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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Stable C, N Isotopes in Human Skeletal Material from the Great Moravian Burial Site at Mikulčice-Kostelisko

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The Great Moravian burial site at Mikulčice-Kostelisko is the largest such site in the subcastle of the Mikulčice power centre, which was one of the main centres of the Great Moravian empire. Analysis of stable C, N isotopes from bone collagen was conducted in 10 skeletons. The skeletons of the Mikulčice burial site (N=10) contain the following range of stable nitrogen isotopes in their bone collagen (δ ^{15}N + 8.8 to 12.5 ‰, with an average of 10.72 ± 1.17 ‰) and of stable carbon isotopes (δ ^{13}C -17.8 to -19.6 ‰, with an average of -18.89 ± 0.5 ‰). During analysis of the stable C, N isotopes from ten skeletons of the Mikulčice burial site, significant social differences were discovered. The averages of stable carbon isotopes in skeletons from rich graves (N-8) (-18.76± 0.46 ‰) are greater than those from poor graves (N- 2) (-19. 42±0.30 ‰) (p= 0.0307) according to Stloukal´s categorisation of grave goods. On comparing the mean values of the group 2 rich graves (N-5) according to Hrubý and those of the united groups 3,4,5 of poor graves (N-5), the stable nitrogen isotopes (δ^{15}N 11.38 ± 0.82 ‰) in rich graves are higher than in the groups of poor graves (δ^{15}N 10.07 ± 1.15 ‰) (p= 0.117). Wealth meant a greater intake of the much-favoured millet (C4 of the photosynthetic cycle) and more meat in the diet.

Key words: Great Moravian population – stable C, N isotopes – skeletal remains – social status – diet

1. Introduction

The stable C,N isotopes were analysed in skeletons from the Slavic burial site at Mikulčice-Kostelisko (Poláček/Marek 1995) with the aim of reconstructing the diet of the given population and of attempting to distinguish social differences on the basis of the organic bone component-collagen. Collagen contains both amino acids produced in the body as well as essential acids acquired from food, predominantly meat. It is thus the most suitable material for reflecting the diet of the objects studied.

2. Method and materials

Human skeletons: Samples of ribs were taken from the skeletons of males (N-5) and females (N-5) from the Mikulčice burial site deposited at the National Museum. These were used to analyse the stable ^{13}C, ^{12}C and ^{15}N, ^{14}N isotopes from the organic component of collagen (Katzenberg 2008; Smrčka 2005).

Samples were taken from grave 1605 (woman 20-25 years), grave 1648 (woman 20-30 years), grave 1742 (woman 20-25 years), grave 1777A (woman 30-40 years), grave 1973 (woman 40-60 years), grave 1809 (man 40-50 years), grave 1861

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Table 1. Summary of the ratios of carbon and nitrogen isotopes in the analysed skeletons from the Slavic burial site at Mikulčice-Kostelisko (with determination of sex and grave equipments according to Stloukal and Hrubý).

sample	N%	C%	C/N	δ15N (‰)	δ13C (‰)	sex	classif. Stloukal (1970)	classif. Hrubý (1955)
Mikulčice-Kostelisko, grave No. 1605 (Inv.No.16799)	5.3	19.5	3.7	11.4	-19.6	female	2	5
Mikulčice-Kostelisko, grave No. 1648, (Inv.No.16831)	11.4	34.9	3.1	10.8	-18.8	female	1	4
Mikulčice-Kostelisko, grave No. 1742, (Inv.No.16889)	9.9	28.6	2.9	11.7	-18.9	female	1	2
Mikulčice-Kostelisko, grave No.1777A (Inv.No.16902)	9.9	28.4	2.9	8.8	-19.2	female	1	3
Mikulčice-Kostelisko, grave No. 1973 (Inv.No.17034)	4.2	12.7	3.0	10.4	-17.8	female	1	4
Mikulčice-Kostelisko, grave No. 1809 (Inv.No.16923)	4.9	14.5	3.0	10.8	-18.4	male	1	2
Mikulčice-Kostelisko, grave No. 1861 (Inv.No.16951)	6.1	18.2	3.0	9.0	-19.2	male	2	4
Mikulčice-Kostelisko, grave No. 1908 (Inv.No. 16998)	13.3	37.8	2.8	11.6	-18.8	male	1	2
Mikulčice-Kostelisko, grave No. 1975 (Inv.No.17031)	4.2	13.1	3.1	12.5	-19.1	male	1	2
Mikulčice-Kostelisko, grave No. 1912 (Inv.No.17167)	7.4	22.0	3.0	10.3	-19.2	male	1	2

