Proximal Femur Bone Density of the Great Moravian Population from Mikulčice Evaluated by Dual-Energy X-ray Absorptiometry

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Osteoporosis is the most frequent and most serious bone disease, which leads to the reduction in normally mineralised bone mass. For our study, we selected individuals from the burial sites in the vicinity of the Ist, IInd and IIIrd church located within the grounds of the Mikulčice castle and from the Kostelisko burial site in the Mikulčice sub-castle area. In total, the proximal ends of the femur of 70 adult individuals were measured. The examination was conducted with the aid of dual X-ray absorptiometry (DXA) using the standard method with the QDR 4500 device from Hologic (USA). There was found a statistically significant difference only between the average Bone Mineral Density (BMD) values of males and females. BDM values of the Great Moravian population were higher both in males and females compared to the Hologic DXA Reference Data Based on NHANES III of the recent population. It may be concluded, if somewhat exaggeratedly, that the inhabitants of the Great Moravian Empire enjoyed better living conditions or health than the recent population. Similar results were also reached by other European institutions.

Key words: BMD – osteoporosis – DXA – Great Moravia – Early Medieval

1. Introduction

1.1 Osteoporosis and bone mineral density

The World Health Organisation defines osteoporosis as a progressive systemic disease of the skeleton, characterised by a reduction in bone mass, disorders of bone tissue micro-architecture and subsequent increased propensity of the bone to fractures (WHO 1994). Currently, osteoporosis is the most common and thus most serious metabolic bone disease. Osteoporosis fractures are a major cause of morbidity in the population.

A bone mass below average for age can be considered a consequence of inadequate accumulation of bone in young adult life (low peak bone mass) or of excessive rates of bone loss. Peak bone mass is usually achieved between 25-30 years of age and is primarily determined by genetic factors. Additional factors such as gonadal steroids, timing of puberty, low body weight at maturity and at 1 year of life, sedentary lifestyle and low calcium intake during childhood are important in the development of peak bone mass. The causes of bone loss in adulthood are multifactorial, because bone mass is influenced by patterns of physical activity, lifestyle and dietary factors such as calcium intake, vitamin D as well as by exposure to toxic agents.

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Bone mineral density (BMD) is the single best predictor of osteoporotic fracture risk and explains about 80% of the variability in bone mechanical resistance (Lauritzen et al. 1996). However, mechanical resistance of the bone depends not only on BMD, but also on bone microarchitecture and bone geometry – length and width of the femoral neck and the femoral neck-shaft angles (Gnudi et al. 2002). BMD can be assessed with a variety techniques. Dual-Energy X-ray Absorptiometry (DXA) is the most widely used bone densitometric technique.

1.2 Osteoporosis and its complications

Osteoporosis has several causes. The term primary osteoporosis refers to idiopathic juvenile osteoporosis, idiopathic osteoporosis in young adults, and to involutional osteoporosis, which is the most frequent of all types of osteoporosis. It is usually classified according to Riggs (Havelka 1990) as type I – post-menopausal and type II – senile. Post-menopausal osteoporosis occurs more frequently in females aged 55-65, than in men, with a ratio of 6:1. Etiologically, hormonal changes (absence of oestrogens) play a key role in this type. Trabecular bones are affected more significantly and vertebral fractures predominate. Senile osteoporosis occurs after the age of 70, and the ratio of affected females to males is 2:1 (in females, though, the boundary between post-menopausal and senile osteoporosis is not completely clear). Etiologically, decreased levels of the active vitamin D metabolite and increased levels of serum parathormone together with decreased intestinal calcium absorption play a key role. Both trabecular and cortical bone are affected. Fractures of the axial and appendicular skeleton occur, with a predominance of fractures of the long bones and fractures of the femoral neck.

Secondary osteoporosis is caused by another, underlying disease. Apart from long-term immobilisation, these causes mainly include endocrine as well as gastrointestinal diseases, kidney disease or malignancies. Osteoporosis may also be induced iatrogenically, for example in association with the long-term administration of corticosteroids (e.g. Broulík 2001).

Osteoporotic changes are significantly associated with changes of bone function, especially with decreased mechanical robustness. This mechanical deficit is associated with a substantial risk of fractures that may occur even following relatively minimal stress. Osteoporosis is characterised by slow and often asymptomatic development, whereby the first symptom may be such a fracture (Broulík 2001). Common sites for osteoporotic fracture are the spine, hip, distal forearm and proximal humerus. Though fractures of the proximal femur are not frequent in archaeological skeletal samples, the more commonly detected fractures of the vertebrae, the distal end of the forearm and of the ribs, all have a clear relationship with fractures of the femoral neck in the current population (Aufderheide/Rodríguez-Martín 1998).

