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SKELETAL HEALTH OF LATE NEOLITHIC POPULATIONS FROM BOHEMIA

ABSTRACT: We studied pathologies of the skeletal remains from 5 Czech burial-grounds dated into late Neolithic – Corded Ware Culture and Bell Beaker Culture, namely Vikletice, Radovesice, Čachovice, Kněževes and Brandýsek. The whole collection consisted of 257 individuals. Our main goal was to document the occurrence of pathologies of these populations in the Bohemia territory. Then we compared body size and shape of late Neolithic with early Neolithic populations (Linear Pottery Culture). Our hypothesis was that these parameters would differ in these two Neolithic periods. Our next hypothesis was that the health status of two studied cultures (CWC and BBC) had not differed and that there would not be significant difference in their Health Indexes, body size and shape.

Firstly we determined basic paleodemographic data as sex, age at death, stature, weight and BMI. Then we macroscopically evaluated skeletal material looking for pathologies as anemia, infections, degenerative joint diseases, dental health, trauma and tumors. As the last thing we calculated Health Index described and used to determine skeletal health by Richard H. Steckel et al. *(2002b) for the American populations from 4000 BC.*

We identified several types of pathologies: hypoplasia, intravital tooth loss, caries, abscesses, cribra orbitalia and porotic hyperostosis, osteoperiostitis/osteomyelitis, traumas as fractures, cut and stab injuries, trephinations and tumors. The Health Index value was 79.87 for this late Neolithic period populations. According to our research, body size of late Neolithic populations changed in comparison with the early Neolithic populations. We did not prove significant differences between Corded Ware and Bell Beaker Culture in body size nor health status.

KEY WORDS: Late Neolithic – Health Index – Pathology – Corded Ware Culture – Bell Beaker Culture

INTRODUCTION

Current researches point out that health status of European populations deteriorated with the approach of the Neolithic period. Transition of the Paleolithic and Mesolithic hunter-gathering society to agricultural and pastoral life style led to lowering the stature, worsening the dental health (Horáčková *et al.* 2004, Larsen 1995, 2006), change in ratio of the trace elements (Fe, Se, Sr, Zn) (Smrčka 2005) in the food income. Many researchers have already analyzed skeletal remains from Bohemia, made paleodemographic analyses, described occurrence of single pathologies (Chochol 1970, Blajerová 1960), or single groups of pathologies as manifestation of anemia and others. However these studies have not analyzed the populations and pathologies as the whole complex, which could bring better insight into the health status of Neolithic populations. A possible way for more compact evaluation of health status could be Health Index described and used by Steckel *et al*. (2002 a, b). It presents a new insight into the study of prehistoric and historic populations based on skeletal material and consists of all important criteria describing health and nutritional status.

This study focused on skeletal material from Bohemia dated to late Neolithic period. The hypothesis is that gradual improvement of the health status occurred with the modification of the land management, technique innovation in crops elaboration and exploitation of domestic animals

(Neustupný *et al.* 2008; Piontek, Marciniak 1992). Therefore the main goal of our study was to document the presence of pathologies of late Neolithic populations from Bohemia, prepare the data for future comparison with early Neolithic and other populations from central Europe and complete evaluation of health status by using Health Index and body size and shape (stature, weight and BMI).

Other goal was to compare health status and body size and shape of early and late Neolithic populations. Our hypothesis is that the body size and shape of late Neolithic populations (CWC and BBC) differed from early Neolithic populations (Linear Pottery Culture), as shows other researches (Piontek, Vančata 2004, Vančata, Charvátová 2001). We also suppose that the health status of two studied cultures (CWC and BBC) did not differ due to similar agricultural and/or pastoral lifestyle and thus there will not be significant difference in their Health Indexes, body size and shape.

MATERIAL

We evaluated 257 skeletons from 5 burial sites located in Bohemia, Czech Republic, central Europe (see *Figure 1*). These sites were Vikletice (county Chomutov), Radovesice (county Litoměřice), Čachovice (county Chomutov) (Neustupný *et al.* 1989), Kněževes (county Praha-západ) (Kytlicová 1956) and Brandýsek (county Kladno) (Kytlicová 1960, Blajerová 1960) (see *Table 1*).

Skeletal material belonged to two cultures, Corded Ware Culture (CWC) (2800 – 2500 BC) and Bell Beaker Culture (BBC) (2500 – 2000 BC) (Sklenář *et al.* 2002). Both cultures inhabited similar environment and they were very often found at the same locality. All structures as settlements and burials were not located higher than 350 m above sea level and not more than 250 m from the water source. Members of Corded Ware and Bell Beaker Culture were farmers, exploited domestic animals for work, meat and milk (Neustupný *et al.* 2008, Sládek *et al.* 2006). Frequent burial components as were well-manufactured arrow-heads, mainly in Bell Beaker Culture (Kytlicová 1956, 1960, Turek, Peška 2001), led firstly archaeologists to the idea of preferably hunter-gathering society, but this was not completely proved (Neustupný *et al*. 2008, Turek 2006). The answer can be somewhere in the middle. Agriculture was not the only food source but meat and milk were consumed as well (Horáčková *et al.* 2004).

Material is currently deposited in the Anthropological Department of National Museum in Prague.

For comparison with studied late Neolithic populations early Neolithic populations from Vedrovice (Linear Beaker Culture), situated in the southeast Czech Republic, and Nitra, situated in Slovak Republic were used. Necessary data were obtained by one of the researchers in previous study (Růžičková 2007). Those populations belonged to the Linear Pottery Culture, Vedrovice was dated by high-precision radiocarbon age calibration into the period of 5500 – 5350 BC (Podborský *et al.* 2002), and Nitra was dated as 200 years younger (Bocquett-Appel 2002).

METHODS

At first, each skeleton was macroscopically evaluated for the presence of pathologies and traumas. We looked for, and then noted, 7 main categories used for calculation of the

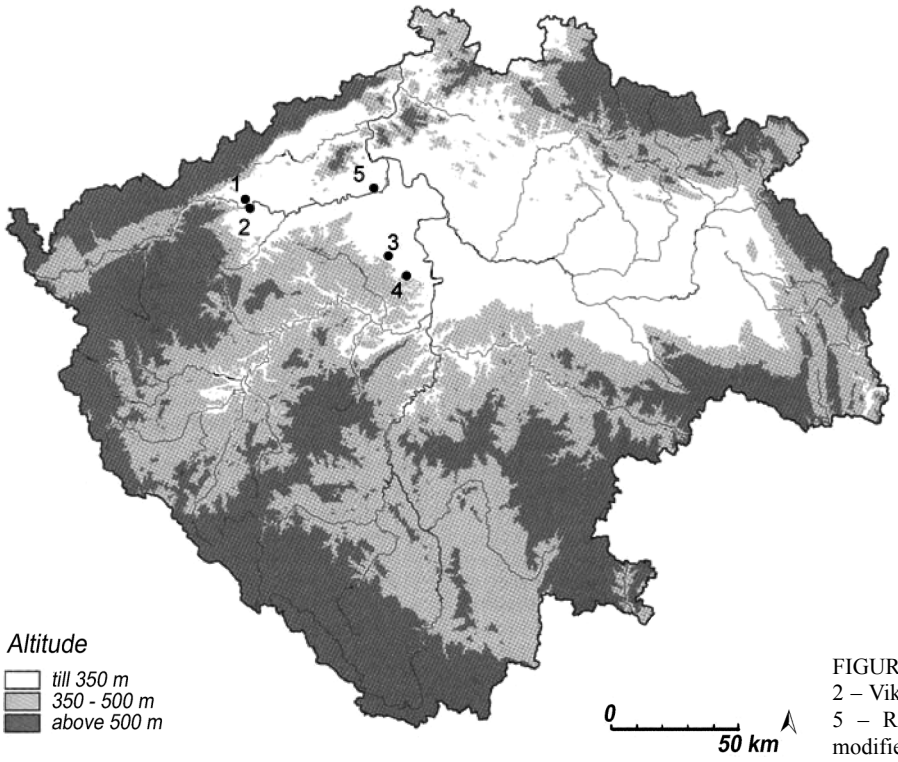

FIGURE 1. Location of studied sites. 1 – Čachovice; 2 – Vikletice; 3 – Brandýsek; 4 – Kněževes u Prahy; 5 – Radovesice. Source: Neustupný *et al.* 2008, modified by authors.

TABLE 1. Localities, amounts and archaeological cultures of the studied skeletal material.

Locality	Amount	CWC (2900/2800 – 2500 BC)	BBC (2500 – 2020 BC)	No culture identified
Vikletice	150	150	0	0
Radovesice	13	0	13	0
Čachovice	59	49	9	1
Kněževes	14	1	13	0
Brandýsek	21	5	16	0
TOTAL	**257**	205	51	1

Health Index. These categories were: stature, hypoplasia, anemia (consisting of *cribra orbitalia* and *porotic hyperostosis*), dental health (divided into tooth loss, caries and abscesses), infections, degenerative joint diseases and traumatic injuries. For each category the average value was calculated. From these averages the Health Index was derived. Scoring and evaluation of each category and the process of Health Index calculation is closely described in Steckel *et al.* 2002 a,b. For each burial site the Health Index was established separately. The final Health Index is the average of these values. For stature estimation we did not follow modern standards established by Maresh (1989) and used for calculation of Health Index of West Hemisphere Project (Steckel *et al.* 2002b). These modern standards were derived from Denver and Colorado. Instead of those standards we used modern standards for Czech population made by Bláha *et al.* (2005).

Apart from the evaluated pathologies used for calculating the Health Index we also identified other, not evaluated, pathologies as Pacchion's granulations, *hyperostosis frontalis interna and tumors*.