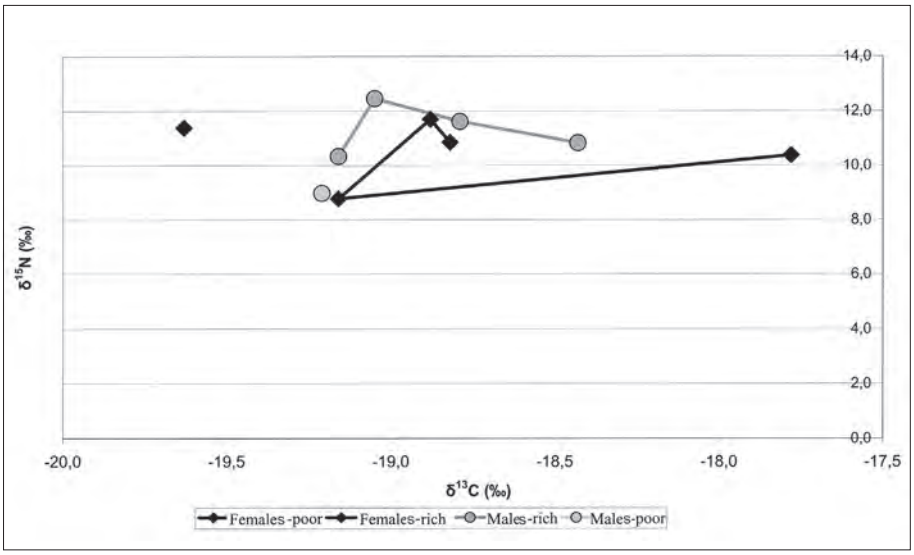
(man 20-30 years), grave 1908 (man 40-50 years), grave 1975 (man 50-60 years) and grave 1912 (man 40-50 years) (Velemínský et al. 2005).

Categorisation of grave goods according to Stloukal (1970) (1= rich graves, 2 = poor graves) and according to V. Hrubý (1955) (1, 2 = rich graves; 3, 4, 5 = poor graves) was used to distinguish the social differences at the burial site.

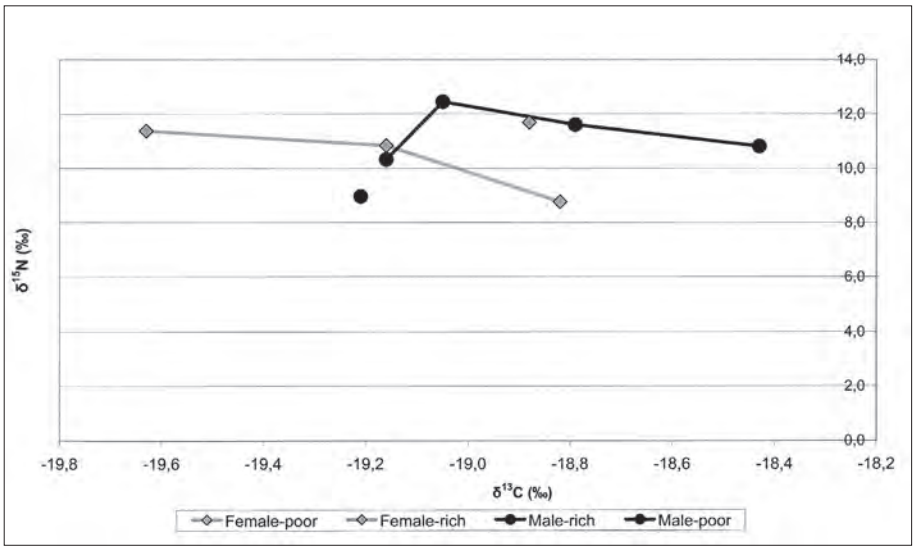
2.1 Processing of samples

For reliable isotope analysis, it is essential to preserve the isotopic composition of the initial organic carbon and nitrogen, and to remove foreign and inorganic material. The well-established method, also used for radiocarbon dating (Stafford/Brendel/Duhamel 1988), was used. Bone samples were broken down to a size of below 1 cm and first cleaned using ultrasound in distilled water. The fragments were then dried at a temperature of 50°C, homogenised to a size of < 63µm and extracted using methanol and water. The remaining material was mineralised (to remove carbonate compounds) using 4°C 0.5N HCl at a constant pH, rinsed with distilled water and again dried at 50°C. Alkalic soaking of samples was avoided in order to minimise collagen losses.

