ABSTRACT

The aim of this study was to detect and describe the trends in shape variability of proximal and distal human tibia related to sex, age, social status and time period. The variability of its shape and form was analysed first in an early medieval sample, then in two modern populations, an early 20th century sample and the contemporary Czech population. Finally, data from the whole studied time span were analysed.

The initial raw data were acquired by optical scanning and computed tomography (CT) scanning of the lower limbs; the three-dimensional bone surfaces of the contemporary tibias were segmented from the clinical CT scan sequences. Geometric morphometrics and multivariate statistical methods were applied to study the variations in shape and form quantitatively. Proximal and distal tibias were evaluated independently, and the potential influence of sex, age at death and time period were investigated. In the early medieval population, we also explored the relationship between tibial morphology and presumed social status derived from the respective grave location within the settlement.

Because traditional morphometric analysis revealed statistically significant sex differences in the parameters of both tibial extremities (e.g., Steyn and Işcan, 1997; Šlaus et al., 2013), we thus assumed the dimorphism of form including its population specificity. Apart from its confirmation, we surprisingly identified sex-related differences in shape concerning all the samples except the distal tibias of the 20th century Czech population. Moreover sex-based divergence varied among the analysed samples, and significant differences were identified even between chronologically close populations (20th vs. 21st century). The contribution of allometry that we detected in almost all dimorphic configurations revealed that the shape differences were due to the different mechanical loads acting on these bones.

Effects of aging include bone loss, microarchitecture changes, activity decrease and reduced bone remodelling. These phenomena are associated with changes in the diaphyseal cross-sectional geometry (Ruff and Hayes, 1983). In our study, significant differences were also identified between the age groups in the shape of the proximal tibia in all samples studied. Thus, morphological changes in the articular ends can be detected before obvious joint degeneration and the onset of osteoarthrosis.

In the prehistoric and historic stratified populations, a higher prevalence of the non-specific stress indicators and the presence of skeletal markers of higher physical load indicate the impact of different environmental and behavioral factors (Larsen, 1999). This was also

shown in the early medieval sample from Mikulčice (e.g., Havelková et al., 2008); however, neither of the tibial parts was affected by the presumed social status in that particular population.

Following up on the previous studies documenting a positive secular trend in body height or long bone length over the past centuries (e.g., Meadows Jantz and Jantz, 1999), we expected to find temporal shape and size changes in the proximal and distal tibia as well. Both the proximal and distal tibias showed pronounced and statistically significant differences between the groups from different time periods (even between the chronologically close samples). Moreover, changes in the proximal tibial morphology occurring since the Early Middle Ages to the 20th century continued to the present. This temporal trend can be interpreted as a reflection of the changing environmental conditions and physical load this part of the tibia has to withstand (in terms of nutrition, improvements in hygienic conditions and decreasing physical activities).

In spite of the generally accepted assumptions about strong genetic determination and phenotypic stability of the shape of the long bone extremities (Lieberman et al., 2001), the analyses of human tibia shape variability revealed factors causing sex, age and diachronic differences. The results show that the most influential factor affecting proximal and distal tibial morphology is the sex of the individual followed by chronological age of the sample. The least influential factor is the age at death. The effect of social status on tibial shape was not shown.