For heights calculation we measured *femur* and *humerus* lengths and calculated stature according to equations proposed by Feldesman *et al.* (1988, 1990), Feldesman and Fountain (1996), Sjøvold (1990), Olivier (1976), Jungers (1988), tested and chosen by Vančata (2000), Vančata (2003), Vančata and Charvátová (2001), Piontek and Vančata (2004). If only *ulna* or *radius* where preserved we estimated the heights using average from Pearsons formulae (1899) and Manouvrier's tables (1892). The weights were estimated from the femoral head, subtrochanteric product, distal *femoral* product, and proximal *tibial* and distal *tibial* products (McHenry 1988, 1991, 1992). These locations were proposed by Vančata (2000) as well. Then we calculated BMI from height and weight.

To determine sex of the skeletons we used several methods. Primary according to *pelvis* by Brůžek (1991), if pelvis was not preserved, the *cranium* and bone morphology had been used. In few cases, we calculated sex from talus according to Novotný (1985). Sex of the infants was determined only when *mandible* and *pelvis* were preserved according to Schutkowski (1990). Finally, we compared anthropologically determined sex with archaeological determination derived from the burial situation and skeletal orientation.

Age was mostly determined from teeth abrasion in adult individuals according to Lovejoy (1985) and teeth mineralization in pre-adult individuals according to Ubelaker (1978). For infants where long bones were preserved, method of Stloukal and Hanáková (1978) was used. The age of juvenile individuals was determined from epiphyseal union by Ferembach *et al*. (1980) in several cases. In one case method of Vlček 1980 (Stloukal *et al.* 1999) was used, where thyroid cartilage ossification stages are being considered.

For comparison of body size and shape between early and late Neolithic populations, and Health Index for males and females as well as for both studied cultures Two-sample T-test and Mann-Whitney U test, both on 5% level of significance were used. We used Multiple Correspondence Analysis (MCA) in Statistica 6.0, to compare the occurrence of pathologies between sexes. One of MCA was divided according to distribution on the skeleton (*head; upper limb; lower limb* and *costae-vertebrae*), the second MCA was divided according to 3 main groups of pathologies (infection; hypoplasia-anemia and trauma-degenerative joint disease).

For the purpose of evaluation OpenOffice Database was created where all information could be inserted including photos and forms showing the preservation of skeletal material. Photos were made by digital camera CANON EOS 400D with ISO 400 or 800 without flash on the black background. Final results were statically evaluated in OpenOffice.org Calc, version 3.0, Statistica 6.0 and NCSS 6.0.

RESULTS

BASIC PALEODEMOGRAPHIC DATA

Sex statistics

By anthropological methods sex was determined for the total number of 81 skeletons. Another 132 individuals and 44 infants could not be determined properly by these methods (see *Figure 2*).

Then we used archaeological data where gender was determined from the burial situation and skeletal orientation (see *Figure 3*) to compare the results obtained by anthropological methods. For 15 individuals archaeological data for comparison were not available. The skeletal gender determined by anthropological methods varied from archaeological data in 7 cases of evaluated individuals.

Total number of individuals who could be used for anthropological and archaeological gender determination can be seen in *Table 2*. Because archaeological and

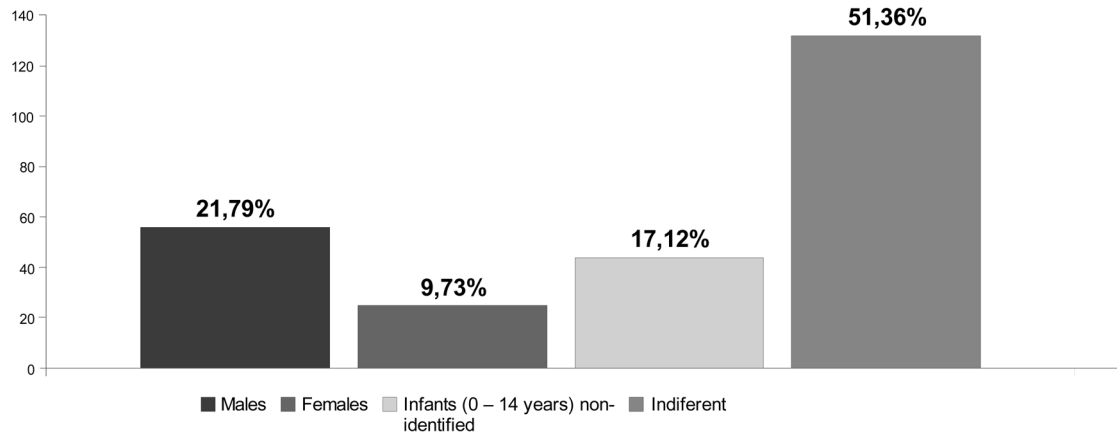

FIGURE 2. Gender by anthropological examination.

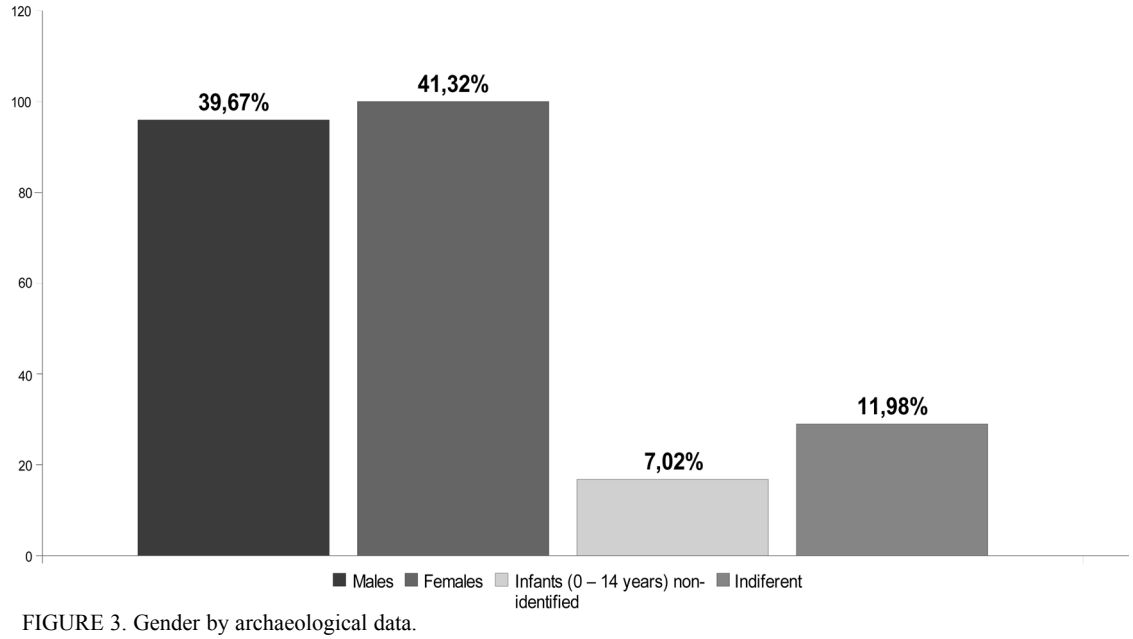

FIGURE 3. Gender by archaeological data.

TABLE 2. Sex according to anthropological examination and archaeological information.

Sex	Amount – Anthropological Examination	Amount – Archaeological Information
Males	56	96
Females	25	100
Infants (0 – 14 years) indifferent	44	17
Indifferent	132	29
Total	**257**	**242**

TABLE 3. Mortality table for studied late Neolithic populations with calculated Life Expectancy; in category Total individuals with unidentified sex are included; Dx: the number of people who died in the age interval, ex: expectation of life at age interval.

	Total		CWC		BBC		Males		Females	
Age (years)	**Dx**	**ex**	**Dx**	**ex**	**Dx**	**ex**	**Dx**	**ex**	**Dx**	**ex**
0 – 4	24	**25.22**	18	**25.95**	6	**22.73**	5	**27.92**	10	**25.28**
5 – 14	30	24.43	20	25.15	10	21.91	14	25.48	9	24.34
15 – 24	43	18.47	33	18.65	10	17.76	18	19.64	24	16.94
25 – 34	41	14.21	33	14.15	8	14.47	21	14.8	17	13.6
35 – 44	27	10.5	23	10.31	4	11.36	10	11.67	15	9.23
45 +	33	5	26	5	7	5	20	5	11	5

anthropological sex determination did not vary considerably we decided to include individuals where gender was determined archaeologically to increase the number of individuals used for further statistical evaluation.

Age Statistics

Age could be determined for the total number of 198 individuals, 76 males, 69 females and 53 individuals with indifferent gender. 153 belonged to CWC and 45 to BBC. We calculated Life Expectancy for the studied populations from these individuals (see *Table 3*), which was 25.22. For CWC it was 25.95 and BBC it was 22.73.

Life Expectancy for males separately was determined as 27.92 years and for females 25.28 years (see *Figure 4*).

Body Size and Shape

The total numbers of individuals used for determining the stature, weight and BMI are in *Table 4*. More detailed information about each criteria are discussed below. We tried to compare body size and shape (stature, weight and BMI) of males from BBC and CWC and we did not found statistically significant difference between these two populations. Unfortunately the statistical evaluation could not be done for females due to low number of individuals (see *Table 5*). Therefore we present box plots comparing body size and shape, weight and BMI of these two cultures only for males (see *Figures 19, 20* and *21*).

Stature

Stature was calculated for 28 individuals, 19 males and 9 females. Average height for males was 167.83 cm, for females it was 158.05 cm (see *Table 4*).

We compared the data derived from late Neolithic populations analyzed in this study with early Neolithic populations from Vedrovice, and Nitra (Růžičková 2007). As we supposed, the average stature of late Neolithic populations increased in comparison with the early Neolithic populations (see *Figure 5*). There was not statistically significant difference between early and late Neolithic males, on the other hand there was statistically significant difference between early and late Neolithic females (see *Table 4*).

Weight and Body Mass Index (BMI)

Weight was calculated for 41 individuals, 27 males and 14 females. Average weight for males was 61.82 kg, for females it was 53.1 kg. Body Mass Index was calculated for 17 males and 7 females. Average BMI for males was 22.36, for females it was 20.29.

