# The Problem of Determining Sex and Species of ancient Animals and their Height in Withers Based on Metapodium

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Abstract

The tasks of reconstruction of a whole object from its fragments are frequent in archaeological research. Usually a part of them is solved with the help of multivariate statistic analysis and another part needs different methods and approaches. This paper deals with questions of reconstruction. The problem of determination of cattle's sex and height in withers on the base of the metapodials. The program was worked out by application of discriminant and regression analyses. Osteological data on the ancient and medieval assemblages found in Eastern and Western Europe were studied by Prof. A. Petrenko.

Animal bones make up the most substantial material in the archaeology. But its fragmentary keeping in hand is the cause for the great importance of the reconstruction problem for the archaeological data.

In the number of works this problem is treated in the aspect of the sex and species determination for ancient animals as well as their height in withers estimate based on the metapodium.

The work of V. Tsalkin (1960) contains the measurements for the Kalmyk breed cattle and for some samples from the archaeological monuments in the Eastern Europe. G. Nobis (1954) put forward the idea to determine the animal sex on the base of the ratio of upper epiphysis x2 and the metapodium length x1 (in percentage). According to his measurements of the metacarpus the value of the ratio x2/x1 for cows, oxen and bulls varies over the intervals (26.5-29.7), (29.0-31.9), (30.6- 39.8), respectively.

V. Tsalkin's experiments showed that the use of these intervals brought to the wrong results in determining of the sex of the Kalmyk breed. The probable explanation is that G. Nobis has developed his methodics using the cattle bones, which were essentially different from the Kalmyk breed.

To decrease the possible errors, V. Tsalkin proposed to use the correlation graphs for the values of the absolute size (metapodium length x1) and the relative size (the ratio of diaphysis width x4 to the length x1).

The modern methods of mathematical statistics allow to use the data to the full extent, thus to decrease the errors when working with the cattle bones of various populations.

In this paper the methods of discriminant analysis are used to determine the cattle sex on the base of the metapodium materials, which were found at the archaeological monuments of the Eastern and Western Europe.
Measurements for the Kalmyk breed metapodium are used as the main training sample. They contain the measurements of the metapodium (the metacarpus and the metatarsus) width of the upper epiphysis $x_2$ and the lower epiphysis $x_3$, and the least width of diaphysis $x_4$. The measurements of other cattle species including materials of Julius- Kuhn Sammlung by courtesy of Dr. H.H. Muller and Dr. M. Teichert were used to correct the discriminant functions.

To solve this problem the absolute and the relative combinations of these four measurements were taken into consideration.

First of all, the index $J=100*(x_2/x_1)$ proposed by G. Nobis was used to determine the sex by the metacarpus method. The calculations are resulted in the following classification table

| | Size | Cow | Ox | Bull |
|---|---|---|---|---|
| Cow | 59 | 54 | 5 | 0 |
| Ox | 13 | 1 | 11 | 1 |
| Bull | 10 | 0 | 2 | 8 |

Percentage of the cases correctly classified is 90.24 %. A little of the cases of the better result was obtained by using an index $I = 100*(x_2 +x_3)/ x_1$. Classification table is as follows

| | Size | Cow | Ox | Bull |
|---|---|---|---|---|
| Cow | 59 | 56 | 3 | 0 |
| Ox | 13 | 0 | 12 | 1 |
| Bull | 10 | 0 | 2 | 8 |

Percentage of the cases correctly classified is 92.68 %. Greatest percentage of the cases correctly classified was obtained by the use of four coefficients $x_1$, $x_2$, $x_4$ and index I. Classification table is as follows

| | Size | Cow | Ox | Bull |
|---|---|---|---|---|
| Cow | 59 | 56 | 3 | 0 |
| Ox | 13 | 0 | 12 | 1 |
| Bull | 10 | 0 | 2 | 8 |

Percentage of the cases correctly classified is 96.34 %. The cattle of the ancient Europe is differ from the one of the Kalmyk breed. Moreover, they had differences at the conditions to the cattle breeding. Therefore it is necessary to make an adjustment of the discriminant functions obtained.

For this goal the mixture histograms concerning the index I for the cows, oxen and bulls of the Kalmyk cattle (Fig.1) were constructed.

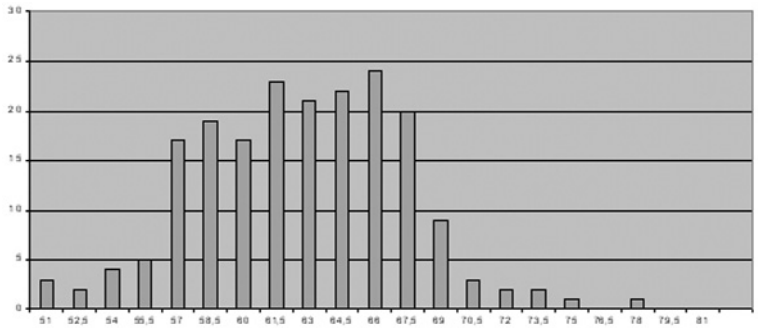


Figure 1 The histograms on index I of the Kalmyk cattle

This histogram contains three top values in the range of the index value: "58", "63" and "70", which are connected with an average value I for the cows (57.7), oxen (63.5) and bulls (69.2).

We assume that the index I have gaussian distribution for cows, oxen and bulls. Then the above expectations and the corresponding variances allow us to find the values of the index I separating the cows, oxen and bulls. These values are 60.8 and 65.8.

The same histograms were drawn for various monuments of Eastern and Western Europe (the part from them is indicated).