The elemental composition of samples, i.e. the content of carbon and nitrogen and the analysis of $\delta^{13}C$ and $\delta^{15}N$, was determined. Analysis was conducted using standard procedures for this type of material – upon burning the collagen in an elemental analyser (Fisons 1108), the resulting products are chromatographically divided into nitrogen and carbon dioxide and analysed in the Mat 251 isotope mass spectrometer by comparing these with reference gases of known isotopic composition. The whole process is controlled with the aid of international reference materials NBS 22 (NIST USA, $\delta^{13}C$ - 29,75‰) and NZ 1, NZ 2 (IAEA Vienna $\delta^{15}N$ 0 and 20‰).



Graph 1. Ratios of carbon and nitrogen isotopes in the skeletons from the Slavic burial site at Mikulčice-Kostelisko, differentiated by sex and grave goods according to Stloukal 1970.



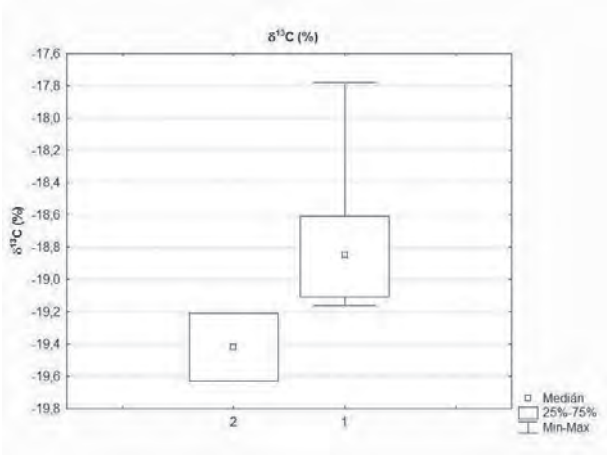
Graph 2. Rations of carbon and nitrogen isotopes in the skeletons from the Slavic burial site at Mikulčice-Kostelisko differentiated by sex and grave goods according to Hrubý 1955.

The sample size was optimised so that the error of measurement did not exceed 0.15‰. The measured data are listed in Table 1.

3. Results

3.1 Reconstruction of diet with the aid of carbon and nitrogen isotopes.

The skeletons from the Mikulčice burial site (N = 10) have the following range of stable nitrogen isotopes in their bone collagen ($\delta^{15}N$ + 8.8 to 12.5‰, with an average of 10.72 ± 1.17‰) and of stable carbon isotopes ($\delta^{13}C$ - 17.8 to - 19,6‰, with an average of - 18.89 ± 0.5‰). This is a population mainly dependent on inland plants of the C3 photosynthesis type (wheat),



Graph 3. Ratios of carbon isotopes in the skeletons of rich (1) and poor (2) graves from the Slavic burial site at Mikulčice-Kostelisko according to Stloukal's garniture of grave goods.

Table 2. Descriptive statistics with arithmetic averages, standard deviations of the ratios of carbon and nitrogen isotopes in five female (F= female) and five male (M = male) and the whole analysed group from the Slavic burial site at Mikulčice-Kostelisko.

Sex	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ^{15}N (%) Means	δ^{15}N (%) Std Dev.	δ^{13}C (%) Means	δ^{13}C (%) Std Dev.
F	35.0	5	8.13	3.16	24.79	8.69	3.11	0.34	10.61	1.15	-18.85	0.68
M	41.0	5	7.19	3.63	21.13	9.94	2.96	0.11	10.84	1.32	-18.93	0.32
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 2a. Comparison of the mean ratios of carbon and nitrogen isotopes according to sex in five female (F= female) and five male (M = male) using the T-test and non-parametric Mann- Whitney test.

	Mean F	Mean M	Std. Dev. F	Std.Dev. M	Std. Dev. F	Number M	t	sv	p	F-rate variance	p variance	Z	M-Wh p	Stat. signif.
N%	8.13	7.19	3.16	3.63	5	5	0.43	8	0.675	1.32	0.797	0.31	0.754	
C%	24.79	21.13	8.69	9.94	5	5	0.62	8	0.552	1.31	0.800	0.52	0.602	
C/N	3.11	2.96	0.34	0.11	5	5	0.93	8	0.378	10.29	0.044	0.63	0.531	
δ^{15}N (%)	10.61	10.84	1.15	1.32	5	5	-0.29	8	0.780	1.32	0.794	-0.10	0.917	
δ^{13}C (%)	-18.85	-18.93	0.68	0.32	5	5	0.22	8	0.832	4.46	0.177	0.00	1.000	

Table 3. Descriptive statistics with arithmetic averages, standard deviations of the ratios of carbon and nitrogen isotopes in the bones of eight rich (1) and two poor (2) graves from the burial site at Mikulčíce-Kostelisko according to Stloukal´s garniture of grave goods.