Then we compared weight (see *Figure 6*) and BMI (see *Figure 7*) of our late Neolithic populations and early Neolithic population from Vedrovice and Nitra. There was statistically significant difference in weight values between early and late Neolithic males and females. However for BMI statistically significant difference was only for males (see *Table 4*).

Health Index

For calculation of Health Index we used 38 skeletons which had at least 5 criteria possible to evaluate. The Health Index of the population was established as 79.87 with SD 4.29 (see *Table 6*). Because there are no published values of Health Index for Europe, we compared the health status of our skeletal material with the results in American Continent calculated by Steckel et al. (2002b) in the same time period and stage of development. The Health Index in the New World in the years from 2800 to 2000 BC was around 3.9 % lower than the Health Index calculated for our studied population (see *Figure 8*). This value is consistent with the health status around 3.500 BC in the results for American Continent (Steckel *et al*. 2002b).

We compared males and females (see *Figure 9*). It seems that females of our studied populations had better health status. However this difference was not statistically significant (t-value = 1.237299; p = 0.223986). This is in contrast with the results of Life Expectancy, described above, which shows that females had lower Life Expectancy than males.

Correlation Matrix of Health Index and its components for these 38 individuals is presented in *Table 7*. The highest correlation was between Health Index and DJD.

All 5 burial sites were compared with each other (see *Figure 10*). It can be seen that higher Health Index was for Vikletice and Čachovice, both mainly belonging to Corded Ware Culture (see *Table 1*), on the other hand Kněževes and Radovesice with majority of Bell Beaker Culture individuals had the lowest Health Index. In Brandýsek 31,25% individuals belonged to Corded Ware Culture (see *Table 1*).

Therefore we also compared values of Health Index of CWC and BBC (see *Figure 9*). Values for CWC were higher than for BBC, but the difference was not statistically significant either (t-value = 0.580509; p = 0.565188).

Degenerative joint diseases

Our findings were divided into 2 subcategories: Arthrosis deformans and Spondylosis deformans.

Arthrosis deformans

We observed *arthrosis deformans* on 6 localizations of the skeleton. Arthrosis of femoral head*, fossa glenoidalis, costae,* articular surface of lower extremity of *humerus,* knee (see *Figure 11*) and metatarsophalangeal joint (see further *Table 8*). Altogether *arthrosis deformans* was found in 6 cases (3.5 % from all cases which could be evaluated).

Spondylosis deformans

Spondylosis deformans was mostly observed on the bodies of lumbar vertebrae. We found *spondylosis deformans* in 2 cases presented together with Schmorl´s nodes and in 4 cases Schmorl´s nodes alone. The occurrence of spondylosis *deformans* was 10.5 %, the occurrence of Schmorl's nodes was 10.5 %, too (see *Table 8, Figure 12*).

Specific and non-specific infections

Most of the findings of infections were located at the visceral surface of ribs. There were severe periosteal reactions causing rough texture of its surface (see *Figure 13*). In one case it was present on the caudal part of right

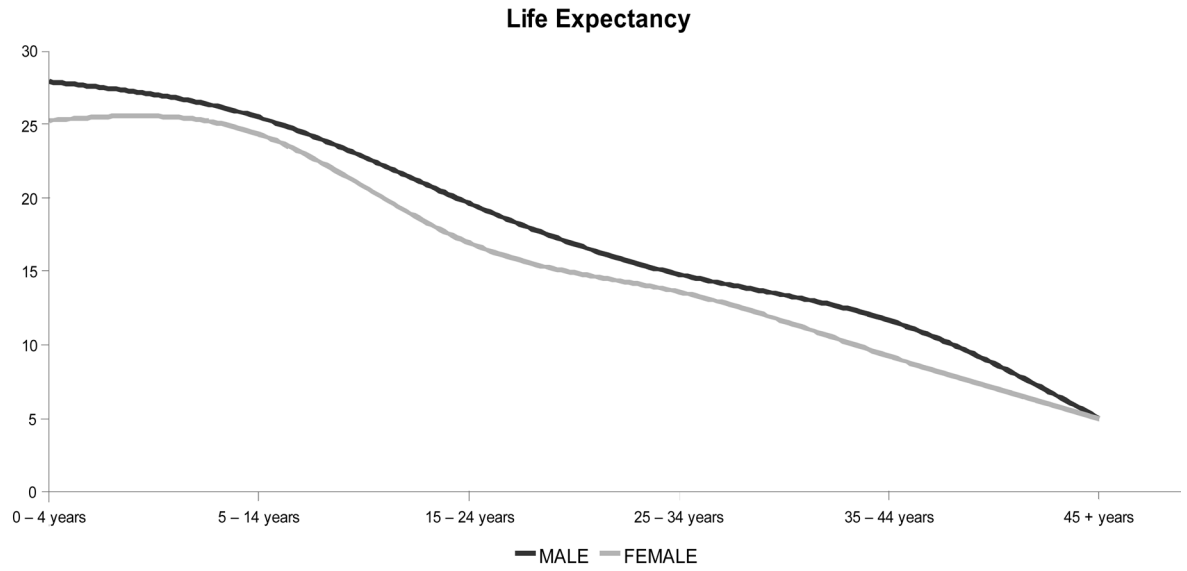

FIGURE 4. Life Expectancy of males and females of late Neolithic.

TABLE 4. Comparison of stature, weight and BMI of males and females from late Neolithic and early Neolithic period; t-test was calculated for groups with unequal number of individuals. Marked results are significant at P < 0.05.

Males of late Neolithic (E) and early Neolithic (N) period	**Mean *(N)***	**Mean *(E)***	**t separ. var.est.**	**p 2-sided**	**Valid N *(N)***	**Valid N *(E)***	**Std.Dev. *(N)***	**Std.Dev. (E)**
Stature	167.1618	167.8300	0.2999	0.765513	33	19	8.029762	7.189942
Weight	58.32864	61.82111	2.6261	**0.010904**	36	27	5.052407	5.445866
BMI	21.23969	22.35647	2.5465	**0.014216**	32	17	1.366389	1.629394
Females of late Neolithic (E) and early Neolithic (N) period	**Mean *(N)***	**Mean *(E)***	**t separ. var.est.**	**p 2-sided**	**Valid N *(N)***	**Valid N *(E)***	**Std.Dev. *(N)***	**Std.Dev. (E)**
Stature	152.6362	158.0544	2.1835	**0.035998**	27	9	6.152232	7.323783
Weight	49.42775	53.09500	2.4577	**0.017226**	42	14	4.312808	6.200862
BMI	20.99497	20.28571	1.2206	0.231156	27	7	1.400829	1.227475

clavicle. It was present on 5 individuals from the total number of 45 individuals who could be evaluated (11.1 %). (We evaluated only individuals who had at least 25 % or more ribs preserved). In 3 cases these reactions were found on males, in one case female and indifferent. In 2 cases there were children 8–9 and 10–13 years old, 2 cases juveniles of age 16–18 and in one case adult 30–40 years old. The pattern of manifestation can mean the possibility of tuberculosis infection (Santos, Roberts 2006). In studied material the presence of tuberculosis was observed previously as well. Vertebral gibbus caused by tuberculosis was present in the individual from Vikletice (Ao 4790), who was determined as male of age 35–40 years (Chochol 1970, Hanáková *et al.* 1981, Likovský *et al.* 2005). This gibbus was missing in studied material at time of our study. In two cases, there were found lesions on the visceral surface of ribs probably caused by TBC as well.

Other observed pathologies were infections as osteomyelitis/periostis and other non-specific infections. Findings of osteomyelitis/periostis were certain in 5 cases, in 1 case there was found Brodi's abcess as special type of chronic osteomyelitis, located on tibia. In one case (Ao

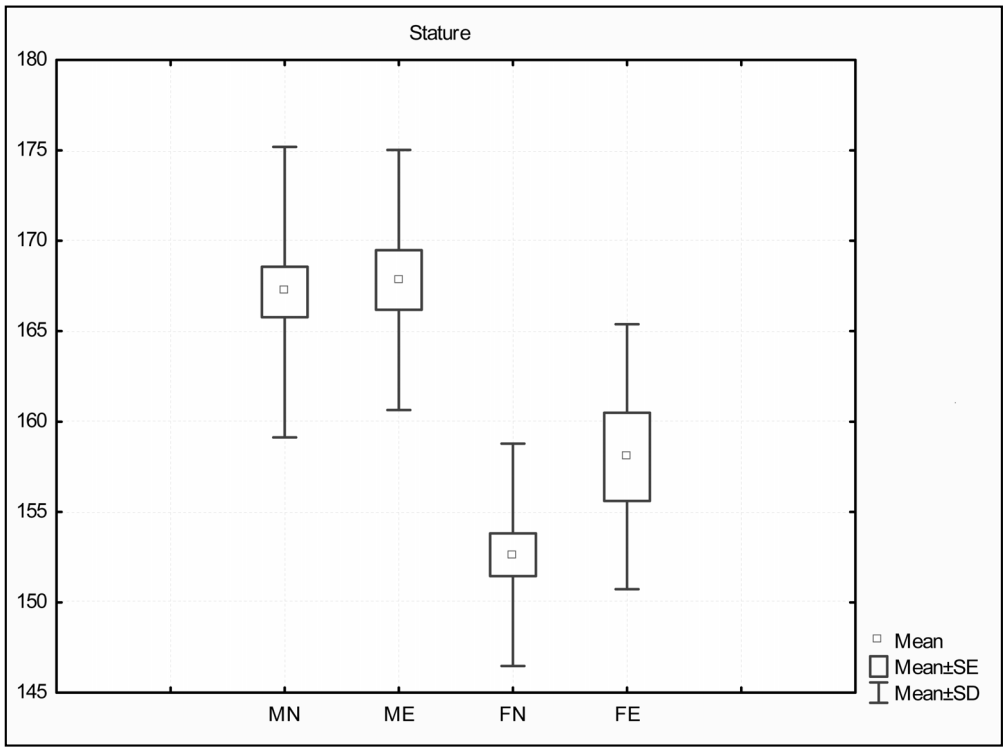

FIGURE 5. Comparison of stature. MN: Early Neolithic males; ME: Late Neolithic males; FN: Early Neolithic females; FE: Late Neolithic females; SE: standard error; SD: standard deviation.

