns and the amount of physical activity of study participants, it can be assumed, given the findings of the previous research, that the participants of the present study also endured some alterations in lifestyle parameters that were critical for the changes in body dimensions. Adoption of unhealthy lifestyle among young adults, especially, the students in higher education, has been reported as global phenomenon (Steptoe and Wardle 2001; Steptoe et al. 2002; Dodd et al. 2010).

The most important finding of the present study is that the magnitudes of the mean changes of the measures in four years period were not identical among the different courses. Groups differed significantly between themselves in the mean amount of increase in BMI during four years of university studies. Gain in BMI was highest in humanities, followed by law, physical education and computer science, respectively. However, the subcutaneous fat deposit showed no significant within group differences, either at the beginning, or after four years of studies. However, groups differed significantly among themselves at the final point, in respect of the mean difference occurred during four years of time span; the Law students gained more subcutaneous fat than the humanities, and the students of physical education gained the least amount. On the other hand, whereas nearly all groups showed significant increase in the mean subcutaneous fat relative to BMI values, physical education students did not show any increase in this ratio during the four years.

Present study indicated that the changes in subcutaneous fat during the four years of study depended on type of study courses, and for that matter, only the students of physical education course managed to keep the harmonious changes in body weight. The increase in fatness was, perhaps, compensated with other body tissue, most probably, the lean mass. On the contrary, the students of law and administration, followed by other two courses, increased their relative proportion of subcutaneous fat substantially. Whereas it would certainly be overambitious to draw a causal explanation for this inter-group differences in the changes in body adiposity, in view of the limited scope of this present study, an attempt could definitely be made on the basis of the background information of the participants and the nature of the respective courses. A plausible explanation of this difference between physical education and other three courses could be postulated as effect of some selection as well as specific lifestyle during the university days. The student of physical education course had to pass an entry examination that included tests of physical fitness. Only the applicants who satisfied some norms of fitness, body weight etc., were admitted to the course. This was also reflected in the lowest mean BMI in physical education students, compared to other three courses, at the beginning of study. During four years of study, they had several lessons demanding vigorous physical activity, which influenced their body composition. On the contrary, the students of the three remaining courses had to pass only theoretical entrance test only. During their study, they had only two hours per week of physical education lessons and probably spent much more time on learning theory, resulting in more sedentary lifestyle. Thus, these students also underwent a selection first, and then a specific lifestyle, both of which acted to the direction opposite to that for the physical education students. Last, but not the least, several inherent limitations of this study should be admitted before going to final conclusions. Firstly, this study did not include female students. The sample sizes for individual courses were small, especially for the computer science. There were no data on the dietary pattern, daily physical activity and specific behavioural changes that took place during the university years. However, despite several limitations, there were some novel aspects, too. No previous study had attempted to compare students of different courses in terms of changes in obesity components during the four university years. Secondly, the same students were measured after four years, thus, making it a prospective study. Many studies showed that males underwent changes in body weight and adiposity more than females. The present study, nevertheless, gave an insight as to how the males also could differ even according to different courses, too.

In conclusion, the changes in body mass, fatness, and composition during the years of study after entering into university differed according to the nature of study courses. During four years of study, the male students in all study courses sowed increase in BMI and skin folds, and the humanities students exhibited the highest increase. The SSF showed a similar trend, except the law students gaining more than those in humanities whereas the students of physical education gained the least. The subcutaneous fat to BMI ratio increased in all groups except the students of physical education showing a decrease. However, it would be too premature to draw firm conclusion and make generalised predictions about the expected changes in body mass, fatness and composition according to the nature of study courses among the 'Freshmen'. Therefore further studies conducted in diverse set ups and various countries is needed in order to conclusively delineate the differential effects of study disciplines on changes in weight and body composition during the university days.

Acknowledgements

The authority of the University of Rzeszów and all the participants of the study are gratefully acknowledged for their kind cooperation for the fulfillment of this study.

Conflicts of interest

None.

Authors' contribution

GB collected and digitalised data; WC supervised collection of data, designed the study; ZI participated in writing first draft and edited final draft; RC wrote first and final draft; SK made an analysis, participated in preparing first draft, edited final draft

Corresponding author

Prof. Raja Chakraborty, Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal 723104, India; Email: rajanth2003@yahoo.co.uk

References

Anderson D, Shapiro J, Lungren J. 2003. The freshman year of college as a critical period for weight gain. Eat Behav 4:363–367. https://doi.org/10.1016/S1471-0153(03)00030-8

Augustynowicz A, Czerw A, Borowska M, Deptała A, Dykowska G, Fronczak A. 2019. Prevention of overweight and obesity undertaken by local government units in Poland. Health Policy 123:499–502. https://doi.org/10.1016/j.healthpol.2019.03.006

Beaudry KM, Ludwa IA, Thomas AM, Ward WE, Falk B, Josse AR. 2019. First-year university is associated with greater body weight; body composition and adverse dietary changes in males than females. PLoS One 14:e0218554. https://doi.org/10.1371/journal.pone.0218554

Breslow RA, Guenther PM, Smothers BA. 2006. Alcohol drinking patterns and diet quality: the 1999–2000 National Health and Nutrition Examination Survey. Am J Epidemiol 163:359–66. https://doi.org/10.1093/aje/kwj050

Butler SM, Black DR, Blue CL, Gretebeck RJ. 2004. Change in diet; physical activity and body weight in female college freshman. Am J Health Behav 28:24–32. https://doi.org/10.5993/ajhb.28.1.3

Cluskey M, Grobe D. 2009. College weight gain and behavior transitions: male and female differences. J Am Diet Assoc 109:325–329. https://doi.org/10.1016/j.jada.2008.10.045

Deforche B, Van Dyck D, Deliens T, De Bourdeaudhuij I. 2015. Changes in weight; physical activity; sedentary behaviour and dietary intake during the transition to higher education: a prospective study. Int J Behav Nutr Phy Activ 12:16. https://doi.org/10.1186/s12966-015-0173-9

Deliens T, Clarys P, De Bourdeaudhuij I, Deforche B. 2014. Determinants of eating behaviour in university students: a qualitative study using focus group discussions. BMC Pub Health 14:53. https://doi.org/10.1186/1471-2458-14-53

Delinsky SS, Wilson T. 2008. Weight gain; dietary restraint; and disordered eating in the freshman year of college. Eat Behav 9:82–90. https://doi.org/10.1016/j.eatbeh.2007.06.001

Dodd LJ, Al-Nakeeb Y, Nevill A, Forshaw MJ. 2010. Lifestyle risk factors of students: A cluster analytical approach. Prev Med 51:73–77. https://doi.org/10.1016/j.ypmed.2010.04.005

Economos CD, Hildebrandt MPH, Raymond RH. 2008. College freshman stress and weight change: Differences by gender. Am J Health Behav 32:16–25. https://doi.org/10.5993/AJHB.32.1.2

Goodyear MDE, Krleza-Jeric K, Lemmens T. 2007. The Declaration of Helsinki. Br Med J 335:624–625. https://doi.org/10.1136/bmj.39339.610000.BE

Gorgulho B, Marchioni DM, Conceicao AB, Steluti J, Mussi MH, Nagai-Manelli R et al. 2012. Quality of diet of working college students. Work 41Suppl 1:5806–9. https://doi.org/10.3233/WOR-2012-0958-5806

Graham MA, Jones AL. 2002. Freshman 15: Valid theory or harmful myth? J Am Coll Health 50:171–173. https://doi.org/10.1080/07448480209596023

Gunes FE, Bekiroglu N, Imeryuz N, Agirbasli M. 2012. Relation between eating habits and a high body mass index among freshman students: a cross-sectional study. J Am Coll Nutr 31:167–74. https://doi.org/10.1080/07315724.2012.10720024

Hodge C, Jackson L, Sullivan L. 1993. The 'freshman 15' facts and fantasies about weight gain in college women. Psychol Women's Health Q 17:119–126. https://doi.org/10.1111/j.1471-6402.1993.tb00680.x

Hoffman DJ, Policastro P, Quick V, Lee SY. 2006. Changes in body weight and fat mass of men and women in the first year of college: A study of the freshman 15. J Am Coll Health 52:41–45. https://doi.org/10.3200/JACH.55.1.41-46

Johnson PH, Annesim JJ. 2018. Factors Related to Weight Gain/Loss among Emerging Adults with Obesity. Am J Health Behav 42:3–16. https://doi.org/10.5993/AJHB.42.3.1

Keller S, Maddock JE, Hannöver W, Thyrian JR, Basler H. 2008. Multiple health riskbehaviors in German first year university students. Prev Med 46: 189–195. https://doi.org/10.1016/j.ypmed.2007.09.008

Kushner RF, Kahan S. 2018. Introduction: the state of obesity in 2017. Med Clin North Am 102:1–11. https://doi.org/10.1016/j.mcna.2017.08.003

Levitsky DA, Halbmaier CA, Mrdjenovic G. 2004. The freshman weight gain: A model for the study of the epidemic of obesity. Int J Obes Relat Metab Disord 28:1435–1442. https://doi.org/10.1038/sj.ijo.0802776

Morrow ML. 2006. Freshman 15: Fact or fiction? Obes 14:1438–1443. https://doi.org/10.1038/oby.2006.163

Morseth B, Jorgensen L, Emaus N, Jacobsen BK, Wilsgaard T. 2011. Tracking of leisure time physical activity during 28 yr in adults: the Tromso study. Med Sci Sports Exerc 43: 1229–34. https://doi.org/10.1249/MSS.0b013e3182084562

Must A, Tybor DJ. 2005. Physical activity and sedentary behavior: a review of longitudinal studies of weight andadiposity in youth. Int J Obes 29: Suppl 84–96. https://doi.org/10.1038/sj.ijo.0803064

Papadaki A, Hondros GJAS, Kapsokefalou M. 2007. Eating habits of university students living at; or away from home in Greece. Appetite 49:169–76. https://doi.org/10.1016/j.appet.2007.01.008

Pliner P, Saunders T. 2008. Vulnerability to freshmen weight gain as a function of dietary restraint and residence. Physiol Behav 93:76–82. https://doi.org/10.1016/j.physbeh.2007.07.017

Pullman AW, Masters RC, Zalot LC, Carde LE, Saraiva MM, Dam YY, Randall Simpson JA, Duncan AM. 2009. Effect of the transition from high school to university on anthropometric and lifestyle variables in males. Appl Physiol Nutr Metab 34:162–171. https://doi.org/10.1139/H09-007

Racette SB, Deusinger PT, Strube MJ, Heghstein RH, Deusinger PT. 2008. Changes in weight and health behaviors from freshmen through senior year of college. J Nutr Educ Behav 40:39–42. https://doi.org/10.1016/j.jneb.2007.01.001

Steptoe A, Wardle J, Cui W, Bellisle F, Zotti AM, Baranyai R, Sanderman R. 2002. Trends in smoking, diet, physical exercise, and attitudes toward health in European university students from 13 countries, 1990–2000. Prev Med 35: 97–104. https://doi.org/10.1006/pmed.2002.1048

Steptoe A, Wardle J. 2001. Health behaviour; risk awareness and emotional wellbeing in students from Eastern Europe and Western Europe. Soc Sci Med 53:1621–1630. https://doi.org/10.1016/S0277-9536(00)00446-9

Sun Y, Liu B, Snetselaar LG, Robinson JG, Wallace RB, Peterson LL et al. 2019. Association of fried food consumption with all cause; cardiovascular; and cancer mortality: prospective cohort study. Br Med J 364:k5420. https://doi.org/10.1136/bmj.k5420

Takomana G, Kalimbira AA. 2012. Weight gain; physical activity and dietary changes druing the first year at college. S Afr J Clin Nutr 25:132–9. https://doi.org/10.1080/16070658.2012.11734417

Vadiveloo M, Dixon LB, Mijanovich T, Elbel B, Parekh N. 2015. Dietary variety is inversely associated with body adiposity among US adults using a novel food diversity index. J Nutr 145:555–63. https://doi.org/10.3945/jn.114.199067

Vella-Zarb RA, Elgar FJ. 2009. The 'freshman 5': a meta-analysis of weight gain in the freshman year of college. J Am Coll Health 58:161–6. https://doi.org/10.1080/07448480903221392

Weiner JS, Lourie JA. 1981. Practical Human Biology. New York: Academic Press.

Wethington E. 2005. An overview of the life course perspective: Implications for health and nutrition. J Nutr Educ Behav 37:115–120. https://doi.org/10.1016/s1499-4046(06)60265-0

WHO (World Health Organisation). 2016. WHO Fact Sheet: Overweight and Obesity (16 February 2016): https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight. Accessed: February 20, 2020.

Yang Y, Fu M, Li M, Zhang K, Zhang B, Wang S et al. 2020. O-GlcNAc transferase inhibits visceral fat lipolysis and promotes diet-induced obesity. Nat Comm 11:181. https://doi.org/10.1038/s41467-019-13914-8

Anthropological Review • Vol. 85(3), 31–46 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.3.03

POLSKIE TOWARZYSTWO ANTROPOLOGICZNE

Body composition and level of physical activity of elderly people living in north-eastern Poland associated with socioeconomic factors

Aneta Anna Omelan[1], *Krzysztof Borysławski*[2], *Robert Stanisław Podstawski*[1]

[1] Department of Tourism, Recreation and Ecology, Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland
[2] Institute of Health, Angelus Silesius State University, Wałbrzych, Poland

ABSTRACT: *Introduction:* Studies conducted in various regions of the world have indicated that physical activity level, body composition and socioeconomic variables can be associated. Therefore, the objective of this study was to determine whether socioeconomic factors are associated with level of physical activity and differences in the body composition of elderly people living in north-eastern Poland.
Materials and Methods: The study involved 774 older residents (60 years or more). Physical activity levels were measured with the International Physical Activity Questionnaire. The respondents' body composition was determined with an InBody 270 analyser. Pairs of means were compared with Student's *t*-test; more than two means were compared with one-way ANOVA; and proportions were compared with the chi-square test. Statistical significance was defined as $p \leq 0.05$.
Results: The marital status of men and women was significantly associated with differences in physical activity level and body composition. The place of residence and level of education of women (but not of men), were also significantly associated with differences in body composition. Age and material situation were not significantly associated with differences in body composition and physical activity level.
Conclusion: The mean values of parameters of body composition in the surveyed group exceeded the norms. The level of physical activity of the subjects is at a sufficient level, but in the case of women it depends on socio-economic characteristics. Therefore, there is a need to find effective ways to support older adults in maintaining (or increase) their physical activity with a particular focus on women.

KEY WORDS: elderly people, socioeconomic factors, physical activity, body composition.

Original article

Received: 29.06.2022; Revised: 26.08.2022; Accepted: 02.09.2022

Introduction

The elderly comprise about 12 per cent of the world's population. The World Health Organization (WHO) predicts that, by 2050, the number of people over 60 will reach 2 billion–22 per cent of the Earth's total population (WHO 2015). In Poland, the percentage of people who are 60 years old or older is 24.8 per cent, and demographic forecasts indicate that, within fifty years, the number of Polish seniors will increase substantially to 33.3 per cent of the population (European Commission 2017).

The aging of the body is a natural process and cannot be avoided. With age come degenerative changes in most physical and physiological functions (Ruiz-Montero and Castillo-Rodriguez 2016). This is also reflected by body composition–as the body ages, the percentage of each component changes. From early adolescence to approximately age 70, body fat increases and fat free mass decreases (Colado et al. 2012). These changes in fat mass and fat free mass may be a factor contributing to increased risk of certain conditions in the elderly, such as frailty, chronic diseases and functional disability, and they are risk factors for the development of Insulin Resistance (IR), Metabolic Syndrome (MS) and Cardiovascular Diseases (CVD), including arterial stiffness (Silva Neto et al. 2019). Changes in the ratio of fat mass to free fat mass lead to sarcopenia, a geriatric syndrome characterized by quantitative and qualitative changes in skeletal muscle, with reductions in fat free mass, muscle strength and physical performance (Ryall et al. 2008). For the elderly, obesity is also a major health risk (Houston et al. 2009; Batsis et al. 2014). When it occurs together with sarcopenia, it is termed sarcopenic obesity, a high-risk geriatric syndrome associated with increased risk of synergistic complications from both sarcopenia and obesity (Tyrovolas et al. 2016; Batsis and Villareal 2018). An elderly person with a more sedentary lifestyle loses fat free mass faster than one who is active. Physical inactivity in older adults (above 65 years) is associated with a higher risk of falling, mobility disorders, low muscle strength and loss of independence (WHO 2017). In contrast, physical activity helps to prevent weight loss and maintain functional capacity in people over the age of 70 (Woo et al. 2013). Thus, an active lifestyle can minimize the development of many disabling conditions and chronic diseases and can help in achieving healthy ageing and well-being (Awais et al. 2019).

Studies conducted in various regions of the world have indicated that physical activity level, body composition and socioeconomic variables can be associated (Dos-Santos et al. 2001; McLaren 2007; Ward et al. 2015; Staatz et al. 2019). Depending on the country and gender of the respondents, the associated socioeconomic variables include education, occupation, and financial situation. In Poland, individuals who are above 60 years of age differ in terms of various characteristics, such as the type of community in which they live, their level of education, or their amount of physical activity (Omelan et al. 2017; Omelan et al. 2020), which may be associated with differences in their body composition. However, to the authors' knowledge, these potential associations have not been examined in north-eastern Poland.

Body composition analyses support the assessment of disease risk factors, and the results can be used in health care and in programs aimed at replacing unhealthy habits with behaviors that promote health and overall well-being. Knowledge of which socioeconomic factors have the greatest impact on body composition will make it easier to identify groups of older people who are most at risk of health problems. Therefore, the objective of this study was to determine whether socioeconomic factors (community of residence, marital status, level of education, financial situation) and age, are associated with level of physical activity and differences in the body composition of elderly people living in north-eastern Poland in view of health problems associated with ageing.

Materials and methods

The study involved 774 older residents (above 60 years of age) of rural and urban areas in north-eastern Poland. These subjects were selected by purposive-probability sampling. The Federation of Social Work Organizations in the Warmia and Mazury Region maintains a database of seniors and helped the researchers in selecting the survey sample and contacting respondents from both urban and rural areas. Suburban areas (so-called satellite villages) are developing rapidly in Poland, attracting urban residents, who nevertheless maintain their urban lifestyles. But the authors wanted to reach seniors who have lived and worked in traditional villages, with a predominantly agricultural function, all their lives. The respondents surveyed in this study lived in rural areas far from urban areas. Access to this population was difficult, and some people were reluctant to participate in the study. It was definitely easier to reach older people living in cities, as they often belong to formal and informal senior organizations, participate in various activities and are more willing to take part in surveys. In addition, a study by Omelan et al. (2017), shows that Polish seniors also differ in terms of their preferred leisure activities – Urban seniors read more and are more physically active, while rural seniors watch more TV, are less physically active, and rarely use a computer. The participants were surveyed with the use of a questionnaire to elicit information about their socioeconomic status (place of residence, education, self-assessment of material situation, marital status). Physical activity (PA) levels were measured with the short version of the International Physical Activity Questionnaire (IPAQ). The IPAQ expresses physical activity in units of MET (Metabolic Equivalent of Work). Physical activity below 600 METs is defined as insufficient, between 600–1500 as sufficient, and above 1500 MET-min/week as high (Biernat, Stupnicki and Gajewski 2007). The interviewers were able to survey all respondents in person (face-to-face). The respondents' body composition was determined with an InBody 270 analyser (Bioelectrical Impedance Analysis, BIA). The following parameters were selected for analysis: Body mass [kg]; FFM (Fat Free Mass) [kg]; FFM control [kg]; SMM (Skeletal Muscle Mass) [kg]; BMI (Body Mass Index) [kg/m^2] – According to the World Health Organisation criteria BMI between: 18.5 and 24.9 kg/m^2 normal weight; 25.0 – 29.9 kg/m^2 pre-obesity; 30 – 34,99 kg/m^2 obesity class I; 35 – 39,99 kg/m^2 obesity class II; ≥40 extreme obesity; TBW (Total Body Water) – the InBody 270 criteria for a healthy values of body water content range from 45–60 per cent in women to 50–65 per cent in men; PBF (Percent Body Fat) – the InBody 270 criteria for a healthy percent body fat were followed: the standard for women is 18–24 per cent and for men 14–20 per cent; WHR (Waist-Hip Ratio) – The male reference values for waist-hip ratio ranges from 0.80 to 0.90, and for women 0.75 to 0.85; VFL (Visceral Fat Level) – The InBody 270 criteria for accepted norm for visceral fat is <100 cm^2 (<10 points); OD (Obesity degree) OD(%)= (current body weight/standard body weight)x100 – The normal norm for the degree of obesity (according to InBody 270 criteria) is 90 – 110%.

Normality was verified with the Shapiro-Wilk test (skewness, As, was also examined). Therefore, Student's t-test was used to compare pairs of arithmetic means. To compare more than two arithmetic means, one-way analysis of variance (ANOVA) was used. The chi-square test was used to compare proportions. Statistical significance was defined as $p \leq 0.05$. Measurements were statistically processed with Statistica PL, v. 13.5.

Most respondents (83%) are aged 60–74 and come from urban areas (65%). Women predominate in the study group. The majority of the respondents were well educated. There were statistically significant differences between the secondary education of men and women – women significantly more often (p=0.020) have a high school education. In other education categories, gender differences are not significant. Half of the respondents lived in single-person households. More men were married or in partnerships than women, and this difference was statistically significant (p<0.001). Almost 60 per cent of the respondents have chronic diseases, and some of them indicated several comorbidities.

Table 1. Age and socio-economic status of the surveyed men (N=121) and women (N=653)

Feature	Category	Sex				Difference (p)	Total	
		Male		Female				
		N	%	N	%		N	%
Age (years)	60–74	103	85.1	540	82.7	ns	643	83.0
	75–89	18	14.9	113	17.3	ns	131	17.0
Place of residence	rural	55	45.5	215	32.9	0.008	270	34.9
	urban	66	54.5	438	67.1	0.008	504	65.1
Education	primary	25	20.7	114	17.5	ns	139	18.0
	vocational	18	14.9	85	13.0	ns	103	13.3
	secondary	42	34.7	302	46.2	0.020	344	44.4
	university	36	29.7	152	23.3	ns	188	24.3
Financial situation (self-assessed)	low or average	59	48.8	373	57.1	ns	432	55.8
	satisfactory or high	62	51.2	280	42.9	ns	342	44.2
Marital status	single	36	29.8	348	53.3	<0.001	384	50.4
	married	85	70.2	305	46.7	<0.001	390	49.6
Chronic disease	no	58	47.9	260	39.8	ns	318	41.0
	yes	63	52.1	393	60.2	ns	456	59.1

Results

There is no statistically significant association between the body composition of seniors and their age and material situation, and for the men only, body composition and place of residence and education. Statistically significant associations were found between body composition and marital status, and for women only, body composition and place of residence and education.

Table 2. Descriptive statistics for the studied anthropometric features, physical activity and body composition of men and women

Feature	Male (N=121)				Female (N=653)				Difference (M-F)	
	Mean	SD	min–max	As	Mean	SD	min-max	As	t	p
Age [years]	68.20	6.58	58–87	0.77	68.69	6.36	58–91	0.75	-0.77	ns
MET	917.09	884.14	50–3150	1.09	782.11	684.25	50–3564	1.10	1.90	ns *)
Body height [cm]	172.58	6.88	150–193	-0.17	160.91	5.62	142–178	-0.03	20.21	<0.001
Body mass [kg]	84.13	12.91	54.7–127.8	0.53	73.94	13.23	37.4–132.4	0.61	7.81	<0.001
TBW (Total Body Water) [L]	45.06	6.10	28.7–69.5	0.35	33.59	4.33	20.5–50.7	0.42	24.93	<0.001
BMI (Body Mass Index) [kg/m^2]	28.21	3.71	21.4–38.2	0.40	28.84	4.84	16.8–51.7	0.83	-0.71	ns
PBF (Percent Body Fat) [%]	26.77	6.63	9.6–42.3	0.17	37.31	6.92	4.2–54.2	-0.55	-15.48	<0.001
WHR (Waist-Hip Ratio)	0.95	0.08	0.75–1.14	0.23	0.92	0.08	0.58–1.19	-0.24	3.44	<0.001
VFL (Visceral-Fat Level)	10.27	3.97	3–21	0.66	13.16	4.68	1–30	0.17	-6.38	<0.001
FFM (Fat Free Mass) [kg]	61.22	8.34	39.1–94.9	0.37	45.74	5.88	28.1–68.8	0.41	24.73	<0.001
FFM control [kg]	0.39	1.18	0.0–6.6	3.54	0.60	1.39	0.0–13.0	3.30	-1.54	ns
SMM (Skeletal Muscle Mass) [kg]	34.31	4.96	21.1–54.7	54.7	24.97	3.49	14.4–38.6	0.39	25.10	<0.001
Obesity degree	128.31	16.83	97–173	0.39	132.75	22.51	78–241	0.83	-2.06	0.039

* close to statistical significance.

The mean values of BMI indicated the presence of obesity in both the male and female groups. Irrespective of the sex of the participants, the normal range was exceeded for Waist-Hip-Ratio, Percent Body Fat, Visceral Fat Level and Obesity degree. However, these measurements remained within the normal range: Fat Free Mass, Skeletal Muscle Mass and Total Body Water. The relationship between the subjects' PA level and their gender is close to statistical significance.

Table 3. Descriptive statistics for the studied anthropometric features, physical activity and body composition of men and women grouped by marital status

Feature	Male						Female					
	Single (n=36)		Married (n=85)		Difference (S-M)		Single (n=348)		Married (n=305)		Difference (S-M)	
	Mean	SD	Mean	SD	t	p	Mean	SD	Mean	SD	t	p
MET	848.3	820.6	981.5	1031.9	-0.69	ns	700.45	618.5	875.0	742.23	-3.27	0.001
Body height [cm]	169.33	7.15	173.95	6.31	-3.54	<0.001	160.74	5.80	161.09	5.41	-0.79	ns
Body mass [kg]	78.65	10.68	86.46	13.12	-3.15	0.002	72.78	13.37	75.27	12.96	-2.41	0.016
TBW (Total Body Water) [L]	42.06	5.78	46.34	5.80	-3.71	<0.001	33.27	4.44	33.95	4.18	-2.00	0.046
BMI (Body Mass Index) [kg/m^2]	27.37	2.90	28.60	3.96	-1.64	ns	28.13	4.80	29.01	4.85	-2.33	0.020
PBF (Percent Body Fat) [%]	27.11	6.40	26.63	6.77	0.36	ns	36.87	7.04	37.80	6.76	-1.71	ns
WHR (Waist-Hip Ratio)	0.94	0.07	0.95	0.08	-0.59	ns	0.91	0.08	0.93	0.07	-2.80	0.005
VFL (Visceral Fat Level)	9.69	3.50	10.52	4.14	-1.04	ns	12.77	4.57	13.61	4.76	-2.31	0.021
FFM (Fat Free Mass) [kg]	57.12	7.85	62.95	7.96	-3.70	<0.001	45.30	6.01	46.23	5.69	-2.02	0.043
FFM control [kg]	0.70	1.48	0.26	1.01	1.88	ns	0.65	1.41	0.53	1.36	1.08	ns
SMM (Skeletal Muscle Mass) [kg]	31.91	4.72	35.32	4.73	-3.62	<0.001	24.67	3.56	25.31	3.38	-2.37	0.018
Obesity degree	124.47	13.18	129.94	17.98	-1.64	ns	130.85	22.33	134.92	22.55	-2.32	0.021

The Fat Free Mass and Skeletal Muscle Mass of men in stable, long-term relationships were significantly higher than those of single men (p<0.001 for both parameters). Apart from these parameters, the differences between men who were in long-term relationships and those who were not in such relationships were not statistically significant. Compared to single women, married women had significantly higher values for BMI (p=0.020), Waist-Hip Ratio (p=0.005), Fat Free Mass (p=0.043), Skeletal Muscle Mass (p=0.018), Visceral Fat Level (p=0.021) and Obesity degree (p=0.021). There is no statistically significant association between the PA level of married men and singles. In contrast, there is a statistically significant association between the PA levels of married and unmarried women (p<0.001) – married women obtain significantly higher average MET value than single women.

Urban men were significantly taller than rural men (p=0.041). Body composition did not differ significantly between men living in rural areas and those in urban areas although percent body fat was on the verge of statistical significance.

Table 4. Descriptive statistics for the studied anthropometric features, physical activity and body composition of men and women grouped by place of residence

Feature	Male						Female					
	Urban (n=66)		Rural (n=55)		Difference (U-R)		Urban (n=438)		Rural (n=215)		Difference (U-R)	
	Mean	SD	Mean	SD	t	p	Mean	SD	Mean	SD	t	p
MET	1015.6	985.6	798.8	735.9	1.35	ns	861.9	686.5	619.9	651.7	4.30	<0.001
Body height [cm]	173.74	6.84	171.18	6.72	2.07	0.041	160.80	5.74	161.13	5.37	-0.71	ns
Body mass [kg]	83.58	11.60	84.80	14.41	-0.52	ns	72.20	12.93	77.49	14.19	-4.88	<0.001
TBW (Total Body Water) [L]	45.49	6.01	44.56	6.22	0.83	ns	32.97	4.09	34.84	4.55	-5.30	<0.001
BMI (Body Mass Index) [kg/m^2]	27.68	3.37	28.85	4.01	-1.74	ns	27.90	4.43	29.85	5.35	-4.94	<0.001
PBF (Percent Body Fat) [%]	25.72	6.49	28.03	6.64	-1.94	ns *)	37.02	6.66	37.89	7.40	-1.50	ns
WHR (Waist-Hip Ratio)	0.94	0.08	0.96	0.09	-1.76	ns	0.92	0.07	0.93	0.09	-0.89	ns
VFL (Visceral Fat Level)	9.68	3.62	10.98	4.28	-1.81	ns	12.81	4.50	13.88	4.95	-2.76	0.006
FFM (Fat Free Mass) [kg]	61.81	8.23	60.51	8.48	0.85	ns	44.92	5.57	47.39	6.15	-5.14	<0.001
FFM control [kg]	0.40	1.18	0.37	1.20	0.12	ns	0.68	1.34	0.43	1.48	2.16	0.032
SMM (Skeletal Muscle Mass) [kg]	34.64	4.87	33.90	5.09	0.82	ns	24.49	3.32	25.95	3.62	-5.11	<0.001
Obesity degree	126.02	15.30	131.07	18.27	-1.66	ns	129.77	20.61	138.83	24.92	-4.92	<0.001

* close to statistical significance.

There is no statistically significant association between body height, Percent Body Fat and Waist-Hip Ratio of women living in rural and urban areas. A statistically significant difference was noted between the other parameters. Apart from Fat Free Mass and Skeletal Muscle Mass, the women living in rural areas obtained lower values for body composition parameters than their urban peers. There is no statistically significant association between the PA level of men living in rural and urban areas. In contrast, there is a statistically significant association between the PA level of women and their place of residence ($p<0.001$) – women living in the city obtain significantly higher average MET value than women living in the countryside.

Table 5. Descriptive statistics for the studied anthropometric features, physical activity and body composition of women grouped by level of education

Feature	Education – women								Difference	
	primary (N=114)		vocational (N=85)		secondary (N=302)		higher (N=152)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	p
MET	457.06	541.06	720.87	658.93	848.75	710.92	928.71	664.15	12.72	<0.001
Body height [cm]	160.13	4.82	160.52	5.51	160.95	6.02	161.63	5.39	1.70	ns
Body mass [kg]	78.68	14.71	75.60	14.30	73.00	12.32	71.33	12.24	8.05	<0.001
TBW (Total Body Water) [L]	34.78	4.26	33.77	4.68	33.21	4.33	33.32	4.04	3.93	0.008
BMI (Body Mass Index) [kg/m^2]	30.67	5.55	29.30	5.24	28.13	4.23	27.31	4.62	12.67	<0.001
PBF (Percent Body Fat) [%]	38.88	7.14	38.32	6.45	37.35	6.48	35.47	7.47	6.27	<0.000
WHR (Waist-Hip Ratio)	0.92	0.09	0.94	0.07	0.92	0.07	0.90	0.07	2.69	0.045
VFL (Visceral Fat Level)	14.29	4.89	14.12	4.90	13.01	4.36	12.06	4.75	6.41	<0.000
BFM (Body Fat Mass) [kg]	31.40	10.63	29.60	9.86	27.75	8.54	35.47	7.47	8.53	<0.000
FFM (Fat Free Mass) [kg]	47.28	5.73	45.99	6.35	45.25	5.90	45.40	5.51	3.58	0.013
FFM control [kg]	0.31	1.05	0.56	1.46	0.64	1.36	0.73	1.59	2.24	ns
SMM (Skeletal Muscle Mass) [kg]	25.85	3.36	25.10	3.79	24.70	3.49	24.76	3.30	3.26	0.021
Obesity degree	142.65	25.89	136.30	24.34	130.87	19.70	127.06	21.48	12.62	<0.000

There was no statistically significant relationship between women's body height and FFM control and their level of education. A statistically significant difference was noted between the other parameters. In general, the higher the level of education that the women had attained, the more often their scores for BMI, body fat percentage, visceral fat level and degree of obesity were in the normal range. On the other hand, for skeletal muscle mass and free fat mass, the less educated women scored higher than the more educated women (the higher the value of these parameters, the more beneficial for the body). There is a statistically significant association between women's PA levels and their education level. The better educated the women, the significantly higher the average MET value.

Discussion

Most respondents are aged 60–74 and come from urban areas. The remaining respondents are older people living in so called traditional villages (far away from cities, whose inhabitants occasionally come into contact with urban areas).

Reaching them and carrying out the research was difficult because they do not belong to senior citizens' organisations and rarely use the Internet (Omelan et al. 2017; Omelan et al. 2020), that is why most of the respondents in this study lived in urban areas. The predominance of women in the study group is not surprising as it has been widely documented that, in developed countries, females live longer than males. This is the result of lower female death rates throughout the lifespan (Poulain et al. 2011), and in Poland, there are 139 women for every 100 men over 60 years of age. This ratio differs by place of residence: in cities, the number of women per 100 men is higher than in rural areas (146 vs. 128) (Statistics Poland 2020).