1.3 Study of the long-term trends in the development of osteoporosis

The clinical significance of osteoporosis lies in the fractures that arise much more rapidly than would be expected according to the demographic data relating to population ageing, especially in developed countries. Research shows that the European population is most affected, demonstrating the highest percentage of fractures (Turner-Walker/Mays/Syversen 2001).

Even within the European continent, there exist certain geographical differences in the prevalence of osteoporosis. Osteoporosis is most widespread in the northern regions of Europe and its incidence decreases southward. In the Czech Republic, a steep increase in osteoporosis-related fractures has been noted, compared to other European countries (Štěpán 1990). The causes of such a great increase in the incidence of osteoporosis and fractures have not as yet been clarified.

Most of the studies mapping the incidence of osteoporosis cover only a very short period of time in view of how long the human population is in existence (Melton/O'Fallon/Riggs 1987; Palvanen et al. 1998). The identification and recognition of the long-term trends of bone density development could help clarify the rising frequency of osteoporosis and thus of fractures in the current population. Consequently, such identification could contribute towards better prevention of this disease. The long-term trends in the development of osteoporosis are studied at some, mostly European, institutions. A number of authors have been involved in the monitoring of osteoporosis, especially in skeleton samples from the Middle Ages since the 1990s (Poulsen et al. 2001; Ekenman/Ericsson/Lindren 1995; Lees et al. 1993; Mays/Lees/Stevenson 1998; Mays 1999). Changes of proximal femur geometry, comparing pre-historical, historical and current populations, have also been the subject of studies (Anderson/Trinkaus 1998).

2. Material

The studied individuals came from the burial sites in the vicinity of the I[st], II[nd] and III[rd] church, located within the grounds of the Mikulčice castle (Stloukal 1963, 1967; Brůžek/Velemínský 2006) and from the Kostelisko burial site in the Mikulčice sub-castle area (Velemínský et al. 2005). It is very probable that both castle burial grounds served the rich classes, while it is expected that the poorer classes were buried at the Kostelisko site. On the other hand, archaeologists presume that the burial sites around the III[rd] church and Kostelisko have a similar socio-economic status, compared to the hinterland burial grounds (Staňa 1997). Selection of these individuals depended on the preservation of their femurs. Only those individuals with both femurs intact were selected (Mazess 2000). Actually, femurs damaged in the area of the head, neck, both trochanters and the intertrochanteric crist were not included in the analysis. Each side of the femur was evaluated separately. Identifying the individual's gender was another criterion used in the selection. We also tried to take the individual's age at death into consideration, but it later became clear that although we worked with only three age categories – 20-35 years, 35-50 years and over 50 years – certain categories were not sufficiently represented to allow statistical evaluation. Finally, we took into consideration whether the given grave lay within Mikulčice within Mikulčice castle itself or within the Mikulčice sub-castle area, as well as the richness of the grave paraphernalia i.e. the social structure of the society (Poláček/Marek 2005).

In total, the proximal ends of the femur of 70 adult individuals – 66 females and 15 males – were measured. In the case of the females, the following graves were involved: 20, 21, 24, 35, 58, 92, 99, 144, 149, 151, 167, 173, 202, 214, 237, 239, 286, 304, 305, 348, 352, 369, 404, 412, 428, 503, 519, 558, 575, 602, 614, 625, 667, 671, 719, 739, 1576, 1578, 1592, 1600, 1605, 1608, 1615, 1636, 1640, 1648, 1680, 1707, 1725, 1775, 1814, 1818, 1820, 1831, 1832, 1835, 1909, 1924, 1938, 1963, 1973, 1998, 1777A, 659-465. The male skeletons included in the study came from the following graves: 130, 1573, 1599, 1784, 1792, 1794, 1809, 1821, 1837, 1854, 1860, 1861, 1908, 1912, 1945, 1980, 1989, 2003, 2005.