Group "Stloukal 1970"	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ^{15}N (%) Means	δ^{15}N (%) Std. Dev.	δ^{13}C (%) Means	δ^{13}C (%) Std Dev.
1	40.6	8	8.15	3.49	23.99	9.91	2.96	0.11	10.86	1.11	-18.76	0.46
2	27.5	2	5.73	0.57	18.83	0.89	3.34	0.52	10.18	1.70	-19.42	0.30
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 3a. Comparison of mean values of the ratios of carbon and nitrogen isotopes using the T- test and Mann- Whitney test in the skeletons divided according to Stloukal´s garniture of grave goods into rich (1) and poor (2). Between groups 1 and 2, there is a significant relationship for δ^{13}C (at a 5% level of significance).

	Mean 2	Mean 1	Std. Dev. 2	Std. Dev. 1	Number 2	Number 1	t	sv	p	F-rate variance	p variance	Z	M-Wh p	stat. signif.
N%	5.73	8.15	0.57	3.49	2	8	-0.94	8	0.376	37.11	0.252	-0.52	0.602	
C%	18.83	23.99	0.89	9.91	2	8	-0.70	8	0.501	123.67	0.138	-0.52	0.602	

	Mean 2	Mean 1	Std. Dev. 2	Std. Dev. 1	Number 2	Number 1	t	sv	p	F-rate variance	p variance	Z	M-Wh p	stat. signif.
C/N	3.34	2.96	0.52	0.11	2	8	2.27	8	0.053	22.80	0.004	1.04	0.296	
δ15N (%)	10.18	10.86	1.70	1.11	2	8	-0.72	8	0.492	2.34	0.339	-0.52	0.602	
δ13C (%)	-19.42	-18.76	0.30	0.46	2	8	-1.88	8	0.097	2.42	0.919	-2.09	0.037	5%

Table 4. Descriptive statistical characteristics of the ratios of C,N isotopes in groups of skeletons at the burial site, divided into groups 1-5 (2.-rich, 3,4,5 poor graves) according to Hrubý´s garniture of grave goods.

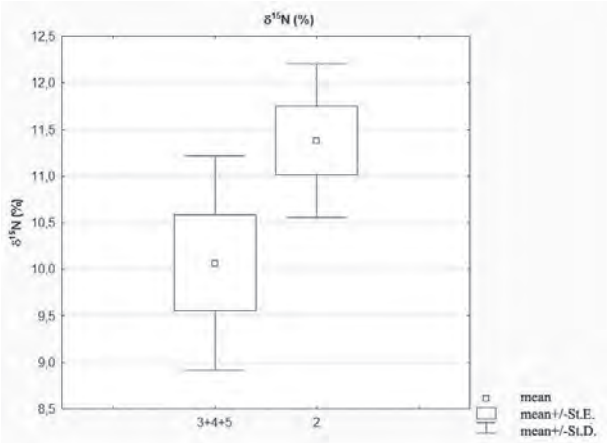
Group "Hrubý 1955"	Age-means	N% N	N% Means	N% Std Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ^{15}N (%) Means	δ^{15}N (%) Std. Dev.	δ^{13}C (%) Means	δ^{13}C (%) Std. Dev.
2	41.0	5	7.94	3.74	23.20	10.25	2.94	0.11	11.38	0.82	-18.86	0.28
3	42.5	1	9.88	0.00	28.35	0.00	2.86	0.00	8.77	0.00	-19.16	0.00
4	35.0	3	7.24	3.73	21.93	11.52	3.02	0.07	10.06	0.97	-18.60	0.74
5	27.5	1	5.32	0.00	19.46	0.00	3.70	0.00	11.38	0.00	-19.63	0.00
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 5. Descriptive statistical characteristics of the ratios of C,N isotopes in the groups of rich (2) and merged poor (3,4,5) skeletons differentiated according to Hrubý´s grave goods at the Mikulčice-Kostelisko burial site.

Mod. classif. "Hrubý 1955"	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ^{15}N (%) Means	δ^{15}N (%) Std. Dev.	δ^{13}C (%) Means	δ^{13}C (%) Std. Dev.
3+4+5	35.0	5	7.39	3.10	22.72	8.80	3.13	0.33	10.07	1.15	-18.92	0.70
2	41.0	5	7.94	3.74	23.20	10.25	2.94	0.11	11.38	0.82	-18.86	0.28
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 5a. Comparison of mean values of the ratios of carbon and nitrogen isotopes using the T-test and Mann- Whitney test in skeletons differentiated according to Hrubý´s garniture of grave goods as poor (3,4,5) and rich (2). Between groups 3,4,5 and group 2, there is a significant relationship for δ^{15}N (at a 10% level of significance).