Half of the respondents lived in single-person households, which is another feature of aging and old age. The growing number of one-person households among the elderly is the result of socio-demographic changes that continue to take place in human history (Piekut 2020). More men were married or in partnerships than women. It can be assumed that this is related to the fact that women statistically live longer than men. Almost 60 per cent of the respondents have chronic diseases, and some of them indicated several comorbidities. This is a dangerous situation because the occurrence of several comorbidities may accelerate the progression of the regressive processes caused by ageing (Vercelli and Ciferri 2018).

Body compositions features and physical activity in men and women

The Body Mass Index (BMI) is generally accepted as an indicator of optimal weight. According to the World Health Organisation (WHO) criteria, a BMI between 18.5 and 24.9 kg/m^2 indicates normal weight. The use of the BMI with elderly populations is sometimes criticized. According to Bahat et al. (2012), the BMI scale recommended by the WHO should not be used with older adults because a higher body weight is better for the health of senior citizens.The standard BMI proposed for people above 60 years of age ranges from 24 to 29 kg/m^2 (Queensland Government 2017). Nevertheless, in this study, it was decided to adopt the scale recommended by the WHO. The average BMI for the studied group of women was 28.84 kg/m2, and for men 28.21 kg/m2. These values are in above normal range, close to the first degree of obesity. Similar results were obtained by Malczyk et al. (2016).

A generally accepted body fat range does not exist, and the proposed models rely on empirically set limits, population percentiles and scores, which all have serious limitations (Gallagher et al. 2000). In this study, the InBody 270 criteria for a healthy percent body fat were followed: the standard for women is 18-24 per cent and for men 14–20 per cent. Both the men and the women in this study were well above the norm, but the situation of the women was worse. This is a very alarming result because a high body fat content in combination with a high BMI significantly increases the risk of functional limitations in older women (Zoico et al. 2004).

Considering the magnitude of their BMI and percent body fat values, it is not surprising that other elements of the subjects' body composition were at alarmingly high levels. The male norm for waist-hip ratio ranges from 0.80 to 0.90, and the men exceeded this norm. A similar situation was observed with the women. Thus, the studied seniors are characterised by so-called abdominal obesity.

Accumulation of excess visceral fat significantly increases the risk of health problems, including proximal aortic dilatation, diabetes, heart disease and cancer (Jiang et al. 2018). The accepted norm for visceral fat is <10 points. The men and women both exceeded the norm, but the visceral fat levels were significantly higher in the women.

The obesity degree results conclusively confirmed that the examined seniors were in a health risk group. Regardless of gender, the subjects exceeded the norm, the upper limit of which is 110 per cent.

In an ageing population, healthy values of body water content range from 45–60 per cent in women to 50–65 per cent in men (Verbalis 2003). During this study, the total body water values were measured in litres (L) and used to calculate percent body water for males and females. The mean value for women's Total Body Water was 45.42 per cent, which is basically the lower limit of the norm. The men scored slightly better with 53.55 per cent, but this is also dangerously close to the lower limit of the norm. Similar results were reported by Malczyk et al. (2016). The above could suggest that senior citizens, regardless of gender, are at risk of dehydration. Research by other authors shows that this is a very dangerous situation. A 1–2 per cent decrease in percent body water can impair physiological and mental functions, compromise endurance and contribute to cardiovascular, neural and renal dysfunctions (Josko-Ochojska et al. 2014). Dehydration is a common cause of hospitalisation among older people (El-Sharkawy et al. 2014). Preventive measures are required to increase hydration, improve health and decrease hospitalisation rates among older adults.

In general, physical activity positively influences health status and improves quality of life, allowing seniors to enjoy their independence (Lampinen et al. 2006). Worldwide, approximately 3.2 million deaths per year are attributed to a lack of physical activity. In highly developed countries, the level of chronic disease increases proportionally as physical activity levels decrease. For improved health, moderate to vigorous intensity exercise at least 5 days per week is a key factor. According to Taylor (2014), few older people achieve this level of activity. Based on the results obtained by Polish seniors in this study, their physical activity can be described as sufficient : men 917.09 MET, women 782.11 MET. These values are very close to the upper limit of insufficient physical activity (600 MET) and at the same time very far from the lower limit of high physical activity (1500 MET). Reducing the activity level of the subjects might negatively affect their functional independence, potentially leading to serious social consequences.

Body composition, physical activity and marital status

In ageing and old age, not being married or living alone has negative consequences for many aspects of life. Similarly, there is research confirming that being married protects health. Married people lead more stable, structured and healthier lifestyles and enjoy more psychological and physical support. As a result, married people enjoy better health than single people (Janghorbani et al. 2008; Mata 2015; Dakowicz 2017). A study by Williams, Zhangb and Packardc (2017) found that older people who were married had higher levels of life satisfaction and lower depression scale scores than those who had never been married, were divorced or were widowed. Entry into marriage is associated with weight gain, and exit from marriage, with weight loss (Dinour et al. 2012).

It is interesting that married men were significantly taller than singles ($p<0.001$). Apart from this, our study found that single men did not differ significantly from married men in terms of important parameters such as BMI, Waist-Hip-Ratio, Percent Body Fat, Visceral Fat Level and Obesity degree. In contrast, single women had a number of statistically significant differences from married women. The single women had lower (and therefore better) values for Waist-Hip-Ratio, Visceral Fat Level and Obesity degree. These are interesting results, as the study showed that single women had significantly lower levels of physical activity than married women. Markey et al. (2005) found that being married as opposed to being single is associated with proactive health beliefs in men but not in women. In addition, they reported that women are socialized to see themselves as caretakers and to selflessly support others. Therefore, the role of wife may make a woman less inclined to prioritize her own health care and more inclined to provide care for other family members (Markey et al. 2005). This may be why married women differ from singles in terms of body composition, while the men (regardless of marital status) do not. The manner in which women think about their individual needs, including their health needs, is the product of many thousands of years of shaping male and female social roles and of being brought up according to gender-specific cultural patterns. As we can see, this is also reflected by the women's body composition. To change such deep-rooted traditions is a huge social challenge.

Body composition, physical activity, and place of residence

Rural residents aged 60 years or more constitute 36.1 per cent of the elderly population in Poland (Czapiński and Bledowski 2013). This group remains poorly studied, especially in terms of health. In rural areas, a combination of unique health problems, resource scarcity, demographic characteristics, cultural behaviours and economic concerns influence the health status of residents (Warren and Smalley 2014). These factors can affect body composition.

Except for height (men living in urban areas were significantly taller than those living in rural areas), place of residence (urban/rural) did not affect the men's body composition parameters. However, place of residence was associated with differences in the body composition of the women. Senior women living in urban areas had significantly lower BMI, Visceral Fat Level and Obesity degree. Rural women had a significantly higher Skeletal Muscle Mass score and a higher Fat Free Mass than their urban counterparts, even though their physical activity expressed in MET was lower than that of their urban peers. Percent Body Fat and Waist-Hip ratio were similar in rural and urban women.

The rural women in this study most likely performed physical labor on farms for most of their lives, which may have been the reason for their increased muscle mass relative to their urban peers. The lifestyle of the people living in traditional Polish villages did not include regular recreational physical activity. They did not form lasting habits of exercising for health in their leisure time and this is probably why, after retirement, their physical activity was at a fairly low level, although their Skeletal Muscle Mass remained at a fairly good level. In contrast, older women living in cities are usually better educated and often have white-collar jobs (Omelan et al. 2017; Omelan et al. 2020). It can also be assumed that they were not physically active in their youth and adulthood. But in retirement, they have ample opportunities to change this. In Polish cities, regardless of their size, Third Age Universities and other social organisations that were established to work with the elderly are thriving. Only 11 per cent of these Universities operate in rural areas (Statistic Poland 2019). Senior organisations offer their students various forms of physical activities, which seniors enjoy. This is probably why both the men and women living in cities had higher physical activity than their rural peers, and in general, urban seniors are more likely to maintain a high quality of life for longer. The rural women in this study may be at greater risk of more rapid loss of muscle strength and mass. An elderly person with a more sedentary lifestyle loses Fat Free Mass faster than one who is active. Consequently, physical activity serves to prevent weight loss and maintain functional capacity in people over the age of 70 (Woo et al. 2013). It is well established that loss of muscle mass and strength in older men and frail elderly women can be reversed with resistance training exercises, even into the seventh decade (Gallagher et al. 2000). An effective effort should be made as soon as possible to facilitate access to Physical Culture for older rural residents in Poland.

Body composition, physical activity and level of education

Education provides individuals with better access to information and greater critical thinking skills, so educated people make better use of health information than less educated people. A better education appears to be associated with a lower likelihood of obesity, especially among women (Devaux et al. 2011). Yoon et al. (2006) analyzed gender differences in a study of socioeconomic factors and obesity and found that higher levels of education resulted in lower BMI and waist circumference in women, but not in men. Similarly, the study presented here found that the body composition of women differed significantly by level of education, but that of men did not. The lower the education of the women in this study, the higher the rates of such parameters as BMI, Waist-Hip-Ratio, percent body fat, visceral fat level and obesity degree. The only exception was skeletal muscle mass: women with the lowest education had a significantly higher value for this index than better educated ones (and the higher the value of these parameters, the more beneficial for the body). It can be assumed that this is the result of doing physical work throughout an occupationally active life. However, due to the fact that this group's levels of physical activity (457.06 MET) were insufficient at the time of this study, they may be at risk of more quickly losing strength and muscle mass. Cutler and Lleras-Muney (2006) found that better educated women are more likely to exercise, which was confirmed by the present study: physical activity among women with a university education was twice as high as among those with only a primary education.

Therefore, it can be assumed that the higher the education of women, the lower their risk of sarcopenia.

Conclusions

In Poland, expenditures on treatment of people 60 years or more constitute a significant part of the costs incurred for health care. In 2018, the National Health Fund spent E 7,456,140.30 (PLN 34 million) for this purpose, which was an increase of 8 per cent compared to the previous year (Statistics Poland 2020). Considering the results of the research presented in this article, it can be expected that spending on seniors will continue to increase, not only because their number is still growing. The data presented here show that older people, regardless of gender, exceed the norms set for body composition parameters, which increases their risk of age-related diseases and of being overweight or obese, which also lead to health complications. Many countries are concerned not only about the rate of increase in overweight and obesity, but also about inequalities in their distribution across social groups, particularly according to educational level, socio-economic status or ethnicity. Inequalities between social groups appear to be particularly high in women (Wardle et al. 2002). Our study confirmed that the situation is similar in Poland, suggesting that the issue of such differences between women in different socioeconomic groups may be a universal problem. The body composition of Polish female seniors differs significantly by their place of residence, marital status, and level of education. Men differ only by marital status, but with respect to only a few body components. However, it should be emphasised again that, irrespective of socio-economic characteristics, the senior citizens exceeded the norms set for individual body composition components. Attention should also be paid to the physical activity of the subjects. In fact, the average value for both genders indicates sufficient PA, but studies have shown that for women PA is dependent on socio-economic characteristics. Therefore, there is a need to find effective ways to support older adults in maintaining (or increase) their physical activity, and subsequently, to develop habitual physical activity behaviors (Taylor 2014). These should be large-scale preventative measures (which are lacking in Poland) with a particular focus on women with a certain socio-economic profile. This is necessary if we are to improve the quality of life of senior citizens, and as a consequence, reduce expenditures on health care.

Declaration of interest statement

The authors declare that they have no conflict of interest.

Authors' contribution

AAO was the initiator of the article, the main executor of the project, the leader of the research team, co-author of working and final version of the paper; KB was the performer of statistical analyses, interpretation of results and co-author of the draft of the paper; RP was the project contractor, co-author of the working and final version of the paper.

Corresponding author

Aneta Anna Omelan, Department of Tourism, Recreation and Ecology, Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, ul. Oczapowskiego 5, 10-719 Olsztyn, Poland, tel. 509 308 742, fax.: (+48 89) 523 35 17; Email: aneta.omelan@uwm.edu.pl

References

Awais M, Chiari L, Ihlen, EAF, Helbostad JL, Palmerini L. 2013. Physical Activity Classification for Elderly People in Free-Living Conditions. IEEE Journal of Biomedical and Health Informatics 23(1):197–207.

Bahat G, Tufan F, Saka B, Akin S, Ozkaya H, Yucel N, Erten N, Karan MA. 2011. Which body mass index (BMI) is better in the elderly for functional status? Archives of Gerontology and Geriatrics 54:78–81.

Batsis J, Mackenzie T, Barre L, Lopez-Jimerez F, Bartels SJ. 2014. Sarcopenia, sarcopenic obesity and mortality in older adults: results from the National Health and Nutrition Examination Survey III. Eur J Clin Nutr 68:1001–1007.

Batsis JA, Villareal DT. 2018. Sarcopenic obesity in older adults: etiology, epidemiology and treatment strategies. Nature reviews. Endocrinology 14(9):513–537.

Biernat E, Stupnicki R, Gajewski A. 2007. International Physical Activity Questionnaire (IPAQ) – Polish version. Physical Education and Sport 51(1):47–54.

Czapińsk J, Bledowski P. 2014. [Social activity of elderly citizens based on the perceptions of Polish respondents. Social diagnosis 2013]. MPiPS, Warszawa (in Polish).

Colado JC, Garcia-Masso X, Rogers ME, Tella V, Benavent J, Dantas EH. 2012. Effects of Aquatic and Dry Land Resistance Training Devices on Body Composition and Physical Capacity in Postmenopausal Women. J Hum Kinet 32:185–195.

Cutler D, Lleras-Muney A. 2006. "Education and Health: Evaluating Theories and Evidence", NBER Working Paper 12352, www.nber.org/papers/w12352 [Accessed 17.05.2021].

Dakowicz A. 2017. [The psychotransgressive approach to marital success]. Kwartalnik Naukowy. Problematyka transgresji i transcendencji 2(30):1–15 (in Polish).

Devaux M, Sassi F, Church J, Cecchini M, Borgonovi F. 2011. Exploring the Relationship Between Education and Obesity. OECD Journal: Economic Studies 1:121–159.

Dos-Santos JE, Oths KS, Dressler WW. 2001. Socioeconomic factors and adult body-composition in a developing socjety. Rev Bras Hipertens 8(2):173–178.

El-Sharkawy AM, Sahota O, Maughan RJ, Lobo DN. 2014. The pathophysiology of fluid and electrolyte balance in the older adult surgical patient. Clin Nutr 33(1):6–13.

European Commission, 2017. The 2018 Ageing Report. Underlying Assumptions & Projection Methodologies. Institutional paper 065, November 2017. ISSN 2443-8014. Available at: https://ec.europa.eu/info/publications/economy-finance/2018-ageing-report-underlying-assumptions-and-projection-methodologies_en [Accessed 17.06.2021].

Gallagher D, Ruts E, Visser M, Heshka S, Baumgartner RN, Wang J. et al. 2000. Weight stability masks sarcopenia in elderly men and women. Am J Physiol Endocrinol Metab 279(2):366–375.

Houston DK, Niclas B, Zizza CA. 2009. Weighty Concerns: The Growing Prevalence of Obesity among Older Adults. Journal of the American Dietetic Association 109/11:1886–1895.

Janghorbani M, Amini M, Rezvanian H, Gouya MM, Delavari A, Alikhani S. et al. 2008. Association of Body Mass Index and Abdominal Obesity with Marital Status in Adults. Arch Iran Med 11(3):274–281.

Jiang Z, Lin B, Liu T, Qin S, Huang S, Shao S. et al. 2018. Visceral fat index/percentage body fat ratio is independently associated with proximal aortic dilatation in a middle-aged and aged Chinese population in Liujiang of Guangxi. Atherosclerosis 268:19–26.

Jośko-Ochojska J, Spandel L, Brus R. 2014. Dehydration in the elderly as a public health problem. Hygeia Public Health 49(4):712–717.

Lampinen P, Heikkinen RL, Kauppinen M, Heikkinen E. 2006. Activity as a predictor of mental well-being among older adults. Aging & Mental Health 10(5):454-466.

Malczyk E, Dzięgielewska-Gesiak S, Fatyga E, Ziółko E, Kokot T, Muc-Wierzgon M. 2016. Body composition in healthy older persons: role of the ratio of extracellular/total body water. Journal of Biological Regulators & Homeostatic Agents 30(3):447–452.

Markey CN, Markey PM, Schneider C, Brownlee S. 2005. Marital Status and Health Beliefs: Different Relations for Men and Women. Sex Roles 53:443–451.

McLaren L. 2007. Socioeconomic Status and Obesity. Epidemiologic Reviews 29:29–48.

Mata J, Frank R, Hertwig R. 2015. Higher body mass index, less exercise, but healthier eating in married adults: Nine representative surveys across Europe. Social Science & Medicine 138:119–127.

Omelan AA, Podstawski RS, Wziątek B, Merino-Marban R, Romero-Ramos O. 2017. Physical activity levels of rural and urban seniors in the region of Warmia and Mazury in Poland. Baltic Journal of Health and Physical Activity 9(4):74–88.

Omelan AA, Zielińska I, Wziątek B, Bielinis E, Podstawski R. 2020. Health-related behaviors of seniors in rural versus urban areas: a cross-sectional study. Health Prob Civil 14(1):1–8.

Piekut M. 2020. Living Standards in One-Person Households of the Elderly Population. Sustainability 12, 992, 1–26.

Poulain M, Pes G, Salaris L. 2011. A Population Where Men Live As Long As Women: Villagrande Strisaili, Sardinia. Journal of Aging Research, https://doi.org/10.4061/2011/153756

Queesland Government 2017. Using Boby Mass Index. Available at: https://www.health.qld.gov.au/__data/assets/pdf_file/0031/147937/hphe_usingbmi.pdf [Accessed 17.04.2021].

Ruiz-Montero P, Castillo-Rodríguez A. 2016. Body composition, physical fitness and exercise activities of elderly. Journal of Physical Education and Sport, 16(3):136, 860–865.

Ryall JG, Schertzer JD, Lynch GS. 2008. Cellular and molecular mechanisms underlying age-related skeletal muscle wasting and weakness. Biogerontology 9:213–228.

Silva Neto LS, Medeiros A, Travassos A, Osório NB, Nunes GF. 2019. Association between sarcopenic obesity, muscle strength and risk of cardiovascular and cardiometabolic diseases in the elderly: A systematic review. Rev Nutr 32, http://doi.org/10.1590/1678-9865201932e180237

Staatz CB, Kelly I, Lacey R, Hardy R. (2019). Socioeconomic position and body composition across the life course: a systematic review protocol. Systematic Reviews 8,263, https://doi.org/10.1186/s13643-019-1197-z

Statistics Poland 2020. The situation of older people in Poland in 2018. Statistical analyses. Statistics Poland Statistical Office in Białystok.

Statistic Poland 2019. [Universities of the Third Age in Poland in 2018]. Warszawa GUS. Available at: https://stat.gov.pl/obszary-tematyczne/edukacja/edukacja/uniwersytety-trzeciego-wieku-w-polsce-w-2018-r-,10,2.html [Accessed 27.03.2022].

Taylor D. 2014. Physical activity is medicine for older adults. Postgrad Med 90:26–32.

Tyrovolas S, Ai Koyanagi A, Olaya B, Ayuso-Mateos JL, Miret M, Chatterji S. et al. 2016. Factors associated with skeletal muscle mass, sarcopenia, and sarcopenic obesity in older adults: a multi-continent study. Journal of Cachexia, Sarcopenia and Muscle 7:312–321.

Verbalis JG. 2003. Disorders of body water homeostasis. Best Pract Res Clin Endocrinol Metab 17(4):471–503.

Vercelli A, Ciferri L. 2018. Ageing and the Grey Society: An Opportunity to Change Our Views in Medicine? DigitCult, Scientific Journal on Digital Cultures 3(1):1–6.

Ward J, de Lima Friche AA, Caiaffa WT, Proietti FA, Xavier CC, Diez Roux AV. 2015. Association of socioeconomic factors with body mass index, obesity, physical activity, and dietary factors in Belo Horizonte, Minas Gerais State, Brazil: The BH Health Study. Social Patterning of Obesity and its Risk Factors 31:182–194.

Wardle J, Waller J, Jarvis MJ. 2002. Sex Differences in the Association of Socioeconomic Status With Obesity. American Journal of Public Health 92(8):1299–1304.

Warren JC, Smalley KB (editors). 2014. Rural Public Health. Best Practices and Preventive Models. LLC New York: Springer Publishing Company.

Williams L, Zhangb R, Packardc KC. 2017. Factors affecting the physical and mental health of older adults in China: The importance of marital status, child proximity, and gender. Population Health 3:20–36.

Woo J, Yu R, Yau F. 2013. Fitness, fatness and survival in elderly populations. Age 35(3):973–984.

World Health Organization, 2015. Action for Ageing. A toolkit for organizing innovative events on the World report on ageing and health. Available at: https://www.who.int/ageing/events/world-report-2015-launch/ageing-health-events-toolkit.pdf?ua=1 [Accessed 17.04.2021].

World Health Organization, 2017. Policies and Priority Interventions for Healthy Ageing. Available at: https://www.euro.who.int/__data/assets/pdf_file/0006/161637/WHD-Policies-and-Priority-Interventions-for-Healthy-Ageing.pdf [Accessed 07.04.2021].

Yoon YS, Oh SW, Park HS. 2006. Socio-Economic Status in Relation to Obesity and Abdominal Obesity in Korean Adults: A Focus on Sex Differences. Obesity (Silver Spring) 14(5):909–919.

Zoico E, Di Francesco V, Guralnik JM, Mazzali G, Bortolani A, Guariento S et al. 2004. Physical disability and muscular strength in relation to obesity and different body composition indexes in a sample of healthy elderly women. Int J Obes 28:234–241.

Anthropological Review • Vol. 85(3), 47–66 (2022)

Anthropological Review

Available online at: https://doi.org/10.18778/1898-6773.85.3.04

Identification of Demographic Crises and Evaluation of Their Intensity in the Kujawy Region (Central Europe) in the 19th Century

Alicja Drozd-Lipińska[1], Arkadiusz Bartczak[2], Michał Krzemiński[3], Tomasz Dziki[4]

[1] Nicolaus Copernicus University in Toruń, Faculty of Biological and Veterinary Sciences, ORCID: 0000-0002-1562-8090
[2] Polish Academy of Sciences, Institute of Geography and Spatial Organization Polish Academy of Sciences, Department of Environmental Resources and Geohazard Toruń, Poland, ORCID: 0000-0002-9285-6273
[3] Gdańsk University of Technology, Faculty of Applied Physics and Mathematics, Department of Probability and Biomathematics, Gdańsk, Poland, ORCID: 0000-0002-5596-366X
[4] Włocławek Society of Arts and Sciences, Włocławek, Poland, Polish Historical Assosiation, Włocławek Branch, Włocławek, Poland, ORCID: 0000-0003-1828-2125

Abstract: Mortality crises are periods of unusually high mortality resulted from a combination of epidemic episodes, climatic phenomena, historical events and sociopolitical factors. The most pronounced setback in the methodology applied to analyse mortality rates of historical populations is the inability to establish their size.

Reference publications do not provide unambiguous measures of the intensity and scale of mortality crisis periods. This problem was approached with the use of the Standardised Demographic Dynamics Rate (*SDDR*) whose value provides information about the condition of a population, disregarding the size of the group. Demographic crises were indicated and identified among the population living in the 19th century in central Poland in the rural parish. The analysis was based on data obtained from parish registers, made use of the measure expressing the ratio of the number of births to the number of deaths, without using the size of the group.

Results obtained from the analysis of data were set against the information about events causing a sudden growth in mortality derived from the widely-accessible literature. Value of the Standardised Demographic Dynamics Rate (*SDDR*) provides information aboutthe condition of a population, disregarding the size of the group. Nevertheless, only by combining the statistically obtained data with the information derived from written records it is possible to attempt to answer the question of the possible root cause of a demographic crisis.

Key words: epidemics, mortality crises, Standardised Demographic Dynamics Ratio (SDDR), Box-Cox transformation, historical demography

Original article

Received: 24.11.2021; Revised: 19.08.2022; Accepted: 30.08.2022

Introduction

The analysis of the 16th–19th century mortality rates reveals the occurrence of repeated periods of sudden and dramatic increases in the number of deaths. Such violent short-run disturbances in the mortality pattern, referred to as mortality crises, their causes and effects on local communities, have been in the centre of attention ever since the interest in the possibility of research into record books appeared (Hinde 2010; Nelson 1991; Humphreys 1987; Landers 2006; Goubert 1960; 1968).

One of the definitions of the phenomenon states that „mortality crises are unusually high mortalities arising from a common, unusual, causal factor operating for a limited time across a given geographical area" (Bouckaert 1989). The death curve rockets and increased mortality lingers for a period of at least several months (Kuklo 2009). Researchers, however, tend to be in disagreement as to the choice of objective methods providing unambiguous identification of crisis periods and their intensity. The most pronounced setback in the methodology applied to analyse mortality rates of historical populations is the inability to establish their size, which stems from the very character of the analysed sources (parish registers, registers and statistics of deaths). Reference publications do not provide unambiguous measures of the intensity and scale of mortality crisis periods that would allow space-time comparison and the description of variation of the observed phenomena (Sawchuk et al. 2013; Kuklo 2009; Goubert 1968).

Consequently, both historians and demographers tend to apply the number of deaths, or less frequently – the number of conceptions, as the measure of demographic crises.

By general agreement, though, researchers point at the necessity to apply a variety of criteria of identification of crises themselves, as well as their intensity, depending on the population size and socio-economic discrepancies within its structure (e.g. urban-rural) (Turner 1973; Lebrun 1977; Hinde 2010; Sawchuk et al. 2013; Bouckaert 1989). Provided that the size of the population and length of the crises are known, crisis intensity index suggested by T. Hollingsworth (Hollingsworth 1979; Hinde 2010) can be applied. The important upside of this method is the possibility to determine the crisis intensity on the basis of the size of the deceased fraction of the population. There are, however, those who assume that during a crisis the number of deaths has increased by 1.5 up to 3 times in comparison to the monthly or yearly moving average for the period directly preceding the crisis. The moving average is calculated for the period of 9 to 25 years, sometimes discarding up to 4 extreme values. The calculation of the moving average may, at times, include periods preceding and following the alleged crisis year (Appleby 1978; Edvinsson 2015; Schofield 1972; Hoch 1998; Kuklo 2009; Hinde 2010; Turner 1973; Humphreys 1987; Lebrun 1977).

The main aim of our research was to indicate and identify demographic crises and/or revivals occurring in the 19th century among the catholic rural population in *North-Eastern Poland* and to suggest a classification allowing the assessment of the magnitude of those events.

The identification of crises was performed with investigating their underlining causes such as epidemics, wars or others. The identification and the evaluation of intensity was carried out according to Jaques Dupâquier (Dupâquier 1979), Pierre Goubert (Goubert 1968) and with the use of the Standardised Demographic Dynamics Rate (*SDDR*).

The results obtained from the analysis of data concerning the residents of Kowal parish in the 19th century were set against the information about events causing a sudden growth in mortality in the local population derived from the widely-accessible literature (Dziki 2007b; 2007a; Rejmanowski 2001; Siudikas 1998; Wrębiak 2010; Korpalska 2011; Evans 1988; Puzyrewski 1899; Budnik 2008; Dorobek 1979; Winkle 1999; Włodarczyk 1998; Zasada 2006; Drozd-Lipińska, Bartczak, and Dziki 2021a; Dziki 2021) as well as the archives.

Material and methods

Historical Background

Kowal is a small town in the Eastern Kujawy region whose written historical records date back at least to the 12th century (Głowacki 2007). The people of the town itself, as well as that of the surrounding villages included in the parish (Fig. 1), largely lived off the land or, less frequently, craftsmanship (Gruszczyńska and Poraziński 2002; Dziki 2007a; 2021; Drozd-Lipińska 2021; Drozd-Lipińska, Bartczak, and Dziki 2021a).

Historical forces of the 19th-century Europe turned the commune of Kowal into a part of the Russian empire on the territory of the Kingdom of Poland (Zasada 2007; 2006). The harrowing political situation, combined with contributions regularly imposed on villages for the sake of marching armies, resulted in a profound economic crisis (Dziki 2007a; 2021). The situation of Kowal was further aggravated by its less-than-favourable location in relation to the existing communications network and the neighbourhood of the dynamically developing industrial centre – the city of Włocławek.

Fig. 1. Map of 19th of Kowal Parish

Consequently, the parish missed out on the benefits potentially flowing from the 19th-century industrial revolution (Dziki 2007a; 2021; Drozd-Lipińska, Bartczak, Dziki 2021a). Moreover, the 1869 administrative reform, depriving the town of its borough rights for nearly half a century, significantly worsened its economic position (Zasada 2006; Dziki 2007a; 2021; Drozd-Lipińska, Bartczak, Dziki 2021a). Given the above, it seems justified to categorise Kowal and the neighbouring villages scattered around the area of approx. 18 km as a "typical" agricultural area.

Data

The analysis was based on data obtained from record books kept by the Włocławek Branch of the National Archive in Toruń. The annual records from Kowal parish written in Polish or Russian contain information on christenings, deaths and weddings reported in the parish during a given year and provide an exact date of the event. On this basis, the information was gathered about 20124 births and 12971 deaths of the parishioners in 35 settlings, towns and villages in the parish of Kowal which happened in the period 1813–1909 (Table 1).

Table 1. Number of births and deaths in Kowal Parish in 1813–1909

Year	Births	Deaths	Year	Births	Deaths	Year	Births	Deaths	Year	Births	Deaths
1813	116	77	**1837**	178	152	**1861**	174	86	**1887**	256	174
1814	146	72	**1838**	159	100	**1862**	217	140	**1888**	256	153
1815	128	44	**1839**	163	82	**1863**	228	140	**1889**	248	179
1816	131	97	**1840**	146	95	**1864**	223	126	**1890**	282	188
1817	138	91	**1841**	161	106	**1865**	239	101	**1891**	246	227
1818	165	73	**1842**	177	101	**1866**	254	94	**1892**	245	206
1819	149	70	**1843**	182	143	**1867**	242	103	**1893**	282	255
1820	168	64	**1844**	163	105	**1868**	200	122	**1894**	283	202
1821	177	73	**1845**	205	77	**1869**	236	95	**1895**	264	125
1822	189	93	**1846**	163	141	**1870**	232	90	**1896**	280	100
1823	181	73	**1847**	160	166	**1871**	220	96	**1897**	295	145
1824	182	134	**1848**	132	162	**1872**	230	94	**1898**	292	136
1825	190	104	**1849**	155	128	**1873**	235	117	**1899**	261	249
1826	206	99	**1850**	189	101	**1874**	209	142	**1900**	323	208
1827	160	112	**1851**	160	83	**1875**	238	101	**1901**	276	180
1828	165	149	**1852**	149	334	**1876**	219	102	**1902**	298	179
1829	166	145	**1853**	178	155	**1879**	236	187	**1903**	306	188
1830	143	148	**1854**	145	167	**1880**	245	117	**1904**	293	146
1831	130	215	**1855**	110	191	**1881**	224	119	**1905**	272	138
1832	99	173	**1856**	151	137	**1882**	247	158	**1906**	275	162
1833	181	90	**1857**	171	154	**1883**	228	250	**1907**	283	134
1834	169	61	**1858**	174	140	**1884**	249	118	**1908**	273	150
1835	175	110	**1859**	214	120	**1885**	249	122	**1909**	284	178
1836	155	101	**1860**	164	77	**1886**	253	161	**Sum**	**20 124**	**12 971**

Moreover, the population size was established based on data from catholic directoriums kept in Dioecesan Archive in Włocławek. Then the mortality rate was calculated (Fig. 2).

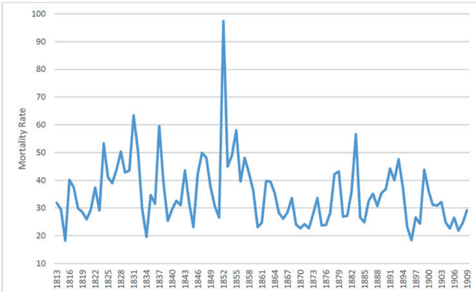

Fig. 2. Values of crude death rates [‰] for Kowal Parish (1813–1909)

The credibility of historical records, and thus their usefulness for our analysis, was tested by making a reference to findings made by Polish and French researchers (Gieysztorowa 1976; Goubert 1960), according to which the percentage of newborn deaths for the period concerned ought to stand at 30% of the total mortality rate. Following the commonly agreed opinion (Sułowski 1962; Kaczmarski 1967; Budnik 2005; Gieysztorowa 1976; Kuklo 2009), that register books of marriages were among the most diligently maintained record books, indicators relating the number of births to the number of marriages as well as the number of deaths to the number marriages were calculated. It was assumed that the ratio of the number of births to the number of marriages (B/M) of 5.0 and that of the number of deaths to the number of marriages (D/M) of 3.0 proved the correct and conscientious maintenance of the records, thus enabling further processing of the data obtained (Gieysztorowa 1962; 1976; Sułowski 1962; Kuklo 2009; Kaczmarski 1967; Budnik 2005).

Methodology Description

The analysis made use of the formula, put forward by J.L. Dupâquier (Dupâquier 1979), makes it possible to classify the intensity of a crisis using the number of deaths, the average value and the standard deviation. According to the assumption, the calculated intensity index falling into intervals 1–2 stands for a minor crises and the subsequent intervals stand formoderate (2–4), high (4–8), major (8–16), super crises (16–32) and catastrophes (32+).

Next, according to Goubert (Goubert 1968), the moment in which the number of deaths has increased twofold during the year regarded as the crisis one in comparison to the preceding 12 months, and the number of conceptions has decreased by 1/3, was regarded to be the onset of a crisis.

The last method was the determination the level of balancing the number of births to the number of deaths – the Demographic Dynamics Rate (*DDR*) – (Holzer 2003) for every year. The assumption about the normal character of the analysed yearly and monthly series of the DDR was statistically verified with the Shapiro–Wilk test (Shapiro, Wilk 1965; Razali, Wah 2011) typically used to prove a hypothesis that a given sample comes from a normal distribution. The analysis was performed on the level of statistical significance $\alpha = 0.05$. It is frequently stated that one of the basic requirements for particular models to be applicable is the normality of the series of data (Sakia 1992; Ajdacic-Gross et al. 2006). The series of demographic data do not tend to have the normal distribution and, as such, they are subject to log transformation, frequently with disputable results (Shang 2015). Bishai and Opuni (Bishai, Opuni 2009) highlighted the importance of selection of an appropriate method of data transformation for the research involving the comparison of various demographic indices. Similarly, H. Booth (Hyndman and Booth 2008), followed by H.L. Shang (Shang 2015), argued that a correctly chosen transformation is prerequisite for correct modelling and predicting various demographic parameters and occurrences.

