In the present paper, the usefulness of the methods recommended by Rössing (1988) is discussed in relation to skeletal materials from Poland (9th–19th century). Stature estimates provided by the application of the method of Fully and Pineau (1960) are compared with seven other ones drawn from the population in Ostrów Lednicki (10th–14th century). On the basis of the sample derived from 43 skeletal populations (about 4400 individuals) the adequacy of the recommended methods in relation to groups that probably differ with regard to social and economic status is discussed.

**Key words:** methods of stature reconstruction, body proportions, skeletal populations, social stratification

**Introduction**

The stature as a measure of biological development of both an individual and a population is commonly used in physical anthropology. Stature evaluation based on the lengths of the limb bones is one of the oldest problems in the history of anthropology. The development of the stature as a very sensitive trait depends on a number of factors, such as sex, age, race, body composition, social stratum, and
secular trend. The proportions of its particular components (extremities, trunk) also reveal great variability in relation to the overall stature within a population and between populations (Strzalko 1971). For this reason, the application of the best formula to a particular population (or a group of individuals) is very difficult, even "illusory" (Rösing 1988). Rösing claims that the method of Fully and Pineau (1960) provides very good estimates, for they are drawn from the trunk and the lower-extremity components. He has also suggested the application of selected methods to particular races and groups of individuals that differ in social and economic level of development. He recommended Pearson’s method (1899) for the groups at the lowest level of development, the method of Olivier et al. (1978) for those at the middle level, and finally the method of Trotter and Gleser (1952) for groups exhibiting the signs of the best developmental conditions.

The aim of this study is to evaluate the usefulness of the methods recommended by Rösing in relation to skeletal materials from Poland. The accuracy of stature reconstruction as well as the adequacy of the method in relation to groups of probably different social and economic status is discussed.

Material and methods

The evaluation of the usefulness of the selected methods of stature estimations based on the lengths of the limb bones was carried out in two steps. In the first step of the analysis the accuracy of the methods was estimated on the basis of the skeletal material from Ostrów Lednicki (10th–14th century). The lengths of humerus (M1), radius (M1), femur (M1, M2) and tibia (M1) of 100 skeletons (50 males and 50 females) were used in the comparison of the estimations provided by seven methods (Pearson, Olivier et al., Trotter and Gleser, Dupupertuis and Hadden, Gralla, Sjøvold, Breittinger, Bach) and the estimations drawn from the method of Fully and Pineau (the length of the lumbar vertebral column and the length of the femur – M2). The differentiation resulting from stature estimations based on the lengths of limb bones in relation to the mean value was evaluated within each of the seven methods.

In the second step of the analysis the usefulness of the selected methods of stature reconstruction in skeletal populations from Poland (9th–19th century) was evaluated. The following methods were taken into consideration: both of them recommended by Rösing (Pearson 1899; Trotter and Gleser 1952), the method of Dupupertuis and Hadden (1951), the method of Breittinger (1937) and the last one elaborated by Gralla (1976) on the basis of Polish materials. Basing on the measurements of long bones and their proportions, the comparison between the data used for the elaboration of the above-mentioned methods and the data on 43 skeletal populations from Poland (about 4400 individuals) was made. The populations were
divided into four categories: rural, urban, of a city and one category grouping probably individuals from the higher strata of society. The distinctions were made according to archaeological and historical data concerning the urbanisation process in Poland, except for the last category. This group consists of those individuals whose skeletal remains were deposited inside the church and monastery crypts and also on the burial grounds localised next to cathedrals, collegiate churches and castles. The principal component analysis and the proportion indexes $H + R/F + T \times 100$ and $F + T/H + R + F + T \times 100$ were used in the comparison.

The analysis of results

Figure 1 presents the comparison of the estimates of stature reconstruction made on the basis of the method suggested by Fully and Pineau and those obtained from the discussed seven methods drawn from 50 male and 50 female skeletons from Ostrów Lednicki. The anatomical method of Fully and Pineau allows to reconstruct stature from the sum of measurements of the lumbar vertebrae and the length of femur made in a natural position (stature = 2.09 (F2 + L1–5) + 42.67). It, similarly to the method of Sjøvold (1990), contains common equations for both sexes. For male skeletons, stature estimates are greater than those provided by the application of the method of Fully and Pineau. The least difference is 2.0 cm (Pearson) and the biggest one amounts to 8.5 cm (Dupertius and Hadden). In women the least