TABLE 5. Comparison of stature, weight and BMI of males from CWC and BBC; t-test was calculated for groups with unequal number of individuals. Marked results are significant at P < 0.05.

Males of Corded Ware Culture (CWC) and Bell Beaker Culture (BBC)	**Mean *CWC***	**Mean *BBC***	**t separ. var.est.**	**p 2-sided**	**Valid N *CWC***	**Valid N *BBC***	**Std.Dev. *CWC***	**Std.Dev. BBC**
Stature	170.2462	166.0727	1.270349	0.221072	8	11	9.489109	4.685491
Weight	61.37938	62.46364	0.500949	0.620789	16	11	6.545456	3.475423
BMI	21.62143	22.87100	1.636365	0.122567	7	10	2.121732	1.000338

4818) we were not sure if the observed periosteal reaction was caused by infection. Infections were located on 5 *tibiae* (bilateral in one case), 1 *fibula*, 1 *femu*r and 1 *humerus* (see *Table 9*).

Trauma

During the study of pathologies of mentioned skeletal material we observed number of evidential traumas. These were located on cranial vault, long bones, and in one case on pelvis and clavicle. They can be divided into fractures (see *Figure 14, 15*), weapon wounds, artificial interventions and in one case dislocation. In *Table 10* you can see the list of traumas with more detailed information. Total number of observed traumas was 20. Most of the traumatic lesions, 13 cases, were located on *cranium*. These are cut and stab injuries, impressive fractures and trephinations.

Anemia

Evidence of anemia in skeletal material research is usually evaluated by using *cribra orbitalia* and *porotic hyperostosis*.

Cribra orbitalia, displayed in *Figure 16*, were divided into 3 categories: males and females of age 15–45+, and infants of age 0–14 years. They were mostly present on infants (57.1 %), then females (21.1%) and less often on males (12.9 %). All *cribra orbitalia* were classified into category 2 which is described as "a cluster of mostly fine foramina covering a small area (≤1 cm^2)" (Steckel *et al*. 2006, p. 13).

Porotic hyperostosis as a mark of iron insufficiency was found in 3 sole cases (4.3%) on parietal bone. Twice they were present in children around 9 years old and once in male 20–30 years old. They belonged to category 2 defined in Data Collection Codebook (Steckel *et al*. 2006).

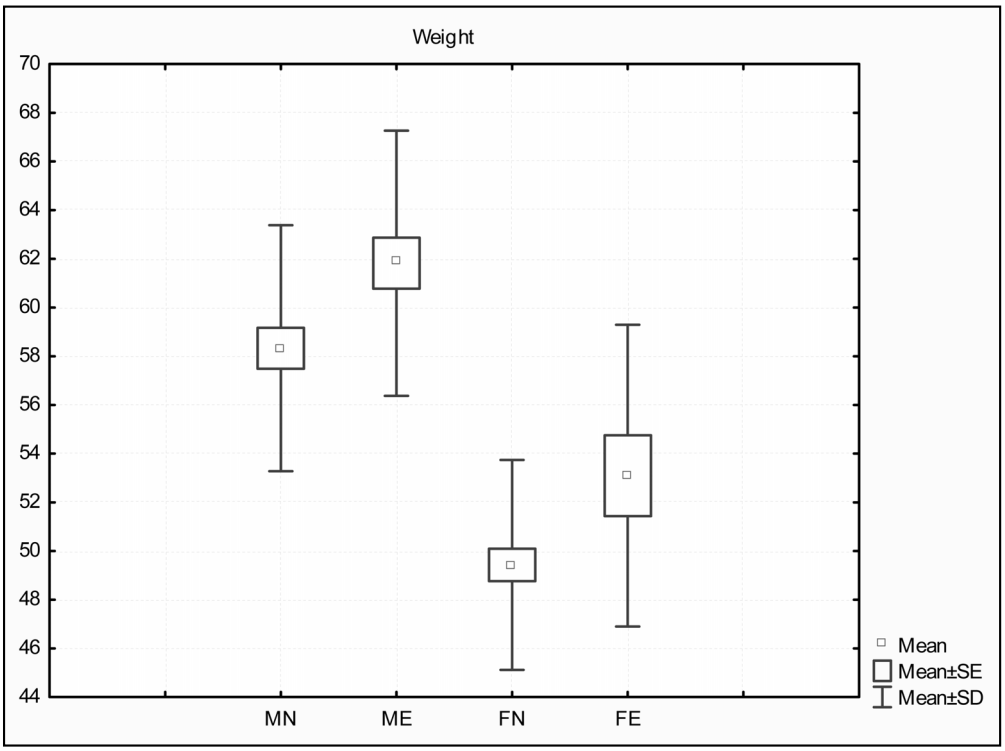

FIGURE 6. Comparison of weight. MN: Early Neolithic males; ME: Late Neolithic males; FN: Early Neolithic females; FE: Late Neolithic females; SE: standard error; SD: standard deviation.

TABLE 6. Health Index from skeletons with 5 criteria and more available.

Statistics	Index	Stature	Hypoplasia	Anemia	Dental	Infections	DJD	Trauma
Average (N = 5 sites)	**79.87**	36.17	97.14	94.5	92.85	88.87	74.06	75.5
Standard Deviation	**4.29**	12.85	6.39	7.58	8.11	12.28	19.38	18.15

Dental Health

As one of health status markers, dental health is evaluated as well. It consists of the hypoplasia, caries, intravital tooth loss and abscesses.

Hypoplasia was observed in 6 cases out of 111 individuals (5.4%). In 4 cases it was present in infants in the age of 3 to 11 years old, in 1 case it was present in female in the age of 17–18 years, and in 1 case in male in the age of 30–40 years.

Caries were present in 10 cases and intravital tooth loss in 11 cases. 3 individuals had caries and intravital tooth loss simultaneously. Both of these categories were present only in individuals over 30 years.

The last category, abscesses, was found just in 2 cases, both males over 45 years.

I-CE and F-CE indexes were used as indicators of caries proportion and intravital tooth loss in population. For use of I-CE 2.589 permanent teeth were evaluated including alveolae of intravital tooth loss, with the result of 4.64 %. The result for I-CE modified by Strouhal (1961) was 1.4%. F-CE was calculated from the total number of 25 individuals with the result of 40 %. For Corded Ware Culture I-CE was established at 3.66 % and for Bell Beaker Culture it was 7.71 %.

Miscellaneous

Apart from mentioned pathologies we observed other features which did not fit into other pathology categories. These were Pacchion's granulations (granulationes arachnoideales) in 8 cases, pseudopathologies, holes of unknown origin, in 1 case prematurely obliterated right squamosal suture of a four-year-child, extended thickness of *diploe*, *hyperostosis frontalis interna* in 2 cases and u-shaped abrasion of cranial and caudal *incisors*. We also observed two cases of tumors. Those were two osteoma, both located on the parietal bone of two males (see *Table 11*).

Strouhal and Němečková (2008) describe one case of possible malign tumor on female from the burial site Kněževes (Bell Beaker Culture), the Grave 1. They describe two periosteal centers located on internal lamina of left parietal and frontal bone which could represent metastatic nidus of carcinoma on *dura mater* or signs of meningitis (Strouhal, Němečková 2008). This skeleton was not available at the time of our research. Other similar observations were made in current study, where pathologies were present on the internal lamina of *occipital* and *parietal bone* of female Ao 4770 from Vikletice. The bone's abnormal thickness and arborisation of surface can indicate possibility of carcinoma or meningitis.

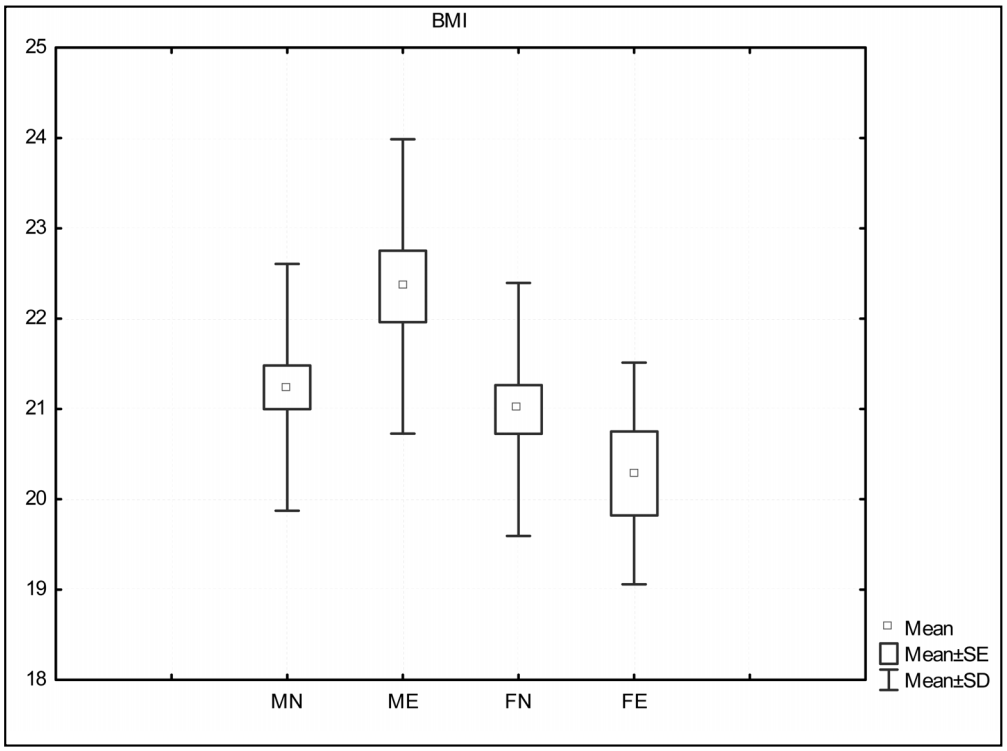

FIGURE 7. Comparison of BMI. FN: Early Neolithic females; FE: Late Neolithic females; MN: Early Neolithic males; ME: Late Neolithic males. SE: standard error; SD: standard deviation.