Therefore all the analysed series were normalised and the values of indicators (*x*) were next subjected to the Box-Cox transformation (Box and Cox 1964; 1982; Bartczak, Glazik, Tyszkowski 2014). With the use of the transformation the skewness of the distribution pattern was eliminated and so were other difficult-to-analyse properties. Selected transformations of the series of monthly values are depicted graphically on the Quantile-Quantile plot (Fig. 3). The effectiveness of the transformation was subsequently re-tested by Shapiro-Wilk test. It is worth mentioning that value 1 of the *DDR* after the transformation, disregarding the λ parameter, takes the value of 0. The applied standardisation process enables the comparison of a number of series characterised by various input data – both in respect of their scale and the unit of measurement. All the above considerations concerning the properties of the normal distribution were used for the sake of classification of the calculated demographic dynamics rates and using them to evaluate the intensity of mortality crises.

The probability of occurrence of a particular value of the Standardised Demographic Dynamic Rate (the area under the density curve of the normal distribution) was used as the basis for classification (Table 2). It was assumed that a crisis year was defined by the value below or equal to -0.61 (differentiating between crises classified as “Very –“, “Anomalous –“ and “Extreme-“). Values of -0.61 to 0.61 stand for the years in which neither positive nor negative factors influencing the population reproduction process were observed

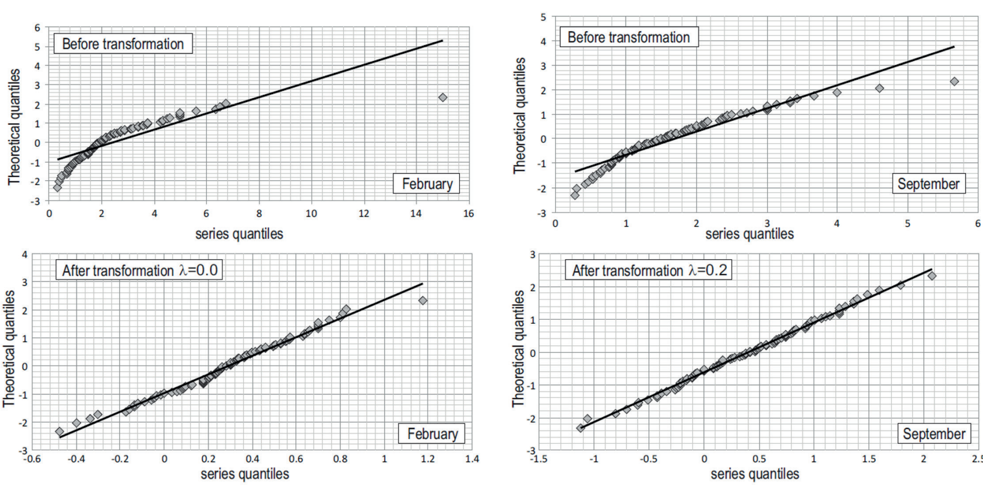

Fig. 3. *Q-Q* plot for the normal distribution of selected series of monthly demographic dynamics index for Kowal Parish (1813–1909) before and after Box-Cox transformation

Table 2. The classification of the probability of the frequency of the occurrence of a value in *SDDR*

Classification	Times the standard deviation from the mean	Probability [%]
Extreme+	≥1.97	2.5
Anomalous+	1.15 ÷ 1.96	10
Very+	0.61 ÷ 1.14	15
Normal	0.60 ÷ -0.60	45
Very-	-0.61 ÷ -1.14	15
Anomalous-	-1.15 ÷ -1.96	10
Extreme-	≤-1.97	2.5

Source: Own study.

(such factors either did not appear or they were mutually offset). Following the normalisation and standardisation procedure, the variability of indicators (Standardised Demographic Dynamics Rate – *SDDR*) in time was depicted with the use of a moving trend (segment, crawling). Next, the structural parameters of the function were estimated for each segment. The number of segments in one series is n-k+1 and the linear functions for each segment are as follows: $\hat{y}_1 = a_1 + b_1 t$ for $1 \leq t \leq k$; $\hat{y}_2 = a_2 + b_2 t$ for $2 \leq t \leq k+1$; .... ; $\hat{y}_{n-k+1} = a_{n-k+1} + b_{n-k+1} t$ for $n-k+1 \leq t \leq n$. The analysis was performed for the constant $k = 15$ years. All calculations were performed using the analytics software package Statistica 13.3.

Results

Dupâquier's Crises Intensity Ratio (*DCIR*) was enabled to identified twelve years of minor, eight years of formoderate and two years of high crises. In nine years *DCIR* reached values between -2 to – 1 (1833, 1834, 1839, 1850, 1851, 1860, 1866, 1895, 1907) and once yearly value was below -2 (1896) (Fig. 4).

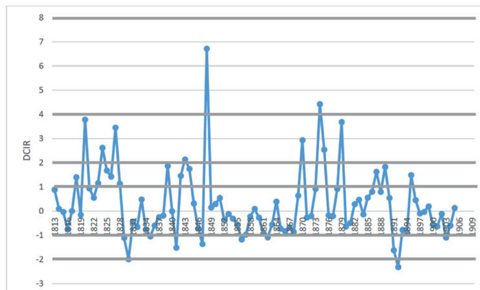

Fig. 4. Values of Dupâquier's Crises Intensity Ratio for Kowal Parish (1813–1909)

Research procedure based on Goubert method allowed to identify only two crises years – 1816 and 1852.

In the third method (*SDDR*), based on yearly (Fig. 5) and monthly (homogenous) (Fig. 6) demographic dynamics ratio values, the distribution of most series of monthly indicators was brought to normality by means of the Box-Cox transformation. The Table 2 presents the obtained values of the parameter λ necessary for appropriate selection of the function transforming the series. Finally, 27 years of crises mortality have been identified for the population of Kowal (17 "Very –"; 6 "Anomalous –"; 4 "Extreme-":) (Fig. 5, Table 3).

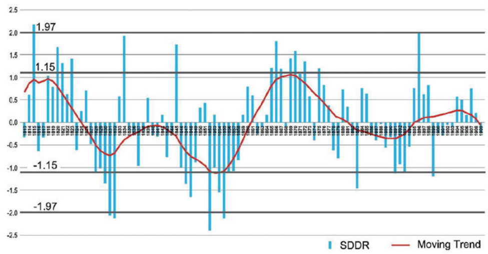

Fig. 5. Values and trend of Standarised Demografic Dynamic Ratio for Kowal Parish (1813–1909)

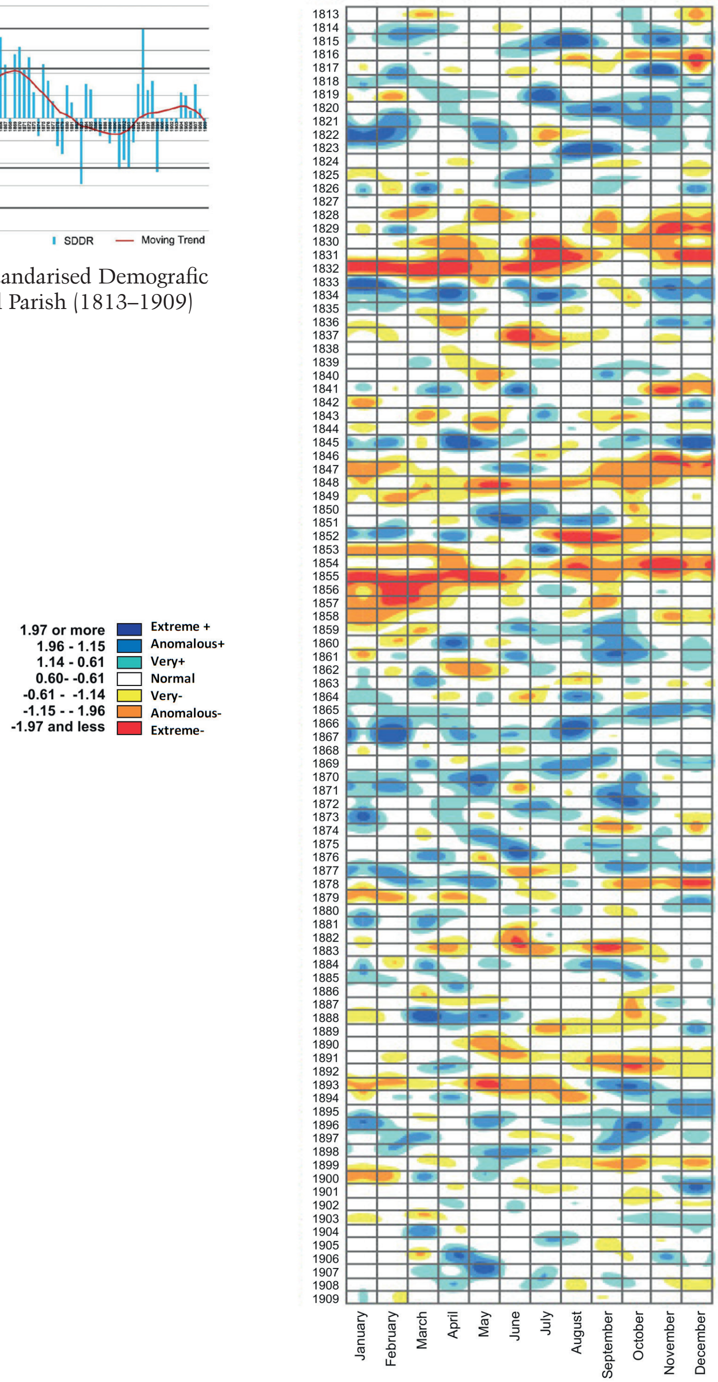

Fig. 6. Values of the monthly Standarised Demographic Dynamics Ratio (*SDDR*) for Kowal Parish (1813–1909)

Table 3. Values of λ parameter for the monthly and yearly Demographic Dynamics Ratio for Kowal Parish (1813–1909)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
λ	0.2	0.0	0.3	-0.1	0.0	-0.2	-0.1	0.2	0.2	0.0	-0.2	0.0	0.9

Source: Own study.

The multi-year span which was investigated revealed a few long-lasting harrowing periods for the local population (Table 4). The first one, recorded in Twenties of the 19th century (as 1822, 1824, 1827–1832 according to *DCIR* and 1824 and 1828–1832 and 1837 according to *SDDR*), seems to have been an upshot of a harsh economic and political situation prevailing in the region following the outbreak of the anti-Russian uprising in November 1830, which engulfed the Kowal parish. A thorough investigation of historical sources suggests a direct link between extremely high/low values of the ratios, particularly in 1831 (annual number of births = 130; annual number of deaths = 215; *DCIR* = 3.45; *SDDR* = -2.07;) and 1832 (annual number of births = 99; annual number of deaths = 173; *SDDR* = -2.13) and a cholera epidemic (1831–1832) which broke out after Russian troops had been sent into the region in order to supress the uprising (Puzyrewski 1899; Włodarczyk 1998). This period was proceeded by one crisis year – 1816 (identified according to all three methods), year after Napoleon's defeat, when soldiers was marched back from France to Russland through Kujavy Land (Dziki 2018; Drozd-Lipińska, Bartczak, and Dziki 2021a; 2021b) and after the Fourth Partition of Poland.

The second long-lasting period of low reproduction rate was recorded in Forties-Fifties of the 19th century (1843, 1846–1848 and 1852 according to *DCIR*; 1843, 1846–1849, 1852–1858 according to *SDDR*, 1852 according to Goubert), which must have been an aftermath of the situation in place in the mid-1840s (food crisis triggered by failing harvest and mass damage to potato plantations) (Myszczyszyn 2013) which preceded the outbreak of the 1848 cholera epidemic (Włodarczyk 1998) and

Table 4. Classification of crises mortality and demographic revivals in Kowal Parish (1813–1909) (*SDDR* method)

Classification	Times the standard deviation from the mean	Number of occurrences
Extreme+	≥1.97	2
Anomalous+	1.15 ÷ 1.96	12
Very+	0.61 ÷ 1.14	16
Normal	0.60 ÷ -0.60	40
Very-	-0.61 ÷ -1.14	17
Anomalous -	-1.15 ÷ -1.96	6
Extreme-	≤ -1.97	4

Source: Own study.

then another wave of the disease that decimated the population of Kujawy in 1852 (Rejmanowski 2001; Włodarczyk 1998). The latter sparked the third successive "High" /"Extreme-" demographic crisis and an increase in the value of the DCIR to 6.72 and a drop in the value of the *SDDR* to -2.39 in 1852 (annual number of births = 149; annual number of deaths = 334), the highest/lowest level recorded in the researched period. The next evident "Extreme-" demographic crisis according to *SDDR* method was recorded in 1855 (*SDDR* = -2.13; annual number of births = 110; annual number of deaths = 191) and, again, it is tied with the appearance of cholera in the area (unidentified by *DCIR* or Goubert's method) (Włodarczyk 1998).

The two last long-lasting mortality crises periods were observed in the late 19th century. Seventies (1874 and 1878–79 according to *DCIR* and 1878–19 according to *SDDD*) and Nineties (respectively: 1891, 1893, 1899 and 1891–1893, 1899) were unfavourable, but it must be noted that the late 19th century manifests a universal tendency to shorten the negatively-marked periods and to diminish the intensity of their negative impact on the population (Fig. 4–6). This may have been caused by the weakening impact of epidemics on the level of mortality owing to improved sanitation and fast-developing medicine. The moving trend for the decade (based on *SDDR* values) suggests the occurrence of several adverse factors, yet successfully offset by various social phenomena like the population migration (Szczechowicz 2013; Jura 2002).

At this stage of research it is not possible to connect sudden increase of *DCIR* value in 1878 (*DCIR* = 4.42) and 1910 (*DCIR* = 2.35) with specific historical or economic event, while increase/decrease of ratios values in 1883 (*DCIR* = 3.68; *SDDR* = -1.46) should be a consequence of some kind of epidemic, as described before (Drozd-Lipińska, Klugier, Kamińska-Czakłosz 2015).

While analysing the distribution of the *SDDR* in an annual cycle (Fig. 6), one is prone to observe that events having an adverse impact on the population do not display any seasonal character lasting up to several months. An example of such an event is the demographic crisis which started in September 1829 and did not finish until July 1832, during which period the *SDDR* stood at the level below -2.00 for as many as 11 months. July 1830 and April 1832 marked the moments of the most severe crisis with the *SDDR* of -3.24 (monthly number of births = 3; monthly number of deaths = 12) and -3.05 (monthly number of births = 7; monthly number of deaths = 26) respectively. The situation was largely repeated in 1854 and 1855 with very low monthly values of the indicator, though the relation of births to deaths was not as dramatically negative as it had been two decades before. The distribution of the indicator in the yearly cycle took a very interesting form in 1852. During the first six months of the year the ratio of births to deaths remained in the positive area with the peak value of the *SDDR* of 1.85 in April. On the other hand, the period from July to October was an extremely unfavourable time for the investigated population with the bottom value of the *SDDR* of 3.37 observed in August 1852 (monthly number of births = 11; monthly number of deaths = 210), which was the lowest level for the whole period included in the research.

Table 5. Years of crises mortality in Kowal Parish (1813–1909)

Year	DCIR	SDDR	Goubert
1816	Minor	Very -	+
1822	Minor		
1824	Formoderate	Very -	
1827	Minor		
1828	Formoderate	Very -	
1829	Minor	Very -	
1830	Minor	Anomalous -	
1831	Formoderate	Extreme -	
1832	Minor	Extreme -	
1837		Very -	
1843	Minor	Very -	
1846	Minor	Very -	
1847	Formoderate	Anomalous -	
1848	Minor	Anomalous -	
1849		Very -	
1852	High	Extreme -	+
1853		Very -	
1854		Anomalous -	
1855		Extreme -	
1856		Very -	
1857		Very -	
1858		Very -	
1874	Formoderate		
1878	High	Very -	
1879	Formoderate	Very -	
1883	Formoderate	Anomalous -	
1891	Minor	Very -	
1892		Very -	
1893	Minor	Very -	
1899	Minor	Anomalous -	
1910	Formoderate		

Discussion

Illnesses of endemic or epidemic character used to be among the most significant regulators of the natural population movement in the pre-industrial era. Their kind and frequency of appearance evolved throughout centuries following cultural transformations. The transformations of the social patterns of health and illness characteristic of subsequent historical periods are known, after A. R. Omran (Omran 1971), as "epidemiological transitions". The 19th century saw a gradual decrease in infectious disease mortality and, at the same time, an increase in the number of deaths resulting from civilization illnesses and other external reasons which became the main cause of deaths. Waves of epidemics which had haunted Europe for centuries, now gave way to chronic and degenerative diseases related to the ageing population. Growing industrialisation brought about civilisation diseases, allergies and depression (Gagnon 2012). This change, known as the second epidemiological transition, was first observed in Sweden, England and Wales, Germany, France and Italy in the mid-19th century and is directly associated with the ongoing industrial revolution, technological development, improved sanitation and progress in medicine (Barrett et al. 1998; Omran 1971). The area of modern Poland did not experience this transition until later time when, as suggested by A. Budnik in her research on Greater Poland (Budnik 2008), rapid industrialisation process took place in Poznań area in the period 1875–1880. The rural populations of Greater Poland waited for this same transition for two decades until the late 19th century (1896–1900) as was the case with Kujawy region. The present research indicates that the onset of the transition in this area fell on the last five years of the 19th century when the epidemics, which had regularly decimated the population, suddenly stopped being the main factor shaping the mortality patterns. Interestingly, then, the second epidemiological transition in the rural community of Kujawy was not delayed by the economic underdevelopment of the region resulting from specific political, economic and social conditioning of this part of the Russian partition (Dziki 2007b; 2021; Drozd-Lipińska, Bartczak, Dziki 2021b; 2021a).

The period directly preceding the second epidemiological transition was the time of many sudden increases in the number of deathsfalling into the category of demographic crises. The methods described earlier in the article enable researchers to identify them in a relatively precise manner without investigating their root causes (Miodunka 2013; Hinde 2010; Kuklo 2009; Appleby 1978; Edvinsson 2015; Turner 1973; Schofield 1972; Hoch 1998; Humphreys 1987; Lebrun 1977). A further analysis of sources other than record books – annuals, diaries, letters, legal documents, or later, daily press, makes it possible to tie the periods of increased mortality with epidemic episodes, climatic phenomena or historical events (Sawchuk et al. 2013), sometimes also offering a chance to capture the phenomenon of social selectivity (SES) which may have resulted in differing rates of mortality between rural and urban communities, or between various social classes (Healey 2008; Breschi, Manfredini, Fornasin 2011).

Most of the identified 19th-century demographic crises were triggered by Asian cholera whose recurrent waves decimated the population of Europe since 1817 (Smith 1978; Straszak-Chandoha 2008; 2013; Rüttimann and Loesch 2012). All of the 5 (in 1817–1823; 1826–1837; 1846–1862; 1864–1875, 1883–1896 (Siudikas 1998) or in 1817–1823; 1826–1837; 1841–1862; 1864–1875; 1882–1896 (Winkle 1999)) or 6 (in 1817–1823; 1826–1837; 1842–1859; 1863–1875; 1881–1896; 1899–1923 (Evans 1988)) strikes of epidemics would decrease the number of marriages due to a natural tendency to postpone vital decisions for better times. Initially, the number of births dropped, yet the number of conceptions went up periodically at the peak moments of an epidemic, which may have been a result of tightening family bonds in harsh times (Kuklo 2009; Miodunka 2013). Owing to this mechanism, at the final stages of an epidemic an increased number of christenings were often recorded, though it was not a rule. Cholera epidemics observed and recorded in Poland (Czapliński 2012; Berner 2008; Budnik, Liczbińska 1997; Liczbińska, Sosinko, Budnik 2007; Liczbińska 2009; 2013; Piasecki 1990; Wrębiak 2010; Rejmanowski 2001; Korpalska 2011; Dorobek 1979; Włodarczyk 1998) perfectly correspond to demographic crises which occurred in 1831–1832, 1848 and 1852 on a given area.

Sources suggest a correlation between the growth in the number of deaths, a decline in the number of marriages and conceptions and an increase in grain prices or the periods of food crises (Appleby 1973; Nelson 1991; Miodunka 2013; Humphreys 1987). Historically, epidemic diseases would frequently strike following periods of famine when the levels of immunity in the population was greatly lowered (Kuklo 2009; Gieysztorowa 1976; Lebrun 1977).

Negative environmental factors are reflected in historical sources especially in relations to the 1840s and the late 1870s. During the first crisis period of 1828–1832 the population of the parish of Kowal most probably failed to resist the negative influence of economic hardships and resulting famine, which led to an increased number of deaths combined with a decreased number of conceptions. Simultaneously, the weakened population became more susceptible to the upcoming waves of epidemics brought by the Russian troops in 1831 and still decimating the population of Kujawy in the following year (Puzyrewski 1899; Włodarczyk 1998).

Similarly, negative events of economic character (food crisis of the mid-1840s caused by failing harvest and widespread damage to potato plantations) (Myszczyszyn 2013) scarred the population of Kowal for the whole period of 1846-1857 marked by three waves of cholera epidemics in 1848 (Włodarczyk 1998), 1852 and 1855 when another demographic crisis appeared (Rejmanowski 2001; Włodarczyk 1998).

Conclusions

The article was an attempt to identify and evaluate the intensity of demographic crises occurring among the catholic rural population in the 19th century. Identification and evaluation of mortality crises in Polish population was carried, thus far, for Gdansk, Warsaw, Poznan and Gubin (17th–18th Centuries) (Guzowski, Kuklo, Poniat 2016; Kuklo 2009). Guzowski et al. (Guzowski, Kuklo, and Poniat 2016) mentioned, that Dupâquier's method works better for years when epidemics and plagues have occurred at significant intervals. Otherwise, the high number of deaths in previous years overestimates the average. Furthermore *DCIR* values are based only on number of deaths and could falsify results during rapid increase in the population size. Hence it seems that Standardised Demographic Dynamics Rate, based both deaths and births numbers, could be the better method to crises identification.

Goubert's method, because of its poor sensitivity, turned out to be the least useful for crises identification in such small, rural population.

Standardised indices are widely used to identify and evaluate the level of intensity of events also in other fields of natural sciences such as climatology

(McKee, Doesken, Kleist 1993; Guttman 1999; Karavitis et al. 2011; Łabędzki 2007; Bonaccorso et al. 2003) or hydrology (Bartczak, Glazik, and Tyszkowski 2014). Standardised index in demography, based on births and deaths numbers, provides information about the condition of a population, disregarding the size of the group. Nevertheless, only by combining the statistically obtained data with the information derived from written records is it possible to attempt to answer the question of the possible root cause of a demographic crisis.

Conflict of interests

All authors declared no conflict of interests.

Authors' contribution

AD-L, AB, MK performed modelling work; AD-L, AB, TD analysed output data; AD-L and AB wrote the manuscript with assistance of MK and TD. All authors substantially contributed to revisions.

Corresponding author

Alicja Drozd-Lipińska, Nicolaus Copernicus University in Toruń, Faculty of Biological and Veterinary Sciences, ul. Lwowska 1, 87-100 Toruń, Poland; e-mail: turdus@umk.pl, phone: 0048 56 611 44 66.

The work was a result of a NSC project no. 2017/25/B/HS3/00243

References

Ajdacic-Gross V, Lauber C, Sansossio R, Bopp M, Eich D, Gostynski M, Gutzwiller F, Rossler W. 2006. Seasonal Associations between Weather Conditions and Suicide–Evidence against a Classic Hypothesis. American Journal of Epidemiology 165(5):561–569, https://doi.org/10.1093/aje/kwk034

Appleby, Andrew B. 1973. Disease or Famine? Mortality in Cumberland and Westmorland 1580-1640. The Economic History Review 26(3):403–432, https://doi.org/10.1111/j.1468-0289.1973.tb01944.x; https://doi.org/10.2307/2593543

Appleby, Andrew B. 1978. Famine in Tudor and Stuart England. Stanford, Calif : Stanford UP.

Barrett R, Kuzawa ChW, McDade T, Armelagos GJ. 1998. Emerging and Re-Emerging Infectious Diseases: The Third Epidemiologic Transition. Annual Review of Anthropology 27:247–271, https://doi.org/10.1146/annurev.anthro.27.1.247

Bartczak A, Glazik R, Tyszkowski S. 2014. The Application of Box-Cox Transformation to Determine the Standardised Precipitation Index (SPI), the Standardised Discharge Index (SDI) and to Identify Drought Events: Case Study in Eastern Kujawy (Central Poland). Journal of Water and Land Development 22(1):3–15, https://doi.org/10.2478/jwld-2014-0017

Berner W. 2008. Stan Sanitarny, Ochrona Zdrowia i Sytuacja Epidemiologiczna Chorób Zakaźnych w Krakowie w Okresie Autonomii Galicyjskiej (Lata 60./70. XIX w. – Do 1914 r.). Przegląd Epidemiologiczny 62:181–91.

Bishai D, Opuni M. 2009. Are Infant Mortality Rate Declines Exponential? The General Pattern of 20thcentury Infant Mortality Rate Decline. Population Health Metrics 7:13, https://doi.org/10.1186/1478-7954-7-13

Bonaccorso B, Bordi I, Cancelliere A, Rossi G, Sutera A. 2003. Spatial Variability of Drought: An Analysis of the SPI in Sicily. Water Resources Management 17(4):273–296, https://doi.org/10.1023/A:1024716530289

Bouckaert A. 1989. Crisis Mortality: Extinction and near-Extinction of Human Populations. In: Ruzicka L, Wunsch G, Kane P. (Eds.), Differential Mortality: Methodological Issues and Biosocial Factors. Oxford: Clarendon Press, 217–230.

Box GEP, Cox DR. 1964. An Analysis of Transformations. Journal of the Royal Statistical Society Series B (Methodological) 26(2):211–252, https://doi.org/10.1111/j.2517-6161.1964.tb00553.x

Box GEP, Cox DR. 1982. An Analysis of Transformations Revisited, Rebutted. Journal of the American Statistical Association 77(377):209–210, https://doi.org/10.1080/01621459.1982.10477788

Breschi M, Manfredini M, Fornasin A. 2011. Demographic Responses to Short-Term Stress in a 19th Century Tuscan Population: The Case of Household out-Migration. Demographic Research 25:491–512, https://doi.org/10.4054/DemRes.2011.25.15

Budnik A. 2005. Uwarunkowania Stanu i Dynamiki Biologicznej Populacji Kaszubskich w Polsce: Studium Antropologiczne. Antropologia 22 – Uniwersytet im. Adama Mickiewicza w Poznaniu. Poznań: Wydawnictwo Naukowe UAM.

Budnik A. 2008. Przejścia epidemiczne na ziemiach polskich. In: Dzieduszycki W, Wrzesiński J. (Eds.), Epidemie, klęski, wojny. Funeralia Lednickie. Spotkanie 10, 53–66. Poznań.

Budnik A, Liczbińska G. 1997. Mortality in the Populations of Danzig and the District of Danzig (Regierungsbezirk Danzig) in the Second Half of the Nineteenth Century. Przegląd Antropologiczny 60:13–24, https://doi.org/10.18778/1898-6773.60.02

Czapliński MP. 2012. Epidemie cholery w rejencji opolskiej w latach 1831–1894.

Dorobek F. 1979. Epidemia Cholery w Królestwie Polskim i Guberni Płockiej w 1848 r. Notatki Płockie 24(1–98):25–36.

Drozd-Lipińska A. 2021. Wielkość populacji i ruch naturalny w parafii Kowal w latach 1815–1914. In: Drozd-Lipińska A. (Ed.), Umieralność mieszkańców wsi kujawskiej w latach 1815–1914 na tle zmian społeczno-gospodarczych i przemian elementów klimatu na przykładzie parafii Kowal, Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 57–73.

Drozd-Lipińska A, Bartczak A, Dziki T. 2021a. Demografia, gospodarka, warunki klimatyczne i życie społeczne. In: Drozd-Lipińska A. (Ed.), Umieralność mieszkańców wsi kujawskiej w latach 1815–1914 na tle zmian społeczno-gospodarczych i przemian elementów klimatu na przykładzie parafii Kowal. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 91–249.

Drozd-Lipińska A, Bartczak A, Dziki T. 2021b. Podsumowanie. In: Drozd-Lipińska A. (Ed.), Umieralność mieszkańców wsi kujawskiej w latach 1815–1914 na tle zmian społeczno-gospodarczych i przemian elementów klimatu na przykładzie parafii Kowal. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 251–267.

Drozd-Lipińska A, Klugier E, Kamińska-Czakłosz M. 2015. Socioeconomic Differences in Child Mortality in Central Poland At the End of the Nineteenth Century. Journal of Biosocial Science 47(4):449–468, https://doi.org/10.1017/S0021932014000376

Dupâquier J. 1979. L'analyse Statistique Des Crises de Mortalité. In: Charbonneau H, La Rose A. (Eds.), Les Grandes Mortalités: Étude Méthodologique Des Crises Démographiques. Liège: Ordina Editions, 83–112.

Dziki T. 2007a. Z dziejów Kowala w latach 1815–1869. In: Zasada ZJ. (Ed.), Kowal poprzez wieki. Materiały do dziejów Kowala i jego okolicy z konferencji naukowej

"Społeczność Kowala i okolic w dawnych czasach oraz dobie współczesnej" zorganizowanej 29 IV 2006 r. w Kowalu. Włocławek–Kowal: Totem, 61–86.

Dziki T. 2007b. Z dziejów Kujaw Wschodnich w II połowie XIX wieku (1851–1914). In: Cieśla A. (Ed.), Spotkanie dwóch cesarzy w Aleksandrowie. Z dziejów miasta i regionu w okresie zaborów, Aleksandrów Kujawski: Miejska Biblioteka Publiczna im. Marii Danilewicz, 11–36.

Dziki T. 2018. Powiat Włocławski w latach 1793–1918. In: Mikulski K, Dziki T. (Eds.), Monografia Powiatu Włocławskiego. Toruń: in press.

Dziki T. 2021. Przynależność administracyjna Kowala i okolic w latach 1815–1914. In: Drozd-Lipińska A. (Ed.), Umieralność mieszkańców wsi kujawskiej w latach 1815–1914 na tle zmian społeczno-gospodarczych i przemian elementów klimatu na przykładzie parafii Kowal. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 45–56.

Edvinsson RB. 2015. Recalculating Swedish Pre-Census Demographic Data: Was There Acceleration in Early Modern Population Growth? Cliometrica 9(2):167–191, https://doi.org/10.1007/s11698-014-0112-z

Evans RJ. 1988. Epidemics and Revolutions: Cholera in Nineteenth-Century Europe. Past & Present 120:123–146. https://doi.org/10.1093/past/120.1.123

Gagnon A. 2012. Crises and Trends: Mortality in Historical Perspective. Canadian Studies in Population 39(3–4):1–7.

Gieysztorowa I. 1962. Badania Demograficzne Na Podstawie Metryk Parafialnych. Kwartalnik Historii Kultury Materialnej X(1–2):103–121.

Gieysztorowa I. 1976. Wstęp do Domografii Staropolskiej. Warszawa: Państwowe Wydawnictwo Naukowe.

Głowacki PS. 2007. Dzieje parafii pod wezwaniem Św. Urszuli w Kowalu i Dekanatu Kowalskiego. In: Zasada ZJ. (Ed.), Kowal poprzez wieki. Materiały do dziejów Kowala i jego okolicy z konferencji naukowej "Społeczność Kowala i okolic w dawnych czasach oraz dobie współczesnej" zorganizowanej 29 IV 2006 r. w Kowalu. Włocławek–Kowal: Totem, 39–55.

Goubert P. 1960. Beauvais et Le Beauvaisis de 1600 à 1730. Contribution à l'histoire Sociale de La France Au XVIIe Siècle. Paris: S. E. V. P. E. N.

Goubert P. 1968. Cent mille provinciaux au XVIIe siècle: Beauvais et le Beauvaisis de 1600 à 1730. Paris: Flammarion.

Gruszczyńska M, Poraziński J. 2002. Opis statystyczny z dnia 11/23 maja 1860 r. sporządzony przez burmistrza miasta Kowala. In: Kallas M, Leliński S, Stelmach R, Tomczak A, Trojanowska M. (Eds.), Opisy miast Kujaw Wschodnich z 1860 r. (Gubernia Warszawska). Nowe Miscellanea Historyczne, Seria Opisy Miast Królestwa Polskiego w XIX Wieku. Opisy Miast z 1860 Roku, t. VI. Warszawa: Naczelna Dyrekcja Archiwów Państwowych, 29–48.

Guttman NB. 1999. Accepting the Standardized Precipitation Index: A Calculation Algorithm. Journal of the American Water Resources Association 35(2):311–22, https://doi.org/10.1111/j.1752-1688.1999.tb03592.x

Guzowski P, Kuklo C, Poniat R. 2016. O metodach pomiaru natężenia epidemii i zaraz w preindustrialnej Europie w demografii historycznej. In: Polek K, Sroka ŁT. (Eds.), Epidemie w dziejach Europy. Konsekwencje społeczne, gospodarcze i kulturowe. Kraków: Wydawnictwo Naukowe Uniwersytetu Pedagogicznego, 119–144.

Healey J. 2008. Socially Selective Mortality during the Population Crisis of 1727–1730: Evidence from Lancashire. Local Population Studies, no. 81:58–74.

Hinde A. 2010. A Review of Methods for Identifying Mortality 'crises' Using Parish Record Data. Local Population Studies 39(84):82–92.

Hoch SL. 1998. Famine, Disease, and Mortality Patterns in the Parish of Borshevka, Russia, 1830–1912. Population Studies 52(3):357–368, https://doi.org/10.1080/0032472031000150526

Hollingsworth TH. 1979. Background Paper to First Theme: An Introduction to Population Crises. In: Charbonneau H, La Rose A. (Eds.), Les Grandes Mortalités: Étude Méthodologique Des Crises Démographiques Du Passé. Liège: Ordina Editions, 17–20.

Holzer JZ. 2003. Demografia. Warszawa: Polskie Wydawictwo Ekonomiczne.

Humphreys R. 1987. Mortality Crises in Sixteenth-Century Dorking. Local Population Studies. ENGLAND.