3. Methods

Not so long ago, decrease of BMD could be dedected only by using X-rays (Allison 1988, Vyhnánek 1999). A radiology exam is indicative of the diagnosis of osteoporosis only when the amount of bone mineral decreases by 25-30% (Siegenthaler et al. 1995; Štěpán 1990, 1997). Nowadays, bone densitometry using DXA is used on archeological material. In contrast to certain other methods, DXA is a non-invasive method, which is good for archaeological studies of bones (Roberts/Manchester 2007). Although, DXA has a number of restrictions when used in palaeopathology. These include, e.g. effects of burial, or post-mortem effects with loss of bone (Roberts/Manchester 2007).

Currently, in clinical practice, DXA is the most widely used diagnostic method in osteoporosis. The widespread clinical use of DXA, particularly at the proximal femur and lumbar spine, arises from

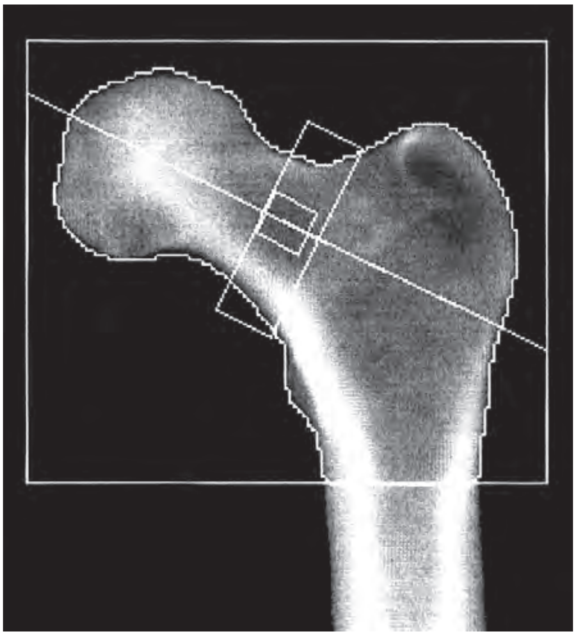


Fig. 1. Densitoetric examination of the proximal femur – the areas of interest (marked graphically)– the whole proximal end of the femur and the femoral neck).

many prospective studies that have documented a strong gradient risk for fracture prediction. This method is based on the utilisation of two defined radiation energy levels, thus eliminating the effect of radiation absorption in soft tissues that envelop non-homogenously the studied bone structure – e.g. the upper femur (Rosa 1999).

The state of bone density is studied not only on the proximal end of the femur, but also on the body of the lumbar vertebra or the second metacarpal. Similar results have been obtained in historical skeletons, where BMD was determined concurrently in several bones. Such an approach is illustrated by the medieval skeletons from Wharram Percy in Norton Yorkshire, England, in which the metacarpal index was measured using radiographs of the second metacarpal (Mays 1996) and, subsequently, DXA of the proximal femurs was conducted (Mays/Lees/Stevenson 1998).

During the archaeological study of bones using methods developed for the current "living" population, one of the problems is the simulation of the soft tissues that envelop the bone in living persons. From the various possibilities available, that using a standardly high layer of rice in which the bone is laid in a clearly defined position appears to be the most suitable (Mays 1999, Turner-Walker/Mays/Syversen 2001).

The examination itself was conducted at the Bone centre of the 3rd Clinic of Internal Medicine, the General Teaching Hospital and the 1st Medical Faculty of Charles University in Prague. BMD was determined on the proximal femur with the aid of double energy X-ray absorptiometry (DXA), using the standard method and the QDR Discovery device from Hologic (USA). For measuring, the femurs were placed in the standard position in a box filled with a 12.5 cm – high layer of rice, simulating soft tissue (e.g. Mays 1999; Turner-Walker/Mays/Syversen 2001). Each femur was measured twice, with reposition of the bone between measurements. For the analysis itself, we then used the average of the values measured in the area of the femoral neck, large trochanter and total femur region. The total femur region of interest encompasses all of the individual regions: the femoral neck, Ward's area, the trochanteric region and the shaft. In this method, the BMD gives an expression of bone mineral content (BMC) per area of bone projection into the picture plane (see. Fig. 1). The paired t-test was used after verification of the significance of differences of the compared groups.

In the adult population, BMD is divided statistically normally, and thus excessive BMD may be expressed as the standard deviation (SD) from the average measured in a population of young, healthy persons of the same sex (Štěpán 1997). In practice, BMD is expressed in T-score units. Every reduction of BMD by 1 SD (1 T-score) doubles the risk of fracture.