The above three top values are clearly recognized at some histograms (see Figure 3 for the cattle of the Manching monument (Durr 1961, Begatov 1994)). At the other histograms (see Figure 2 for cattle of the Bilyarsk monument of Volga Bulgaria XI - beginning XIII century (Begatov 1994)) they are diffused.

The consideration of these histograms allows us to assume that the distance between the top values with regard to definite sex is not practically changed from one monument to another, and that the value of the shift is determined by the position of the left maximum (for most of the cows).

The analysis of histograms leads to the conditional division of the cows into the species: the small size "forest" and the large size "steppe".

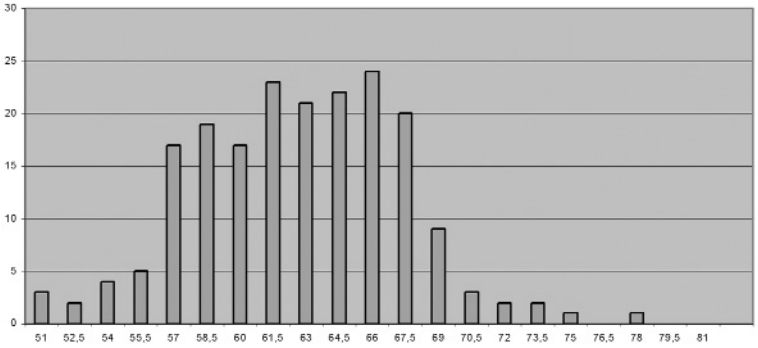


Figure 2 The histograms on index I for cattle of the Bilyarsk monument

The separating point of an index I for the cows and the oxen of the steppe" breed is 60.8, the one for the "forest" breed is 58. The points separating the oxen and the bulls of the "steppe" and "forest" breeds have the values 65.8 and 63.0, respectively.

The separating point of an index J for the cows and the oxen of the "steppe" breed is 30.2, the one for the "bulls" breed is 28.5. The points separating the oxen and the bulls of the "steppe" and "forest" breeds are 33.3 and 31.5, respectively.

Generally, it is necessary to define a displacement of the left maximum of the index histogram with respect to the left maximum for the Kalmyk cattle. This displacement will define an appropriate displacement of the separating points.

The further researches using the measurements of the metapodium of the ancient and modern cattle allow us to verify the distributions of the sexes for various archaeology monuments and to correct the coefficients of the discriminant function.
The discriminant functions for the cows, oxen and bulls are as follows:

$F\ cow = 12.51x_1 - 26.04x_2 - 15.33x_4 + 44.28I - 2489$
$F\ ox = 12.21x_1 - 26.05x_2 - 15.51x_4 + 45.67I - 2580$
$F\ bull = 12.15x_1 - 26.21x_2 - 15.23x_4 + 46.69I - 2635$

They allow us to determine the cattle sex by the single metacarpus. When the monument has a great number of the cattle metacarpus, it is recommend to draw histograms for an index I to ensure the better results.

The problem of determining the sex by metatarsus was considered in this work too. This method is less reliable than the one by V. Tsalkin.

Now researchers use one-dimensional homogeneous model of regression $h=bx_1$ to define the height in withers by the metapodium length $x_1$. Here the coefficient of the regression depends on a sex of an animal. Some best result can be received, if it can be taken multivariate, homogeneous or non-uniform regression model. For the definition coefficient of the regression we used papers of V. Tsalkin (1960), J. Boessneck (1956), J. Matolcsi (1970), where the calculations have been made for metacarpus and metatarsus. They have shown that the mistake in the determination of height has the identical order to the cases of the known metacarpus and metatarsus. However, it is better to determine the sex by the metacarpus, than by the metatarsus. As a result, it is better to define the height by the metacarpus.

The following formulas are received for the calcu-

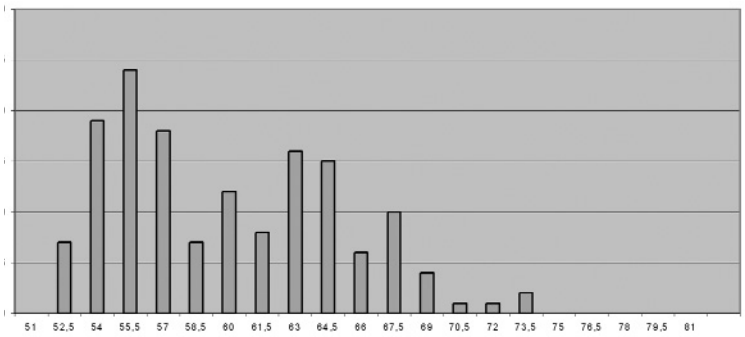


Figure 3 The histograms on index I for cattle of the Manching monument

lation of the height in withers on the base of the metacarpus length at homogeneous ($h_h$), non-uniform ($h_n$), V. Tsalkin's ($h_t$) models.

For cows
$h_h = 0.410x_1 + 0.066x_2 + 0.409x_3 + 0.321x_4$;
$h_n = 0.143x_1 + 0.393x_2 + 0.133x_4 - 0.524I + 97.4$;
$h_t = 0.598x_1$.

For oxen
$h_h = 0.815x_1 - 1.297x_2 + 0.256x_3 + 0.732x_4$;
$h_n = 0.557x_1 - 1.137x_2 + 0.463x_4 + 1.1010I + 5.6$;
$h_t = 0.613x_1$.

For bulls
$h_h = 0.680x_1 + 0.029x_2 - 0.777x_3 + 0.995x_4$;
$h_n = -0.157x_1 + 1.180x_2 + 0.582x_4 - 1.612I + 165.6$;
$h_t = 0.624x_1$.

A question about the preference between the homogeneous and non- uniform models remains open. This question is important because the calculation of the height in withers depending on metapodium length can strongly different from one to another for the homogeneous and non-uniform models.

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