TABLE 7. Correlation Matrix of the Health Index and its Components using Spearman Rank Order Correlations, marked correlations are significant at P < 0.05.

	Health Index	Stature	Hypoplasia	Anemia	Dental	Infections	DJD	Trauma
Health Index	1.000							
Stature	**0.585**	1.000						
Hypoplasia	0.161	0.223	1.000					
Anemia	0.032	-0.360	-0.083	1.000				
Dental	**0.609**	0.403	-0.189	-0.255	1.000			
Infections	0.162	-0.337	0.215	0.215	-0.143	1.000		
DJD	**0.750**	0.340	-0.026	0.029	**0.736**	0.025	1.000	
Trauma	**0.653**	**0.445**	-0.120	-0.183	**0.341**	-0.120	**0.363**	1.00

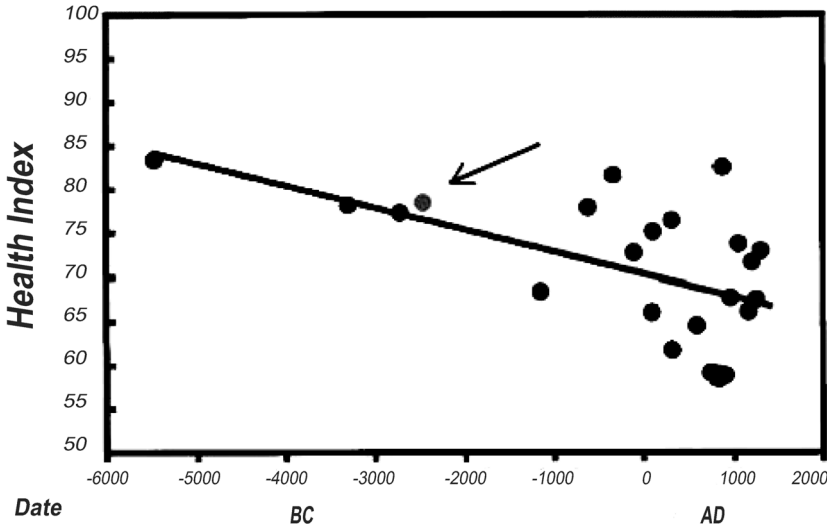

FIGURE 8. Comparison of our result (grey point with an arrow) with the result of West Hemisphere Project. Source: Steckel *et al.* 2002b; modified by authors

TABLE 8. Degenerative-joint diseases of late Neolithic skeletal material; SD: spondylosis deformans, AD: arthrosis deformans.

ID	Grave No.	Sex	Age	DJD	Stage/ Classification by	
VIKLETICE						
Ao 4780	36/63	F	45+	SD of Cervical Vertebrae	3 Walker (2001)	
				AD of fossa glenoidalis	2 Schultz (1988)	
Ao 4824	147/63	M	45+	SD of Thoracic Vertebrae	2 Walker (2001)	
				AD of costae	2 - 3 Schultz (1988)	
Ao 5365	4/64	M	45+	SD of Thoracic Vertebrae	3 Walker (2001)	
				Schmorl´s nodes (Th 6 – 8)	-	
				AD of humerus dx.	2 Schultz (1988)	
Ao 5367	6/64	F	40 – 45	SD of Lumbar Vertebrae	2 Walker (2001)	
Ao 5373	14/64	F	16 – 25	Schmorl's Nodes (Th + L)	-	
RADOVESICE						
P7A 9321	117/78	F	45+	SD of Th Vertebrae	3 Walker (2001)	
P7A 9325	53/80-I	M	20 – 30	Schmorl's Nodes (Th)	-	
P7A 9328	59/80-II	M	30 – 40	Schmorl's Nodes (Th + L)	-	
P7A 9329	67/80	M	40 – 50	Schmorl's Nodes (L3 – L4)	-	
P7A 9330	68/80	M	40 – 50	AD of elbow joint of humerus dx., olecranon et caput radii (fracture of ulna and radius at distal part)	2 Schultz (1988)	
KNĚŽEVES						
Ao 769	5/63	M	45+	SD C 5 – 7 (fusion)	3 Walker (2001)	
Ao 1169	12/54	M	45+	SD Th 9 – 10	3 Walker (2001)	
				Schmorl´s Nodes (Th)	-	
Ao 1607	15/54	M	45+	AD of knee joint sin.	3 Schultz (1988)	
				SD Th + L	3 Walker (2001)	
				AD metatarsophalangeal joint	3 Schultz (1988)	
				SD dens axis	3 Walker (2001)	
BRANDÝSEK						
Ao 2159	79/57	M	< 30	SD (vertebrae)	2	Walker (2001)
Ao 1633	26/56	M	45+	SD (Th)	2	Walker (2001)

Correspondence of pathologies and sex

As mentioned above, we used two Multiple Correspondence Analyses to evaluate the occurrence of pathologies on male and female parts of skeleton (see *Figure 17*), and to set the correspondence of the types of more common pathologies for each sex (see *Figure 18*). These figures show that cranial pathologies (mainly hypoplasia and anemia) corresponded more with females, on the other side pathologies on *costae-vertebrae* and upper extremity (mainly degenerative joint diseases and traumas) corresponded mostly with males. These figures also show no correspondence of sex and infections.

DISCUSSION

The occurrence of pathologies from criteria showing the nutritional status of the populations was not extremely numerous. Although the presence of *cribra orbitalia* indicating iron deficiency, or other type of cause as a lack of folid acid, vitamin C and others (Smrčka 2005), was quite common, mainly in children, there was no stage 3 present showing the most serious deficiency (Steckel *et al.* 2006). The occurrence of other criteria as *porotic hyperostosis* and dental enamel hypoplasia were quite rare.

Other criteria describing health status of the populations were dental health consisting of dental caries, intravital tooth loss and abscesses. I-CE and F-CE indexes show the distribution of two dental pathologies in studied populations. These indexes, mainly I-CE index, can be compared with similar studies made by Caselitz (1998) for Europe, Mediterranean area and Arabia and America, or by Strouhal (1961) for central Europe through history. Caselitz specified I-CE as 4% for Europe till the beginning of 4500 B.C. With the beginning of transition from the hunter-gathereing society to agricultural life style I-CE increased to 7% and then oscillated until the Middle Bronze Age 1500 B.C. After that it increased again (Horáčková *et al.* 2004). Our result (4.64%) shows, that presently studied population had probably better dental health than early agriculturalists from Caselits's study. Strouhal (1961) with his modified I-CE (for use of caries without intravital tooth loss and abscesses) (Horáčková *et al*. 2004) determined its value as 2–5 % for

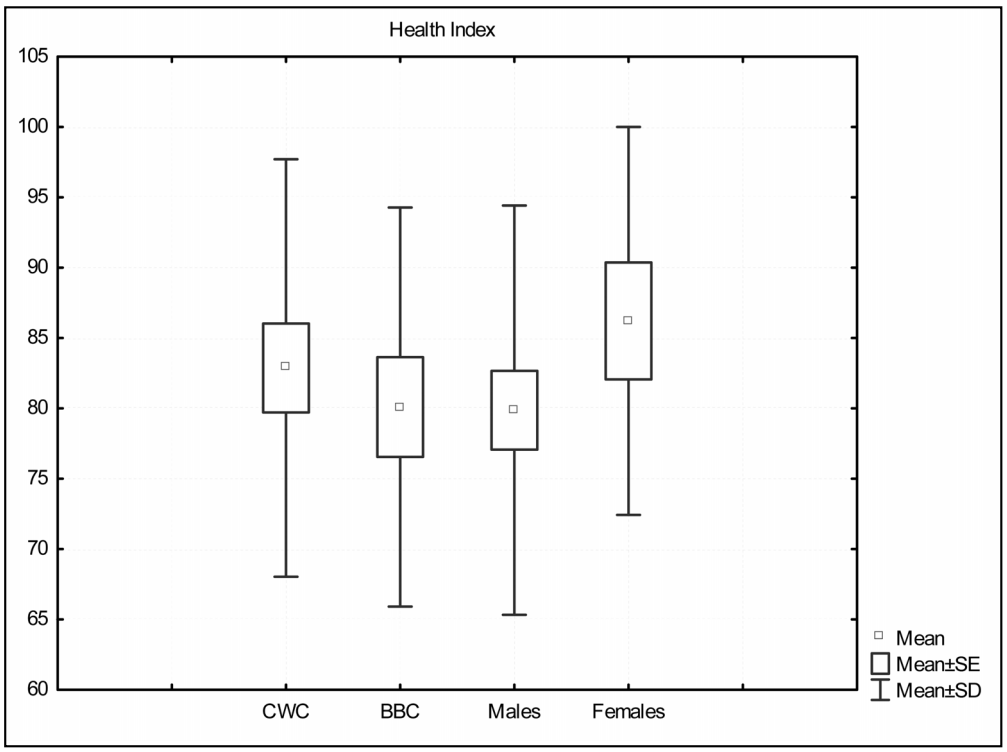

FIGURE 9. Health Index of males and females from studied late Neolithic populations and Corded Ware Culture (CWC) and Bell Beaker Culture (BBC). SE: standard error; SD: standard deviation.

TABLE 9. List of non-specific infections.