4. Results

Table 1 lists the actual average values of bone density measurements in g/cm^2 for the whole proximal end of the femur and for the femoral neck. These values are divided not only with regards to sex, but also with regards to the laterality of the femur.

Table 1. Mikulčice – the values of BMD of whole femoral end and only femoral neck (dx) with regard o sex nad side and Hologic DXA Reference Data for recent population (BMD, SD).

	Males			Females		
	sin	dx	Ref.Data	sin	dx	Ref.Data
N	14	15		55	53	
TOTAL						
Mean of BMD (g/cm^2)	1.1652	1.1224	1,01	1.0247	1.0387	0.8433
min	1	0.907	0.151	0.677	0.693	0.111
max	1.373	1.395		1.323	1.415	
Std.Dev.	0.1223	0.1237		0.1486	0.1493	
T-Score	1,821	1,58		0,6709	0.7906	
NECK						
Mean of BMD (g/cm^2)	1,0147	0.957	0.8808	0.8546	0.8772	0.8128
min	0.853	0.672	0.136	0.592	0.612	0.136
max	1.231	1.231		1.114	1.229	
Std.Dev	0,1259	0.129		0.1182	0.1194	
T-Score	1,4929	1,1867		0.0327	0.2865	

Table 2a. Mikulčice – the values of BMD of whole femoral end and only femoral neck (dx) with regard to sex, age and side.

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
N	3	11	13	10	23	6
	TOTAL					
Mean of BMD (g/cm^2)	1.1087	1.1094	1.0533	1.0493	1.0352	1.0135
min	0.971	0.907	0.754	0.865	0.693	0.840
max	1.179	1.204	1.279	1.290	1.415	1.298
Std.Dev	0.096	0.1287	0.1471	0.1469	0.1477	0.1341
T-Score	1.333	1,3727	0.9076	0.89	0,76	0.5833
	NECK					
Mean of BMD (g/cm^2)	0.9460	0.9239	0.9034	0,8784	0.8666	0.8712
min	0.758	0.672	0.744	0,7100	0.697	0.707
max	1.069	1.109	1.193	1.111	1.229	1.035
Std.Dev	0.0996	0.1329	0.1162	0,1216	0.1189	0.1024
T-Score	0.9	0.9636	0.4769	0,4333	0.1695	0.2167

Table 2b. Mikulčice – the values of BMD of whole femoral end and only femoral neck (sin) with regard to sex, age and side.

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
N	3	11	14	10	24	5
	TOTAL					
Mean of BMD (g/cm^2)	1.0517	1.1592	1.0294	1.0188	1.0088	1.0996

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
min	0.875	1	0.69	0.847	0.677	0.874
max	1.143	1.314	I.29	1.245	1.309	1.323
Std.Dev	0.1012	0.1306	0.1489	0.1441	0.1439	0.1325
T-Score	0.9	1,7727	2,80	0.62	0,5417	1,28
	NECK					
Mean of BMD (g/cm2)	0.9053	1.0119	0.8524	0,8743	0.8289	0.9428
min	0.732	0.869	0.595	0,6910	0.592	0.771
max	1.039	1.231	1.083	0,9840	1.114	1.058
Std.Dev	0.1061	0.1281	0.1182	0,1189	0.1155	0.0951
T-Score	0.5	1,4727	0.0286	0,2400	0.225	0.84

Table 3. Mikulčice - the values of BMD transformed into z score of whole femoral end and only femoral neck (dx) with regard to sex nad side.

	Males		Females	
	sin	dx	sin	dx
N	16	19	65	58
	TOTAL			
Mean of BMD (g/cm^2)	2,338	2,137	1,011	1,116
min	0,7	-	-1,9	-1,4
max	4,2	4	3,6	4,5
Std.Dev	0,952	0,953	1,278	1,288
	NECK			
Mean of BMD (g/cm^2)	2,188	1,711	0,609	0,779
min	0,4	-1,2	-1,9	-1,2
max	4,3	3,8	3,5	3,2
Std.Dev	1,084	1,096	1,168	1,176

Table 4. The comparison Great Moravian population with Norwegian and English Mediaeval skeletons (Mays et al. 2001) on the base the BMD of femoral neck.