Hyndman R., Booth H. 2008. Stochastic Population Forecasts Using Functional Data Models for Mortality, Fertility and Migration. International Journal of Forecasting 24(3):323–342, https://doi.org/10.1016/j.ijforecast.2008.02.009

Jura J. 2002. Emigracja z Galicji w drugiej połowie XIX i na początku XX wieku na przykładzie wybranych powiatów. Zeszyty Naukowe Ostrołęckiego Towarzystwa Naukowego 16:227–270.

Kaczmarski B. 1967. Ocena spisów ludności na Śląsku z pierwszej połowy XIX wieku. Przeszłość Demograficzna Polski 1:33–63.

Karavitis ChA, Alexandris S, Tsesmelis DE, Athanasopoulos G. 2011. Application of the Standardized Precipitation Index (SPI) in Greece. Water (Switzerland) 3(3):787–805, https://doi.org/10.3390/w3030787

Korpalska WK. 2011. Pacjenci i Lekarze w Czasie Epidemii Cholery 1831–1832 Na Ziemiach Polskich Pod Pruskim Zaborem. In: Felsmann MZ, Szarek J, Felsmann M. (Eds.), Dawna Medycyna i Weterynaria. Pacjent. Chełmno: Muzeum Ziemi Chełmińskiej w Chełmnie, 69–85.

Kuklo C. 2009. Demografia Rzeczypospolitej Przedrozbiorowej. Warszawa: Wydawnictwo DiG.

Łabędzki L. 2007. Estimation of Local Drought Frequency in Central Poland Using the Standarized Precipitation Index SPI. Irrigation and Drainage 56:67–77, https://doi.org/10.1002/ird.285

Landers J. 2006. Death and the Metropolis Studies in the Demographic History of London, 1670–1830. Cambridge: Cambridge University Press.

Lebrun F. 1977. Les Épidémies En Haute-Bretagne à La Fin de l'Ancien Régime (1770–1789). Présentation d'une Enquête Collective. Annales de Démographie Historique, 181–206, https://doi.org/10.3406/adh.1977.1348

Liczbińska G. 2009. Umieralność i Jej Uwarunkowania Wśród Katolickiej i Ewangelickiej Ludności Historycznego Poznania. Poznań: Biblioteka Telgete.

Liczbińska G. 2013. Fertility Patterns and Reproductive Behaviours in the Lutheran and Catholic Populations from Historical Poland. Advances in Anthropology 03(03):149–156, https://doi.org/10.4236/aa.2013.33020

Liczbińska G, Sosinko A, Budnik A. 2007. Uwarunkowania Stanu Zdrowia w XIX-Wiecznym Poznaniu. Nowiny Lekarskie 76(4):357–362.

McKee TB, Doesken NJ, Kleist J. 1993. The Relationship of Drought Frequency and Duration to Time Scales. AMS 8th Conference on Applied Climatology, no. January 179–184.

Miodunka P. 2013. Staropolskie księgi metrykalne jako źródło do badania klęsk elementarnych. In: Głowiński T, Kosik E. (Eds.), Od powietrza, głodu, ognia i wojny… Klęski elementarne na przestrzeni wieków. Wrocław: Gajt Wydawnictwo 1991 s.c.

Myszczyszyn J. 2013. Kryzys żywnościowy w latach 1845–1847 ze szczególnym uwzględnieniem zarazy ziemniaczanej na przykładzie Prus. In: Głowiński T, Kosik E. (Eds.), Od powietrza, głodu, ognia i wojny… Klęski elementarne na przestrzeni wieków. Wrocław: Gajt Wydawnictwo 1991 s.c., 129–142.

Nelson I. 1991. Famine and Mortality Crises in Mid-Sussex, 1606–1640. Local Population Studies. ENGLAND.

Omran AR. 1971. The Epidemiologic Transition. A Theory of the Epidemiology of Population Change. The Milbank Memorial Fund Quarterly 49(4):509–538, https://doi.org/10.2307/3349375

Piasecki E. 1990. Ludność Parafii Bejskiej (Woj. Kieleckie) w Świetle Ksiąg Metrykalnych z XVIII-XX W. Warszawa–Wrocław: PWN.

Puzyrewski AK. 1899. Wojna Polsko-Ruska 1831 R. Kraków: Krajowa Agencja Wydawnicza.

Razali N, Wah Y. 2011. Power Comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. Journal of Statistical Modeling and Analytics 2:21–33.

Rejmanowski T. 2001. Przyczynek do walki z cholerą na przykładzie jej epidemii w Osięcinach na Kujawach Wschodnich w 1852 r. Archiwum Historii i Filozofii Medycyny, nr 1.

Rüttimann D, Loesch S. 2012. Mortality and Morbidity in the City of Bern, Switzerland, 1805–1815 with Special Emphasis on Infant, Child and Maternal Deaths. HOMO – Journal of Comparative Human Biology 63(1):50–66, https://doi.org/10.1016/j.jchb.2011.11.001

Sakia RM. 1992. The Box-Cox Transformation Technique: A Review. Journal of the Royal Statistical Society. Series D (The Statistician) 41(2):169–178, https://doi.org/10.2307/2348250

Sawchuk LA, Tripp L, Damouras S, Debono M. 2013. Situating Mortality: Quantifying Crisis Points and Periods of Stability. American Journal of Physical Anthropology 152(4):459–470, https://doi.org/10.1002/ajpa.22380

Schofield R. 1972. 'Crisis' Mortality. Local Population Studies 9:10–22.

Shang HL. 2015. Selection of the Optimal Box-Cox Transformation Parameter for Modelling and Forecasting Age-Specific Fertility. Journal of Population Research 32(1):69–79, https://doi.org/10.1007/s12546-014-9138-0

Shapiro SS, Wilk MB. 1965. An Analysis of Variance Test for Normality (Complete Samples). Biometrika 52(3/4):591–611, https://doi.org/10.1093/biomet/52.3-4.591

Siudikas V. 1998. Choleros Epidemijos Lietuvoje 1831–1921 Metais : Daktaro Disertacijos Santrauka : Biomedicinos Mokslai, Medicina. Kaunas: Kauno medicinos akademija.

Smith PC. 1978. Crisis Mortality in the Nineteenth Century Philippines: Data from Parish Records. The Journal of Asian Studies 38(1):51–76, https://doi.org/10.2307/2054237, https://doi.org/10.1017/S0021911800139816

Straszak-Chandoha S. 2008. Epidemie cholery a reformy sanitarne w Wielkiej Brytanii w latach 40. i 50. XIX wieku. Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu Nr 26. Nauki Humanistyczne 12:187–198.

Straszak-Chandoha S. 2013. Nieudane Próby Opanowania Epidemii Cholery w Wielkiej Brytanii w Latach 1831–1832. In: Głowiński T, Kosik E. (Eds.), Od powietrza, głodu, ognia i wojny… Klęski elementarne na przestrzeni wieków. Wrocław: Gajt Wydawnictwo 1991 s.c., 117–127.

Sułowski Z. 1962. O właściwą metodę wykorzystywania metryk kościelnych dla badań demograficznych. Kwartalnik Historii Kultury Materialnej X(1–2):81–101.

Szczechowicz H. 2013. Kujawy Wschodnie i Ziemia Dobrzyńska w II Rzeczypospolitej. Administracja, Gospodarka, Życie Społeczno-Polityczne, Szkolnictwo 1918–1928. Włocławek: Państwowa Wyższa Szkoła Zawodowa we Włocławku.

Turner D. 1973. 'Crisis' Mortality in Nine Sussex Parishes. Local Population Studies 11:40–43.

Winkle S. 1999. Kulturgeschichte Der Seuchen. Frechen : Komet.

Włodarczyk D. 1998. Od Powietrza, Głodu, Ognia i Wojny. Inowrocław: Zakład Poligraficzno-Wydawniczy POZKAL.

Wrębiak A. 2010. Cholera and Typhoid Fever in 19th-Century Bielitzer Zion. Anthropological Review 73(1):37–46, https://doi.org/10.2478/v10044-008-0020-6

Zasada Z.J. 2006. Kowal i okolice w okresie zaborów i walk Narodowowyzwoleńczych (1772–1918). In: Zasada ZJ. (Ed.), Kowal poprzez wieki. Materiały do dziejów Kowala i jego okolicy z konferencji naukowej "Społeczność Kowala i okolic w dawnych czasach oraz dobie współczesnej" zorganizowanej 29 IV 2006 r. w Kowalu. Włocławek–Kowal: Totem, 283–294.

Zasada ZJ. 2006. 2007. Wstęp. In: Zasada ZJ. (Ed.), Kowal poprzez wieki. Materiały do dziejów Kowala i jego okolicy z konferencji naukowej "Społeczność Kowala i okolic w dawnych czasach oraz dobie współczesnej" zorganizowanej 29 IV 2006 r. w Kowalu. Włocławek–Kowal: Totem, 7–10.

Anthropological Review • Vol. 85(3), 67–82 (2022)

Anthropological Review

Available online at: https://doi.org/10.18778/1898-6773.85.3.05

A life on horseback? Prevalence and correlation of metric and non-metric traits of the "horse-riding syndrome" in an Avar population (7^{th}-8^{th} century AD) in Eastern Austria

Birgit Bühler[1,3], *Sylvia Kirchengast*[2,3]

[1] VIAS Vienna Institute of Archeological Science, University of Vienna
[2] Department of Evolutionary Anthropology, University of Vienna
[3] Human Evolution and Archaeological Sciences-HEAS, University of Vienna, Vienna, Austria

Abstract: Musculoskeletal stress markers allow the reconstruction of occupational and habitual activity patterns in historical populations. The so-called horse-riding syndrome summarizes several musculoskeletal markers which are commonly interpreted as indicators of habitual horse riding. The individual symptoms of the horse-riding syndrome, however, are still critically discussed. The skeletal remains of mounted warriors are especially suited for the analysis of skeletal markers commonly associated with a life on horseback. According to historical sources, early medieval Avar warriors were highly skilled in mounted archery and other types of mounted combat. An "equestrian lifestyle", with many hours per day spent on horseback, was presumably a precondition for this. Hence, the historical and archaeological context of the human osteological material examined in this study is a particular asset for analyzing the so-called "horse-riding syndrome".

The aim of this study is to contribute to methodological research on the "horse-riding syndrome", by testing possible associations between different characteristics of this syndrome within the adult population of the Avar cemetery Csokorgasse (7^{th}-8^{th} century AD) from Vienna, Eastern Austria. 149 Avar adult individuals (72 females and 77 males) were included in the study. Poirier´s facets, cribiform changes, plaque, as well as five qualitative traits of the *Os coxae* and the lower limb bones, the index of ovalization of the acetabulum (IOA), and the entheses robusticity score (ERS) were determined.

Males and females differed significantly in the prevalence of Poirier´s facets, cribriform changes, and gluteal entheses. Furthermore, males showed significantly higher IOAs and ERS than females. Significantly positive associations between quantitative and qualitative traits of the horse-riding syndrome could be documented. Poirier´s facets, pronounced gluteal entheses, the index of ovalization of the acetabulum (IOA), and the entheses robusticity score were significantly related independent of sex and age. From the results of the present study we can conclude, that the association patterns between three major characteristics of the "horse-riding syndrome", i.e. "Poiriers Facet" on the proximal femur, ovalization (vertical elongation) of the acetabulum, and pronounced entheses on the bony pelvis and the lower limb bones – typical markers of the "horse-riding syndrome" - may indeed be a valid set of traits for detecting habitual horse riders in archaeological contexts.

Key words: horse-riding syndrome, life on horseback, Avar warriors, Poirier´s facets, entheses robusticity

Original article

Received: 29.06.2022; Revised: 26.08.2022; Accepted: 02.09.2022

Introduction

During the last decades, interest in the analysis of association patterns between occupational or habitual activity and the occurrence of musculoskeletal stress markers in historical populations has increased steadily (Palfi & Dutour 1996; Pany-Kucera et al. 2008; Villotte et al. 2010; Havelkova et al. 2011), although, from a methodological point of view, the interpretation of such traits is still difficult (Jurmain et al. 2012). A typical activity pattern that might result in manifest skeletal markers is horse-riding because it is an activity for which *Homo sapiens* is not really adapted. Horse riding and spending a lot of time on horseback has a long tradition, especially in Eurasia. The prerequisite for horseback riding, was the domestication of the horse. Archeological evidence associated the earliest horse domestication with the Botai culture of northern Kazakhstan around 3500 BC (Outram et al. 2009). Recent DNA analyses, however, falsified the assumption that this prehistoric breed is the ancestor of all recent horses, and therefore it is still controversially discussed when and wherein Eurasia the earliest horse domestication took place (Li et al. 2020; Taylor, Barron-Ortiz 2021; Librado et al. 2021). Despite these ongoing debates, there is no doubt that the domestication of the horse (*Equus caballus*) had an enormous impact on human cultural evolution, subsistence, economy, mobility warfare, and social organization (Anthony 2007). Horses and first of all horse riding changed the human lifestyle substantially and accelerated human migration and cultural interactions across huge distances. People learned to spend many hours per day on horseback, a behavior that brought many cultural and economic advantages for humans, but also led to painful pathological changes in the musculoskeletal system of horses and riders. Several studies described the pathological manifestations of horse riding on the skeletons of horses (Bulatovic et al. 2014; Pluskowski et al. 2010; Taylor et al. 2015). The impact of life on horseback for humans and the identification of skeletal markers indicating habitual horse riding among humans however are still discussed controversially. Several pathological conditions such as fractures associated with falls from the horse, coxarthrosis, schmorl´s nodes, osteoarthritis of the spine and the upper and lower limb bones, enthesopathy but also non-pathological joint changes, and pronounced muscle marks or entheses have been associated with habitual horse riding (Palfi 1992; Bagagli et al. 2012; Baillif-Ducos et al. 2012; Khudaverdyan et al. 2016; Pany-Kucera, Willtschke-Schrotta 2017; Fornaciari et al. 2014; Anđelinović et al. 2015).

For more than 20 years the so-called "horse-riding syndrome" which comprises a number of traits on the human skeleton that are discussed as indicators that the individual in question practiced horse riding as a habitual lifetime activity (Anđelinović et al. 2015; Baillif-Ducros, McGlynn 2013; Berthon et al. 2019; Belcastro et al. 2001). The majority of these traits are non-metric, such as the so-called "Poirier's Facet", plaque, cribriform changes of the femoral neck, pronounced entheses of the upper limbs, and the *Os coxae* (Radi et al. 2013; Lawrence et al. 2018), spinal changes, coxarthrosis, but also traumatic lesions and fractures of the limb bones, thorax, shoulder girdle or the skull (Anđelinović et al. 2015; Bagagli et al. 2012; Bailif-Ducros 2012; Baillif-Ducros, McGlynn 2013; Belcastro et al. 2001). Berthon et al. (2019) developed the "Index of Ovalization of Acetabulum (IOA)", a useful tool for quantifying one of the major characteristics of the "horse-riding syndrome": The vertical elongation (i.e. ovalization) of the acetabulum. In addition, Berthon et al. (2019) analyzed and discussed the usefulness of entheseal changes as indicators of horseback riding. However, entheseal changes differ between age groups and the sexes and might be the results of pathologies such as traumata, metabolic diseases, or inflammatory processes (Jurmain et al. 2012) Therefore, the interpretation of entheseal changes as indicators of habitual riding is quite bold.

The identification of valid indicators of habitual horse riding is of great bioarchaeological and historical interest. Hence, we aim to contribute to this ongoing methodological research, by analyzing the association patterns between entheseal changes of the lower limbs and the *Os coxae* in relation to other non-metric and metric traits frequently used as indicators of habitual horse-riding, within the adult population of the early medieval (7^{th}–8^{th} century AD) Avar cemetery Vienna-Csokorgasse from Eastern Austria.

The Avar mounted warriors

The Avars, a nomadic tribal confederation originating in Inner or Central Asia, ruled over the entire Carpathian Basin from the year 568 AD, when their allies, the Lombards, migrated to Italy, to around 800 AD, when Charlemagne's Frankish armies destroyed the Avar Empire (Anke et al. 2008; Daim 2003; Pohl 1988). The majority of the archaeological evidence from the Avar period, including the earliest Avar burials from the end of the 6^{th} or the beginning of the 7^{th} century AD, was found in present-day Hungary. However, Avar burials were also found in present-day Slovakia, Romania, Croatia, Serbia, the Czech Republic and the Eastern part of present-day Austria, where several large Avar burial grounds such as Leobersdorf (Grefen-Peters 1987), Vienna-Csokorgasse (Grossschmidt 1990), Münchendorf (Berner et al. 1992), Zillingtal (Herold 2011), or Vösendorf (Pany-Kucera, Willtschke-Schrotta 2017) have been excavated. In this paper, we focused on the human skeletal remains of the burial ground Vienna-Csokorgasse, which was used during the entire period of Avar settlement in present-day Eastern Austria – from at least the mid-7th century until the end of the 8th century AD.

Previous research (Hyland 1994; Bede 2012; Baron 2018; Anke et al. 2008; Daim 2003) has demonstrated that horses were an important aspect of life in the Avar Empire. According to the historical sources (for example the Byzantine military handbook "Strategikon"; see Dennis 1984; Hyland 1994), the Avars, at least in the initial period of their history, were not only equestrian nomads but also accomplished mounted warriors. Avar warriors' outstanding skills in mounted archery, but also in fighting alternately with different weapons from horseback, appear to have been a major cause of their military success, especially when they first arrived in Europe in the late sixth and early seventh century AD. The archaeological evidence (more than 60,000 Avar-period burials from Central and Eastern Europe, but only few excavated settlement sites; Anke et al. 2008) supports this view, although it is clear that the Avar Empire was extremely diverse regarding the cultural and ethnic background, as well as the subsistence strategies and ways of life, of its population. A considerable proportion of men's burials in Avar cemeteries includes weapons (arrowheads, remains of compound bows, lance-heads, sabers, swords, axes) as grave goods. Significantly, the phenomenon of horse-human burials and other rituals involving horses and horse tack as part of the burial custom in the Avar period is diverse, with considerable regional and chronological differences, which appear to reflect a range of cultural traditions (Fedele 2020; Bede 2012; Baron 2018; Anke et al. 2008). Throughout the Avar period, horse-human burials constitute only a small, variable proportion of all Avar period burials (10% on average; see Bede 2012), which could suggest that this burial custom was reserved for high-status individuals. Similarly, the abundance of a wide range of valuable items of personal adornment and grave goods in horse-human burials may indicate that only members of the Avar elite were buried with horses and/ or horse riding equipment (such as the metal components of horse tack). Significantly, stirrups also occur in horse-human burials, from the Early Avar Period (late 6th–early 7th century AD) onwards. Some researchers have suggested that Avar mounted warriors were the first "cavalry" that used stirrups on a regular basis (Anke et al. 2008; Daim 2003) and that the Avars may have played an important role in transmitting this innovation in early medieval Europe (Curta 2008; Csiky 2021). In principle, mounted combat is possible without stirrups or saddle. However, the use of stirrups has several advantages, such as stabilization of the rider when fighting with a lance, or in horseback archery: If the horseback archer stands up in the saddle using the stirrups, this can facilitate fast, precise shooting with a bow and arrow. In this context, it is not surprising that the Avar mounted warriors, with their outstanding skills in mounted archery, appear to have played a major role in the transmission of this equestrian innovation in Eurasia (Curta 2008; Csiky 2021).

The aim of this paper is to contribute to the methodological discussion on the "horse-riding syndrome", by examining whether specific morphological variations of the anterior femoral head-neck junction ("Poirier's Facet", "Plaque" and "Cribra", according to Radi et al. (2013) and the index of ovalization of acetabulum IOA (Berthon et al. 2019) associate with other potential characteristics of the "horse-riding syndrome". Avar populations are ideally suited for methodological research on the skeletal indicators of horse-riding, because, due to the historical context, it is likely that Avar adult populations include a considerable number of individuals who had spent much time on horseback.

The following hypotheses were tested:

1) The index of ovalization of the acetabulum (IOA) is significantly higher for adults with a "Poiriers Facet", plaque, cribriforme changes, pronounced gluteal entheses, a pronounced *Linea aspera* on the *Os femoris,* a curved *Trochanter major,* exostosis ("spicules") in the *Fossa trochanterica*, exostosis ("spicules") in the *Fovea capitis* and osteoarthritis on the upper outline of the patellar surface on the same side.

2) The index of ovalization of the acetabulum (IOA) correlates positively with the entheses robusticity scores of the lower limbs.

Material & Methods

Sample

The sample for this study was taken from the adult population of the Avar cemetery of Vienna-Csokorgasse (Großschmidt 1990): The early medieval burial ground Csokorgasse in Vienna is one of the largest cemeteries of the Avar period in present-day Austria, consisting of 755 burials within 705 graves (Streinz 1977; Streinz & Daim 2018). According to archeological and zooarcheological data, this Avar cemetery was in use from the second quarter of the 7th century AD (Early Avar Period 2) to the final Third of the 8th century (Late Avar Period 3). The latest phase of the cemetery includes four "equestrian burials" (Streinz 1977; Baron 2018), where the deceased was buried with a horse (including equipment for riding), and rich grave goods, including weapons (bow and arrow, sword, saber).

In the present sample, all individuals of the age groups adult and older, with at least one proximal femur and one *Os coxae* (sufficiently well-preserved for scoring non-metric and metric traits), were included. The reason for focusing exclusively on the age groups "adult and above" was the consideration that non-metric traits of the proximal femur, in particular, "Poirier's Facet" could be observed best only if the epiphysis of the femoral head is already closed.

The total sample consists of 149 individuals – 60 individuals with both proximal femora well-preserved and 89 with either the left or the right proximal femur sufficiently well-preserved to record the traits in question. Approximately half of the 149 individuals in our sample were identified as female (n=72), the other as male (n=77).

Sex and age determination

Sex and age at death of the individuals were estimated by a combination of various standard techniques (Phenice 1969; Meindl, Lovejoy 1985; Lovejoy 1985; Lovejoy et al. 1985; Brooks, Suchey 1990; Buikstra, Ubelaker 1994; White, Folkens 2005). For details regarding methods applied to sex and age determination see Bühler and Kirchengast (2022a). In terms of chronology, the sample is evenly distributed, one third belongs to the early (625 to 675 AD), middle (675 to 735 AD), and late phases (735 to 800AD) of the cemetery, respectively. For a detailed description see Bühler and Kirchengast (2022a).

Qualitative (non-metric) traits

As classical components of the horse-riding syndrome, „Poirier's facets" (Anđelinović et al. 2015), as well as associated traits, such as Allen's fossa/ cribriform changes, and plaque (Lawrence 2018; Radi 2013), were examined. For definitions and scoring, we used the methods described by Radi et al. (2013).

The following qualitative traits were scored as present or absent, according to the method described by Anđelinović et al. (2015): On *Os femoris* a pronounced *Linea aspera*, a curved, pronounced *Trochanter major*, exostosis in *Fossa trochanterica*, exostosis in *Fovea capitis*, and pronounced entheses (of gluteal muscles) on *Os coxae.* According to Bailiff-Ducros and McGlynn (2013), we scored the presence of osteoarthritis on the upper outline of the patellar surface on *Os femoris*, as an indication of possible stirrup use.

Quantitative (metric) traits

To calculate the index of ovalization of acetabulum (IOA); according to Berthon et al. (2018), the maximum vertical diameter of acetabulum (VEAC) and the maximum horizontal diameter of acetabulum (HOAC) were measured twice by one investigator (B.Bühler) in mm, to 1 decimal using a digital caliper. The IOA is defined as VEAC/ HOAC and facilitates the detection of the "vertical elongation of the acetabulum" ("Ovalization") in quantitative terms. For a detailed description of reliability control, see Bühler and Kirchengast (2022a).

In addition, the entheses robusticity score was determined. Entheses robusticity was scored according to Mariotti et al. (2007) for the 7 entheses of the lower limb on a scale of 0 (absence), 1 (weak), 2 (moderate) to 3 (very pronounced): For each individual, the average entheses robusticity score was calculated from 7 entheses, separately for the left and right side. These 7 entheses are 3 entheses per side on the femur (*M. gluteus maximus, M. vastus medialis, M. iliopsoas)*, 2 entheses per side on the tibia (Quadriceps tendon; *M. soleus*), 1 enthesis per side on the patella (Quadriceps tendon) and 1 enthesis per side on the calcaneus (Achilles tendon).

Statistical Analysis

Statistical analyses were performed using the SPSS program version 25.0. Although a normal distribution can be assumed for some metric parameters according to the results of the Kolmogorov-Smirnov test, mainly nonparametric tests were applied due to the small sample size. Group differences were tested for statistical significance using Mann-Whitney U-tests and Kruskal-Wallis-tests. In addition, Spearman correlations, crosstabs, and multiple regression analyses were computed. Results were considered significant when p = 0.05 and highly significant when p = 0.001.

Results

Prevalence of non-metric traits

Table 1 demonstrates the prevalence of qualitative traits according to sex for the left and the right side separately. Significant sex differences could be proved for Poirier´s facets, cribriform changes, gluteal entheses, and osteoarthritis at the patella for both sides. With the exception of the curved Trochanter major, males showed always a higher prevalence of the qualitative traits. The two quantitative traits, IOA and Entheses robusticity score differed significantly, between the sexes, males showed a significantly higher IOA and significantly higher Entheses robusticity scores than females.

Table 1. Prevalence of traits associated with horse-riding according to sex (chi-squares, Mann-Whitney U-tests)

	right side							left side						
	total		males		females			total		males		females		
Qualitative traits	n	%	n	%	n	%	Sig.	n	%	n	%	n	%	sig
Poirier's Facet	26	27.9	16	34.8	10	21.3	**0.011**	29	24.8	20	35.1	9	15	**0.046**
Plaque proximal femur	42	45.2	23	50.0	19	40.4	0.512	57	48.7	29	50.9	28	46.7	0.883
Cribriform changes proximal femur	125	83.9	59	76.6	63	87.5	**0.014**	123	82.6	62	80.5	64	88.9	**0.002**
gluteal enthuses	98	76.0	63	96.9	35	54.7	**0.001**	98	76.0	63	95.5	35	55.6	**0.001**
pronounced *Linea aspera*	90	88.2	45	90.0	45	86.5	0.817	104	83.2	56	88.9	48	77.4	0.220
curved *Trochanter major*	31	50.0	12	37.5	19	63.3	**0.040**	60	61.9	26	56.5	34	66.7	0.154

	right side							left side						
	total		males		females			total		males		females		
Qualitative traits	n	%	n	%	n	%	Sig.	n	%	n	%	n	%	sig
exostosis in the *Fossa trochanterica*	39	58.2	25	73.5	14	42.4	**0.010**	68	66.7	36	73.5	32	60.4	0.161
exostosis in the *Fovea capitis*	42	48.8	26	63.4	16	35.6	**0.010**	50	44.2	29	51.8	21	36.8	0.267
osteoarthritis on the upper outline of the patellar surface	43	62.3	27	81.8	16	44.4	**0.005**	60	67.4	39	83.0	21	50.0	**0.004**
Quantitative traits	x	sd	x	sd	x	sd		x	sd	x	sd	x	sd	
Index of ovalization (IOA)	1.04	0.02	1.05	0.02	1.04	0.02	**0.020**	1.04	0.02	1.05	0.02	1.04	0.02	**0.037**
Entheses robusticity score	1.99	0.41	2.12	0.38	1.85	0.40	**0.001**	1.92	0.38	2.14	0.36	1.87	0.45	**0.001**

Associations between quantitative (metric) and qualitative (non-metric) traits associated with the "Horse Riding Syndrome"

As demonstrated in table 2, the IOA was higher among Avars with a Poirier's Facet than among those without a Poirier's Facet. On the left side, this difference was statistically significant. A significantly higher IOA was found among adults with pronounced gluteal entheses on the *Os coxae*. This was true of the right as well as on the left side. No significant group differences in the IOA of the right as well as left acetabulum were found between Avar individuals showing a pronounced *Linea Aspera*, a curved *Trochanter major*, an exostosis in the *Fossa trochanterica*, exostosis of the *Fovea capitis,* and those Avar adults who did not show these traits. In contrast, the average IOA of the left proximal femur was significantly higher among Avar individuals showing signs of osteoarthritis along the upper edge of the patellar surface.

The entheses robusticity scores of the left and right side were always higher among Avar adults showing the quantitative traits mentioned above. Significant group differences were found for Poirier´s facet, gluteal entheses, pronounced *Linea aspera*, exostosis in the *Fossa trochanterica*, exostosis in the *Fovea capitis,* and osteoarthritis on the patellar surface.

The IOA of the left acetabulum correlated significantly positively with the entheses robusticity score for the left (rho=0.243; p=0.033) as well as the entheses robusticity score of the right lower limb (rho=0.326; p=0,005). No significant associations between the IOA of the right acetabulum and the entheses robusticity scores for the left and the right lower limb could be observed.

In the last step, the association patterns between the entheses robusticity scores and Poirier´s facets and IOA corrected for sex, age group, and chronological phase, were tested using multiple regression analyses. The entheses robusticity score of the left side was independently significantly associated with the occurrence of Poirier´s facet, the IOA, and the age group. The entheses robusticity score of the right lower limb was independently significantly associated with sex, the age group, and the Poirier´s facet as well as the IOA (table 3).

Table 2. IOA and Entheses score according to the prevalence of qualitative traits (Mann-Whitney U-tests)

	Index of Ovalization right (IOA)							Index of Ovalization left (IOA)						
Trait	trait present			trait absent				trait present			trait absent			
	n	x	sd	n	x	sd	sig	n	x	sd	n	x	sd	sig
Poirier's Facet	10	1.053	0.018	29	1.042	0.020	0.112	14	1.061	0.015	47	1.037	0.017	**<0.001**
Plaque proximal femur	22	1.043	0.019	18	1.042	0.021	0.479	32	1.038	0.018	34	1.046	0.018	0.087
Cribriform changes	56	1.041	0.018	12	1.049	0.027	0.207	55	1.041	0.019	13	1.042	0.024	**0**.342
gluteal enthuses	57	1.046	0.021	16	1.031	0.016	**0.011**	54	1.045	0.020	17	1.033	00.02	**0.030**
pronounced *Linea aspera*	40	1.048	0.021	3	1.033	0.006	0.169	57	1.044	0.020	6	1.042	0.018	0.741
curved *Trochanter major*	16	1.045	0.018	17	1.045	0.017	0.790	42	1.049	0.020	14	1.040	0.021	0.508
exostosis in the *Fossa trochanterica*	22	1.046	0.019	17	1.039	0.016	0.136	46	1.041	0.019	21	1.041	0.017	0.871
exostosis in the *Fovea capitis*	20	1.042	0.023	24	1.044	0.019	0.774	26	1.045	0.021	37	1.043	0.018	0.613
osteoarthritis on the upper outline of the patellar surface	20	1.050	0.019	14	1.039	0.018	0.115	38	1.044	0.017	17	1.037	0.020	0.062
	Entheses score lower limbs right							Entheses score lower limbs left						
Trait	trait present			trait absent				trait present			trait absent			
	n	x	sd	n	x	sd	sig	n	x	sd	n	x	sd	sig
Poirier's Facet	19	2.23	0.28	60	1.92	0.42	**0.004**	18	2.22	0.44	78	1.94	0.36	**0.005**
Plaque proximal femur	41	2.07	0.33	41	1.91	0.47	0.110	56	2.04	0.31	51	1.95	0.45	0.103
Cribriform changes proximal femur	116	1.98	0.41	22	2.06	0.43	0.217	119	2.02	0.43	25	1.98	0.34	0.303
gluteal enthuses	91	2.09	0.36	20	1.64	0.38	**0.001**	96	2.10	0.35	21	1.62	0.39	**0.001**
pronounced *Linea aspera*	86	2.00	0.39	3	1.50	0.44	**0.015**	103	2.06	0.39	8	1.59	0.43	**0.001**
curved *Trochanter major*	31	1.98	0.37	27	1.87	0.43	0.167	60	2.01	0.45	28	1.89	0.43	0.127
exostosis in the *Fossa trochanterica*	39	2.11	0.34	27	1.67	0.35	**0.001**	67	2.09	0.43	33	1.79	0.39	**0.001**
exostosis in the *Fovea capitis*	40	2.13	0.38	43	1.81	0.38	**0.001**	49	2.16	0.35	58	1.89	0.41	**0.001**
osteoarthritis on the upper outline of the patellar surface	43	2.04	0.39	25	1.73	0.39	**0.001**	60	2.12	0.39	25	1.76	0.35	**0.001**

Table 3. Association patterns between the main characteristics of the horse-riding syndrome corrected for sex, age, and chronological period. Multiple regression analyses

	R^2	B	Sig	95% CI	R^2	B	Sig	95% CI
dependent parameter	Entheses robusticity score right				Entheses robusticity score left			
Sex	0.716	-0.23	**0.046**	-0.45 - -0.01	0.704	-0.22	0.059	-0.45 – 0.01
Age group		0.39	**0.001**	0.22 – 0.57		0.37	**0.001**	0.20 – 0.55
Chronological phase		0.02	0.856	-0.16 – 0.19		-0.01	0.954	-0.18 – 0.17
Poirier facet		0.22	**0.011**	0.06 - 0.39		0.24	**0.008**	0.07 – 0.41
Gluteal entheses		0.08	0.285	-0.08 – 0.40		0.09	0.271	-0.08 – 0.26
IOA		13.23	**0.011**	3.35 – 23.11		13.93	**0.009**	3.90 – 23.95

Discussion

Horses played a significant role in cultural evolution and had a lasting influence on human lifestyle: A good example is the historical importance of mounted warriors of equestrian nomadic societies (such as the Huns, Avars, Hungarians, and Mongols) in late antique and medieval Eurasia. The horse-riding techniques of all these equestrian nomadic societies must have focused on controlling the horse effectively without reins, using only the rider's seat and legs, because this is crucial for horseback archery and other types of mounted combat, as well as for daily life activities such as herding and hunting from horseback. As documented, for example, by a Byzantine military handbook compiled around 600 AD (Dennis 1984; Hyland 1994), the Avars, at least in the initial period of their European history, were not only equestrian nomads, but also outstanding mounted warriors. In particular, horseback archery and other types of mounted combat require many hours of training from an early age, in order to master these skills at the level of proficiency required for successful participation in battle and attested by the historical sources. As outlined above, the prevalence of horse-human burials and other burial rituals involving horses and horse tack, frequently together with the weapon types mentioned by the historical sources, indicates the importance of horses for Avar populations, in particular in a military context.