	Mean 3+4+5	Mean 2	Std. Dev. 3+4+5	Std. Dev. 2	Number 3+4+5	Number 2	t	sv	p	F-rate variance	p variance	Z	M-Wh p	Stat. signif.
N%	7.39	7.94	3.10	3.74	5	5	-0.25	8	0.806	1.46	0.724	-0.10	0.917	
C%	22.72	23.20	8.80	10.25	5	5	-0.08	8	0.939	1.36	0.774	-0.31	0.754	
C/N	3.13	2.94	0.33	0.11	5	5	1.16	8	0.279	8.94	0.057	1.04	0.296	10%
δ^{15}N (%)	10.07	11.38	1.15	0.82	5	5	-2.08	8	0.072	1.96	0.532	-1.57	0.117	
δ^{13}C (%)	-18.92	-18.86	0.70	0.28	5	5	-0.17	8	0.868	6.18	0.106	-0.84	0.403	



Graph 4. Ratios of nitrogen isotopes of rich (2) and poor (3,4,5) graves from the Slavic burial site at Mikulčice-Kostelisko according to Hrubý´s garniture of grave goods .

and in some individuals on the C4 cycle type (Table 1). For example, the woman from grave 1973 (40-60 years) with very rich grave goods (δ^{13}C - 17.8‰) and probably the man from grave 1809 (δ^{13}C - 18.4‰) had a diet of the C4 photosynthetic cycle type (corresponding to millet). The others correspond to the C3 type of cycle (wheat) (Graph 1, 2).

The averages of stable nitrogen isotopes in male s(N = 5) (10.84 ± 1.32‰) are insignificantly higher than in females (N = 5) (10.61 ± 1.15‰).

The averages of stable carbon isotopes in females (N = 5) (- 18.85 ± 0.68‰) are insignificantly higher than in males (N = 5) (- 18.93 ± 0.32‰) (Table 2, 2a).

3.2 Social differences at the burial site

Because of the small number of observations, only the basic characteristics of categorisation according to sex and grave goods as per Stloukal were calculated. The differences in medians between the Stloukal first group (rich graves) and Stloukal second group (poor graves) were tested using the Mann – Whitney test only for both sexes together (Table 3).

The difference was manifested in the δ^{13} C variable (z = -2.1, p = 0.037). The averages of stable carbon isotopes in skeletons from rich graves (N = 8) (- 18.76 ± 0.46‰) are greater than in the case of poor graves (N = 2) (- 19.42 ± 0.30‰) (p = 0,0307) according to Stloukal's categorisation of grave goods (Table 3a, Graph 3).

Two of the four rich males, according to the categorisation of grave goods as per Hrubý, have δ^{15}N greater than poor females (see Graph 2). When comparing the mean values of rich graves (N-5) from group "2" according to Hrubý (Table 4) and the united groups 3, 4, 5 (Table 5) of poor graves (N = 5), the stable nitrogen isotopes (δ^{15}N 11.38 ± 0.82‰) in the rich graves are higher than in the group of poor graves (δ^{15}N 10.07 ± 1.15‰) (p = 0.117) (Table 5a; Graph 4).

4. Discussion

In the case of the C, N isotopes, we did not discover any difference between the sexess, but we did uncover social differences between the rich and the poor, namely involving the type of cereal diet used and the access to a meat-based diet.

The rich appear to give preference to a cereal diet of the C4 photosynthetic cycle, represented by millet.

An example of this is the females from grave No. 1973 (40-60 years) with the rich grave goods (δ^{13}C - 17.8‰) and the males from grave No.1809 (δ^{13}C - 18.4‰).

According to historical reports, The Slavs appear to have taken a liking to millet. It was an expensive cereal, though. Millet purée was often a festive or prestigious food (Beranová 2005).

At the same time, the rich probably had more meat in their diet than did the poor. An example of this is the man from grave No.1975 (δ^{15}N 12.5‰) with the most meat-based diet (Table 1, Graph 2).

5. Conclusion

During the analysis of stable C,N isotopes of 10 skeletons from the Mikulčice burial site, significant social differences were discovered. It must be taken into account, though, that the tested sample was very small. It may thus be presumed

that the diet of richer, socially more successful individuals included a greater quantities of meat and the favoured millet.

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