		BMD at the femoral neck (g/cm^2)		
		Great Moravian population	Mediaevel Norway	Mediaeval England
Female	18-29 yrs	0.903	0.953	0.951
	30-49 yrs	0.867	0.783	0.808
	50+ yrs	0.871	0.702	0.724
Male	18-29 yrs	0.946	0.981	0.988
	30-49 yrs	0.924	0.886	0.934
	50+ yrs	-	0.828	0.826

In total, the proximal femurs of 60 adult individuals were measured – 55 females and 15 males. Regardless of the age at death, the average bone density in g/cm^2 (BMD) in the whole proximal right femur was 1.039 (SD 0.149) in females, and 1.122 (SD 0.124) in males. As for the left femur, it was 1.025 (SD 0.149) in females, and 1.165 (SD 0.122) in males. Femoral neck BMD values were as follows: females 0.86 g/cm^2 (SD 0.12) and males 0.94 (SD 0.13).

A statistically significant difference was shown between the average BMD values in males and females, both in the case of the whole proximal femur ($p < 0.01$), and in the case of the femoral neck BMD (dx = $p < 0.05$, sin = $p < 0.01$)

We worked with three age groups – 20-35 years, 35-50 years and over 50 years. The results are summarised in Tables 2a, b. The average value of bone density in g/cm^2 in females younger than 35 years (N=13) for the whole proximal end of the right femur was 1.053 (SD 0.147), for the femoral neck 0.903 g/cm^2 (SD 0.116). In the age group of 30-40 years (N=10), the average value of bone density of the proximal end of the right femur was 1.049 g/cm^2 (SD 0.147), and that of the femoral neck was 0.878 g/cm^2 (SD 0.122). Finally, in the largest group of females, those aged 35-50 years (N=23), the average value of bone density of the proximal end of the femur was 1.035 g/cm^2 (SD 0.148), and that of the femoral neck was 0.867 g/cm^2 (SD 0.119). Our group included only six females whom we presume to have died aged over 50. BMD values of the left femurs were similar in the individual age groups, or slightly lower. If we look at the BMD values of the whole femur end and of the femoral neck, it is clear that these more or less decrease with increasing age. The differences, though, are not statistically significant. In males aged 35-50 years (N=11), the average value of the bone density of the whole proximal end of the right femur was 1.109 g/cm^2 (SD 0.129), and that of the left femur was 1.159 g/cm^2 (SD 0.131). In the case of the femoral neck, these values were 0.924 g/cm^2 (SD 0.133) and 1.012 g/cm^2 (SD 0.128) respectively. The group of males younger that 35 is represented by only three individuals. Males who reached an age over 50 were not present in this group. No statistically significant differences were found between the age groups. However, the results may haven been influenced by the rather low number of individuals assessed.

From Tables 1, 2 it is clear that the bone tissue (mineral) density of the proximal femur is higher than that of the femoral neck, regardless of gender, age group or laterality. The BMD values of the femoral neck are on average lower by 0.15 g/cm^2 ($p < 0.01$). No statistically significant results were found between the BMD values of the right and left femurs.

5. Discussion

From the aspect of the incidence of osteoporosis, only one skeleton group has been examined in the Czech Republic– adult individuals from the burial site on Chelčického Square in Žatec, dating from the 11th-13th century (Likovský 2005). Although 265 individuals from this burial site were examined anthropologically, only 32 individuals of determined age and sex – 15 females and 17 males – remained for bone density evaluation, once femurs damaged in the area of the head, neck, trochanters and intertrochanteric crist were excluded. Only two age groups could be used in the evaluation – individuals who died before the age of 30 and individuals older than 50. The possibilities of interpreting the results of such a small group are quite restricted. Moreover, there was a significant variance among the values measured in young individuals.

The BMD values of this group did not essentially differ from those of the Mikulčice population. In the most represented group of males aged over 50 (N = 13), the average density value of the whole proximal end of the femur was 1.20 g/cm^2 (SD 0.15) and that of the femoral neck was 0.97 g/cm^2 (SD 0.11). Both values were statistically non-significantly higher than those of the analogical BMD values of Great Moravian males aged 35-50 years. In the population sample from Žatec, the density of bone tissue of the proximal end of the femur was also altogether higher than that of the femoral neck, but the difference in values was statistically significant only in females over the age of 50. The differences between the BMD values of both sexes were statistically significant (Likovský 2005).