![Fig. 1. Mean of the stature estimations of the individuals from Ostrów Lednicki provided by particular methods](image)
difference was also obtained by the method of Fully and Pineau and it is greater by 0.7 cm. The other methods yielded greater estimates (from 2.8 cm for the method of Olivier et al. to 8.2 cm for Bach formulae). Figures 2 and 3 present differences between stature evaluations based on the equations for single long bones and the mean value derived from the measurements of the lengths of all long bones. The results obtained from the application of the seven methods were compared for both sexes (the stature estimations from radius, however, was not taken into account for the method of Olivier et al.). The least difference (in both sexes) can be observed for the methods of Pearson, Olivier et al. and Sjøvold. The application of the other methods revealed considerable differences resulting from the estimates based on particular bones. They are, however, smaller in male than in female skeletons. In females the evaluations based on humerus and femur usually overestimate stature while those based on radius and tibia underestimate it. This regularity does not concern the methods of Bach and the method of Gralla and also is not fully confirmed in the case of male skeletons.

The best approximation of an average individual’s stature was obtained from different long bones in the analysed methods. It may be due to the dissimilarity of the relations between the lengths of the long bones of the investigated individuals and their stature that, in turn, was used to construct the particular methods. In the second step of the analysis basing on the skeletal materials derived from 43 cemeteries from Poland an attempt of the estimation of the usefulness of several methods...
of stature reconstruction was made. These are methods of: Pearson (1899), Breitinger (1937), Dupertuis and Hadden (1951), Trotter and Gleser (1952) and finally, the method of Gralla (1976) elaborated on the basis of Polish materials. The above-mentioned estimation was carried out through the comparison between the measurements of the initial materials used in the construction of the mathematical formulae of stature reconstruction and the relative values of long bones for skeletal populations. The results were elaborated mainly by the application of the principal component analysis. Figures 4 and 5 represent the distribution of the investigated populations described by the first and the second principal component, taking into account the settlement population categories (village – W, town – M, city – M1) and also the category grouping, probably, individuals from the higher strata of society (K). The two principal components put together account for 80% and 75% of the variance for males and females respectively. The first principal component (for both sexes) does not differentiate distinctly the initial materials from the skeletal populations. In the case of male skeletons (Figure 4) the values of the second component indicate the materials of Breitinger and Gralla to be the least different from the values for the analysed skeletal samples. The similarity between the other materials, and, thereby, between the methods of stature reconstruction, seems to be considerable for male skeletons. In the case of female skeletons (Figure 5) the differentiating influence of the values of the second principal component reveals that Pearson’s materials are the most similar ones to most of the skeletal populations.
The above-mentioned analysis has confirmed the usefulness of the method of Pearson for both sexes. However, the method of Dupertuis and Hadden and also the method of Trotter and Gleser can be applied only to male skeletons.

The next attempt carried out to estimate the usefulness of the methods mentioned earlier was the comparison of the values of the intermembral index calculated for the initial materials and the values for skeletal populations. Of course, the comparison of the estimates of this index (derived from the mean of long bones) has limited cognitive value. Figure 6 presents the comparison of the intermembral index estimates calculated for the whole material as well as for the particular settlement categories and probably individuals of higher social position. The estimates made for male skeletons elaborated by Pearson, Dupertuis and Hadden, and Trotter and Gleser are the least different in comparison with those obtained for the whole material from the investigated period (intermembral index = 69.8). The individuals from the

Fig. 4. Distribution of the investigated skeletal populations from Poland (9th–19th century) and the initial materials for the stature reconstruction described by two principal components – male skeletons

B – Breitinger, D – Dupertuis and Hadden, G – Gralla, P – Pearson, T – Trotter and Gleser, W – rural populations, M – town populations, M1 – city populations, K – groups of higher social status
higher strata of society (intermembral index = 69.5) are the most similar as for the estimates to the materials of Trotter and Gleser, while the populations representing the particular settlement categories to the materials of Pearson. In the case of female skeletons the nearest values for the total analysed period can be observed for Pearson materials (intermembral index = 68.6), while the privileged individuals reveal great similarity to the samples of Dupertuis and Hadden (Intermembral index = 68.3) and also to the samples of Trotter and Gleser (intermembral index = 68.4).

The last attempt of the estimation of the usefulness of the selected methods of stature reconstruction was the percentage comparison of the lengths of lower extremity bones $(F + T)$ that contribute to the overall lengths of long bones $(H + R + F + T)$. This comparison was carried out in the same way as in the case of the intermembral index. The results are presented graphically in Figure 7. In relation to male skeletons, the materials used by Gralla and Breitinger are definitely different from the ones of

![Graph showing distribution of skeletal populations](image-url)
Fig. 6. Comparison of the intermembral index $H + R/F + T \times 100$ between skeletal populations from Poland (9th–19th century) and the initial materials calculated for the selected methods of stature reconstruction.