In the present study, the associations between typical, quantitative, and qualitative characteristics of the so-called "horse-riding syndrome", were analyzed using an early medieval, Avar-period (7th–8th century AD) sample from Austria. From a methodological point of view, the historical and archaeological context (Daim 2003; Baron 2018; Fedele 2020; Bede 2012) of the human osteological material examined in this study is a particular asset for analyzing the so-called "horse-riding syndrome": For example, Berthon et al. (2019) have stressed the relevance of the archaeological context for research on the "horse-riding syndrome". Due to the historical and archaeological context summarized above, variations in habitual activity patterns detected within the adult Avar population of the Csokorgasse burial ground may be the result of social, chronological, and sex differences regarding the habitual horse-riding activity. In previous studies, we could show, for example, that habitual horse riding was more common among men than among women (Bühler, Kirchengast 2022a) and also more common among men of higher socioeconomic status than among lower-status men (Bühler, Kirchengast 2022b).

The results of our present study suggest a significant association between four traits interpreted commonly as indicators of habitual horseback-riding: Poirier´s facets, gluteal entheses at the *Os coxae*, the IOA (= quantifying the vertical elongation of the acetabulum), and pronounced robusticity of the entheses of the lower limbs. These particular traits have already been described as potential indicators of habitual horse riding in previous bioarchaeological research on other populations of habitual horse riders (Anđelinović et al. 2015; Bagagli et al. 2012; Bailif-Ducros 2012; Baillif-Ducros, McGlynn 2013; Berthon et al. 2019; Belcastro et al. 2001). This result is in accordance with the biomechanics of horse riding: The pelvis and legs of the rider play a central role in the communication between rider and horse (Pugh, Bolin 2004), even more so when riding without reins, for example during horseback archery. Hence, it is not surprising that osteological traits detected on the bony pelvis, hip joint, and proximal femur are major characteristics of the "horse-riding syndrome". Even the prevalence of Poirier´s facet within the Avar population from the Csokorgasse burial ground (15–20%) resembles those in the adult population from the nearby Avar cemetery of Vösendorf, where the prevalence of "Poirier's Facet" averaged at 16.3% for adult individuals of both sexes (Pany, Wiltschke-Schrotta 2017).

No significant associations with the IOA or the Entheses robusticity score were found for other non-metric variations of the femoral head-neck junction such as different types of plaque and cribriform variations, which have also been associated with the horse-riding syndrome. Although the different types of plaque may be caused by mechanical stress, at present, they can only be interpreted as unspecific "markers of physical activity" (Lawrence et al. 2018; Radi et al. 2013), because their etiology is still unclear (Radi et al. 2013; Mellado et al. 2014). The interpretation of cribriform changes of the proximal femur is, at present, even more problematic: It is, as yet, not possible to ascertain whether they should be interpreted as general stress markers, caused by malaria or anemia (Pany et al. 2006) or as unspecific markers of physical activity (Radi et al. 2013). Therefore, it may be important to discriminate between pathophysiological cribriform changes occurring by themselves and other types of cribriform lesions, which form on the plaque as herniation pits. The latter may be indeed a result of activity, as suggested by clinical research (Mellado et al. 2014).

Furthermore, for the five other, non-metric traits of the "horse-riding syndrome" which were taken into consideration in this study, the differences regarding IOA between adults with the presence/ absence of the trait in question were relatively small and statistically insignificant. Therefore, in this study the five traits (pronounced *Linea aspera*, curved *Trochanter major*, exostosis at the *Fovea trochanterica*, exostosis in the *Fovea capitis*, and osteoarthritis at the upper outline of the patellar surface maybe not regarded as specific characteristics of habitual horse riding activity, but as indicators of general mobility.

Hence, we could verify our first hypothesis partly. This is also true of the second hypothesis because significant correlations between the left IOA and the entheses robusticity scores were found.

Limitations

Due to the poor preservation of the leg bones and bony pelvis, the actual sample sizes were considerably smaller than the total sample size (n = 149). Another limitation of the research carried out here was the lack of an "outgroup", such as a population of non-horse-riders from a modern reference collection.

Conclusions

The association between several major characteristics of the "horse-riding syndrome" – i.e. "Poirier´s Facet" on the proximal femur, ovalization (vertical elongation) of the acetabulum, and pronounced entheses on the bony pelvis and the lower limb bones, detected within the adult population from the Avar cemetery Csokorgasse – suggests that the "horse-riding syndrome" may indeed be a valid set of traits for detecting habitual horse riders in archaeological contexts.

Authors' contribution

Birgit Bühler designed the study and collected the data. Sylvia Kirchengast formulated the hypotheses. Sylvia Kirchengast did the analysis. Both authors formulated the hypotheses and wrote the text.

Conflict of interest

The authors declare that they have no competing interests concerning this study.

Corresponding author

Univ. Prof. Dr. Sylvia Kirchengast, Department of Evolutionary Anthropology, University of Vienna, Djerassiplatz 1, A-1030 Vienna, Austria; Email: sylvia.kirchengast@univie.ac.at

References

Anđelinović S, Anterić I, Škorić E, Bašić Z. 2015. Skeleton Changes Induced by Horse Riding on Medieval Skeletal Remains from Croatia. Int J History Sport 32:708–721.

Anke B, Révész L, Vida T. 2008. Reitervölker im Frühmittelalter. Hunnen – Awaren – Ungarn. Theiss Verlag, Stuttgart.

Bagagli E, Cantini F, Mallegni F, Bartoli F. 2012. "Horseman syndrome" in the Tuscan Early Middle Age: the Sk888 case. Journal of Biological Research – Bollettino Della Societŕ Italiana Di Biologia Sperimentale 85(1), https://doi.org/10.4081/jbr.2012.4107

Baillif-Ducros C. 2012. Nouvelles données a propos du "syndrome du cavalier": presentation des lesions et de l'adaption osseuse structurelle du sujet de la sépulture 11 du site "la Tuilerie" a Saint-Dizier (Haute Marne), VIe siècle. Bulletin der Schweizerischen Gesellschaft für Anthropologie 18(1):55–56.

Baillif-Ducros C, McGlynn G. 2013. Stirrups and archaeological populations: Bio-anthropological considerations for determining their use based on the skeletons of two steppe riders. Bull Schweiz Ges Anthrop 19:43–44.

Baron H. 2018. Quasi liber et pictura. Die Tierknochenfunde aus dem Gräberfeld an der Wiener Csokorgasse. Eine anthrozoologische Studie zu den awarischen Bestattungssitten. Monographien des Römisch-Germanischen Zentralmuseums 143, Mainz.

Bede I. 2012. The status of horses in late Avar-period society in the Carpathian Basin. In The very beginning of Europe? Cultural and Social Dimensions of Early Medieval Migration and Colonisation (5th–8th century). Archaeology in Contemporary Europe Conference, Brussels May 17–19 2011. Relicta Monografien 7:41–50.

Belcastro MG, Facchini F, Neri R, Mariotti V. 2001. Skeletal markers of activity in the Early Middle Ages necropolis of Vicenne-Campochiaro (Molise, Italy). J Paleopathol 13:9–20.

Berner M, Kritscher H, Szilvássy J. 1992. Die Skelette des awarischen Gräberfeldes von Münchendorf, N iederösterreich. – Archaeologia Austriaca, Monographien 1:1025–1191.

Berthon W, Tihanyi B, Kis L, Révész L, Coqueugniot H, Dutour O, Pálfi G. 2019. Horse riding and the shape of the acetabulum. Insights from the bioarchaeological analysis of early Hungarian mounted archers (10th century). Int J Osteoarchaeol 29(1):117–126, https://doi.org/10.1002/oa.2723

Brooks S, Suchey JM. 1990. Skeletal age determination based on the Os pubis. A comparison of the Acsadi and Nemeskeri and Sucey Brooks methods. Hum Evol 5:227–238.

Bulatović J, Bulatović A, Marković N. 2014. Paleopathological changes in an early iron age horse skeleton from the Central Balkans (Serbia). Int J Paleopathol 7:76–82, https://doi.org/10.1016/J.IJPP.2014.07.001

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains: proceedings of a seminar at the Field Museum of Natural History. Fayetteville: Arkansas Archeological Survey.

Bühler B, Kirchengast S. 2022a. Horse-riding as a habitual activity among the early medieval Avar population of the cemetery of Csokorgasse (Vienna): Sex and chronological differences. Int J Osteoarchaeol 1–11, https://doi.org/10.1002/oa.3107

Bühler B, Kirchengast S. 2022b. High-status Avar warriors identified. Differences in the prevalence of the horse riding syndrome in “high-status” vs. “low-status” adult male burials in the Avar cemetery of Wien11-Csokorgasse (seventh-eighth century AD). Acta Archaeologica Academiae Scientiarum Hungaricae 73:81–92.

Csiky G. 2021. The transformation of horse riding in the steppes during the 1st millennium AD. Considerations on the spread of stirrups in Eurasia. In: Daim F, Meller H, Pohl W. (Eds.), From the Huns to the Turks – Mounted Warriors in Europe and Central Asia. Tagungen des Landesmuseums für Vorgeschichte Halle 23 (Halle/Saale) 15–27.

Curta F. 2008. The earliest Avar-age stirrups or the “stirrup controversy” re-visited. In: Curta F, Kovalev R. (Eds.), The Other Europe in the Middle Ages. Avars, Bulgars, Khazars and Cumans (Leiden) 297–326.

Daim F. 2003. Avars and Avar Archaeology – An Introduction. In: Goetz HW, Jarnut J, Pohl W. (Eds.), Regna and Gentes. The Relationship between Late Antique and Early Medieval Peoples and Kingdoms in the Transformation of the Roman World. Brill, Leiden/ Boston 463–570.

Dennis GT. 1984. Maurice’s Strategikon. Handbook of Byzantine Military Strategy, University of Pennsylvania Press.

Dutour O. 1986. Enthesopathies (lesions of muscular insertions) as indicators of the activities of Neolithic Saharan populations. Am J Phys Anthrop 71:221–224, https://doi.org/10.1002/ajpa.1330710209

Fedele A. 2020. Horse Burials among the Lombards and Avars: Some Differences and Similarities between the Germanic and Nomadic Rituals. In: Bibby MA, Scott BG. (Eds.), The Materiality of the Horse (Budapest 2020) 239–259.

Fornaciari G, Bartolozzi P, Bartolozzi C, Rossi B, Menchi I, Piccioli A. 2014. A great enigma of the Italian Renaissance: paleopathological study on the death of Giovanni dalle Bande Nere (1498–1526) and historical relevance of a leg amputation. BMC Musculoskeletal Disorders 15:301, https://doi.org/10.1186/1471-2474-15-301

Grefen-Peters S. 1987. Das awarische Gräberfeld von Leobersdorf, N.Ö. In: Daim F. (Ed.), Das awarische Gräberfeld von Leobersdorf, N.Ö. – Studien zur Archäologie der Awaren 3/2:470.

Großschmidt K. 1990. Paläopathologische Untersuchungen an den menschlichen Skeletten des awarenzeitlichen Gräberfeldes Csokorgasse in Wien-Simmering – Schmelzhypoplasien, Cribrosierungen und Harris'sche Linien als Streßindikatoren. Unpublished PHD thesis, University of Vienna.

Havelková P, Villotte S, Velemínský P, Poláček L, Dobisíková M. 2011. Enthesopathies and activity patterns in the Early Medieval Great Moravian population: Evidence of division of labour. Int J Osteoarcheol 21:487–504.

Herold H. 2011. Die Awarenzeit im Burgenland – Archäologische Forschungsergebnisse zur Siedlung und zum Gräberfeld Zillingtal. Burgenländische Heimatblätter 73:134–157.

Hyland A. 1994. The medieval warhorse from Byzantium to the Crusades. London: Alan Sulton Publ. Ltd.

Jurmain R, Cardoso FA, Henderson C, Villotte S. 2012. Bioarchaeology's Holy Grail. The Reconstruction of Activity. In: Grauer AL. (Ed.), A companion to paleopathology, Wiley-Blackwell, Hoboken NJ 531–552.

Khudaverdyan A, Khachatryan H, Eganyan L. 2016. Multiple trauma in a horse rider from the Late Iron Age cemetery at Shirakavan, Armenia. Bioarchaeology of the Near East 10:47–68.

Larsen CS. 2015. Bioarchaeology. Interpreting behavior from the human skeleton, Cambridge University Press.

Lawrence AB, Sandberg PA, Van Gerven DP, Sponheimer M. 2018. Evidence for differences in activity between socioeconomic groups at Kulubnarti, Nubia (550-800 CE), from osseous modifications of the proximal femur. Int J Osteoarchaeol 28:735–744.

Li Y, Zhang C, Taylor WTT, Chen L, Flad RK, Boivin N, Liu H, You Y, Wang J, Ren M, Xi T, Han Y, Wen R, Ma J.2020. Early evidence for mounted horseback riding in northwest China. PNAS 117:29569–29576, https://doi.org/10.1073/pnas.2004360117

Librado P, Khan N, Fages A. et al. 2021. The origins and spread of domestic horses from the Western Eurasian steppes. Nature 598:634–640, https://doi.org/10.1038/s41586-021-04018-9

Lovejoy CO. 1985. Dental wear in the Libben population. Its functional pattern and role in the determination of adult age at death. Am J Phys Anthropol 68:47–56.

Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP 1985. Chronological metamorphosis of the auricular surface of the ilium. A new method of the determination of adult skeletal age at death. Am J Phys Anthropol 68:15–28.

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 68:57–66.

Milella M, Alves Cardoso F, Assis S, Perréard Lopreno G, Speith N. 2015. Exploring the relationship between entheseal changes and physical activity: A multivariate study. Am J Phys Anthropol 156:215–223, https://doi.org/10.1002/ajpa.22640

Mariotti V, Facchini F, Belcastro MG. 2007. The Study of Entheses. Proposal of a Standardised Scoring Method for Twenty-Three

Entheses of the Postcranial Skeleton. Coll Antrop 31:291–313.

Mellado JM, Quintana I, Yanguas N, Salceda Artola J, Sanmartin I, Cozcolluela Cabrejas RM. 2014. Normal anatomy and variations of the proximal femur. A reappraisal with 64-slice MDCT. Eur Soc Radiol 1–70, https://doi.org/10.1594/ecr2014/C-1825

Outram AK, Stear NA, Bendrey R, Olsen S, Kasparov A, Zaibert V, Thorpe N, Evershed RP. 2009. The earliest horse harnessing and milking. Science. 6; 323:1332–5, https://doi.org/10.1126/science.1168594

Pálfi G. 1992. Traces des activités sur les squelettes des anciens Hongrois. Bulletins et Mémoires de la Société d'Anthropologie de Paris 4:209–231, https://doi.org/10.3406/bmsap.1992.2318

Pálfi G, Dutour O. 1996. Activity-induced skeletal markers in historical anthropological material. Int J Anthrop 11:41–55. https://doi.org/10.1007/BF02442202

Pany D, Teschler-Nicola M, Prohaska T, Kucera M. 2006: Anthropologische Analyse. In: Daim F, Lauermann E.: Das frühungarische Reitergrab von Gnadendorf (Niederösterreich). Monographien des Römisch-Germanischen Zentralmuseums 64, Mainz, 29–67.

Pany-Kucera D, Viola B, Teschler-Nicola M. 2008. Analysis of musculoskeletal stress markers and joint disease on the early medieval skeletons from Thunau. Am J Phys Anthrop 135:167–168.

Pany-Kucera D, Wiltschke-Schrotta K. 2017. Die awarische Bevölkerung von Vösendorf/S1. Ann Naturhist Mus Wien 119:5–31.

Phenice TW. 1969. A newly developed visual method of sexing the Os pubis. Am J Phys Anthrop 30:297–301.

Pluskowski A, Seetah K, Maltby M. 2010. Potential osteoarchaeological evidence for riding and the military use of horses at Malbork Castle, Poland. Int J Osteoarcheol 20:335–343, https://doi.org/10.1002/oa.1048

Pohl W. 1988. Die Awaren. Beck Verlag, München.

Pugh TJ, Bolin D. 2004. Overuse Injuries in Equestrian Athletes. Curr Sports Med Reports 3:297–303.

Radi N, Mariotti V, Riga A, Zampetti S, Villa C, Belcastro MG. 2013. Variation of the Anterior Aspect of the Femoral Head-Neck Junction in a Modern Human Identified Skeletal Collection. Am J Phys Anthrop 152:261–272.

Rothschild BM, Zdilla MJ, Jellema LM, Lambert HW. Cribra orbitalia is a vascular phenomenon unrelated to marrow hyperplasia or anemia: Paradigm shift for cribra orbitalia. Anat Rec (Hoboken). 2021 Aug, 304(8):1709–1716, https://doi.org/10.1002/ar.24561 [Epub 2020 Nov 9. PMID: 33135369; PMCID: PMC8386693].

Streinz L. 1977. Wien 11 – Csokorgasse. Fundberichte aus Österreich 16:475–531.

Streinz L, Daim F. 2018. Zur Belegungschronologie der Nekropole von Wien 11 – Csokorgasse. In: Baron H.: Quasi liber et pictura. Die Tierknochenfunde aus dem Gräberfeld an der Wiener Csokorgasse. Eine anthrozoologische Studie zu den awarischen Bestattungssitten. Monographien des Römisch-Germanischen Zentralmuseums 143, Mainz, 615–626.

Taylor WTT, Barrón-Ortiz CI. 2021. Rethinking the evidence for early horse domestication at Botai. Sci Rep 11, 7440, https://doi.org/10.1038/s41598-021-86832-9

Taylor WTT, Bayarsaikhan J, Tuvshinjargal T. 2015. Equine cranial morphology and the identification of riding and chariotry in late Bronze Age Mongolia. Antiquity 89:854–871. https://doi.org/10.15184/aqy.2015.76

Villotte S, Castex D, Couallier V, Dutour O, Knüsel CJ, Henry-Gambier D. 2010. Enthesopathies as occupational stress markers: Evidence from the upper limb. Am J Phys Anthrop 142:224–234. https://doi.org/10.1002/ajpa.21217

Walker PL. 2005. Greater sciatic notch morphology: Sex, age and population differences. Am J Phys Anthrop 127:385–391.

White TD, Folkens PA. 2005. The human bone manual. Elsevier Academic Press.

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.3.06

POLSKIE TOWARZYSTWO ANTROPOLOGICZNE

Osteoarthritis in early modern population from Dąbrówki (Podlaskie Province)

Anna Kątniak, Joanna Podladowska, Joanna Wawrzeniuk, Jacek Tomczyk, Zbigniew Wyżewski, Anna Myszka

Institute of Biological Sciences, Cardinal Stefan Wyszyński University in Warsaw, Wóycickiego 1/3, building 23, 01-938 Warsaw

ABSTRACT: The aim of this analized is to evaluate the frequency of osteoarthritis in the early modern population of Dąbrówki (Poland). Evaluation of degenerative joint changes was based on standard methods commonly used in physical anthropology. Three types of changes were studied: osteophytes, porosities, and eburnations. They were analyzed in the shoulder, elbow, wrist, hip, knee, and proximal ankle joints. Osteoarthritic changes were assessed in 24 female, 20 male, and 8 undetermined sex individuals in the Dąbrówki population.

In the population from Dąbrówki the highest frequency of degenerative changes was noted in the hip joint, and the lowest in the knee joint. Osteophytes were the predominant type of lesions. The less frequent type was porosity, while polishing of the articular surfaces did not occur. In males, degenerative changes were noted more frequently than in females. Due to the existence of many interpretative limitations (there is no a complete picture of the population from Dąbrówki - skeletal material under exploration; not entirely clear and multifactorial etiology of degenerative joint changes), further analysis of the markers of environmental stress in the population from Dąbrówki is necessary.

KEY WORDS: osteoarthritis, skeletal population, osteophytes, porosity, eburnation

Original article

Received: 18.07.2022; Revised: 7.09.2022; Accepted: 8.09.2022

Introduction

Osteoarthritis (OA) is the most ubiquitous pathological condition in skeletal populations (Ortner, Putschar 1985; Weiss, Jurmain 2007). It is also the most common joint condition observed today (Arden, Nevitt 2006; Rothschild, Woods 2012).

The aetiology of osteoarthritis is multifactorial (Felson 2003; Gabay et al. 2008; Roach and Tilley 2007; Teichtahl et al. 2005). In the clinical literature, an influence of several main factors has been considered. Age, sex, genes, metabolic and endocrine factors, obesity, bone density, articular cartilage nutrition, joint injuries and infection, joint instability, congenital and/or developmental joint deformities, physical activity and occupation, muscle weakness (Anderson, Loeser 2010; Arden, Nevitt 2006; Felson 2003; Gabay et al. 2008; Teichtahl et al. 2005; Guan et al. 2019), or even nutritional factors (Guan et al. 2019; Tetlow and Woolley 2001) are considered.

Given a high prevalence and availability of osteoarthritis in skeletal material (Weiss, Jurmain 2007; Plomp et al. 2015), the analyses of these skeletal markers of environmental stress have an important place in anthropology (Weiss, Jurmain 2007; Jurmain 1991; Klaus et al. 2009; Molnar et al. 2011; Schrader 2012; Woo, Pak 2013; Rojas-Sepúlveda, Dutour 2014; Palmer et al. 2016).

In spite of the fact that osteoarthritic changes are very common in historical populations, these pathological traits still raise many methodological and interpretative problems (Weiss, Jurmain 2007). The present study aimed to examine the osteoarthritic changes in the early modern skeletal material from Dąbrówki (Poland), the OA changes presence and the way they are expressed. It enriches the knowledge about these conditions in past skeletal populations, what is important in a reliable interpretation of the biology, ecology, and behaviour of past human populations.-

Material and methods

All analysed specimens were excavated from a cemetery located in Dąbrówki (Poland). „Dąbrówki" as the name first appeared in 1559 (due to the presence of oaks in the local part of Podlasie). In 1568, the village of Dąbrówki was mentioned when the parish near Wasilków was established (Wawrzeniuk 2021a).

Fot. 1. The location of the Dąbrówki (red drop).

The cemetery with skeleton burials was discovered by accident in 2018, during earthworks. The cemetery on the hill is locally called „Brama Cygańska". However, it is not known where this name comes from. There is also no information about the cemetery itself (Wawrzeniuk 2021a). With the help of the found burial equipment, the chronology of the cemetery can be estimated. The coins from the times of Sigismund Augustus and Sigismund III Vasa, a metal cross, a copper ring and a rosary bead, may indicate that this part of the cemetery under study dates back to the beginning of the 17th century. It cannot be ruled out that in the remaining areas of the cemetery there are burials from younger and older periods (Wawrzeniuk 2021b).

Numerous human remains were found on the hillside (Wawrzeniuk 2021a). Research work has revealed 62 graves (41 have been explored, 21 in total). Most of the individuals were adults. There were few children's burials and they were usually buried with adults (Wawrzeniuk 2021a; Wawrzeniuk 2021b).

The samples evaluated for this analysis is a part of the osteological collection of the Institute of Biological Sciences Cardinal Stefan Wyszynski University (Poland). The exact number of male and female individuals in each historical group examined in this study is presented in Table 1.

Standard anthropological methods were applied to determine the age and sex of the individuals. The sex of the individuals was estimated using the Phenice (1969) and Buikstra, Ubelaker (1994). This includes visual assessments of pelvic and cranial features. The age-at-death of the individual was estimated based on changes in the morphology of the pubic symphysis, using the Brooks and Suchey (1990) system and standards for changes in the topography of the auricular surface (Buikstra, Ubelaker 1994). Only adult remains were included in this study. Individuals without any observable (except from osteoarthritic) skeletal changes (like observable bone illnesses, traumas, fractures, or bone deformities) were included into the analyses.

Osteoarthritic changes were examined in accordance with the methods by Buikstra and Ubelaker (1994). Three types of OA changes were examined: (a) osteophytes (OP) – a marginal proliferation of new bone in either the horizontal or vertical direction that produces a change in the shape of the joint contour; (b) porosity (POR) – pitting and/or erosion of the joint surface; (c) eburnation (EB) – polished subchondral bone with or without ridges) (Buikstra & Ubelaker 1994). OA changes were scored in: (a) shoulder (articular surface of the scapula and humeral head); (b) elbow (articular surfaces of the distal end of the humerus and articular surfaces of the proximal end of the ulna and radius); (c) wrist (articular surfaces of the distal end of the ulna and articular surfaces of the distal end of the radius); (d) hip (acetabulum [pelvic bone] and articular surface of femoral head); (e) knee (articular surface of the distal end of the femur and articular surfaces of the proximal end of the tibia); and (f) ankle (distal end of the tibia). Due to the small size of the sample, statistical analyzes did not include the gradation of changes, but only their presence (1) or their absence (0). The data on degenerative changes were analyzed separately for female, male and indeterminate sex, by joint analysis.

The statistical significance of the differences in the frequency of the degenerative changes between males and females in the analyzed skeletal material was investigated using the unilateral test for two components of the structure. The test analyses the significance of the differences between the frequencies of the two compared traits. Statistical significance was determined at the level of $p \leq 0.05$. All analyses were done using Statistica 13.3.

Results

In the population from Dąbrówki, degenerative changes in joints were reported in 81% of individuals. The highest rates of degenerative changes were recorded in the hip joint (55%). Lower rates were recorded in the following joints: wrist (40%), shoulder (40%), elbow (40%), ankle (33%) and knee (27%). In the material studied, osteophytes were the predominant type of lesions (59%). The less frequent type of lesions was porosity (5.5%). There was no sanding of the articular surfaces (Tab. 1).

In the examined skeletal material, osteophytes were the most frequently observed degenerative changes in the knee (67%) and elbow (63%). Fewer osteophytes were observed in the shoulder (60%), hip (57%), wrist (57%) and ankle (55%) joints, respectively. The highest porosity was recorded in the hip joint (21%). Less in the shoulder (5%), elbow (2%) and knee (1%) joints. There was no porosity in the wrist and ankle joints (Tab. 1).

In females, degenerative changes in joints were reported in 79% of individuals. The highest number of changes of the osteophyte type was recorded in the ankle joint (75%). Less occurred in the knee (70%), wrist (63%), elbow (57%), hip (53%) and hip (45%) joints. Porosity occurred only in the hip joint with a frequency of 9% (Tab. 2). In males, degenerative changes were reported with a frequency of 100%. The greatest number of osteophytes was found in the shoulder joint (71%). Slightly less in the following joints: elbow (67%), knee (65%) and hip (59%). The lowest rates were recorded in the wrist (52%) and ankle (37%). Porosities occurred only in the joints: hip (36%), shoulder (12%) and elbow (3%) (Tab. 2). In the group of skeletons of undefined sex, the frequency of degenerative changes was 38%. Osteophytes, reported with a frequency of 100%, occurred in four joints (shoulder, elbow, hip and ankle). They occurred in the knee joint with a frequency of 67%. However, no osteophytes were found in the wrist joint. Porosity occurred only in the knee joint (14%) (Tab. 2).

When examining the significance of differences between males and females in the rates of degenerative changes in joints (all types of changes jointly), it was found that in men degenerative changes were recorded more often than in females (33% – females, 48% – males, p = 0.001). They were observed more often in men in each of the examined joints, with significantly higher rates reported for the shoulder joint (27% – females, 59% – males, p = 0.005) and elbow (32% – females, 53% – males, p = 0.005). = 0.04) (Tab. 3).

Table 1. Frequencies (%) of osteoarthritic changes in Dąbrówki sample

Joint	N/n (% n)			
	Osteophytes	Porosity	Eburnation	All changes
Shoulder	45/27 (60,0%)	62/3 (4,84%)	63/0 (0,00%)	67/27 (40,3%)
Elbow	46/29 (63,04%)	61/1 (1,64%)	61/0 (0,00%)	72/29 (40,28%)
Wrist	37/21 (56,76%)	52/0 (0,00%)	52/0 (0,00%)	52/21 (40,38%)
Hip	72/41 (56,94%)	81/17 (20,99%)	83/0 (0,00%)	83/46 (55,42%)
Knee	30/20 (66,67%)	68/1 (1,47%)	72/0 (0,00%)	75/20 (26,67%)
Ankle	44/24 (54,55%)	73/0 (0,00%)	73/0 (0,00%)	73/24 (32,88%)
All joints	274/162 (59,12%)	397/22 (5,54%)	404/0 (0,00%)	422/167 (39,57%)

N – numer of the examined joints, n – number of joints with registered osteoarthritic changes

Table 2. Frequencies (%) of osteoarthritic changes in Dąbrówki sample according to sex

Joint	N/n											
	Males				Females				Undefined sex			
	OP	Porosity	EB	All changes	OP	Porosity	EB	All changes	OP	Porosity	EB	All changes
Shoulder	20/9 (45%)	33/0 (0,00%)	32/0 (0,00%)	34/9 (26,47%)	24/17 (70,83%)	25/3 (12%)	27/0 (0,00%)	29/17 (58,62%)	1/1 (100%)	4/0 (0,00%)	4/0 (0,00%)	4/1 (25%)
Elbow	21/12 (57,14%)	27/0 (0,00%)	27/0 (0,00%)	38/12 (31,58%)	24/16 (66,67%)	30/1 (3,33%)	30/0 (0,00%)	30/16 (53,33%)	1/1 (100%)	4/0 (0,00%)	4/0 (0,00%)	4/1 (25%)
Wrist	16/10 (62,5%)	25/0 (0,00%)	25/0 (0,00%)	25/10 (40%)	21/11 (52,38%)	25/0 (0,00%)	25/0 (0,00%)	25/11 (44%)	0/0 (0,00%)	2/0 (0,00%)	2/0 (0,00%)	2/0 (0,00%)
Hip	38/20 (52,63%)	43/4 (9,3%)	44/0 (0,00%)	44/21 (47,73%)	32/19 (59,38%)	36/13 (36,11%)	36/0 (0,00%)	36/23 (63,89%)	2/2 (100%)	2/0 (0,00%)	3/0 (0,00%)	3/2 (66,67%)
Knee	10/7 (70%)	28/0 (0,00%)	29/0 (0,00%)	31/7 (22,58%)	17/11 (64,71%)	33/0 (0,00%)	34/0 (0,00%)	35/11 (31,43%)	3/2 (66,67%)	7/1 (14,29%)	9/0 (0,00%)	9/2 (22,22%)
Ankle	12/9 (75%)	32/0 (0,00%)	32/0 (0,00%)	32/9 (28,13%)	27/10 (37,04%)	30/0 (0,00%)	30/0 (0,00%)	30/10 (33,33%)	5/5 (100%)	11/0 (0,00%)	11/0 (0,00%)	11/5 (45,45%)
All joints	117/67 (57,26%)	188/4 (2,13%)	189/0 (0,00%)	204/68 (33,33%)	145/84 (57,93%)	179/17 (9,5%)	182/0 (0,00%)	185/88 (47,57%)	12/11 (91,67%)	30/1 (3,33%)	33/0 (0,00%)	33/11 (33,33%)

N – numer of the examined joints, n – number of joints with registered osteoarthritic changes, OP – osteophytes, EB – eburnation

Table 3. Differences in the frequencies (%) of degenerative changes in joints in males and females in the population from Dąbrówki

Joint	Osteophytes		Porosity		Eburnation		All changes	
	M/F	p	M/F	p	M/F	p	M/F	p
Shoulder	45/71%	**0,04***	0/12%	**0,021***	0/0%	–	27/59%	**0,005***
Elbow	57/67%	0,251	0/3%	0,182	0/0%	–	32/53%	**0,040***
Wrist	63/52%	0,252	0/0%	1,0	0/0%	–	40/44%	0,387
Hip	53/59%	0,307	9/36%	**0,002***	0/0%	–	48/64%	0,076
Knee	70/65%	0,395	0/0%	1,0	0/0%	–	23/31%	0,233
Ankle	75/37%	**0,026***	0/0%	1,0	0/0%	–	28/33%	0,335
All joints	57/58%	0,436	2/10%	**0,001***	0/0%	–	33/48%	**0,001***

p – statistically significant differences at the level of p≤0.05; F – frequency of degenerative changes in females, M – frequency of degenerative changes in males

The frequencies of osteophytes were similar in both sexes (57% – females, 58% – men). When examining the difference in the frequency of osteophytes in individual joints, significantly higher frequencies of these changes were noted in men in the shoulder joint (45% - females, 71% – males, p = 0.04), and in females in the ankle joint (75% – females, 37% – males, p = 0.04). In the wrist and knee joints, osteophytes were more common in females, in the elbow and hip joints – in males, however, these differences are not statistically significant (Table 3).

Porosity of the articular surface was noted more often in men in the shoulder joint (0% – females, 12% – males, p = 0.021), hip (9% – females, 36% – males, p = 0.002) and when all joints were analyzed jointly (2% – females, 10% – males, p = 0.001) (Tab. 3).

Discussion

In the population from Dąbrówki, degenerative changes in joints were reported in 81% of individuals. The highest rates of degenerative changes were recorded in the hip joint (55%). Lower rates were recorded in the following joints: wrist (40%), shoulder (40%), elbow (40%), ankle (33%) and knee (27%). In the material studied, osteophytes were the predominant type of lesions (59%). The less common type of lesions was porosity (6%). There was no sanding of the articular surfaces (Tab. 1, Fot. 1).

In this population, degenerative joint changes were reported more often in men (48%) than in females (33%) (Table 3). They were observed more often in males in each of the examined joints, with significantly higher rates reported for the shoulder (27% – females, 59% – males) and elbow (32% – females, 53% – males) (Tab. 3). The frequencies of osteophytes were similar in both sexes (57% – females, 58% – males). When examining the difference in the frequency of osteophytes in individual joints, significantly higher frequencies of the changes were noted for males in the shoulder joint (45% – females, 71% – males), and for females in the ankle joint (75% – females, 37% – males). The porosity of the articular surface was noted more often in males in the shoulder (0% – females, 12% – males), in the hip (9% – females, 36% – males) and when all joints were analyzed together (2% for females, 10% for males) (Table 3).