If we do not take into account Central Europe, then the bone density of the proximal femur has been evaluated mainly in the medieval populations of Northern and Western Europe (e.g. Mays 1999, Mays/Turner-Walker/Syversen 2005, 2006). There definitely are not too many studies dedicated to this issue. If we compare, for example, the Great Moravian BMD values with those determined in medieval skeletons from burial sites in Trondheim, Norway and Wharram Percy, England, then the Mikulčice females have a slightly higher BMD (by approx. 0.1-0.05). This applies to all age categories, with the exception of the youngest. This, though, may be due to the fact that in the Great Moravian group, the lowest age category was defined somewhat more widely, from 18-34 years, while in the Norwegian/English population it was only 18-29 years. On the contrary, the following age category in the Great Moravian population was 5 years shorter at 35-49, compared to 30-49 years (Table 4). The BMD values of Mikulčice males were lower in both comparable age groups, compared to the BMD values of males from the English burial site at Wharram Percy. Compared to the Norwegian medieval population, these values were higher in males in the age category of 30-49 years, while in males in the age category of 18-29 years, BMD values were lower. Nonetheless, these results may again be influenced by the different definition of the age groups (Mays/Turner-Walker/Syversen 2005).

If we compare our results with the reference BMD data from the recent population (Hologic DXA Reference Data Based on NHANES III; Caucasian Female and Male), the Great Moravian population BMD values are clearly higher both in males and females (Bonnick/Miller 2004) (see Table 1). This applies especially in the case of BMD values of the total femur. The difference in BMD values of the femoral neck in females is no longer statistically significant. For comparison with the current population, it is to some extent possible to also apply the so-called z-score BMD values ($BMD_{z\text{-score}}$) (see Table 3). The BMD of medieval bones ($BMD_{medieval}$) are transformed into z-scores using the formula:

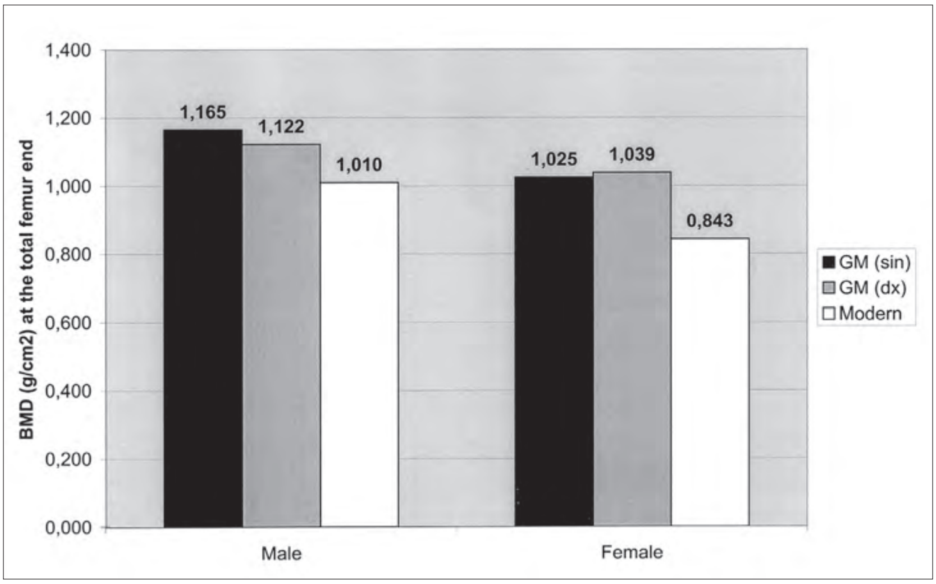
$$BMD_{z\text{-score}} = (BMD_{medieval} - BMD_{contemporary}) / SD_{contemporary}$$

. $BMD_{z\text{-score}}$ values correspond to the results, if we compare the Mikulčice BMD values with the Hologic DXA Reference BMD Data from the recent population. From this aspect, it may be concluded, though this may appear exaggerated, that the residents of the Great Moravian Empire had better living conditions than the recent population.