Site	ID	Grave no.	Sex	Age	Location	Type
Vikletice	Ao 4797	112/63	M	?	Femur dx. et sin. + tibia sin.	3
Kněževes	Ao 1167	13/54	F	2 years	Tibia dx. et sin. + fibula dx.	2
Brandýsek	Ao 2159	73/57	M	< 30 years	Humerus sin. distal part	7
Brandýsek	Ao 1675	69/56	F	maturus	Tibia dx. proximal part	2
Brandýsek	Ao 1625	18/56	M	17 – 22 years	Tibia sin. Proximal part	2
Vikletice	Ao 4820	142/63	F	35 – 40 years	Brodi's abcess/tibia dx.	-
Vikletice	Ao 4818	140/63	F	> 50 years	Lamina interna ossis parietalis	-

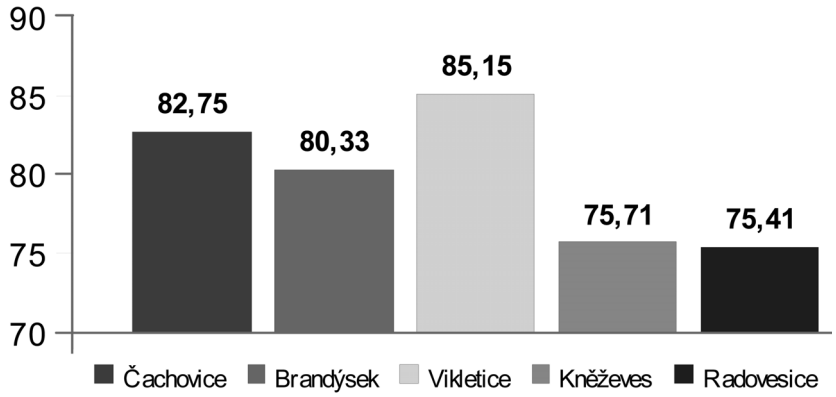

FIGURE 10. Health Index for each burial site.

FIGURE 11. Arthrosis deformans of the knee joint. Kněževes Ao 1607.

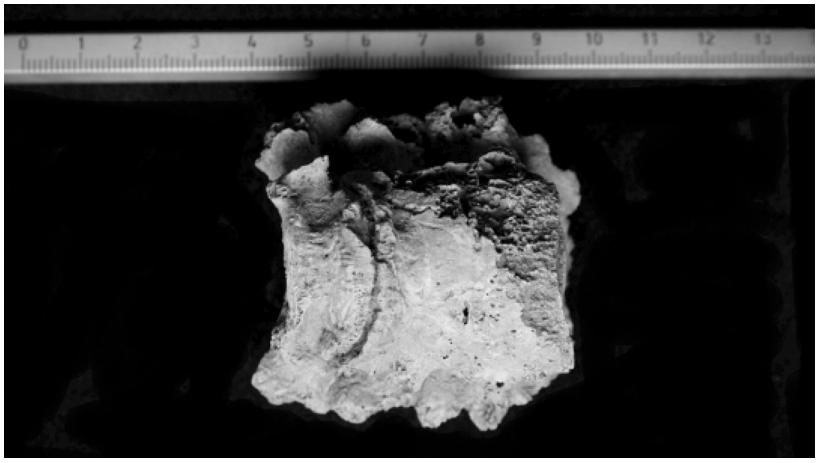

FIGURE 12. Spondylosis deformans of C 5–C 7. Kněževes Ao 769.

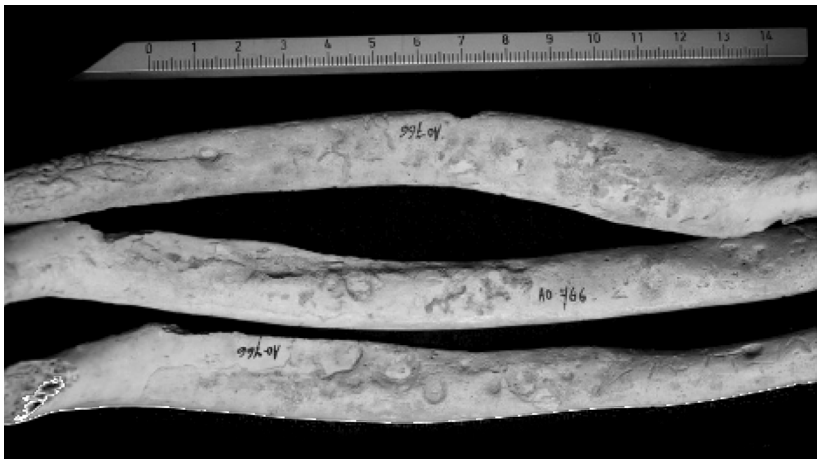

FIGURE 13. Periostal reaction located at the visceral surface of the rib. Kněževes Ao 766.

FIGURE 14. Partially – healed fracture of distal part of left ulna and radius. Čachovice Ao 8606.

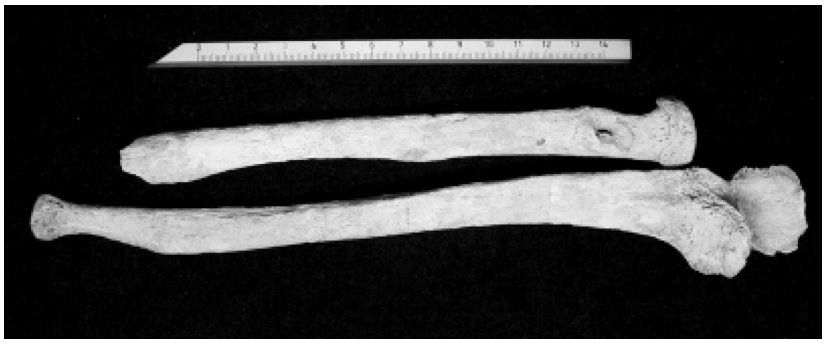

FIGURE 15. Well – healed "parry" fracture of distal part of right ulna and radius. Radovesice P7A 9330.

early Neolithic populations. The lower values of this range occurred more often in our geographical area than in Western Europe (Horáčková *et al.* 2004). These values slightly decreased later in late Neolithic (Horáčková *et al*. 2004). For our studied populations this index was established as 1.4%, which again shows that dental health of late Neolithic populations did improve. This might be due to different nutritional income of Corded Ware Culture and Bell Beaker Culture consisting of more meat and milk (Horáčková e*t al*. 2004).

Degenerative joint diseases were more common on *vertebrae* than other joints. This category had the highest correlation with Health Index (see *Table 7*). Most of the individuals belonged to the category of senilis. The occurrence among younger individuals was not frequent; therefore we think that work-load was not so extremely heavy. The situation was different with Schmorl's nodes when they were not present only in the category of senilis but in the category of younger individuals as well. Schmorl's nodes can be caused by three main factors. Those are traumatic events, congenital defect as morbus Scheuermann and aging (Faccia and Williams 2008). Congenital defect could not be proved in any case. Traumatic events should be considered as the main reason for Schmorl's nodes mainly in the category of younger individuals.

Traumas were more numerous in these populations. Location of wounds on the left cranial vault was the most common and can indicate face-to-face interaction between two rivals with preferred right handed aggressors. On the left cranial vault it can indicate the opposite (Dawson *et al.* 2003). Many of the crania were preserved in fragments which could be the result of a weapon attack, work injuries or postmortal activities as the ground pressure or not carefull archaeological excavation. Despite of possible higher number of traumatic pathologies on the cranium we mentioned only the cases which were obvious. Other traumas were located on post-cranial skeleton, mostly fractures of long bones. Two fractures of both forearm bones, one on the left and one of the right side, can be interpreted as „parry" fractures made when the individuals tried to protect themselves against attack or falling object from above (Horáčková *et al.* 2004). Other specific traumas were trephinations, which could be the result of medical treatment of impressive fractures, mental problems, headaches (Horáčková *et al.* 2004, p. 80). Only 9 findings of trephinations from late Neolithic in the Czech Republic were described (Malyková 2002). In our studied populations two of them were found (see *Table 10*). Other very good proof of the interpersonal violence, except the impressive fractures on the cranial vaults, is presence of cut marks (Hanáková *et al.* 1981), but their frequency was low.

Infections were probably quite common judging from the number of the cases which affected the skeletons; however the infections affect bones in low percentage level. In one case there was periostitis connected with trauma. No chronic signs of these pathologies were found. On the other hand the occurrence of tuberculosis was confirmed in 1 case and there are other two probable cases manifested as lesions on the visceral surface of ribs. We suppose that these are not the only cases of tuberculosis because of the infectious character of TBC. There is question of the other periosteal reactions located on the visceral surface of ribs, mostly younger individuals. Two possible reasons causing the periosteal reaction on the visceral surface of ribs were mentioned in the study made by Santos and Roberts (2006) on the differential diagnosis of tuberculosis based on rib lesions. For all studied individuals in above mentioned research medical records were available where cause of death was noted. In 85.2% of pulmonary and extra pulmonary tuberculosis and in 17.8% of pulmonary and extra pulmonary non-tuberculosis periosteal reactions on the ribs were found (Santos, Roberts 2006). It is very problematic to diagnose TBC based on the periosteal reaction and is not possible to determine certainly that our pathologies on ribs were caused by this disease. However, there is still higher probability of possible tuberculosis than other cause.

One approach of complex pathology evaluation was made by Multiple Correspondence Analyses (see *Figures 17, 18*). It seems that males had more common degenerative joint diseases and traumas while females were more susceptible to lack of suitable nutrition, resulting in more common hypoplasia and anemia. This all can be the result of labour distribution, where males had heavier work-load on the fields, woodcutting etc., and females had nutritional stress from pregnancies and lactation.

However from the complex evaluation of pathologies made by Health Index it seems that the health status of sexes did not differ much, we did not prove any statistically

TABLE 10. List of traumas of studied skeletal material.