The present study results are similar to other anthropological data (Weiss, Jurmain 2007). In majority of studies males were usually more affected than females (Šlaus 2002; Klaus et al. 2009; Eng 2016). In some skeletal materials, females (or some joints in females) have higher frequencies of OA than males (Molnar et al. 2011; Eng 2016). Some researchers did not find any significant (or very small) sex differences in OA (Eshed et al. 2010; Schrader 2012; Woo, Pak 2013; Palmer et al. 2016). Taking that osteoarthritic changes are treated by some researchers as physical activity markers (Capasso et al. 1999; Kennedy 1989), the obtain differences (or its lack) were connected with differences/similarities in lifestyle between sexes. Taking the above, it could be hypothesised that the sex differences in osteoarthritis in Dąbrówki population are a result of differences in daily activity patterns. Certain limitations dictate caution in drawing final conclusions. Firstly, archaeological, historical, and anthropological data about population from Dąbrówki is poor now, therefore at this stage of the studies it is not possible to say something about health, lifestyle of each individual. Finding out the relationships between osteoarthritic changes and physical activity is possible now and further studies are needed. Secondly, some researchers dictate caution in using OA changes as physical activity markers (e.g. Schrader 2012; Woo, Pak 2013), emphasizing mutifactorial etiology of these skeletal features. Finally, specifics of the skeleton material (usually small sample size, not well preserved bones, problems with sex determination) could not be omitted. It inflences the obtained results and its interpretation.

The skeleton material from Dąbrówki slightly differs in terms of the frequency of degenerative changes from other historical populations in Poland. In the population from Cedynia (14th–17th century) (Malinowska-Łazarczyk 1982; Porzeziński 2006), degenerative changes occurred with a frequency of 36% in men and 29% in females. The most common type of changes in both females and men were osteophytes. The joint with the most degenerative changes was the elbow joint (Myszka 2016).

In the modern population of Radom (17th-19th century), degenerative changes were reported with a frequency of 26% in the group of men and in 27% of females. The greatest number of lesions was observed in the hip (46%) and elbow (42%). Osteophytes were present in 24% of cases and it was the most frequently reported type of lesions (Myszka 2022).

In the population from Słaboszewo (14th–19th century) (Piontek 1977), degenerative changes occurred with a similar frequency in both sexes (24% in men and 25% in females). The most common type of changes in both sexes were osteophytes, and the joint where degenerative changes occurred most often - also regardless of sex – was the hip joint (Myszka 2016).

In the population from Łekno (14th–16th century) (Wyrwa 2003), degenerative changes occurred with a frequency of 38% in males and 32% in females. The most common type of lesions, as well as in the above-mentioned populations, were osteophytes. In males, degenerative changes were most often found in the elbow joint, while in females – in the hip joint (Myszka 2016).

Compared to the above-mentioned populations, degenerative changes in the population from Dąbrówki were more common in males (Dąbrówki 48%, other populations 24%–38%). In females, however, this difference was not significantly higher. Another point that distinguishes the population from Dąbrówek is the lack of polishing of the pond surfaces. Although in other populations they were rare, they were nevertheless recorded. Of particular interest is the fact that in the population from Dąbrówki, porosity in the hip joint was much more common in males (36%) than in females (9%), which significantly differs from the results of other populations (Myszka 2016).

Given the inadequate etiology of the degenerative changes, it is difficult to explain the cause of these discrepancies. Taking into account the fact that degenerative changes in joints are considered by some researchers as markers of physical activity (Capasso et al. 1999; Kennedy 1989), it can be assumed that one of the possibilities of explaining this phenomenon may be, different from other populations, the motor activity of individuals from Dąbrówek. However, nothing can be said about the physical activity of this population, because there is insufficient historical and archaeological data.

The obtained inter-population differences can be also a result of the differences between the type of settlement complexes. Cedynia (Zachodniopomorskie) was functioning as an early town settlement (Malinowska-Łazarczyk 1982). Łekno (Wielkopolska) was a part of the Łekno settlement complex where in historical times settlements and architectural structures of considerable political, administrative, socio-economic and religious significance were located (Wyrwa 1989). Population from Radom was characterised as a town population (Tomczyk et al. 2017). The population of Słaboszewo (Kujawsko-Pomorskie) represented a typical local rural society (Piontek 1981). Differences in technological development, architectural structures of the complexes, their political, administrative, socio-economic and religious significance influenced the socio-economic position of each populations and thus its health status, and biology. Different localization and not entirely convergent chronology of the compared archaeological series could also play a role in the obtained results. Another factor influencing the observed discrepancies may be the size of the sample, which is not large in the population from Dąbrówki.

Further studies of degenerative changes in the population from Dąbrówek are necessary, inter alia, to complete the knowledge about the population itself and to enrich knowledge about degenerative changes in joints in old skeletal populations, which due to the not fully understood etiology of changes and difficulties interpretative is of great importance.

Summary and Conclusions

In the population from Dąbrówki, degenerative changes in joints were reported in 81% of individuals. The most frequently reported type of lesions were osteophytes (59%). Porosity was noted with a frequency of 6%. Eburnation was not observed here. The highest rates of degenerative changes were recorded in the hip joint (55%). Lower rates were recorded in the following joints: wrist (40%), shoulder (40%), elbow (40%), ankle (33%) and knee (27%). In this population, degenerative changes in joints were reported more often in males (48%) than in females (33%). They were observed more often in males in each of the examined joints, with significantly higher rates reported for elbow and shoulder. The frequencies of osteophytes were similar in both sexes. Taking individual joint osteophytes were more frequently observed for males in the shoulder, for females in the ankle. The porosity of the articular surface was noted more often in males with higher frequencies in shoulder, and hip.

Due to the existence of many limitations resulting from the fact that the skeletal material is being explored and the etiology of degenerative changes in joints is not entirely clear and multifactorial, it is necessary to further analyze these determinants of environmental stress in the population from Dąbrówki.

Conflict of interests

Authors declared no conflict of interests.

Authors' contribution

AK – carrying out skeletal analyses, preparation and description of the statistical part; JP – carrying out skeletal analyses, preparation and description of the statistical part; JW – preparation and description of the archaeological part; JT – content supervision; ZW – helping in statistical analysis; AM – planning and supervision of the research, setting a goal, substantive supervision, corresponding author.

Corresponding author

Anna Myszka, Institute of Biological Sciences, Cardinal Stefan Wyszyński University in Warsaw, Wóycickiego 1/3, building 23, 01-938 Warsaw; Email: a.myszka@uksw.edu.pl

References

Anderson AS, Loeser RF. 2010 Why is osteoarthritis an age-related disease? Best Practice & Research Clinical Rheumatology 24(1):15–26, https://doi.org/10.1016/j.berh.2009.08.006

Arden N, Nevitt MC. 2006. Osteoarthritis: epidemiology. Best Practice & Research Clinical Rheumatolog 20(1):3–25, https://doi.org/10.1016/j.berh.2005.09.007

Brooks S, Suchey JM. 1990. Skeletal age determination based on the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods, https://doi.org/10.1007/BF02437238

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains.

Capasso L, Kennedy KAR, Wilczak CA. 1999. Atlas of Occupational Markers on Human Remains, Journal of Paleontology, Monographic Publication, 3,Edigrafital S.p.A., Teramo.

Eng JT. 2016. A bioarchaeological study of osteoarthritis among populations of northern China and Mongolia during the Bronze Age to Iron Age transition to nomadic pastoralism. Quaternary International 405:172–175, https://doi.org/10.1016/j.quaint.2015.07.072

Eshed V, Gopher A, Pinhasi R, Hershkovitz I. 2010. Paleopathology and the origin of agriculture in the Levant. American Journal of Physical Anthropology 143(1):121–133, https://doi.org/10.1002/ajpa.21301

Felson DT. 2003. Epidemiology and osteoarthritis in: Osteoarthritis. Second edition. Oxford: Oxford Medical Publications 9–16.

Gabay O, Hall DJ, Berenbaum F, Henrotin Y, Sanchez C. 2008. Osteoarthritis and obesity: experimental models. Joint Bone Spine 75(6):675–679, https://doi.org/10.1016/j.jbspin.2008.07.011

Guan VX, Mobasheric A, Probsta YC. 2019. A systematic review of osteoarthritis prevention and management with dietary phytochemicals from foods. Maturitas 122:35–43, https://doi.org/10.1016/j.maturitas.2019.01.005

Jurmain RD. 1991. Degenerative changes in peripheral joints as indicators of mechanical stress: opportunities and limitations. International Journal of Osteoarchaeology 1(3–4):247–252, https://doi.org/10.1002/oa.1390010319

Kennedy KAR. 1989. Skeletal Markers of Occupational Stress. In: Iscan MY, Kennedy KAR. (Eds.), The reconstruction of Life from Skeleton. New York. Alan, R. Liss. Inc. 129–160.

Klaus HD, Spencer Larsen C, Tam ME. 2009. Economic intensification and degenerative joint disease: life and labor on the postcontact north coast of Peru. American Journal of Physical Anthropology 139(2):204–221, https://doi.org/10.1002/ajpa.20973

Malinowska-Łazarczyk H. 1982. Cmentarzysko średniowieczne w Cedyni, Muzeum Narodowe-Szczecin.

Molnar P, Ahlstrom TP, Leden I. 2011. Osteoarthritis and activity-an analysis of the relationship between eburnation, musculoskeletal stress markers (MSM) and age in two Neolithic hunter-gatherer populations from Gotland, Sweden. International Journal of Osteoarchaeology 21(3):283–291, https://doi.org/10.1002/oa.1131

Myszka A. 2016. Osteoarthritis in past human populations. An anthropological perspective. Poznań 2016, Wydawnictwo Naukowe UAM.

Myszka A, Popowska-Nowak E, Tomczyk J. 2022. Osteoarthritis in past human populations from Radom (14th–17th and 18th–19th century). Anthropologischer Anzeiger, https://doi.org/10.1127/anthranz/2022/1557

Ortner DJ, Putschar WGJ. 1985. Identification of Pathological Conditions in Human Skeletal Remains. Smithsonian Contribute Anthropology. 28, https://doi.org/10.5479/si.00810223.28.1

Palmer JLA, Hoogland MHL, Waters-Rist AL. 2016. Activity Reconstruction of Post--Medieval Dutch Rural Villagers from Upper Limb Osteoarthritis and Entheseal Changes. International Journal of Osteoarchaeology 26:78–92, https://doi.org/10.1002/oa.2397

Phenice TW. 1969. A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 30(2):297–301, https://doi.org/10.1002/ajpa.1330300214

Plomp KA, Roberts CA, Strand Viðarsdóttir U. 2015. Morphological characteristics of healthy and osteoarthritic joint surfaces in archaeological skeletons. International Journal of Osteoarchaeology 25(4):515–527, https://doi.org/10.1002/oa.2319

Porzeziski A. 2006. Wczesnośredniowieczne cmentarzysko szkieletowe na stanowisku 2a w Cedyni, województwo zachodniopomorskie. Muzeum Narodowe, Szczecin.

Roach HI, Tilley S. 2007. The pathogenesis of osteoarthritis. In: Bronner F, Farach-Carson MC. (Eds.), Bone and osteoarthritis (Vol. 4). Springer Science & Business Media 1–18, https://doi.org/10.1007/978-1-84628-701-5_1

Rojas-Sepulveda MC, Dutour O. 2014. Degenerative joint disease and entheseal changes in six Pre-Columbian skeletal collections from the northwest of south America. Chungara-revista de Antropologia Chilena 46(1):1532169.

Rothschild BM, Woods RJ. 2012. Epidemiology and biomechanics of osteoarthritis. INTECH Open Access Publisher.

Schrader SA. 2012. Activity patterns in New Kingdom Nubia: an examination of entheseal remodeling and osteoarthritis at Tombos. American Journal of Physical Anthropology 149(1):60–70, https://doi.org/10.1002/ajpa.22094

Šlaus M. 2002. Demography and pathology of the medieval population from Stenjevec. Opuscula Archaeologica Radovi Arheološkog Zavoda 26(1):257–273.

Teichtahl AJ, Wluka AE, Proietto J, Cicuttini FM. 2005. Obesity and the female sex, risk factors for knee osteoarthritis that may be attributable to systemic or local leptin biosynthesis and its cellular effects. Medical Hypotheses 65(2):312–315, https://doi.org/10.1016/j.mehy.2005.02.026

Tetlow LC, Woolley DE. 2001. Expression of vitamin D receptors and matrix metalloproteinases in osteoarthritic cartilage and human articular chondrocytes in vitro. Osteoarthritis Cartilage 9:423–431, https://doi.org/10.1053/joca.2000.0408

Tomczyk J, Nieczuja-Dwojacka J, Zalewska M, Niemiro W, Olczyk W. 2017. Sex estimation of upper long bones by selected measurements in a Radom (Poland) population from the 18th and 19th centuries AD. Anthropological Review 80:287–300, https://doi.org/10.1515/anre-2017-0019

Wawrzeniuk J. 2021a. Sprawozdanie wstępne z archeologicznych badań ratowniczych cmentarzyska szkieletowego w miejscowości Dąbrówki, st. 11, gm. Wasilków, woj. podlaskie, AZP 35-87/25 – nazwa lokalna "Cygańska Brama". Warszawa.

Wawrzeniuk J. 2021b. Zapomniane wiejskie nowożytne cmentarze Podlasia – stan badań a perspektywy badawcze. Saeculum Christianum 28:133–148, https://doi.org/10.21697/sc.2021.28.1.10

Weiss E, Jurmain R. 2007. Osteoarthritis revisited: a contemporary review of aetiology. International Journal of Osteoarchaeology 17(5):437–450, https://doi.org/10.1002/oa.889

Woo EJ, Pak S. 2013. Degenerative joint diseases and enthesopathies in a Joseon Dynasty population from Korea. HOMO-Journal of Comparative Human Biology 64(2):104–119, https://doi.org/10.1016/j.jchb.2013.02.001

Wyrwa AM. 2003. Stanowisko Ł3 Klasztorek, [Online], Uniwersytet im. A. Mickiewicza w Poznaniu. http://historia.amu.edu.pl/Lekno/lokalizacja-3.htm [2003 April 23].

Anthropological Review • Vol. 85(3), 95–106 (2022)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.85.3.07

Is digit ratio (2D:4D) associated with a religious profession? An exploratory study on male Polish seminary students

Marek Kociuba[1], Tomasz Kulik[2], Raja Chakraborty[3], Zofia Ignasiak[4], Andrzej Rokita[4], Sławomir Kozieł[2]

[1] Department of Physical Education, Military University of Technology, Warsaw, Poland
[2] Department of Anthropology, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wrocław, Poland
[3] Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal, India
[4] Faculty of Physical Education, University School of Physical Education, Wroclaw, Poland

ABSTRACT: Human females demonstrate higher religiosity than men in populations. Digit ratio (2D:4D), being a putative indicator of prenatal testosterone, is associated in varying degrees with characters that show sexual dimorphism. A small number of studies have indicated that religiosity may be associated with the biological basis of sex differences in humans. The objective of the present study was to ascertain whether 2D:4D in religiously oriented seminary students is different from individuals in other occupations. The study followed a cross-sectional design. Male participants of the study included 13 seminary students, 18 military chaplains and 91 control students from study courses relating to civil occupations. Lengths of second (2D) and fourth (4D) digits and their ratio (2D:4D) for each hand, height and weight were the variables and 2D:4D was the outcome measure. The results demonstrated that the seminary students had significantly higher 2D:4D than both the military chaplains and civil students. The military chaplains had the lowest 2D:4D. The study also revealed that the choice of religious occupation, and for that matter, religiosity, could be linked with the prenatal hormonal environment, particularly lower intrauterine testosterone compared to oestrogen.

KEY WORDS: prenatal testosterone, foetal androgen, 2D:4D, digit ratio; occupation, religiosity.

Original article

Received: 15.07.2022; Revised: 22.08.2022; Accepted: 23.08.2022

Introduction

Digit ratio (2D:4D), more specifically, the ratio of the lengths of the second (index) to the fourth (ring) finger is considered to be a proxy marker of androgen exposure during an early period of prenatal development (Manning 2011). Compared to female, male foetus gets exposed to relatively higher levels of prenatal testosterone (PT) responsible for lengthening the 4th finger, whereas, prenatal oestrogen (PE), which is higher in case of female foetus, slows down the growth of the 4th digit. This phenomenon results in the sex difference in 2D:4D; males tend to have longer 4th digits relative to the 2nd than do females, i.e. male 2D:4D<female 2D:4D at the population level (Manning et al. 1998; Cohen-Bendahan et al. 2005). The sex difference in 2D:4D can be identified at the end of the first trimester (Malas et al. 2006; Galis et al. 2010). The 2D:4D reflects this relative concentration of PT and PE in a narrow developmental window during foetal growth (Zheng, Cohn 2011). During this brief phase of prenatal development, this relative balance of intrauterine sex hormones plays significant role in the "organisational" development of brain which, in turn, leave an enduring influence on behavioural and personality characteristics, which, particularly, show sexual dimorphism in the population (Manning 2011; Hines et al. 2015). Although, there was evidence showing a lack of association between 2D:4D and prenatal hormones (Hikey et al. 2010; Nave et al. 2021), it was confirmed via animal models (Zheng, Cohn 2011; Auger et al. 2013). On average, males show lower 2D:4D than females at the population level and this sexual dimorphism is established during the end of the first trimester of foetal development (Malas et al. 2006; Galis et al. 2010). After this period, the ratio remains almost unchanged for the rest life and remains stable even during puberty (McIntyre et al. 2005). The 2D:4D was linked with several physical and behavioural traits in humans (Manning 2008; 2011). Nevertheless, in congruence with the role of prenatal androgens to manipulate behaviour through brain "organisation", several behavioural traits having sex variation, such as, assertiveness and risk-taking behaviour, also showed clear associations with higher PT level (Manning, Taylor 2001; Manning et al. 2010; Apicella et al. 2008). All these characteristics, on the other hand, showed association with lower 2D:4D (Garbarino et al. 2011; Hönekopp 2011). Lower 2D:4D was also shown to be associated with the choice of participation in specific types of sports, especially, those with relatively higher risk profiles, such as contact sports, among Polish men and women (Koziel et al. 2016; Kociuba et al. 2017; Tomaszewska, Lubońska 2022) and also with 'male-typical' jobs in a range of occupations among women (Manning et al. 2010; Kociuba et al. 2016; Koziel et al. 2018).

One broad dimension of human behaviour that shows considerable sexual dimorphism across culture is 'religiosity' (Schmitt, Fuller 2015). Greater affiliation to religion in females than males across cultures were reported several times in scientific literature (Roth and Kroll 2007; Voas et al. 2013). In many religions, females tend to be more involved in a variety of religious practices and to report stronger religious beliefs, commitment, salience, and spirituality than males (Hoffmen 2019). Most theories used the universally similar gender specific socialization and also the sex oriented biological differences between male and female in order to explain such gender difference in religiousness (Trzebiatowska 2012; Hoffmann 2019). However, one theory suggested that sexual dimorphism in risk preferences might also be attributed to the association of gender and religiousness in a broader extent. In general, males, compared to females, tend to prefer risks and this translates into less frequent religious behaviours, such as attendance and prayer, and a diminished sense of importance of religion in life (Miller, Hoffmann 1995). However, a growing body of evidence has indicated that religiosity not only has psychosocial, but also a physiological basis. For instance, data from large national surveys among older U.S. adults revealed that higher baseline levels of testosterone and dehydroepiandrosterone was clear predictors of religiousness whether measured by attendance at services or network connections to clergy (Das 2018).

As mentioned above, 2D:4D, being a marker of PT and sexually dimorphic, has been linked with several other sexually dimorphic characters in humans. Thus, one might expect that it would also correlate with religiosity and other associated personality characters, as the former also shows a distinct sex difference. However, studies showing associations of 2D:4D with such characteristics are hitherto limited. For example, development of 'paranormal' and 'superstitious' beliefs, both suggested to rely upon a common underlying factor (see Lindeman, Aarnio 2006), were reported to be associated with high 2D:4D (Rogers et al. 2017; Voracek 2009). Besides, higher religiousness was associated with lower risk-taking behaviour (Pitel et al. 2012). On the other hand, risk taking was linked with both testosterone (Apicella et al. 2008; Sapienza et al. 2009; Stark 2002) and 2D:4D (Garbarino et al. 2011; Hönekopp 2011). The 2D:4D in males was positively associated with beliefs in superstitions and the paranormal (Voracek 2009), but not in females. On the other hand, Richards (2017) could not replicate similar associations and Ellis et al. (2016) reported no association between 2D:4D and religiosity. Another recent study (Richards et al. 2018) pointed out that high 2D:4D may be relatively-specifically associated with increased religious affiliation in young and highly-educated females. However, in this study, the association with religious affiliation was observed in females but not males and the correlations with trait measures were all non-significant. Moreover, this study was a conglomeration of two studies, of which, only one found a significant association.

Therefore, the previous studies provided mixed evidence regarding the plausible connection between 2D:4D and religious attitude and/or choice for a relatively more religious life, albeit, collateral evidence indicated a possible link. It is worth mentioning here that Polish students undertaking military courses showed lower 2D:4D than civil students in previous studies. The former two groups represented two contrasting occupations based on risk profiles; the military chaplains involving higher involvement with and exposure to risk related to a war front, whenever required, whereby, the seminary students were the religious leaders always serving in the ambit of a religious institution and living in a religious way. In a previous study, Polish students who chose military services as a future career path showed lower 2D:4D than those who preferred civil jobs (Kociuba et al. 2016). Hence, in this present study, it was hypothesised that seminary students would show a higher 2D:4D than male military chaplains and civil course students. The aim of this study was thus to assess the association of 2D:4D with a religiously oriented occupation in contrast to others.

Material and methods

Participants and settings

This cross sectional study included 122 Polish male participants, 13 of whom were seminary students (students of theological seminary) as the experimental group with a mean (SD) age of 24.2 (2.7) years. They were included from the Metropolitan Higher Theological Seminary in Wroclaw (MHTS). The second group consisted of 18 military chaplains (mean age 33.5; SD 3.6 years). Another 91 males as a control group were included from the students undertaking civil study courses (mean age 29.9, SD 4.9, years) at the General Kuściuszko Military Academy of Land Forces (GKMALF) in Wrocław. All participants were apparently and reportedly healthy and devoid of any abnormality or deformity in hands and fingers, in particular. Before inclusion, it was ensured if they were not compelled by any circumstance to choose the occupation, especially, for the clerks and chaplains. The seminary students, belonging to the MHTS, Wroclaw, had chosen this opportunity for a religious occupation and were admitted in that institute. These students came from small towns and villages of South-Western Poland. They had to live in a hostel located within a closed campus and their daytime is strictly scheduled beginning and ending with common prayers in the seminary chapel. They took meals together and slept in shared rooms. They required obtaining permission of the authority to go out of the seminary campus. On the other hand, the military chaplains were recruited during their officer's course that took place in Academy of Land Forces in Wroclaw. All chaplains were graduates from several different civil theological seminaries. After the completion of the course they were commissioned and delegated to military units as members of the clerics.

Necessary permission was obtained from the authority of GKMALF and MHTS for conducting the study. Informed consents from all participants were also obtained during study. Ethical guidelines as per Helsinki Declaration were adhered to (Goodyear et al. 2007). Permission was granted to measure the seminary students for only one day during the lessons. On the day, 13 students agreed to participate in the study. Military chaplains, as other professional soldiers, were subject to periodical tests of physical fitness at their institute (GKMALF), where they were measured on this occasion.

Anthropometry

Measurements of height with a stadiometer to the nearest 1 mm and body weight with a standardized digital scale to the nearest 1g were recorded. During measurement the subjects wore light garments. The lengths of the second and fourth digits of each hand were measured to the nearest 0.1 mm by trained physical anthropologists (MK and TK) using a digital caliper (TESA SHOP-CAL). The finger lengths were recorded on the ventral surface of the hand, from the midpoint of the basal crease (most proximal to palm) to the tip of the digit. While measuring, the participant was asked to rest the hand on a flat table surface with the ventral surface facing upward. The digits, except the thumb, were kept fully extended but relaxed and touching each others laterally (Manning et al. 1998). Another variable, right minus left hand 2D:4D difference (D_{R-L}), is considered to be an alternative marker of PT, and thus, is a sex dependent character in adults. It is also a measure of "directional asymmetry". Larger or rightward biased D_{R-L} values are, generally, expected in women compared to men (Rogers et al. 2017). In the present study, D_{R-L} was also calculated and tested for its association, if any, with religiosity.

Statistics

Descriptive statistics of mean and standard deviation were calculated for 2D:4D of each hand and for the average of two hands. As the sample size of the study appeared to be low and there was no option to increase the number of seminary student participants, we attempted to check if the sample was statistically sufficient. As it was difficult to obtain a sufficient sample from among the religious students due to some reservations against permitting for such studies, we calculated *a priori* the minimum number of experimental subjects for the analyses to be carried out. For one-way ANOVA with 3 groups, with RMSSE fixed on 0.25, α error type-I at 0.05, power of test 0.80, the estimated required sample size was 79. Our number in ANOVA was 122 for all individuals. Therefore, we expected a fair statistical result from a small sample size. One-way analysis of variance was employed to observe the significance of difference in 2D:4D between the groups. Analyses of covariance (ANCOVA) with generalized linear model (GLM) were conducted to test the differences in 2D:4D between the groups, allowing for age, height and BMI. These covariates were included in the model as controls as there is evidence that these might be correlated with 2D:4D in European – (Manning et al. 2021) and in Polish populations (Tomaszewska, Lubońska 2022). Differences in mean (±SE) 2D:4D between the groups were assessed by Tukey's post-hoc test for unequal sample size. The differences were also presented by appropriate diagrams (Fig. 1). All the statistical analyses were performed by Statistica 13.1 software (Dell Inc. 2016).

Results

Table 1 Shows the descriptive statistics of mean and corresponding standard deviation (SD) for 2D:4D between the study groups. The mean (SD) 2D:4D in right hand ($F=4.20$, $p<0.05$) and for average of both hands ($F=3.67$, $p<0.05$) differed significantly between the groups, whereas for left hand differences were not significant. Differences were also not significant for D_{R-L}. The military chaplains showed the lowest and the seminary students the highest, while the civil students showed intermediate values.

Table 2 presents the results of ANCOVA performed to assess the significance of difference in 2D:4D among the three study groups after controlling for the independent effects of age, BMI and body height. The groups differed in respect of the right hand – ($F=8.09$, $p<0.05$) and also for both hands – ($F=7.64$, $p<0.05$) 2D:4D, allowing for age, height and BMI. No significant effect of any of these confounding variables on digit ratio was observed for any hand. Also, the D_{R-L} did not exhibit any significant difference. Figure 1 also demonstrates the differences between groups in each hand and for the average 2D:4D of both hands together.

Table 1. Descriptive statistics of 2D:4D according to study groups and results of one-way ANOVA

	Clergyman (N=13)		Military chaplains (N=18)		Civil students (N=91)			
2D:4D	Mean	SD	Mean	SD	Mean	SD	F	p
Right	0.993	0.039	0.962	0.036	0.970	0.027	**4.20**	**0.0173**
Left	0.995	0.029	0.974	0.030	0.984	0.030	1.90	0.1539
Average	0.994	0.029	0.968	0.030	0.977	0.026	**3.67**	**0.0284**
D_{R-L}	-0.013	0.030	-0.003	0.037	-0.013	0.026	0.86	0.4278

Table 2. Results of MANOVA where the DR was dependent variables, groups independent and age, height and BMI covariates

	Right hand		Left hand		Average of both hands		D_{R-L}	
	Wald's χ^2	p	Wald's χ^2	p	Wald's χ^2	p	Wald's χ^2	p
Group	**8.09**	**0.0175**	4.32	0.1153	**7.64**	**0.0219**	0.54	0.7630
Age	0.50	0.4776	0.49	0.4836	0.63	0.4264	0.04	0.8454
Height	0.02	0.8967	0.32	0.5693	0.06	0.8044	0.59	0.4420
BMI	2.38	0.1229	0.30	0.5819	1.42	0.2340	0.61	0.4360

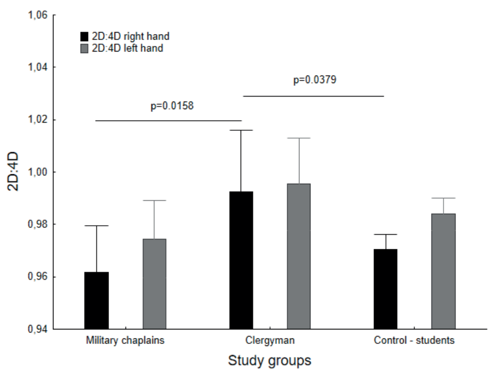

Fig. 1. Mean and 95% CI of 2D:4D for three study groups.

Discussion

The present exploratory study included Polish seminary students, military chaplains and civil course students and assessed the association of 2D:4D with religiously oriented occupation by comparing the values of 2D:4D between these groups. The objective was to observe whether it differed between groups of participants belonging to religious and non-religious affiliations. The results revealed that the seminary students had significantly higher 2D:4D than both the military chaplains and civil students, whereas, the military chaplains had the lowest 2D:4D. It has been well known that religious characteristics in humans have gender differences that have been confirmed by recent studies in European populations (Robinson et al. 2018). It indicated that prenatal androgen, particularly, testosterone exposure, might be somehow linked with the choice for a religious life and occupation, such as, a seminary student. However, there was no significant difference in D_{R-L} between the groups, similar to the studies by Voracek (2009) and Rogers et al. (2017), where this variable did not show a significant association with superstitious and paranormal beliefs.

Religious, paranormal, and superstitious beliefs could be associated with each other (Orenstein 2001; Ilory 2014). On the other hand, paranormal and superstitious beliefs were reported to be associated with higher 2D:4D in males in one study (Voracek 2009) and in females in another (Rogers et al. 2017). However, a plausible explanation for such associations is still lacking. Religiosity, however, was associated with lower risk-taking behaviour (e.g. Pitel et al. 2012), and 'irreligiousness' was associated with short-sighted risky behaviours that might have a physiological basis, too (Stark 2002). As discussed earlier, Miller and Hoffmann (1995) proposed that one key reason females were reported to be more inclined towards religious affiliations was their lower risk preference or higher average levels of risk aversion relative to males of the same population. In spite of many studies failing to show such association (Roth and Kroll 2007; Freese and Montgomery 2007), a recent replication study on European populations seemed to revive the possible role of risk preference, or at least, of risk behaviour, to account for sex difference in religiousness (Hoffman 2019).

It was shown in several studies that males, relative to females, tend to prefer risk and get more engaged in risk-taking behaviours (Byrnes et al. 1999; Charness and Gneezy 2012; Harris et al. 2006; Niederle 2015). Thus, the risk preference theory of religion advanced the analogical notion that risk preferences might explain why males were also less "religious" than females (Hoffman 2019). Thus the preliminary findings of association of 2D:4D with religiousness or, in present case, with the occupation of seminary students, might correspond with the finding that higher 2D:4D is associated with lower levels of risk-taking behaviour or higher risk aversion (e.g. Hönekopp 2011), compared to military chaplains, who showed significantly lower 2D:4D. However, such an analogy is based on the assumption that a lower risk taking attitude is correlated with higher religiosity (Hoffman 2019; Miller and Hoffmann 1995). In that case, the underlying association between risk preferences and religiosity might have their common association with 2D:4D, and thus, with prenatal androgen exposure and resulting brain organization during foetal development. The origin of religiosity and it's variation at the gender and population level could, thus, be comprehended within the theoretical doctrine of intrauterine origin of human behaviour.

Studies have also identified that occupational choices could be linked with PT exposure represented by 2D:4D measures. In a study on the Polish population, it was shown that individuals who chose study courses leading to military jobs (high risk) had lower 2D:4D compared to their civil courses (low risk) peers (Kociuba et al. 2016). Similarly, individuals choosing to become a police officer had lower 2D:4D than those preferring civil professions

(Koziel et al. 2018). Even the voluntary selection of high risk sport, such as judo, as compared to low risk ones, such as aerobic exercises, was associated with relatively lower 2D:4D (Kociuba et al. 2017). In brief, the findings of these studies together indicated that the choice of careers based on their respective risk profiles, or elements associated with those jobs, may be correlated with prenatal androgen environment, and therefore, pointing to 2D:4D value. Perhaps, one of the most important findings of this present study was that the seminary students not only showed higher 2D:4D values than the military chaplains, but also than with the civil courses students. This indicated that individuals with a higher religious orientation, or at least with higher religiosity, may constitute a distinct group with higher 2D:4D within the population. This relatively higher ('feminine') digit ratio among seminary students is probably linked through broader associations between higher risk aversion, and 'femininity'. However, it is too premature to conclude on this issue without further detailed analyses using objective measures of risk taking and religiosity along with 2D:4D.

As stated earlier, hitherto there has been only one study (Richards et al. 2018) available on the online database regarding the association of 2D:4D with self-reported religious affiliation, general religiosity, spirituality, religious fundamentalism, and religious commitment among the university students and in the general population. Females who were affiliated with organised religions had higher digit ratios compared to agnostic or atheist females. No other measure of religiosity was related to 2D:4D in either of the two study groups (Richards et al. 2018). In this context, the present study is novel and needs further confirmation based on a larger sample and precise measures of religiosity. The small sample of the seminary students was an acute limitation of our study, albeit, it narrowly fulfilled statistical requirements. However, from another point of the findings, the reliability of the study, perhaps, increased as there was a significantly clear distinction of the seminary students from both military chaplains, as well as from another set of the general population. Besides, it is worth mentioning here that the development of religiosity since childhood may also be influenced by parental belief patterns and also by the cultural environment. Therefore, some consideration of cultural/societal influences on the development of religious beliefs would be very useful in further studies in order to evaluate the chance that the effects of PT are overwritten by the much larger effects of cultural upbringing of an individual. Besides, parental/societal influences regarding paranormal/superstitious beliefs may be much less pervasive than those relating to religion. This could potentially explain why 2D:4D effects relating to the former have been observed but there is currently much less evidence for the latter. However, before attempting to draw some conclusion on the outcome of the study this is worth reminding that the first study by Voracek (2009) which had reported a link between paranormal belief and 2D:4D is not highly confirmative and the attempt of Rogers et al (2017) could not satisfactorily replicate it. It is also not clear whether we should consider paranormal behaviour in the same way that we do for religiosity in the context of their plausible associations with 2D:4D. Furthermore, as regards religiosity, Richards (2017) could not replicate similar associations and Ellis et al. (2016) reported no association between 2D:4D and religiosity.