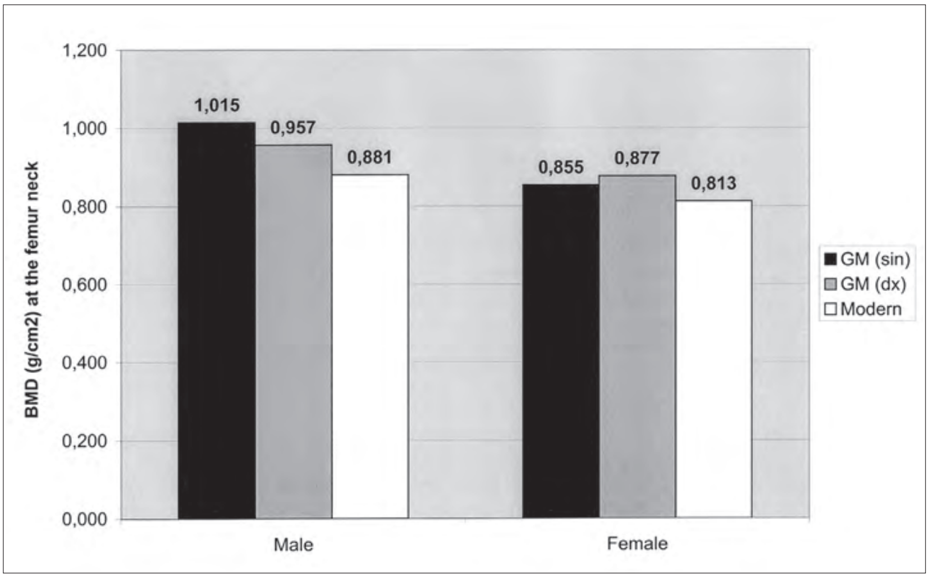
The BMD values measured in the Žatec -Chelčického Square were as a rule also above the norm for the current population group (Likovský 2005). Similar results were also reached by other European institutions (e.g. Ekenman/Ericsson/Lindgren 1995).

The Poulsen et al. (2001) study cited above showed that medieval females had lower BMD compared to contemporary females, but this relationship was reversed in females who survived into older age. In contrast, medieval males had significantly higher BMD compared to contemporary males at all ages. Authors explain the observed lower BMD in medieval females by the well-known selective mortality among younger females. A high birth rate and prolonged periods of lactation are the main reasons for the observed increased mortality, and therefore can also very likely explain the associated low BMD. The increase in the incidence of osteoporosis in modern elderly females could possibly, or partially, be explained by the survival of females who would have died prematurely had they lived in earlier centuries (Poulsen et al. 2001). Another study involving medieval populations from Norway and England reached similar conclusions (Turner-Walker/Mays/Syversen 2001).

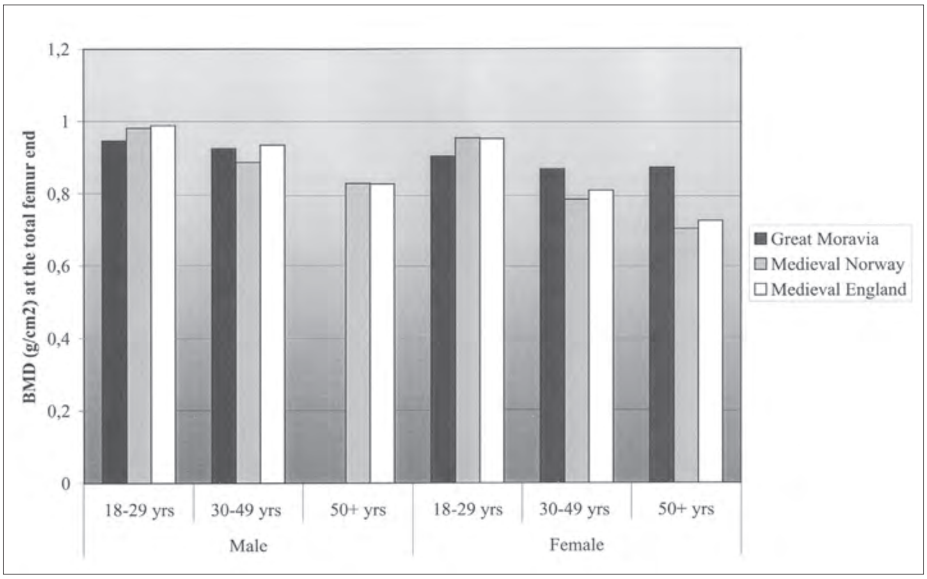
Correlation of BMD values with age, more precisely their decrease with increasing age, valid for the current population has been shown by a number of works. For example, research involving the burial sites in Trondheim, Norway and Wharram Percy, England reached analogical conclusions (Mays/Turner-Walker/Syversen 2005, 2006). On the other hand, another Danish study found that medieval females of



Graph 1a. The comparison of medieval Great-Moravian and recent populations on the base BMD at the whole femur end.