ID	Grave No.	Sex	Age	Location	Trauma	Notes
VIKLETICE						
Ao 4776	30/63	M	16 – 24	Left hip joint	Articular dislocation	-
Ao 4818	140/63	F	45+	Parietal bone	Foramen with signs of healing process	On lamina interna signs of local periostitis
Ao 4821	143/63	M	6 years ± 24 months	Right parietal bone	Foramen of size 7 x 1 mm on lamina externa, 7,5 x 5 mm on lamina interna	Probable arrow trauma
Ao 5367	6/64	F	40 – 45	Right internal part of pelvis	Non-penetrating longitudinal foramen	Probable weapon wound with no healing signs
				Cranium	Foramen of size 2 x 2,5 cm	Probable weapon wound with no healing signs
Ao 5393	59/64	M	35 – 40	Neurocranium	Vulnus sectum sanatum	Found in literature (Hanáková and Vyhnánek 1981), material missing
Ao 5402	70/64	M	Adultus	Cranium	Not healed Trephination	Found in literature (Hanáková and Vyhnánek 1981), material missing
				Cranium	Healed impressive fracture	Found in literature (Hanáková and Vyhnánek 1981), material missing
RADOVESICE						
P7A 9330	68/80	M	40 – 50	Distal part of right ulna and radius	Well – healed fracture	Probable protective fracture
ČACHOVICE						
Ao 8551	85/81	M	30 – 35	Cranium – left frontal bone	Non-penetrating wound with healing signs	Probable weapon wound
				Cranium – left frontal bone	Lamina interna with foveae	Probable epidural hematom
Ao 8568	Obj. 12/80	M	24 – 30	Right parietal bone	Fracture impressiva sanata	-
Ao 8591	47/80	F	25 – 35	2. and 3. left metatarsals	Well-healed part fracture	-
Ao 8606	79B/81	M	45+	Distal part of left ulna and radius	Fracture wrong-aligned, partially-healed	-
				Unknown cranial fragment	vulnus sectum non sanata	-
KNĚŽEVES						
Ao 767	7/53	M	20 – 24	Occipital bone	Penetrating longitudinal foramen with no healing signs	possible perimortem weapon wound
Ao 769	5/53	M	45+	Caudal part of left clavicle	Vulnus sectum	Origin unknown
Ao 1607	15/56	M	45+	Left parietal bone	Fractura or trephination well-healed	Weapon wound or posttraumatic surgery
				Left frontal bone	Fractura impressiva	Weapon wound
BRANDÝSEK						
Ao 2159	73/57	M	30	Distal part of left humerus	Well-healed circular fracture or vulnus sectum	Signs of periostitis

TABLE 11. Tumors found in skeletal material.

Site	ID	Grave no.	Sex	Age	Location	Size
Vikletice	Ao 4769	5/63	M	30 – 35	Os parietale sin.	4 × 5 mm
Kněževes	Ao 769	5/53	M	45+	Os parietale sin.	4 × 4 mm

significant difference. Although it seems that health status of females was slightly better (see *Figure 9*).

Similar result of Health Index was for individuals of CWC and BBC (see *Figure 9*), where we did not prove any statistically significant difference between their health status but from figure 9 it seems that CWC had higher Health Index than BBC. It is interesting that even Life Expectancy was lower for BBC (see *Table 3*). We did not prove statistically significant difference in their body size and shape either. We think that the reason why we could not prove statistically significant differences might have been due to low number of individuals. As we can see in the *Figures 19, 20, 21*, males of BBC were probably lower and more robust than males of CWC. Further research would be recommended.

Our main hypothesis was to demonstrate that the body size and shape of late Neolithic populations changed in comparison with early Neolithic populations. This was

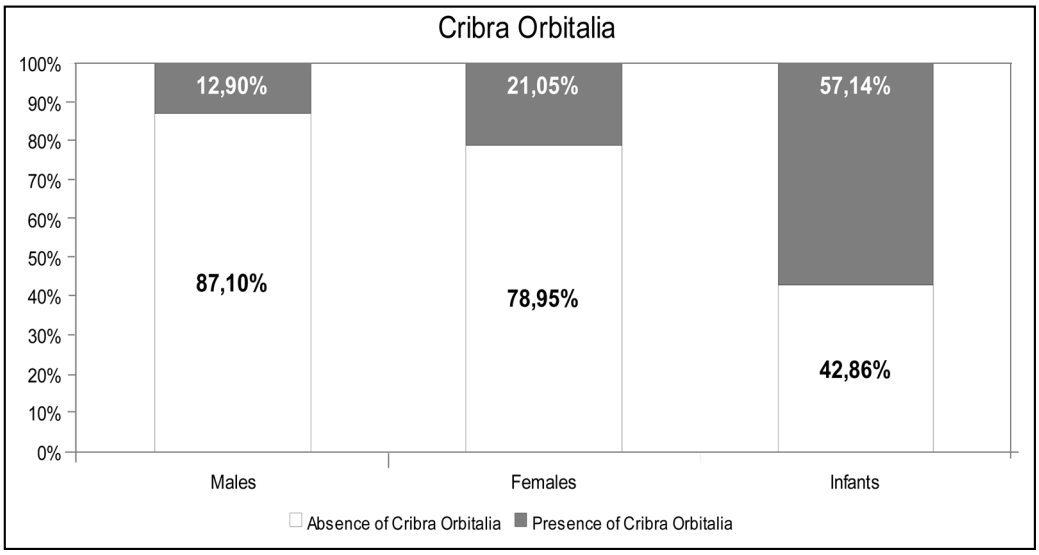

FIGURE 16. Occurrence of *cribra orbitalia* in males, females and infants.

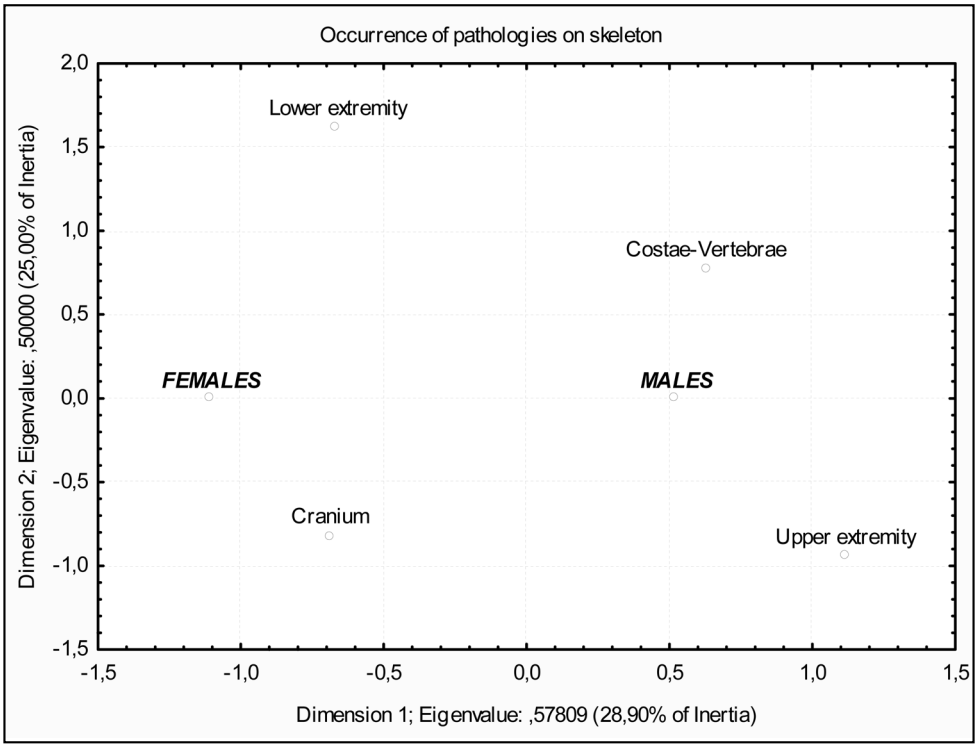

FIGURE 17. Occurrence of pathologies on skeleton with correspondence to sex.

proved in other researches as well where they showed very different body size and shape between late Neolithic and early Neolithic populations (Piontek, Vančata 2004). We also confirmed statistically significant differences between these two periods (except the stature of males and BMI of females) but our results showed that late Neolithic males were more robust than early Neolithic ones, which is in contrast with Piontek and Vančata (2004) published research. This difference could be the result of choosing different groups of Linear Pottery population for evaluation, and that the studied population of Piontek and Vančata (2004) lived in more severe ecological environment (Piontek, Marciniak 1990). For more precise perspective of the body size and shape of Neolithic population groups, further research of more localities would be advisable.

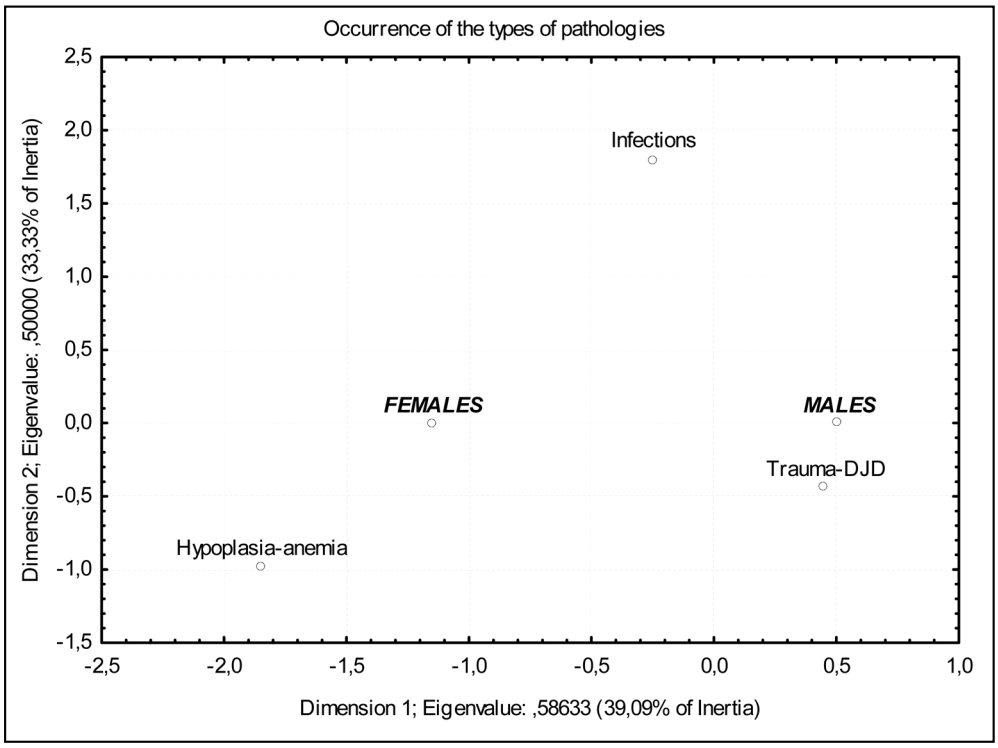

FIGURE 18. Occurrence of the types of pathologies with correspondence to sex.