To conclude, our study, in congruence with that of Richards et al. (2018) indicated that the individuals with higher digit ratio might relatively be more disposed to religious life, in males. However, every conclusion drawn from this study should be treated with caution in view of the inherent limitations of the study, such as the participants' religiosity was not measured in this study. Only the choice of study course was perceived as a proxy to religious inclination. as stated above, particularly, the low sample of one participant group. Besides, the study included only male participants. Data on religiosity of females might provide further insights into the plausible association of religiousness and prenatal condition. However, the most crucial limitation of this study, perhaps, was the small sample of seminary students. Finally, although the risk preference theory has been popular in religious studies, its efficacy to explain religious differences in terms of biological differences between females and males has been controversial (Stark 2002; Miller, Stark 2002; Sullin 2006). Studies on religiosity relating to testosterone and digit ratio across cultures in varied social contexts would add to the knowledge of prenatal origin of human behaviours.

Acknowledgements

The authorities of General Kuściuszko Military University of Land and the Metropolitan High Theological Seminary, Wroclaw, and all the participants of the study are gratefully acknowledged.

Conflicts of interest

The authors do not have competing interests.

Authors' contributions

MK collected part of data and build the database, wrote Material section of the draft, TK collected data of clergymen, wrote part of draft, RC interpreted the results and wrote the final manuscript, ZI interpreted the results and edited final manuscript, AR interpreted the results and edited final manuscript, SK conceptualised, designed and supervised the study, analysed data and edited the final manuscript for intellectual contents.

Corresponding author

Prof. Raja Chakraborty, Department of Anthropology and Tribal Studies, Sidho-Kanho-Birsha University, Purulia, West Bengal, India; Email: rajanth2003@yahoo.co.uk

References

Apicella CL, Dreber A, Campbell B, Gray PB, Hoffman M, Little AC. 2012. Testosterone and financial risk preferences. Evol Hum Behav 29:384–390, https://doi.org/10.1016/j.evolhumbehav.2008.07.001

Auger J, Le Denmat D, Berges R, Doridot L, Salmon B, Canivenc-Lavier MC. 2013. Environmental levels of oestrogenic and antiandrogenic compounds feminize digit ratios in male rats and their unexposed male progeny. Proc Roy Soc Biol 280, https://doi.org/10.101098/rspb2013

Byrnes JP, Miller DC, Schafer WD. 1999. Gender differences in risk taking: A meta-analysis. Psychol Bull 125:367–83.

Charness G, Gneezy U. 2012. Strong evidence for gender differences in risk taking. Journal of Econ Behav Org 83:50–58, https://doi.org/10.1016/j.jebo.2011.06.007

Cohen-Bendahan CC, van de Beek C, Berenbaum SA. 2005. Prenatal sex hormone effects on child and adult sex-typed behavior: methods and findings. Neurosci Biobehav Rev 29:353–384.

Das A. 2018. Are Men's Religious Ties Hormonally Regulated? Adaptive Human Behaviour and Physiology 4:306–320, https://doi.org/10.1007/s40750-018-0094-3

Dell Inc. Dell Statistica (data analysis software system), version 13. software.dell.com, 2016.

Ellis L, Hoskin AW, Ratnasingam M. 2016. Testosterone, risk taking, and religiosity: Evidence from two cultures. J Sci Study Rel 55:153-173. https://doi.org/10.1111/jssr.12248

Freese J, Montgomery JD. 2007. The devil made her do it? Evaluating risk preference as an explanation of sex differences in religiousness. In: Correll SJ. (Ed.), Social Psychology of Gender (Advances in Group Processes, Vol. 24). Bingley: Emerald Group Publishing Limited. 187–229. https://doi.org/10.1016/S0882-6145(07)24008-1

Galis F, Ten Broek CM, Van Dongen S, Wijnaendts LC. 2010. Sexual dimorphism in the prenatal digit ratio. Arch Sex Behav 39:57–62, https://doi.org/10.1007/s10508-009-9485-7

Garbarino E, Slonim R, Sydnor J. 2011. Digit ratios (2D:4D) as predictors of risky decision making for both sexes. J Risk Uncertainty 42:1–26.

Goodyear MDE, Krleza-Jeric K, Lemmens T. 2007. The Declaration of Helsinki. Br Med J 335:624–625. https://doi.org/10.1136/bmj.39339.610000BE

Harris CR, Jenkins M, Glaser D. 2006. Gender differences in risk assessment: Why do women take fewer risks than men? Judgement Decis Making 1:48–63. http://journal.sjdm.org/jdm06016.pdf

Hickey M, Doherty DA, Hart R, Norman RJ, Mattes E, Atkinson C et al. 2010. Maternal and umbilical cord androgen concentrations do not predict digit ratio (2D:4D) in girls: A prospective cohort study. Psychoneuroendocrinol 35:1235–1244. https://doi.org/10.1016/j.psyneuen.2010.02.013

Hines M, Constantinescu M, Spencer D. 2015. Early androgen exposure and human gender development. Biol Sex Differ 6:3. https://doi.org//10.1186/s13293-015-0022-1

Hoffmann JP. 2019. Risk preference theory and gender differences in religiousness: a replication and extension. J Sc Study Rel 58:210–230.

Hönekopp J. 2011. Relationships between digit ratio 2D:4D and self-reported aggression and risk taking in an online study. Pers Ind Differ 51:77–80. https://doi.org/10.1016/j.paid.2011.03.010

Ilori OS. 2014. Religiosity, paranormal beliefs, and psychopathological symptoms in two ethnic samples. Human Soc Sci Lett 2:192–202.

Kociuba M, Koziel S, Chakraborty R. 2016. Sex differences in digit ratio (2D:4D) among the students of military and civil courses at military academy in Wroclaw, Poland. J Biosoc Sci 48:658–671. https://doi.org/10.1017/S0021932015000401

Kociuba M, Koziel S, Chakraborty R, Ignasiak Z. 2017. Sport preference and digit ratio (2D:4D) among female students in Wroclaw, Poland. J Biosoc Sci 49:623–633, https://doi.org/10.1017/S0021932016000523

Koziel S, Kociuba M, Chakraborty R, Sitek A, Ignasiak Z. 2018. Further evidence of association of low second-to-fourth digit ratio (2D:4D) with selection in uniformed services – a study among police personnel from Wroclaw, Poland. J Biosoc Sci 50:527–539. https://doi.org/10.1017/S0021932017000438

Koziel S, Kociuba M, Ignasiak Z, Chakraborty R. 2016. Is sport choice and participation related to 2D:4D? A study among adult male student in Wroclaw, Poland. Coll Antropol 40:105–110, hrcak.srce.hr:166686

Lindeman M, Aarnio K. 2006. Paranormal beliefs: Their dimensionality and correlates. Eur J Pers 20:585–602. https://doi.org/10.1002/per.608

Malas MA, Dogan S, Evcil EH, Desdicioglu K. 2006. Fetal development of the hand, digits and digit ratio (2D:4D). Early Hum Dev 82:469–475. https://doi.org/10.1016/j.earlhumdev.2003.12.002

Manning JT. 2011. Resolving the role of prenatal sex steroids in the development of digit ratio. Proc Nat Acad Sci, USA 108:16143–16144. https://doi.org/10.1073/pnas.1113312108

Manning JT, Fink B. 2008. Digit ratio (2D:4D), dominance, reproductive success, asymmetry, and sociosexuality in the BBC Internet Study. Am J Hum Biol 20:451–461, https://doi.org/10.1002/ajhb.20767

Manning JT, Fink B, Trivers R. 2021. Digit ratio (2D:4D) and body mass index in the BBC Internet Study: prenatal sex steroids and a Trivers-Willard effect on body composition. J Biosoc Sci (online first), https://doi.org/10.1017/S0021932021000390

Manning JT, Scutt D, Wilson J, Lewis-Jones DI. 1998. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. Hum Reprod 13:3000–3004. https://doi.org/10.1007/s11166-010-9109-6

Manning JT, Taylor RP. 2001. 2nd to 4th digit ratio and male ability in sport: implications for sexual selection in humans. Evol Hum Behav 22:61–69. https://doi.org/10.1016/S1090-5138(00)00063-5

Manning JT, Reimers S, Baron-Cohen S, Wheelwright S, Fink B. 2010. Sexually dimorphic traits (digit ratio, height, systemizing-empathizing scores) and gender segregation between occupations. Evidence from the BBC internet study. Pers Ind Differ 49:511–515. https://doi.org/10.1016/j.paid.2010.05.015

McIntyre MH, Ellison PT, Lieberman DE, Demerath E, Towne B. 2005. The development of sex differences in digital formula from infancy in the Fels Longitudinal Study. Proc Biol Sci 272:1473–1479. https://doi.org/10.1098/rspb.2005.3100

Miller AS, Hoffmann JP. 1995. Risk and religion: An explanation of gender differences in religiosity. J Sci Study Rel 34:63–75. https://doi.org/10.2307/1386523

Miller AS, Stark R. 2002. Gender and religiousness: Can socialization explanations be saved? Am Journal Sociol 107:1399–1423. https://doi.org/10.1086/342557

Nave G, Koppin CM, Manfredi D, Richards G, Watson SJ, Geffner ME et al. 2021. No evidence for a difference in 2D:4D ratio between youth with elevated prenatal androgen exposure due to congenital adrenal hyperplasia and controls. Horm Behav 128:104908. https://doi.org/10.1016/j.yhbeh.2020.104908

Niederle M. 2015. Gender. In: Kagel JH, Roth AE (Eds.), The handbook of experimental economics. Princeton, NJ: Princeton University Press. 481–561.

Orenstein A. 2001. Religion and paranormal belief. J Sci Study Rel 41:301–311. https://doi.org/10.1111/1468-5906.00118

Pitel L, Geckova AM, Kolarcik P, Halama P, Reijneveld SA, van Dijk JP. 2012. Gender differences in the relationship between religiosity and health-related behaviour among adolescents. J Epidemiol Comm Health 66:1122–1128. http://doi.org/10.1136/jech-2011-200914

Richards G. 2017. Digit ratio (2D:4D) and belief in superstitions, conspiracy theories, and the paranormal. PsyPAG Quart 10321-26.

Richards G, Davies W, Stewart-Williams S, Bellin W, Reed P. 2018. 2D:4D digit ratio and religiosity in university student and general population samples. Transpers Psychol Rev 20:23–36.

Robinson O, Hanson K, Hayard G, Lorimer D. 2018. Age and cultural gender equality as moderators of the gender difference in the importance of religion and spirituality: comparing the United Kingdom, France, and Germany: age, gender, and spirituality across three cultures. J Scic Study Rel 58:301–108. https://doi.org/10.1111/jssr.12567

Rogers P, Caswell N, Brewer G. 2017. 2D:4D digit ratio and types of adult paranormal belief: An attempted replication and extension of Voracek (2009) with a UK sample. Pers Ind Differ 104:92–97. https://doi.org/10.1016/j.paid.2016.07.038

Roth LM, Kroll JC. 2007. Risky business: Assessing risk preference explanations for gender differences in religiosity. Am Sociol Rev 72:205–220. https://doi.org/10.1177/000312240707200204

Sapienza P, Zingales L, Maestripieri D. 2009. Gender differences in financial risk aversion and career choices are affected by testosterone. Proc Nat Acad Sc, USA 106:15268–15273. https://doi.org/10.1073/pnas.0907352106

Schmitt DP, Fuller RC. 2015. On the varieties of sexual experience: Cross-cultural links between religiosity and human mating strategies. Psychol Rel Spiritual 7:314–326. https://doi.org/10.1037/rel0000036

Stark R. 2002. Physiology and faith: Addressing the "universal" gender difference in religious commitment. J Sci Study Rel 41:495–507. https://doi.org/10.1111/1468-5906.00133

Sullins DP. 2006. Gender and religion: Deconstructing universality, constructing complexity. Am J Sociol 112:838–80. https://doi.org/10.1086/507852

Tomaszewska A, Lubońska JA. 2022. 2D:4D digit ratio and its relationship to BMI, sporting choices and physiological predispositions among women. Anthropol Rev 85(2):135–146.

Trzebiatowska M, Bruce S. 2012. Why are women more religious than men? Oxford University Press: Oxford, UK.

Voas D, McAndrew S, Storm I. 2013. Modernization and the gender gap in religiosity: Evidence from cross-national European surveys. Cologne J Sociol Soc Psychol 65:259–283. http://doi.org/10.1007/s11577-013-0226-5

Voracek M. 2009. Who wants to believe? Associations between digit ratio (2D:4D) and paranormal and superstitious beliefs, Pers Ind Differ 47:105–109. https://doi.org/10.1016/j.paid.2009.01.051

Zheng Z, Cohn MJ. 2011. Developmental Basis of Sexually Dimorphic digit ratios. Proc National Academy of Science, USA 108:16289–16194. https://doi.org/10.1073/pnas.1108312108

Anthropological Review • Vol. 85(3), 107–124 (2022)

Anthropological Review

Available online at: https://doi.org/10.18778/1898-6773.85.3.08

Factors associated with low birth weight among tribal and non-tribal population in India: Evidence from National Family Health Survey-4 (2015–2016)

Sima Dey[1], *Nitish Mondal*[2], *Kaushik Bose*[3]

[1] Guest Faculty, Sports Authority of India, Netaji Subhas National Institute of Sports, Patiala, India

[2] Associate Professor, Department of Anthropology, School of Human Sciences Sikkim University, Gangtok 737102, Sikkim, India

[3] Professor, Department of Anthropology, Vidyasagar University, Vidyasagar University Rd, Rangamati, Midnapore, West Bengal 721102

Abstract: The tribal population (8.6%) is vulnerable to neonatal mortality and morbidity in India. Birth weight is an important decisive factor for most neonatal survival and postnatal development. The present study aims to compare the prevalence and associations of certain socio-economic, demographic, and lifestyle variables with low birth weight (LBW) among tribal and non-tribal populations in India. The present investigation utilized retrospective data of the National Family Health Survey (NFHS-4, 2015–16) among tribal (N=26635) and non-tribal (N=142162) populations in India. Birth weight variation of the newborn was categorized into LBW (<2500 gm) and NBW (≥2500 gm). ANOVA, chi-square ($\chi2$) analysis, and binary logistic regression (BLR) were applied using SPSS (version 16.0). The prevalence of LBW was higher in non-tribal (17.2%) than tribal (13.5%), and the population-specific birth weight was significantly higher in tribal than non-tribal population ($p<0.01$). Higher tribal population concentration (47.0%) areas has a lower (7.4%) prevalence of LBW in the northeast zone, whereas greater non-tribal population concentration (27.1%) areas was found higher in the central zone (19.2%). The BLR analysis showed that rural habitat, lower educational attainment, lack of own sanitary toilet facility, a lower wealth index, absence of electricity, high pollutant fuel exposure, Hindu and Muslim religion, elevated maternal age at first birth, maternal anemia as well as home delivery of newborn have greater odds for LBW ($p<0.05$). In India, tribal populations are vulnerable and marginalised; their birth weight is significantly higher than that of non-tribals, and they have a lower prevalence of LBW and higher female birth rates. Mother's socio-economic status and perceptions towards hygiene and better lifestyles acquired by educational upliftment positively affect the birth weight of the newborn in both the tribal and non-tribal population in India.

Key words: Birthweight, Low Birth Weight, Tribal population, Socio-Demographic variables

Original article

Received: 16.06.2021; Revised: 12.08.2022; Accepted: 19.08.2022

Introduction

Birth weight is the most decisive single most factor associated with perinatal, postnatal and neonatal mortality in several developing countries. It has a long-term negative impact on neonate's survival, physical growth and development, health status, anthropometric parameters and cognitive development during childhood to adulthood (Mondal, Dey, Sen 2018; Khan, Mozumdar, Kaur 2020). The birth weight is defined as the first weight of the newborn, which is classified as Normal birth weight (NBW) ≥2500 gm, and Low birth weight (LBW) <2500 gm (WHO 2004). The LBW encounters due to intrauterine growth retardation, preterm deliveries and growth retardation are attributed to mortality, morbidity, environment conditions, maternal characteristics and health status, poverty, social-demographic disparities and economic burden among vulnerable segments of the population (Metgud, Naik, Mallapur 2012; Talie, Taddele, Alemayehu 2019). Although, the prevalence of LBW has declined over the past decade, it is still considered as one of the major public health problems in India, where a sizable number of research studies have reported the population-specific prevalence of LBW (ranged between 10% to 56%) (Sen, Roy, Mondal 2010; Ravikumar, Rajeshkannan 2016; Toshniwal et al. 2017; Dey, Mondal, Dasgupta 2019; Khan, Mozumdar, Kaur 2020). The population-specific birth weight variation has been a prime concern that has been significantly influenced by certain determinant factors including parental genetic (Lunde et al. 2007; Mallia et al. 2017), maternal anthropometrics and nutritional status (Papazian et al. 2017; Azcorra and Mendez 2018), demographic condition (Haldre et al. 2007; Schempf et al. 2007), socio-economic status (Olson et al. 2010; Martinson, Reichman 2016), lifestyle factors (Abraham et al. 2017; Kataoka et al. 2018) and seasonal variations (Mondal, Dey, Sen 2018; Zhang, Yu, Wang 2017).

In the present globalized and ever--changing world, the tribal populations are also facing difficulties to sustain a strategic distance from its impact in India. These populations have experienced significant socio-economic, demographic and epidemiological transitions that directly or indirectly affect their health status, nutrition and disease outcomes (Kumar, Pathak, Ruikar 2020; Bharali, Mondal 2021). As per Census (2011), a total of 8.6% population belongs to various tribal communities dispersed over 30 states and 6 union territories across India. The tribal populations has remained isolated from the mainland development activities to a greater extent compared to non-tribal community; often living in distant, hilly and forest areas. However, owing to their unique cultural practices and ethnic distinctions, these populations have always been focused on population investigations (Kshatriya, Acharya 2016; Singh et al. 2020). The tribal populations have a rich ethno-medicine knowledge and strictly follow their traditional practices. Presently, in spite of coexisting with other non-tribal communities, the tribal populations are still following their inherited traditional knowledge for their livelihood (Ministry of Tribal Affairs 2018; Narain 2019). The prevalence of poverty and inaccessibility of healthcare facilities make the tribal populations exceptionally vulnerable in terms of health status, maternal morbidity and mortality, nutritional status and poor reproductive outcomes (Moosan et al. 2019; Das et al.

2020; Bharali, Mondal 2021). Moreover, the health status of indigenous or tribal population provides important insight in terms of implementation of appropriate public health strategies to the concerned population. National Family Health Survey -4 (2015–16) reported that the child mortality (<5 years) was 57.2 per 1000 live births among the tribal population, significantly higher as compared to 38.5 per 1000 live births among non-tribal populations. The infant mortality rate was 44.4 per 1000 live births while others of 32.1 per 1000 live births in India (IIPS 2017; Ministry of Health & Family Welfare and Ministry of Tribal Affairs 2018). The tribal newborns have 19.0% greater risks of neonatal morbidity and 45.0% higher chance of post-neonatal morbidity compared to non-tribal newborns in India (Anderson et al. 2016). Several researchers have reported that majority of the tribal populations are suffering from a high disease burden which includes communicable and non-communicable disease, poor reproductive outcomes, mental health, malnutrition (both overweight-obesity and undernutrition) and poor health-seeking behaviours in the population (Kshatriya, Acharya 2016; Kumar, Pathak, Ruikar 2020; Bharali, Mondal 2021). Maternal healthcare service utilization, antenatal care, immunizations services and healthcare delivery were significantly lower among tribal than non-tribal population due to the lack of education, awareness and lack of transportation facilities in India (NFHS-4 2015–16; IIPS 2017; Ministry of Health & Family Welfare and Ministry of Tribal Affairs 2018; Bharali, Mondal 2021). Recent investigations have shown a large birth weight variations (i.e., LBW) among numerous tribal populations across India (Thakre et al. 2018; Narwade, More 2018). The prevalence of LBW has shown multiple causes and manifestations, and reducing such magnitude has been recognized as a public health priority, as population-specific, systematic and comprehensive strategies are necessary for the target population. Moreover, the population-specific investigations are necessary to understand and identify the possible association between determinant variables. This, in turn, requires a special attention to the researcher due to estimating the magnitude, ethnic variations and possible mechanism of a biological variable (i.e., LBW). The present study attempts to compare the prevalence of LBW among the tribal and non-tribal populations in India and ascertain the associations of socio-economic, demographic and lifestyle variables with newborn's birth weight in India. The findings of the present investigation are essential to implementation of appropriate intervention strategies in order to improve the overall health status, socio-economic conditions, related to specific reproductive outcomes (e.g., LBW) among the vulnerable segment of populations.

Material and methods

The present cross-sectional investigation was carried out utilising the secondary data from the National Family Health Survey (NFHS-4, 2015–16) undertaken by the International Institute for Population Sciences (IIPS), Mumbai, India. This study sample consists of 259627 birth weight data from a total of thirty states and six Union Territories of India. The sample included 168797 neonates were analysed in the present investigation, where a total of 142162 and 26635 of the neonates belonged to various non-tribal and tribal populations, respectively. It is to be mentioned that the decrease in analysed sample size was due to the elimination of outlying observations along with twin or multiple births and 'not adjure resident' (not present during data collection).

Variables

The dependent variable was birth weight variation of the newborn and was categorized into LBW (<2500 gm) and NBW (≥2500 gm) (WHO, 2011). The birth weight ranges are selected from 1500–4500 gm as extreme LBW (<1500 gm), and extreme overweight (>4500 g) newborns were excluded from employing outliers. The independent variables were the type of place of residence (rural, urban), religion (Hindu, Muslim, Other), age of respondent at 1st birth (≤19 years, 20–29 years, ≥30 years), level of anaemia (severe, moderate, mild, not anaemic), level of mother's education (illiterate, primary, secondary, higher), presence of electricity (yes, no), type of toilet facility (sanitary, not sanitary), toilet facilities shared with other households (yes, no), type of cooking fuel (high pollutant, low pollutant), sex of child (male, female), place of delivery (home, institution), family wealth index (poorest, poorer, middle, richer, richest) and zone (central, east, north, north-east, south, west). High pollutant fuel group consists of kerosene, coal, lignite, charcoal, wood, straw, shrubs, grass, agricultural crop, animal dung and others, whereas low pollutant fuel group consists of electricity, Liquified Petroleum Gas (LPG), natural gas and biogas. A total of 30 Indian states and union territories were divided into six zones/regions as per NFHS categorization. The wealth index was measured on household assets and facilities. Households were given scores based on the number and kinds of consumer goods they owned, ranging from a television to a bicycle or car, and housing characteristics such as the source of drinking water, toilet facilities and flooring materials. These scores were derived using principal component analysis. The calculation of the wealth index was done by the IIPS itself and was contained in the data supplied. In case of sharing of toilet facility, those who have no toilet facility excluded from the overall data set. Therefore, a total of 70317 cases are not included, and a total of 5% (821) data on maternal anaemia was also found to be missing from the dataset.

Statistical Analysis

The statistical analyses were conducted using the Statistical Package of Social Sciences (SPSS, version 16.0). Data were divided into two sub-groups, i.e. tribe and non-tribe, all the data mentioned as scheduled tribes were clustered in Tribe groups and the remaining populations were accumulated into the non-tribe community. The frequency distribution was depicted in terms of descriptive statistics (mean and standard deviation). The mean comparisons of birth weight between the sexes (male and female) and the populations (tribal and non-tribal) were analysed using One-Way Analysis of Variance (ANOVA). The chi-square (χ^2) analysis was performed to assess the significant prevalence of LBW among newborns. The binary logistic regression (BLR) analysis was carried out to determine the simultaneous effects of covariates on the dependent variable (i.e. LBW). The dependent variables were dichotomous in nature and entered in the BLR analysis, where newborns with LBW were coded as '0' and NBW as '1'. A p-value of

<0.05 was considered being significant, and 95% Confidence Interval (CI) was used to determine the strength of association between independent and dependent variables in separate population-specific regression analysis. Similarly, the independent variables were entered as a set of dummy variables and odds were obtained by comparing the reference category. The reference categories for the independent variables were 'urban' residence, 'Other' religion, '≥30' years age of respondent at 1st birth, 'non-anaemic', 'higher' educational status, presence of 'electricity' and 'sanitary toilet facility', 'own' toilet, 'low pollutant' cooking fuel, 'richest' wealth index, 'male' child, 'institutional' delivery and 'West' zone of India.

Results

A total 168797 birth records were selected, of which 26635 (15.8%) and 142162 (84.2%) were tribal and non-tribal, respectively. However, while the overall prevalence of LBW was 16.6%, the tribal population was 13.5% and the non-tribal group had 17.2% LBW neonates independently. The results of ANOVA showed that, the population specific mean difference was significantly higher among tribal population (2919.23±539.299 gm over 2809.30±540.480 gm), and sex-specific mean difference was lower among male children (2855.16±547.149 gm over 2794.99±533.970 gm), though in both population the mean birth weight was lower in case of girl child (Table 1).

Descriptive analysis of independent variables among Tribal and Non-tribal communities

The descriptive statistics of newborn's birth weight and maternal variables are presented in (Table 2). The prevalence of girl child is higher among tribes (51.5% over 47.2%) and in both communities' girls have a greater prevalence of LBW. In the study population, the tribes have maximum numbers of Hindus (53.0%), followed by the 'other' religious group (47.6%) and very nominal frequency of Muslims (2.6%), though Muslims have 17.5% LBW babies nearer to the Hindus (18.7%). On the other hand, the distribution of population according to religious belief widely ranged from Hindus (82.2%), Muslims (12.9%) and others (5.3%) but the prevalence of LBW newborns was not very much dispersed among the various religious groups i.e. Hindu (17.4%), Muslims (16.5%) and others (16.0%) among non-tribal populations. The early age of first child birth i.e., teenager mothers (≤19 years) having maximum (14.7%) number of LBW followed by the age groups 20–29 years (13.1%) and elderly (10.4%) mothers, though among the non-tribal group the elderly (18.1%)

Table 1. Descriptive statistics and mean differences of newborn's birth weight among tribal and non-tribal population in India

Variables		Tribe	Non-tribe	F-value	P-value
Birth weight	LBW	2044.88±237.099	2010.15±245.933	63.167	<0.001
	NBW	3055.96±435.066	2975.25±424.336	691.151	<0.001
Sex	Female	2886.03±524.589	2777.46±533.982	95.275	<0.001
	Male	2950.46±550.979	2837.74±544.651	442.089	<0.001

Table 2. Profile of socio-economic, demographic, lifestyle variables and prevalence of LBW among tribal and non-tribal population in India

VARIABLES	CATEGORY	TRIBE				NON-TRIBE			
		LBW (%) [N= 3602 (13.5)]	NBW (%) [N=23033 (86.5)]	Total (%) [N=26635]	Chi²-value	LBW (%) [N=24445 (17.2)]	NBW (%) [N=117717 (82.8)]	Total(%) [N=142162]	Chi²-value
Type of residence	Rural	3159 (14.7)	18363 (85.3)	21522 (80.8)	1.278 **	17545 (17.3)	83925 (82.7)	101470 (71.3)	2.278
	Urban (R)	443 (8.7)	4670 (91.3)	5113 (19.2)		6900 (17.0)	33792 (83.0)	40692 (28.7)	
Religion	Hindu	2642 (18.7)	11455 (81.3)	14097 (53.0)	6.913 **	20198 (17.4)	95997 (82.6)	116195 (81.7)	16.678 **
	Muslim	121 (17.5)	570 (82.5)	691 (2.6)		3031 (16.5)	15337 (83.5)	18368 (12.9)	
	Others (R)	984 (7.8)	11688 (92.2)	12672 (47.6)		1216 (16.0)	6383 (84.0)	7599 (5.3)	
Age of respondent at 1st birth	≤19 (R)	1373 (14.7)	7965 (85.3)	9338 (35.1)	24.484 **	8329 (17.8)	38360 (82.2)	46689 (32.8)	24.750 **
	20-29	2100 (13.1)	13951 (86.9)	16051 (60.3)		15403 (16.8)	76137 (83.2)	91540 (64.4)	
	≥30	129 (10.4)	1117 (89.6)	1246 (4.7)		713 (18.1)	3220 (81.9)	3933 (2.8)	
Anemia level #	Severe	58 (22.5)	200 (77.5)	258 (1.0)	1.196 **	266 (21.8)	956 (78.2)	1222 (0.9)	66.906 **
	Moderate	567 (16.0)	2975 (84.0)	3542 (13.3)		3597 (18.8)	15576 (81.2)	19173 (13.5)	
	Mild	1577 (15.2)	8806 (84.8)	10383 (39.0)		10056 (17.2)	48341 (82.8)	58397 (41.1)	
	Not anemic (R)	1376 (11.2)	10945 (88.8)	12321 (46.2)		10401 (16.6)	52279 (83.4)	62680 (44.1)	
Highest educational level	No education	1338 (19.1)	5671 (80.9)	7009 (26.3)	2.989 **	6323 (18.8)	27295 (81.2)	33618 (23.6)	2.552 **
	Primary	611 (14.2)	3688 (85.8)	4299 (16.1)		3626 (18.9)	15551 (81.1)	19177 (13.5)	
	Secondary	1513 (11.1)	12063 (88.9)	13576 (51.0)		12105 (16.8)	59841 (83.2)	71946 (50.6)	
	Higher(R)	140 (8.0)	1611 (92.0)	1751 (6.6)		2391 (13.7)	15030 (86.3)	17421 (12.3)	
Electricity	No	504 (17.5)	2383 (82.5)	2887 (10.8)	42.85 **	2664 (17.9)	12238 (82.1)	14902 (10.5)	5.432 *
	Yes (R)	3098 (13.0)	20650 (87.0)	23748 (89.2)		21781 (17.1)	105479 (82.9)	127260 (89.5)	
Type of toilet facility	Not sanitary	2533 (16.7)	12671 (83.3)	15204 (57.1)	2.980 **	12753 (17.8)	58885 (82.2)	71638 (50.4)	37.348 **
	Sanitary (R)	1069 (9.4)	10362 (90.6)	11431 (42.9)		11692 (16.6)	58832 (83.4)	70524 (49.6)	

Toilet shared with other households ##	Yes	212 (11.2)	1681 (88.8)	1893 (7.1)	5.786 *	2647 (18.2)	11881 (81.8)	14528 (10.2)	37.178 **
	No (R)	1302 (9.5)	12466 (90.5)	13768 (51.7)		11030(16.2)	57261 (83.8)	68291 (48.0)	
Type of cooking fuel	High pollutant	3043 (15.2)	17005 (84.8)	20048 (75.3)	1.899 **	16238 (17.9)	74278 (82.1)	90516 (63.7)	96.914 **
	Low pollutant (R)	559 (8.5)	6028 (91.5)	6587 (24.7)		8207 (15.9)	43439 (84.1)	51646 (36.3)	
Wealth index	Poorest	1550 (18.8)	6680 (81.2)	8230 (30.9)	3.682**	4867(18.4)	21537 (81.6)	26404 (18.6)	1.428 **
	Poorer	911 (13.4)	5876 (86.6)	6787 (25.5)		5464 (18.1)	24704 (81.9)	30168 (21.2)	
	Middle	656 (11.7)	4965 (88.3)	5621 (21.1)		5314 (17.3)	25322 (82.7)	30636 (21.5)	
	Richer	328 (8.5)	3523 (91.5)	3851(14.4)		4888 (17.0)	23845 (83.0)	28733 (20.2)	
	Richest(R)	157 (7.3)	1989 (92.7)	2146 (8.1)		3912 (14.9)	22309 (85.1)	26221 (18.4)	
Sex of child	Female	1831 (14.2)	11081 (85.8)	13723 (51.5)	9.251 *	12355 (18.4)	54712 (81.6)	67067 (47.2)	1.342 **
	Male(R)	1771 (12.9)	11952 (81.7)	12912 (48.5)		12090 (16.1)	63005 (83.9)	75095 (52.8)	
Place of delivery	Home	628 (15.0)	3570 (85.0)	4198 (15.8)	8.787 *	1947 (20.0)	7780 (80.0)	9727 (6.8)	58.370 **
	Institution (R)	2974 (13.3)	19463 (86.7)	22437 (84.2)		22498 (17.0)	109937 (83.0)	132435 (93.1)	
Zone	Central	953 (17.5)	4483 (82.5)	5436 (20.4)	7.830 **	7377 (19.2)	31131 (80.8)	38508 (27.1)	3.823 **
	East	685 (18.8)	2953 (81.2)	3638 (13.6)		4707 (15.2)	26170 (84.8)	30877 (21.7)	
	North	422 (21.0)	1591 (79.0)	2013(7.5)		5655 (18.7)	24578 (81.3)	30233 (21.3)	
	North-east	933 (7.4)	11642 (92.6)	12575 (47.2)		1183 (13.1)	7875 (86.9)	9058 (6.4)	
	South	169 (19.2)	709 (80.8)	878 (3.3)		3267 (15.7)	17594 (84.3)	20861 (14.6)	
	West (R)	440 (21.0)	1655 (79.0)	2095 (7.9)		2256 (17.9)	10369 (82.1)	12625 (8.9)	

#821 (0.5%) cases are missing from data set ; ##70317 (41.7%) cases are excluded from data set due to not having any toilet facility; *p<0.05; **p<0.01

mothers having maximum numbers of LBW followed by teenager mothers i.e. ≤19 years (17.4%) among the tribal population. Zone wise distribution of birth weight differed considerably between the tribe and non-tribe communities. The tribal population was highly concentrated with a minimum LBW prevalence (7.4%) to the North east (47.2%), while the LBW level to the North and West region was highest (21.0%) whereas the overall tribal population was 7.5% and 7.9% respectively. The non-tribal population, on the other hand, had the highest LBW prevalence (19.2%) and population concentration (27.1%) in Central region and the lowest LBW prevalence (13.1%), and population concentration (6.4%) in the North east region.

BLR analysis of independent variables among tribal population

In BLR analysis, all the independent variables had significant association with the prevalence of LBW ($p<0.05$). Rural population had greater chance (odds: 1.814; 95% CI: 1.634–2.013; $p<0.001$) of having LBW new-born. There was a clear indication that the Hindus having the highest odds (odds: 2.741; 95% CI: 2.534–2.964; $p<0.001$), followed by the Muslims (odds: 2.537; 95% CI: 2.055–3.133; $p<0.001$). Additionally, mother's age at first pregnancy between 20–29 years (odds: 1.145; 95% CI: 1.064–1.232; $p<0.05$) and ≥30 years (odds: 1.493; 95% CI: 1.233–1.807; $p<0.05$) had higher odds of having LBW. Severe (odds: 2.307; 95% CI: 1.713–3.106; $p<0.001$) and even moderate level (odds: 1.516; 95% CI: 1.364–1.685; $p<0.001$) of anaemic mothers have higher odds. Women who were non-educated (odds: 2.715; 95% CI: 2.262–3.259; $p<0.001$) exhibited a higher odds value than those with primary education (odds: 1.906; 95% CI: 1.572–2.312; $p<0.001$). The results further showed that absence of electricity (odds: 1.410; 95% CI: 1.271-1.563; $p<0.001$), having shared (odds: 1.207; 95% CI: 1.035–1.408; $p<0.001$) and no sanitary toilet (odds: 1.938; 95% CI: 1.796–2.091; $p<0.001$), high pollutant fuel users (odds: 1.930; 95% CI: 1.755–2.122; $p<0.001$), female child (odds: 1.115; 95% CI: 1.039-1.196; $p<0.001$) and home delivery (odds: 1.151; 95% CI: 1.049–1.264; $p<0.001$) had highly significant effects on the birth weight of newborn. Decrease in wealth index indicates an increased odd of having LBW.