Graph 1b. The comparison of medieval Great-Moravian and recent populations on the base BMD at the femur neck.



Graph 2. The comparison of medieval Great-Moravian, Norway and English populations on the base BMD at the femur neck.

a lower age category showed lower BMD, while bone mass increased with age in older females. This, though, did not apply to males (Poulsen et al. 2001).

In other studies, BMD values similar to those of the current population were recorded. Given that great difference in lifestyles as well as lifestyle factors are widely held to influence the severity of bone loss in osteoporosis, the similarities between medieval and modern populations in the patterns of bone loss are surprising. (e.g. Mays/Lees/Stevenson 1998). This may be a case of a population specific phenomenon, and the results may also be related to the method of evaluation – the technique of BMD measurement in the femur and the "adequate" simulation of soft tissue.

Moreover, generally, pathological conditions that reduce bone density, such as osteoporosis, also reduce the ability of bones to resist decomposition. Osteoporosis is thus one of the causative factors of fractures (e.g. Leppälä et al. 1999). The incidence of osteoporosis is most often associated with fractures of the femoral neck, radial Colles' fractures and vertebral compressive fractures (e.g. Brickley 2002; Mays/Turner-Walker/Syversen 2006). We did not find any osteoporosis-related femoral fractures or Colles' fractures in our evaluated sample. Also, we did not evaluate vertebral fractures.

We also tested the degree of correlation between bone mineral density (BMD) and certain traits considered to be manifestations of environmental stress. For example, no relationship was found between BMD and the presence or absence of Harris lines or cribra orbitalia (e.g. McEwan/Mays/Blake 2005).

The basic problem of proximal femur bone density studies in previous populations is the lack of a "norm" for the bone density of the given previous population, to which it would be possible to relate the acquired results. This means that the interpretation of the acquired results is problematic. One must realise that the clinical studies with which we attempt to compare our observations deal with a living population. Moreover, norms are drawn up based on a healthy population. Works studying historical material operate with the dead, and if we cannot prove that sudden death occurred in a completely healthy individual (e.g. violent death), we must take into account that the individual in question suffered from a chronic underlying disease that may have affected the mineral concentration in bones.

6. Summary

The skeleton is metabolically active and bone remodeling occurs throughout life. Currently, osteoporosis is the most frequent and most serious bone disease, which leads to the reduction in normally mineralised bone mass. This is a progressive systemic disease of the skeleton, characterised by a decrease in bone mass, disorders of bone tissue micro-architecture and the subsequent increased propensity of the bone to fractures (WHO 1994). The clinical symptoms of osteoporosis in the current population are increasing much more rapidly than would be expected based on demographic data related to population ageing. Understanding the long-term trends of bone density development is one of the possible means of clarifying the rise of osteoporosis and thus of fractures in the current population. Thus, a number of authors have been monitoring osteoporosis since the 1990s. Medieval skeletal samples have been studied especially (Poulsen et al. 2001; Ekenman/Ericsson/Lindgren 1995; Lees et al. 1993; Mays/Lees/Stevenson 1998; Mays 1999).

For our study, we selected individuals from the burial sites in the vicinity of the Ist, IInd and IIIrd church located within the grounds of the Mikulčice castle (Stloukal 1963, 1967; Brůžek/Velemínský 2006) and from the Kostelisko burial site in the Mikulčice sub-castle (Velemínský et al. 2005). Selection of these individuals depended on the preservation of their femurs. In total, the proximal ends of the femur of 70 adult individuals – 66 females and 15 males – were measured. The examination was conducted with the aid of dual X-ray absorptiometry (DXA) using the standard method with the QDR 4500 device

from Hologic (USA). For measuring, the femurs were placed in the standard position in a box filled with a 12.5 cm-high layer of rice, simulating soft tissue (e.g. Mays 1999; Turner-Walker/Mays/Syversen 2001).

The results may be summarised as follows:

- a statistically significant difference was only found between the average Bone Mineral Density (BMD) values of males and females
- no statistically significant difference was found between the average BMD values of the individual age groups
- no statistically significant difference was found between the average BMD values at the whole femur end and the femoral neck
- BDM values of the Great Moravian population were higher both in males and females compared to the Hologic DXA Reference Data Based on NHANES III of the recent population. It may be concluded, if somewhat exaggeratedly, that the inhabitants of the Great Moravian Empire enjoyed better living conditions or health than the recent population.

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