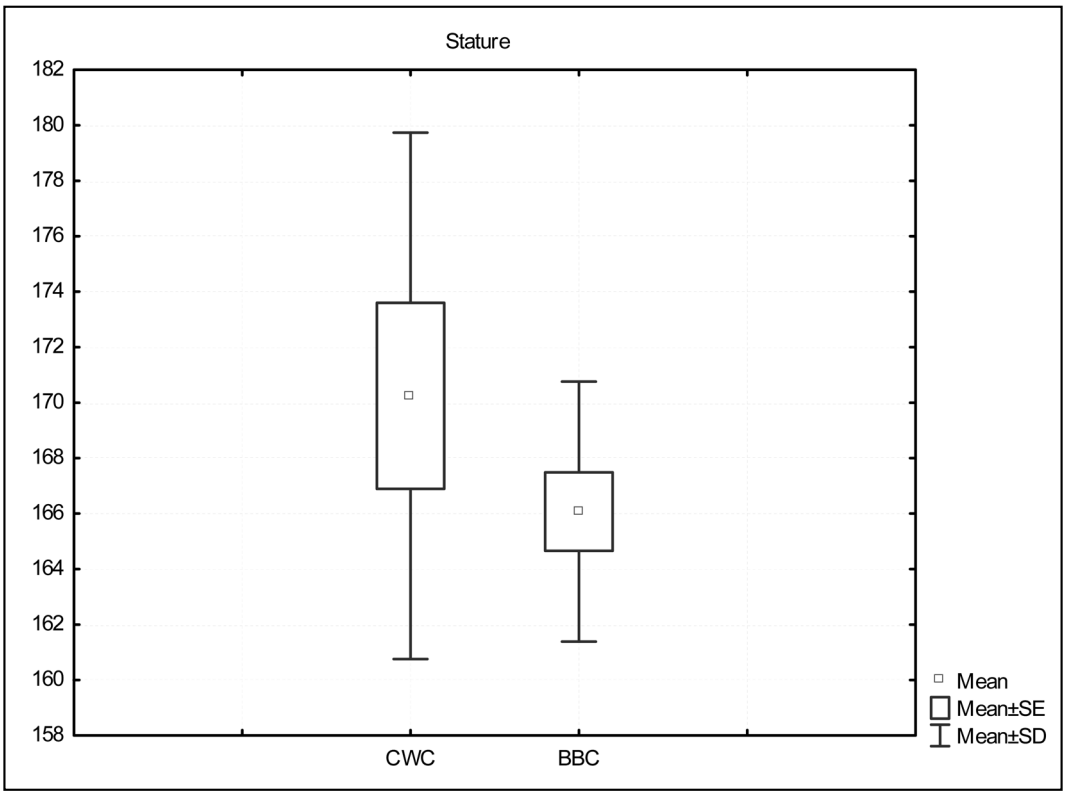

FIGURE 19. Comparison of stature: Corded Ware Culture (CWC) versus Bell Beaker Culture (BBC). SE: standard error; SD: standard deviation.

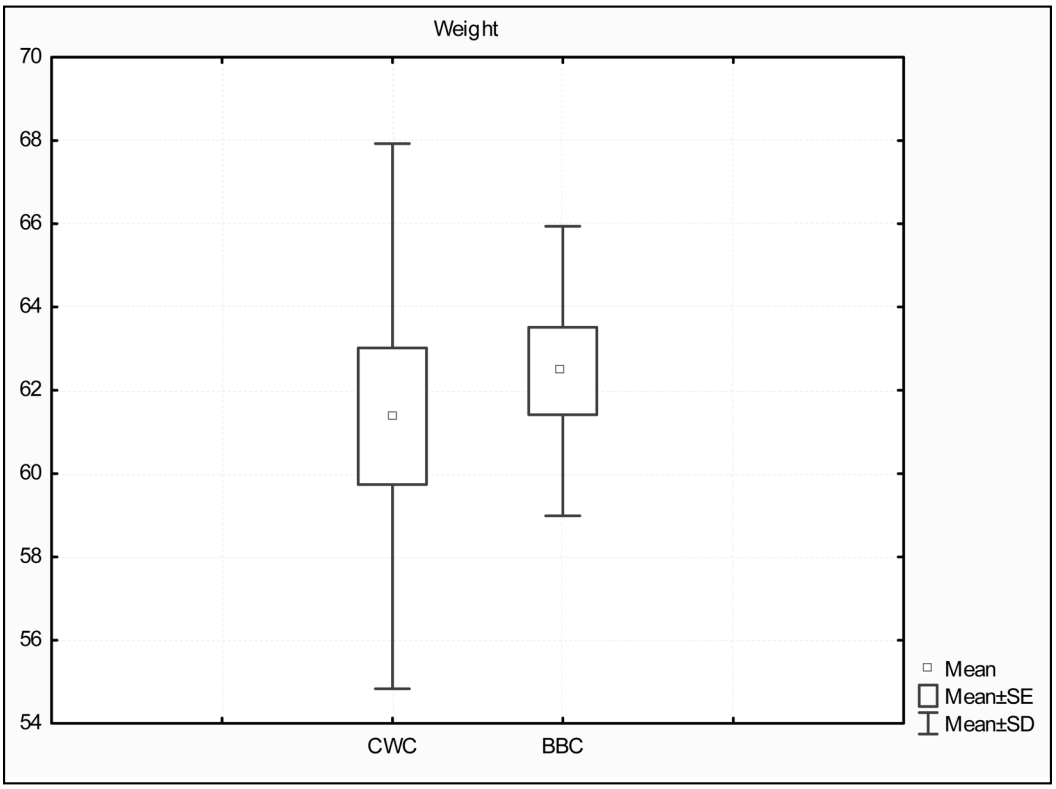

FIGURE 20. Comparison of weight: Corded Ware Culture (CWC) versus Bell Beaker Culture (BBC). SE: standard error; SD: standard deviation.

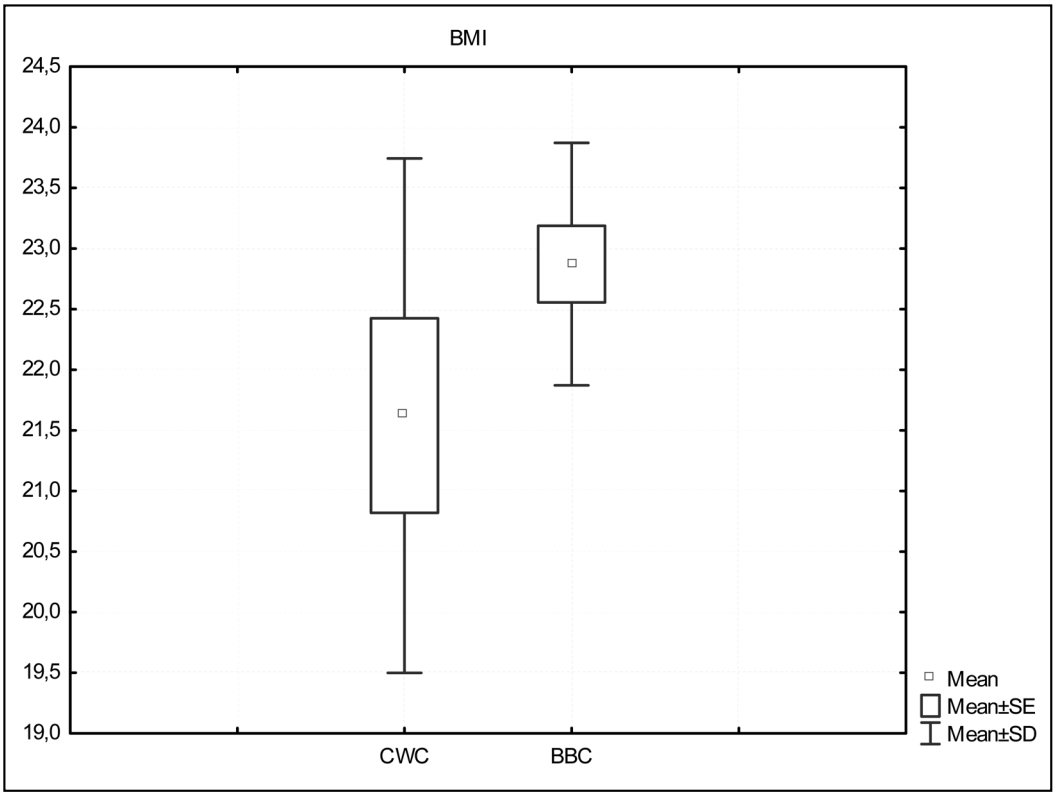

FIGURE 21. Comparison of BMI: Corded Ware Culture (CWC) versus Bell Beaker Culture (BBC). SE: standard error; SD: standard deviation.

CONCLUSION

In our research we listed and analyzed pathologies found on studied skeletal material and tried to compare their occurrence on males and females. It seems that work-load was more intense for males than females, but females had more often nutritional stress. However, the value of Health Index did not significantly differ between sexes.

We also compared health status of the two studied cultures, CWC and BBC. There is no statistically significant proof that their health did differ, but there are some indications from presented results other than t-tests, that there might have been difference. Therefore higher number of studied individuals is necessary together with further and more sophisticated research of this topic.

We assume that body size and shape did change from early to late Neolithic period. Males increased mainly their weight and females increased their height and weight as well. However, to conclude this change as general, further research would be needed with more individuals and more localities included.

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