BLR analysis of independent variables among non-tribal population

In BLR analysis, among the non-tribes, no significant association was found among the rural people with the prevalence of LBW ($p>0.05$) though higher odds are found among rural population (odds: 1.024; 95% CI: 0.993–1.056; $p<0.001$). Women faithful to Hindu (odds: 1.104; 95% CI: 1.037–1.176; $p<0.001$) and Muslim (odds: 1.037; 95% CI: 0.965–1.116; $p<0.001$) religion having significantly higher odds of being LBW babies. The results further showed that age at first pregnancy between 20–29 years (odds: 1.073; 95% CI: 1.042–1.105; $p<0.05$) had higher and age at first pregnancy ≥30 years (odds: 0.981; 95% CI: 0.901–1.067; $p<0.05$) had lower odds of having LBW. Moreover severe anaemic level (odds: 1.399; 95% CI: 1.219–1.605; $p<0.001$), no education (odds: 1.456; 95% CI: 1.384–1.533; $p<0.001$), primary education (odds: 1.466; 95% CI: 1.385–1.551; $p<0.001$), absence of electricity (odds: 1.054; 95% CI: 1.008–

1.102; p<0.001), sharing (odds: 1.157; 95% CI: 1.104–1.212; p<0.001) and without sanitary toilet (odds: 1.090; 95% CI: 1.060–1.120; p<0.001), high pollutant fuel (odds: 1.157; 95% CI: 1.124–1.191; p<0.001), lesser wealth index (odds: 1.289; 95% CI: 1.231–1.349; p<0.001), female child (odds: 1.177; 95% CI: 1.145–1.210; p<0.001), home delivery (odds: 1.223; 95% CI: 1.161–1.288; p<0.001) and North-east zone (odds: 1.448; 95% CI: 1.342–1.563; p<0.001) had highly significant effects on the birth weight of a new born (Table 2).

Discussion

The prevalence of LBW is one of the most significant measures of reproductive outcomes of intrauterine growth retardation, and determines the risks of mortality, morbidity and inadequate development and overall survival of newborns (Sen, Roy, Mondal 2010; Dey, Mondal, Dasgupta 2019; Khan, Mozumdar, Kaur 2020). The present investigation reports the existence of the newborn's birth weight variations among tribal and non-tribals populations in India, utilizing NFHS-4 data (2015–2016) (Table 1). The prevalence of LBW was significantly higher among the non-tribal groups than the tribal populations (p<0.001). Similarly, the mean birth weight was significantly higher among tribal than non-tribal populations (p<0.01) (Table 1). The sex-specific mean LBW was higher among females than males in both tribal and non-tribal populations (p<0.05). The overall prevalence of LBW was observed to be 13.5% and 17.2% among tribal and non-tribal populations, in India utilizing NFHS-4 (2015–16), respectively (Table 2). Interestingly, the present investigation showed that regions with a higher concentration of tribal populations had a lower prevalence of LBW, and higher magnitude of LBW observed among the non-tribal population in India. Thus, present study suggests that a lower prevalence of LBW among tribal than the non-tribal population in India, is attributed to community unity and rich indigenous knowledge, traditional healthcare practices, ethnomedicine use and cultural practices in population (Narwade, More 2018; Pushpangadan, George 2010).

Several researchers have reported that aside from the health concern, LBW is a socio-economic burden due to socio-economic inequality (Borah, Agarwalla 2016; Patale, Masare, Bansode 2018). They argue that an improvement in socio-economic status can provide better facilities such as nutritious food, electricity, appropriate sanitary facilities, improved education, which may act as a safeguard to the attainment of appropriate newborn's birth weight for future generations. Therefore, the wealth index is strongly associated with the LBW prevalence, which has lower odds of being LBW in the higher ranges of wealth indices (Table 3). The advent of electricity appears to be related to development and modernity, with the acquisition of lights and improvement as well as the better use of time and staying connected with the outside world on electronic media by another. It can be confirmed that electricity's presence does not influence the imminent newborn's birth weight directly, but influences with major determinants may be found very powerful to describe the biological outcome in a population. Tshotetsi et al. (2019) have reported that the absence of electricity independently increased the odds of being LBW in the South African population.

Table 3. Binary logistic regression analysis and association of socio-economic, demographic, lifestyle variables and LBW among tribal and non-tribal population in India

VARIABLES	CATEGORY	TRIBE						NONTRIBE					
		(B)	SE	Exp (B) odds	95% CI of ODDs	R^2	P value	(B)	SE	Exp (B) odds	95% CI of ODDs	R^2	P value
Type of residence	Rural	0.595	0.053	1.814	1.634 -2.013	0.010	<0.001	0.024	0.016	1.024	0.993-1.056	<0.001	0.131
	Urban (R)	-	-	-	-			-	-	-	-		
Religion	Hindu	1.008	0.040	2.741	2.534-2.964	0.048	<0.001	0.099	0.032	1.104	1.037-1.176	<0.001	<0.001
	Muslim	0.931	0.108	2.537	2.055-3.133			0.037	0.037	1.037	0.965-1.116		
	Others (R)	-	-	-	-			-	-	-	-		
Age of respondent at 1st birth	≤19 (R)					0.002	<0.001					<0.001	<0.001
	20-29	0.136	0.037	1.145	1.064-1.232			0.071	0.015	1.073	1.042-1.105		
	≥30	0.401	0.097	1.493	1.233-1.807			-0.02	0.043	0.981	0.901-1.067		
Anemia level #	Severe	0.836	0.152	2.307	1.713-3.106	0.008	<0.001	0.335	0.070	1.399	1.219-1.605	0.001	<0.001
	Moderate	0.416	0.054	1.516	1.364-1.685			0.149	0.021	1.161	1.113-1.210		
	Mild	0.354	0.040	1.424	1.318-1.539			0.045	0.015	1.046	1.015-1.078		
	Not anemic (R)	-	-	-	-			-	-	-	-		
Highest educational level	No education	0.999	0.093	2.715	2.262-3.259	0.020	<0.001	0.376	0.026	1.456	1.384-1.533	0.003	<0.001
	Primary	0.645	0.098	1.906	1.572-2.312			0.382	0.029	1.466	1.385-1.551		
	Secondary	0.367	0.092	1.443	1.205-1.729			0.240	0.024	1.272	1.213-1.333		
	Higher(R)	-	-	-	-			-	-	-	-		
Household has: electricity	No	0.343	0.053	1.410	1.271-1.563	0.003	<0.001	0.053	0.023	1.054	1.008-1.102	<0.001	0.020
	Yes (R)	-	-	-	-			-	-	-	-		

Type of toilet facility	Non-sanitary	0.662	0.039	1.938	1.796-2.091	0.021	<0.001	0.086	0.014	1.090	1.060-1.120	<0.001	<0.001
	Sanitary (R)	-	-	-	-			-	-	-	-		
Shared Toilet facilities ##	Yes	0.189	0.078	1.207	1.035-1.408	0.001	0.016	0.145	0.024	1.157	1.104-1.212	0.001	<0.001
	No (R)							-	-	-	-		
Type of cooking fuel	High pollutant	0.657	0.048	1.930	1.755-2.122	0.014	<0.001	0.146	0.015	1.157	1.124-1.191	0.001	<0.001
	Low pollutant (R)	-	-	-	-			-	-	-	-		
Wealth index	Poorest	1.078	0.088	2.940	2.476-3.490	0.025	<0.001	0.254	0.024	1.289	1.231-1.349	0.002	<0.001
	Poorer	0.675	0.090	1.964	1.646-2.344			0.232	0.023	1.261	1.206-1.319		
	Middle	0.515	0.093	1.674	1.396-2.007			0.180	0.023	1.197	1.144-1.252		
	Richer	0.165	0.101	1.179	0.968-1.438			0.156	0.023	1.169	1.117-1.224		
	Richest (R)	-	-	-	-			-	-	-	-		
Sex of child	Female	0.109	0.036	1.115	1.039-1.196	0.001	0.002	0.163	0.014	1.177	1.145-1.210	0.002	<0.001
	Male (R)	-	-	-	-			-	-	-	-		
Place of delivery	Home	0.141	0.048	1.151	1.049-1.264	0.001	0.003	0.201	0.026	1.223	1.161-1.288	0.001	<0.001
	Institution (R)	-	-	-	-			-	-	-	-		
Zone	Central	0.224	0.064	1.251	1.102-1.419	0.055	<0.001	-0.085	0.027	0.918	0.872-0.967	0.005	<0.001
	East	0.136	0.068	1.146	1.002-1.310			0.190	0.028	1.210	1.145-1.278		
	North	0.002	0.077	1.002	.863-1.165			-0.056	0.028	0.946	0.896-0.998		
	North-east	1.199	0.064	3.317	2.929-3.757			0.370	0.039	1.448	1.342-1.563		
	South	0.109	0.101	1.115	.915-1.360			0.158	0.030	1.172	1.105-1.243		
	West (R)	-	-	-	-			-	-	-	-		

821 (0.5%) cases are missing from data set; ##70317 (41.7%) cases are excluded from data set due to not having any toilet facility.

However, these types of research investigations are rare in the Indian context. In this study, it has been observed that tribal people mostly use high pollutant fuel (e.g., wood, coal, straw, grass) (75.3% vs. 63.7%) which may be due to the easier availability of these resources near their habitat. Interestingly, they also produce a lesser frequency of LBW babies than the non-tribal group (15.2% vs. 17.9%), possibly due to the overall prevalence of LBW, the number of babies are much higher among non-tribal compared to tribal groups (Table 2). Households using high polluting fuels find adverse in contrast with safer fuels, with increased chances of LBW in populations in already reported by other investigations (e.g., Pope et al. 2010; Milanzi, Namacha 2017). Biomass as fuel has released high levels of harmful chemicals, such as carbon dioxide, suspended particulate matter, ozone and formaldehyde, which are likely to penetrate into maternal blood and directly impact the foetus and may result in a rise in the risks of LBW (e.g., Glinianaia et al. 2004; Naeher et al. 2007).

Researchers have reported that maternal education has a protective effect on newborns birth weight. It is evident from the present study that lack of education has significantly increased the prevalence of LBW babies in both tribal and non-tribal populations ($p<0.01$). In this sense, tribal populations are more vulnerable to the better-educated mother than the non-tribal populations in India (Table 3). Similar findings reported in the case of a sanitary toilet facility, and its sharing with other households in non-tribal populations ($p<0.05$). The event of home delivery was remarkably high in both populations (Table 3). The total home delivery preferences were observed to be lower in the non-tribe group; meanwhile, the magnitude of LBW was observed to be higher among the non-tribe community. Perhaps the tribal's are more acquainted with prenatal care in their homes. Level of education seems to be a significant predictor of maternal nutrition and health status by taking wise decision while choosing food or eating habits and utilizations of healthcare facilities (Hassan et al. 2017; Bharali, Mondal 2021), although, some contradictory studies reported insignificant association in populations (Solanki et al. 2012; Noor et al. 2015). Several researchers have also reported that education increases the safe hygiene practices in communities (Dreibelbis et al. 2013; Padhi et al. 2015), which may prevent adverse pregnancy outcomes from infections or stress during pregnancy. A hospital-based study from sub-Saharan Africa has reported a higher risk of poor obstetrics outcome among babies born to mothers using shared sanitation facilities (e.g., Olusanya, Ofovwe 2010). Similarly, recent research investigation has reported a significant associations between sanitation, types and sources of drinking water and poor reproductive outcomes (i.e., preterm birth and LBW) among women in India (Baker et al. 2018; Patel et al. 2019). Moreover, mother's education influences them to choose the right place of delivery, which may not directly affect the variation of birth weight, but may be due to enriched medical facilities and the skilled help of the health worker during the delivery crisis.

The analysis of the demographic factors showed that the urban populations found to have many benefits, such as better access to healthcare services, which may support a healthier child and proper antenatal and natalcare in comparison to the rural population. However, in rural non-tribal people, the LBW prevalence is higher than in a rural population. In the present investigation, most of the mothers in both the non-tribal and tribal groups (96.7% and 89.6%, respectively) believed in the Hindu religion and comparison, with Muslim and other religious believes, and Hindu mother experiencing higher LBW newborns. Moreover, this could be attributed to a particular religion having some significance in various cultural practices, which in turn may affect the newborn's birth weight. Previously reported studies are in support of the present investigation that maternal religious attendance was found to have protection against LBW (Burdette et al. 2012; Shahnawaz et al. 2014). However, several investigations have reported inconsistency in the population (Van Den Oord, Rowe 2001; Khatun, Rahman 2009). There are plenty of studies in which the effect of maternal age (i.e. their chronological age) has ascertained the associations with birth weight. However, in Indian literature, the effect of age at first childbirth of mother is uncommon. Further, height and pelvic dimensions are almost complete by two years after menarche, which supports the importance of low maternal age at first birth as an exposure. A recent study conducted in the USA has indicated that at first births the increased risk of adverse pregnancy and birth outcomes are more prevalent among the women of young and advanced maternal ages (Schummers et al. 2019). This research has a conflicting impact between tribal and non-tribal populations, based on the influence of mother's age at first birth on birth weight. Elevated maternal age has a negative effect on the birth weight of the newborn in non-tribal communities, but it does not work for the tribal population in India. Anaemia is one of the most prominent haematological predictors of gestational complications and adverse birth outcomes. Earlier studies have reported that maternal anaemia has remarkable effects on birth weight of a child (Figueiredo et al. 2018; Kumari et al. 2019), which is supported by this investigation results that higher odds of having LBW is assistance by the severe anaemic mother both tribal and non-tribal population (Table 3).

Conclusion

The tribal population of India is predominantly inhabited in mostly rural and remote areas. Despite being most disadvantaged, oppressed and showed higher mean birth weight, the tribal population exhibits a lesser prevalence of LBW and played a better role in sex ratio and a higher percentage of birth of girl child in comparison to the non-tribal population in India. Home deliveries are preferable for the tribal population, and the LBW prevalence was lower than the non-tribes population because of their rich traditional healthcare practices. Therefore, neonatal and post-natal care should be improved immensely in the tribal population in order to reduce neonatal mortality and morbidity, which may be due to higher household deliveries performed in population. The analysis of socio-economic status and perceptions towards hygiene and better lifestyle acquired by educational upliftment have been found to have an equally positive impact on birth weight of newborn on both tribal and non-tribal populations. Prevalence of LBW among the tribes was observed to be lower than the overall scenario of the country but still has found to be an alarming situation. Therefore, an appropriate healthcare intervention and awareness programme are necessary to improve the existing LBW statistics among tribal as well as the non-tribal population as well as enhance the overall child health scenario.

Acknowledgement

Authors are gratefully acknowledging the authorities of Demographic and Health Surveys (DHS) Program for providing the dataset.

Conflict of interests

The authors have no conflicts of interest to declare.

Authors' contribution

Conceptualised and designed by SD and NM. Analysed the data by SD. Wrote the paper by SD and NM. Revised and finalised the manuscript by SD, NM and KB.

Funding

No funding is required for this investigation.

Corresponding author

Dr. Sima Dey, Guest Faculty, Sports Authority of India, Netaji Subhas National Institute of Sports, Patiala, India; Email: simadey.cu@gmail.com

References

Abraham M, Alramadhan S, Iniguez C, Duijts L, Jaddoe VW, Den Dekker HT et al. 2017. A systematic review of maternal smoking during pregnancy and fetal measurements with meta-analysis. PLoS ONE 12(2):e0170946, https://doi.org/10.1371/journal.pone.0170946

Anderson I, Robson B, Connolly M, Al-Yaman F, Bjertness E, King A. et al. 2016. Indigenous and tribal peoples' health (The Lancet-Lowitja institute global collaboration): A population study. Lancet 388(10040):131–157, https://doi.org/10.1016/S0140-6736(16)00345-7

Azcorra H, Mendez N. 2018. The influence of maternal height on offspring's birth weight in Merida, Mexico. Am J Hum Biol 1-7, https://doi.org/10.1002/ajhb.23162

Baker KK, Story WT, Walser-Kuntz E, Zimmerman MB. 2018. Impact of social capital, harassment of women and girls, and water and sanitation access on premature birth and low infant birth weight in India. PLoS One 13(10):e0205345, https://doi.org/10.1371/journal.pone.0205345

Bharali N, Mondal N. 2021. Association of Age at Marriage, Early childbearing, Use of contraceptive Methods and Reproductive Health Consequences among Mishing tribal women of Assam, Northeast India. The Online Journal of Health and Allied Sciences 20(3):2, https://www.ojhas.org/issue79/2021-3-2.html

Borah M, Agarwalla R. 2016. Maternal and socio-demographic determinants of low birth weight (LBW): A community-based study in a rural block of Assam. J Postgrad Med 62(3):178–181, https://doi.org/10.4103/0022-3859.184275

Burdette AM, Weeks J, HillIsaac TD, Eberstein W. 2012. Maternal religious attendance and low birth weight. Soc Sci Med 74(12):1961–7, https://doi.org/10.1016/j.socscimed.2012.02.021

Das S, Ghritlahre M, Siddiqui A, Meitei KS. 2020. Nutritional status of Hill Korwa preschool children of Jashpur: A particularly vulnerable tribal group of Chhattisgarh. Blde Univ J Health Sciences 5(1):20–25.

Dey S, Mondal N, Dasgupta P. 2019. Head Circumference and Birth Length as Predictor of Low Birth Weight among Bengali Hindu Population of Kolkata, West Bengal, India. J. Clin. Diagn. Res 13(8):LC01–LC05, https://doi.org/10.7860/JCDR/2019/39757.13043

Dreibelbis R, Winch PJ, Leontsini E, Hulland KR, Ram PK, Unicomb L et al. 2013. The Integrated Behavioural Model for Water, Sanitation, and Hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. BMC Public Health 26(13):1015, https://doi.org/10.1186/1471-2458-13-1015

Figueiredo A, Gomes-Filho IS, Silva RB, Pereira P, Mata F, Lyrio AO et al. 2018. Maternal Anemia and Low Birth Weight: A Systematic Review and Meta-Analysis. Nutrients 10(5):601, https://doi.org/10.3390/nu10050601

Glinianaia SV, Rankin J, Bell R, Pless-Mulloli T, Howel D. 2004. Particulate air pollution and fetal health: a systematic review of the epidemiologic evidence. Epidemiology 15(1):36–45, https://doi.org/10.1097/01.ede.0000101023.41844.ac

Haldre K, Rahu K, Karro H, Rahu M. 2007. Is a poor pregnancy outcome related to young maternal age? A study of teenagers in Estonia during the period of major socio-economic changes (from 1992 to 2002). Eur J Obstet Gynecol Reprod Biol 131:45–51, https://doi.org/10.1016/j.ejogrb.2006.05.002

Hassan F, Asim M, Salim S, Humayun A. 2017. House ownership, frequency of illness, fathers' education: the most significant socio-demographic determinants of poor nutritional status in adolescent girls from low income households of Lahore, Pakistan. Int j equity health 16:122, https://doi.org/10.1186/s12939-017-0621-z

International Institute of Population Sciences. 2017. National family health survey (NFHS-4) 2015–16. Mumbai [accessed on July 13 2020]. Available from: http://rchiips.org/NFHS/NFHS-4Reports/India.pdf

Jose JA, Sarkar S, Kumar SG, Kar SS. 2014. Utilization of maternal health-care services by tribal women in Kerala. J Nat Sc Biol Med 5(1):144–147, https://doi.org/10.4103/0976-9668.127314

Kataoka MC, Carvalheira APP, Ferrari AP, Malta MB, Carvalhaes MABL, Parada CMGL. 2018. Smoking during pregnancy and harm reduction in birth weight: a cross-sectional study. BMC Pregnancy and Childbirth 18:67, https://doi.org/10.1186/s12884-018-1694-4

Khan N, Mozumdar A, Kaur S. 2020. Determinants of low birth weight in India: An investigation from the National Family Health Survey. Am J Hum Biol 32(3):e23355, https://doi.org/10.1002/ajhb.23355

Khatun S, Rahman M. 2009. Socio-economic determinants of LBW in Bangladesh. A multivariate approach. Bangladesh Med Res Counc Bull 34(1):81–86, https://doi.org/10.3329/bmrcb.v34i3.1857

Kshatriya GK, Acharya SK. 2016. Triple Burden of Obesity, Undernutrition, and Cardiovascular Disease Risk among Indian Tribes. PLoS One 11(1):e0147934, https://doi.org/10.1371/journal.pone.0147934

Kumar MM, Pathak VK, Ruikar M. 2020. Tribal population in India: A public health challenge and road to future. J Family Med Prim Care 9(2):508–512, https://doi.org/10.4103/jfmpc.jfmpc_992_19

Kumari S, Garg N, Kumar A, Guru P, Ansari S, Anwar S et al. 2019. Maternal and severe anaemia in delivering women is associated with risk of preterm and low birth weight: A cross sectional study from Jharkhand, India. Pols One Health. 8:100098, https://doi.org/10.1016/j.onehlt.2019.100098

Lunde A, Melve KK, Gjessing HK, Skjærven R, Irgens LM. 2007. Genetic and environmental influences on birth weight, birth length, head circumference, and gestational age by use of population-based parent-offspring data. Am J Epidemiol 165:734–741, https://doi.org/10.1093/aje/kwk107

Maiti S, Ghosh D, Paul S 2012. Determinants of Nutritional Status among Tribal Adolescent in Girls Paschim Medinipur District of West Bengal. IJPM 3(4):298–299.

Mallia T, Grech A, Hili A, Calleja-Agius J, Pace NP. 2017. Genetic determinants of low birth weight. Minerva Ginecol 69(6):631–643, https://doi.org/10.23736/S0026-4784.17.04050-3

Martinson ML, Reichman NE. 2016. Socioeconomic Inequalities in Low Birth Weight in the United States, the United Kingdom, Canada, and Australia. Am. J. Public Health 106(4):748–754, https://doi.org/10.2105/AJPH.2015.303007

Metgud CS, Naik VA, Mallapur MD. 2012. Factors Affecting Birth Weight of a Newborn – A Community Based Study in Rural Karnataka, India. PLoS ONE 7(7):e40040, https://doi.org/10.1371/journal.pone.0040040

Ministry of Health & Family Welfare and Ministry of Tribal Affairs. 2018. Report of the expert committee on tribal health, tribal health in India: Bridging the gap and roadmap for the future-Policy brief [accessed on August 14, 2020]. Available from: http://nhsrcindia.org/news/report-expert-committee-tribal-health

Ministry of Tribal Affairs. 2018. Report of the high-level committee on socio-economic, health and educational status of tribal communities of India [accessed on August 14, 2020]. Available from: http://www.indiaenvironmentportal.org.in/files/file/Tribal%20Committee%20Report,%20May-June%202014.pdf

Milanzi EB, Namacha NM. 2017. Maternal biomass smoke exposure and birth weight in Malawi: Analysis of data from the 2010 Malawi Demographic and Health Survey. Malawi Med J 29(2):160–165, https://doi.org/10.4314/mmj.v29i2.16

Moosan H, Stanley A, Prabhakaran AO, Vijayakumar K, Jayasree AK, Gopakumar S. 2019. Comparison of Health-care Utilization Pattern and its Correlates among the Tribal and NonTribal Population of Kerala. Indian J Community Med 44(1):S57–S61, https://doi.org/10.4103/ijcm.IJCM_46_19

Mondal N, Dey S, Sen J. 2018. Maternal age, birth order and Seasonal variation on the prevalence of Low Birth Weight in West Bengal India. J Life Sci 10(1):1–9, https://doi.org/10.31901/24566306.2018/10.01.221

Mumbare SS, Rege R. 2011. Ante natal care services utilization, delivery practices and factors affecting them in tribal area of north Maharashtra. Indian J Community Med 36(4):287–90, https://doi.org/10.4103/0970-0218.91331

Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ et al. 2007. Wood smoke health effects: a review. Inhal Toxicol 19(1):67–106, https://doi.org/10.1080/08958370600985875

Narain JP. 2019. Health of tribal populations in India: How long can we afford to neglect?. Indian Journal of Medical Research 149(3):313–316, https://doi.org/10.4103/ijmr.IJMR_2079_18

Narwade RG, More UB. 2018. Comparative study of birth weight in newborns in tribal and non-tribal area in Marathwada region of Maharashtra, India. Indian J Obstet Gynecol Res 5(4):496–499, https://doi.org/10.18231/2394-2754.2018.0112

NFHS-4 (2015–16). National Family Health Survey. International Institute for Population Sciences Deonar, Mumbai 400 088. Retrieved from http://rchiips.org/NFHS/ NFHS-4Reports/India.pdf on August 2, 2020.

Niswade A, Zodpey SP, Ughade S, Bangdiwala SI. 2011. Neonatal morbidity and mortality in tribal and rural communities in central India. Indian J Community Med 36(2):150–158, https://doi.org/10.4103/0970-0218.84137

Noor N, Kural M, Joshi T, Pandit D, Patil A. 2015. Study of maternal determinants influencing birth weight of newborn. Arch Med Health Sci 3(2):239–243, https://doi.org/10.4103/2321-4848.171912

Office of Registrar General & Census Commissioner India. CensusInfo. Ministry of Home Affairs, Government of India. 2011 [accessed on August 14, 2020]. Available from: http://www.censusindia.gov.in/2011census/HLO/HH14.html

Olson ME, Diekema D, Elliott BA, Renier CM. 2010. Impact of income and income inequality on infant health outcomes in the United States. Pediatrics 126:1165–1173, https://doi.org/10.1542/peds.2009-3378

Olusanya BO, Ofovwe GE. 2010. Predictors of preterm births and low birthweight in an inner-city hospital in sub-Saharan Africa. Matern. Child Health J. 14(6):978–986, https://doi.org/10.1007/s10995-009-0528-4

Padhi BK, Baker KK, Dutta A, Cumming O, Freeman MC, Satpathy R. 2015. Risk of Adverse Pregnancy Outcomes among Women Practicing Poor Sanitation in Rural India: A Population-Based Prospective Cohort Study. PLoS Medicine 12(7):e1001851, https://doi.org/10.1371/journal.pmed.1001851

Papazian T, Abi Tayeh G, Sibai D, Hout H, Melki I, Khabbaz RL. 2017. Impact of maternal body mass index and gestational weight gain on neonatal outcomes among healthy Middle-Eastern females. PLoS ONE. 12(7):e0181255, https://doi.org/10.1371/journal.pone.0181255

Patale PJ, Masare MS, BansodeGokhe SS. 2018. A study of epidemiological co relates of low birth weight babies born in tertiary care hospital. Int J Res Med Sci 6:1006–10, https://doi.org/10.18203/2320-6012.ijrms20180631

Patel R, Gupta A, Chauhan S, Bansod DW. 2019. Effects of sanitation practices on adverse pregnancy outcomes in India: a conducive finding from recent Indian demographic health survey. BMC Pregnancy Childbirth 19(1):378, https://doi.org/10.1186/s12884-019-2528-8

Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M et al. 2010. Risk of Low Birth Weight and Stillbirth Associated With Indoor Air Pollution From Solid Fuel Use in Developing Countries. Epidemiol Rev 32(1):70–81, https://doi.org/10.1093/epirev/mxq005

Pushpangadan P, George V. 2010. Ethnomedical practices of rural and tribal populations of India with special reference to the mother and child care. IJTK 9(1):9–17.

Rao KM, Balakrishna N, Laxmaiah A, Venkaiah K, Brahmam GN. 2016. Diet and nutritional status of adolescent tribal population in nine states of India. Asia Pac J Clin Nutr 15(1):64–71.

Ravikumar K, Rajeshkannan B. 2016. A descriptive study of maternal risk factors in term Babies with IUGR, IOSR. IJSRDMS 15(12):48–51.

Schempf AH, Branum AM, Lukacs SL, Schoendorf KC. 2007. Maternal age and parity-associated risks of preterm birth: differences by race/ethnicity. Paediatr Perinat Epidemiol 21:34–43, https://doi.org/10.1111/j.1365-3016.2007.00785.x

Schummers L, Hacker MR, Williams PL, Hutcheon JA, Vanderweele TJ, McElrath et al. 2019. Variation in relationships between maternal age at first birth and pregnancy outcomes by maternal race: a population-based cohort study in the United

States. BMJ Open 9(12):e033697, https://doi.org/10.1136/bmjopen-2019-033697

Sen J, Roy A, Mondal N. 2010. Association of maternal nutritional status, body composition and socio-economic variables with low birth weight in India. J Trop Pediatr 56(4):254–259, https://doi.org/10.1093/tropej/fmp102

Shahnawaz K, Choudhary SK, Sarker G, Das P, Pal R, Kumar L. 2014. Association between maternal socio-demographic factors and low birth weight newborn in a rural area of Bihar, India. Southeast Asian J Trop Med Public Health 4(1):30–34, https://doi.org/10.3329/seajph.v4i1.21836

Singh RK, Kumar A, Singh A, Singhal P. 2020. Evidence that cultural food practices of Adi women in Arunachal Pradesh, India, improve social-ecological resilience: insights for Sustainable Development. Ecological Processes 9:29, https://doi.org/10.1186/s13717-020-00232-x

Solanki N, Kavishwar A, Chaudhari V, Chhasatiya N. 2012. The effect of maternal anthropometric characteristics and social factors on birth weight of child in small town hospital of dandevi block of Navsari district. Int J Med Sci Public Health 1(2):32–37, https://doi.org/10.5455/ijmsph.2012.1.32-37

Talie A, Taddele M, Alemayehu M. 2019. Magnitude of Low Birth Weight and Associated Factors among Newborns Delivered in Dangla Primary Hospital, Amhara Regional State, Northwest Ethiopia. 2017. J Pregnancy Article. ID 3587239, 6 pages, https://doi.org/10.1155/2019/3587239

Thakre SB, Thakre SS, Kaware AC, Adikane H. 2018. Original Research Article Predictors of low birth weight babies born in tribal tertiary health care setting: a cross sectional study. Int J Community Med Public Health 5(7):3049–3055, https://doi.org/10.18203/2394-6040.ijcmph20182647

Toshniwal S, Toshniwal P, Bhabhor N, Bhabhor A, Chaudhary R. 2017. A community based cross sectional study on the prevalence of low birth weight neonates and maternal factor responsible for the low birth weight. Asian Pac J Health Sci 4(3):239–244, https://doi.org/10.21276/apjhs.2017.4.3.36

Tshotetsi L, Dzikiti L, Hajison P, Feresu S. 2019. Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. PloS one 14(3):e0213058, https://doi.org/10.1371/journal.pone.0213058

Van Den Oord EJCG, Rowe DC. 2001. A step in another direction looking for maternal genetic and environmental effects on racial differences in birthweight. Demography 38(4):573-6, https://doi.org/10.2307/3088321, https://doi.org/10.1353/dem.2001.0040

WHO 2004. International statistical classification of diseases and related health problems, tenth revision, 2nd ed. World Health Organization.

Zhang Y, Yu C, Wang L. 2017. Temperature exposure during pregnancy and birth outcomes: An updated systematic review of epidemiological evidence. Environ Pollut 225:700–712, https://doi.org/10.1016/j.envpol.2017.02.066

Notes for Authors

The Anthropological Review is the official journal of the Polish Anthropological Society, founded by Adam Wrzosek in 1926. It succeeds the Przegląd Antropologiczny (1926–2000; vols. 1–63) and Przegląd Antropologiczny – Anthropological Review (2001–2006; vols. 64–69), and it is abstracted in: Index Copernicus (Medical Science Int.), IBSS: International Bibliography of the Social Sciences (LSE), SCOPUS (Elsevier), Zoological Record (Thomson Reuters).

Open access to the journal is via https://czasopisma.uni.lodz.pl/ar/index. Anthropological Review comes out four times a year in print and online. It publishes peer-reviewed papers from physical anthropology and related disciplines, including: biology, ecology, human auxology, population genetics, bio-demography and bio-archeology. The journal accepts original research reports, overview articles, literature reviews and meta-analyses, short notes and communications and book reviews.

Submission of a paper to Anthropological Review implies that the paper is not being considered for publication elsewhere. The paper (in English) should be prepared in accordance with the instruction for authors and submitted electronically by https://czasopisma.uni.lodz.pl/ar/index.

Each submission should be accompanied by a cover letter, and the istructions can be downloaded from https://czasopisma.uni.lodz.pl/ar/index.

Preliminary accepted articles are subject to evaluation by two anonymous reviewers and, where appropriate, by the Statistical Advisor. The principle of double-blinded reviewing applies with names of both the authors and reviewers concealed. The reviews received, including Editors' comments, are forwarded to the Author as PDF documents. Author's revisions must be in PDF format within the deadline set by the journal Editors. The corrected version will be re-evaluated where nessesary, and the Editors will notify the Author whether the article has been accepted for publication.

The Editors' correspondence is conducted by e-mail. Editorial corrections are permitted to authors only in substantial matters and the Editors reserve the right to make necessary corrections and shortenings without the authors' prior consent. The Editors may refuse article publication following consultation with Editorial Board members.

Material accepted for publication becomes the property of the Editors and may not be published in whole or in part in other journals without prior written consent.

Initiating Editor: Katarzyna Smyczek
Language Editor: Arthur Saniotis, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences
Technical Editor: Anna Jakubczyk
Typesetting: Munda – Maciej Torz
Cover design: Tomasz Kasperczyk
Adjusting the cover design: Monika Rawska
Cover photos: stock.adobe.com/klevo; stock.adobe.com/adimas

Łódź University Press
90-237 Łódź, ul. Jana Matejki 34A
www.wydawnictwo.uni.lodz.pl
e-mail: ksiegarnia@uni.lodz.pl
tel. 42 635 55 77