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BILATERAL ASYMMETRY OF LONG BONES IN BRONZE AND EARLY IRON AGE PASTORALISTS OF THE ALTAI*

The aim of the study is to explore patterns of directional asymmetry (DA) of long bones among the ancient pastoralists of the Russian Altai. Long bones of the upper and lower limbs and clavicles were measured bilaterally in two temporally diverse skeletal samples dating to the Middle Bronze Age and the Early Iron Age. Statistically significant sex and chronological differences were found in DA of the upper limb diaphyseal breadths, which are strongly influenced by mechanical factors during life. These results suggest that manual loadings were bilaterally symmetric in males, but not in females. Sexual dimorphism in the upper-limb-use asymmetry was greater in the later group than in the earlier group. Besides, the female subgroups exhibited strong DA in features evidencing biomechanical stress on the femur. Temporal differences in DA of the upper limb length are possibly due to changes in the level of environmental and/or genetic stress.

Keywords: *Bilateral asymmetry, physical activity, long bones, pastoralists, Bronze Age, Early Iron Age, Scythian period, Altai.*

Introduction

The degree of bilateral asymmetry of human bones can be an indicator of biological adaptation to various factors of external and internal environment. There are three basic types of bilateral asymmetry: fluctuating (*FA*), directional (*DA*), and antisymmetry (*AnS*), which differ in the nature of differences between the right and left sides. *FA* indicates minor random differences that are normally distributed around zero mean. In *DA*, also described as fixed asymmetry, one side is larger than the other on average (the differences are also normally distributed whereas the mean is significantly greater than zero). In *AnS*, or random asymmetry, the difference between sides is significant, but the larger side is determined randomly (the distribution of differences is bimodal or platykurtic with zero mean (Palmer, Strobeck, 1986, 2003)). Various types of asymmetry often interact. The most informative types in the study of ancient populations are *FA* and *DA*.

FA measures the level of developmental instability, which increases under environmental and genetic stress (Harris, Nweeia, 1980; Livshits, Kobyliansky, 1991; Hershkovitz et al., 1993; Markow, Martin, 1993; Gray, Marlowe, 2002; Guatelli-Steinberg, Sciulli, Edgar, 2006;

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Schaefer et al., 2006; DeLeon, 2007; Hoover, Matsumura, 2008; Graham et al., 2010; Özener, 2010). However, measuring *FA* under considerable *DA* is technically very difficult (Palmer, 1994; Graham et al., 1998), which imposes certain restrictions on the choice of traits. Studies of *FA* in ancient populations are normally based on dental and cranial characters.

DA of human bones is related to functional asymmetry (motor, sensory, and psychic). Motor asymmetry may be related to unilateral motions, when mostly one (dominant) arm is used, to functional specialization of the legs, to the development of motor capacities, and to the conditional response speed. *DA* of long bones is largely caused by functional adaptation to mechanical factors. Relationship between *DA* and mechanical loading on limb bones, especially on those of the upper limbs, is widely used in the study of physical stress in ancient populations with regard to lifestyle and work, and of the sexual division of labor. Most such studies, however, focused on hunter-gatherers and farmers residing in regions other than Russia (Ruff, Jones, 1981; Bridges, 1989; Fresia, Ruff, Larsen, 1990; Stirland, 1993; Sakaue, 1998; Mays, 1999; Bridges, Blitz, Solano, 2000; Stock, Pfeiffer, 2004; Westcott, Cunningham, 2006; Sládek et al., 2007; Wanner et al., 2007; Kujanová et al., 2008; Maggiano et al., 2008; Sparacello, Marchi, 2008; Pomeroy, Zakrzewski, 2009; Weiss, 2009; Sparacello et al., 2011).

The objective of the present study is to evaluate directional asymmetry of long limb bones and clavicles in Bronze and Early Iron Age pastoralists of the forest-steppe zone of the Altai.

Materials and methods

Long bones of upper and lower limbs and clavicles from burials associated with two cultures of the forest-steppe Altai were studied: Middle Bronze Age Andronovo Culture (AC) and Early Iron Age (Scythian era) Staroaleika Culture (SC). The economy of both groups was mainly pastoral. The AC sample includes skeletons from Barsuchikha-1, Zolotushka, Malopanyushevsky, Manzhikha-5, Teleutsky Vzvoz-1, Firsovo-14, Chekanovsky Log-2 and 10, whereas the SC sample consists of skeletons from Firsovo-14 and Tuzovskie Bugry-1. Collections are owned by the Altai State University Museum of Archaeology and Ethnography Department of Anthropology.

Sex and age were estimated by standard methods. Age differences between the two samples are insignificant. Long bones of arms and legs (humeri, ulnae, radii, femora, tibiae), and clavicles were measured on both sides. Bones with incompletely fused epiphyses as well as deformed and pathologically affected ones were excluded. Limb bones were oriented in the medio-lateral and sagittal planes according to the technique proposed by C. Ruff (Ruff, Hayes, 1983; Ruff, 2002). The midshaft of tibiae was assessed on the basis of total length (T1) whereas that of other bones (H1, R1, U1, F1) was based on maximal length. The accuracy of longitudinal measurements was within 0.5 mm, and that of transverse diameters of the shaft, within 0.05 mm.

Apart from standard measurements, numbered after R. Martin (Alekseyev, 1966), several additional ones were taken in the study of *DA*. These include the average midshaft diameter, calculated as a half-sum of the sagittal and medio-lateral diameters. Also midshaft diameters of humeri (sagittal, medio-lateral, and average) were taken at 35 % maximal length from the distal end. On the tibiae, minimal and maximal midshaft diameters were measured.

To calculate the measurement error, long bones of seven individuals were measured three times with an interval of several weeks. The error was calculated by the method proposed by T.D. White (White, Folkens, 2005): deviations from the mean were averaged and divided by the mean. For most measurements, the error was less than 0.5 % and therefore could not have affected the results in an appreciable way (Table 1).

For a qualitative evaluation of *DA* the standardized directional asymmetry coefficient, %DA, was calculated according to the formula:

$$\%DA = \frac{(R-L)}{0{,}5(R+L)} \times 100,$$

R being the dimension on the right side, *L*, that on the left side

This formula, which is widely used (Steele, Mays, 1995; Čuk, Leben-Seljak, Štefančič, 2001; Mays, 2002; Auerbach, Ruff, 2006; Blackburn, Knüsel, 2006; Sládek et al., 2007; Auerbach, Raxter, 2008; Kujanová et al., 2008; Jaskulska, 2009; Pomeroy, Zakrzewski, 2009; Weiss, 2009; Stock et al., 2013), makes it possible to compare the asymmetry of dimensions regardless of their absolute value as in the case of bone length and shaft breadth. The %DA value is positive if the right dimension is larger, and negative in the opposite case.

The normality of the %DA distribution was assessed with the Lilliefors test. If no significant departures from normality were found, the one-sample *t*-criterion was applied to test if the mean %DA significantly differs from zero. In case the distribution of %DA was significantly non-normal, the Wilcoxon nonparametric statistics was used to test the significance of difference between the sides. To evaluate the sexual and temporal differences, the nonparametric Mann-Whitney U-test was employed.

For calculating the proportion of individuals with the predominance of the right and left side, only %DA > 0,5 %, were used to avoid the effect of measurement error and *FA* (Auerbach, Ruff, 2006). Significance of between-