Fig. 7. Comparison of the index $F + T/H + R + F + T \times 100$ between skeletal populations from Poland (9th–19th century) and the initial materials calculated for the selected methods of stature reconstruction.
feudal Poland. For female skeletons the findings are similar, however, the lower-extremity components contribute to the sum of the lengths of four bones \((H + R + F + T)\) to considerably lesser degree in the case of the materials from Poland. For both sexes the process of gaining greater values of the intermembral index by the members of the higher strata of society is observed.

**Discussion**

The findings have confirmed to a large extent the usefulness of the methods of stature reconstruction recommended by Pearson concerning the groups of different social and economic level. However, the problem of the selection of the method providing the best estimations in relation to the real stature is still unsolved. The estimations obtained from the seven methods are considerably different (except for the method of Pearson for females) from the one calculated on the basis of the recommended method of Fully and Pineau. Similar regularity for the Neolithic skeletons from Europe was found by Formicola (1993) whose results revealed the best approximations for both sexes in the case of the method of Pearson (stature estimations were greater by 2.2 cm and 1.2 cm for males and females respectively). The use of Breitinger and Bach methods gave the greatest differences (3.7 cm and 5.2 cm respectively). The method of Fully and Pineau – that is sometimes described as a “anatomical” one – should correspond to the measurements of the skeleton “in situ”. This assumption was confirmed by the study of Gralla (1964) for the skeletal materials from Milicz (9th–13th century). Comparing the lengths of the skeletons measured “in situ” with those obtained from the long bones she found that the best approximations were provided by Pearson’s method (estimations greater by 1.9 cm and 1.8 cm for males and females respectively). In the case of the method of Trotter and Gleser the estimations were considerably greater (5.5 cm and 5.6 cm). Similar differences were also found for other methods (Breitinger, Dupertuis and Hadden, Telkka).

The findings are consistent with Rösing’s suggestions that Pearson’s method is of greater value in stature reconstruction for groups derived from lower classes of society. However, when we consider in the analysis also the individuals characterised by a probable higher social status the methods of Trotter and Gleser or Dupertuis and Hadden can be successfully applied (especially for male skeletons). Piontek et al. (1974) has declared for the common use of Trotter and Gleser method (including also the prehistoric skeletal materials) for it provides the best estimations as compared with the real values of stature. This opinion is confirmed by Polish anthropological literature concerning the application of different methods of stature reconstruction (Fig. 8). While the increased interest among physical anthropologists of Trotter and Gleser’s method seems to be justifiable, the question arises concerning the usefulness of Breitinger’s formulae. The proportions of the extremities of the individuals whose measurements were used in the construction of this method were
different from those that are represented by the skeletal populations from the feudal period. Similar body proportions can be observed in almost fully neglected method of Gralla. The dissimilarity of the proportions of the trunk and the extremities in relation to the total skeletal height between the contemporary samples (that were used in the construction of the methods) and the historical groups seems to create just the main problem of the accuracy of stature estimation. No significant correlation between the stature and the lengths of the trunk in parents and their children as well as the correlation between the lengths of the trunk and the lower extremities of the same individuals have been found for contemporary groups (Szopa 1976). Therefore two questions arise: (1) whether the secular trend of the stature that has been observed for over one hundred years concerns the proportional increase of the trunk and the extremities or mainly the later component (2) whether the intermembral index has changed significantly within the last millennium. Frequent studies undertaken to answer these questions yielded unsatisfactory results (for example Charzewski and Bielicki 1978; Wiercińska 1980). An understanding of these phenomena should allow the application of the most appropriate method to predict stature of individuals from a given historical period or individuals characterised by a particular social status.

![Graph showing % of studies before and after 1980 for different methods of stature reconstruction](image)

Fig. 8. The application of the selected methods of stature reconstruction presented in the Polish anthropological literature
Conclusions

1. The method of stature reconstruction elaborated by Fully and Pineau (1960) provides lower estimates in comparison with other methods.

2. Pearson’s method (1899) enables research, in the case of the material from the feudal period, to obtain estimates probably the nearest to the ones of the living individuals (for both sexes).

3. The use of the analysed methods of stature reconstruction reveals considerable differences resulting from the estimations based on the lengths of single long bones. The least differences, for both sexes, are obtained from the methods of Pearson (1899), Olivier et al. (1978) and Sjøvold (1990).

4. The method of Trotter and Gleser (1952) is recommended for individuals from the higher strata of society of European origin (especially for males).

References

