Stature estimation in central Europe (5500 BC-2000 AD): methodological considerations and diachronic trends

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1. Introduction and aim

Stature estimation from skeletal remains is of great importance in anthropology and related disciplines. Besides the accuracy of single estimations it is important to get comparable results in order to recognise historical trends (e.g. Young et al., 2008; Komlos, 2009; Auerbach & Ruff, 2010). A large number of different regression formulae exist, but intra- and interpopulation variability in long bone (LB) proportions is high and an optimal formula suitable for all populations is difficult to select.

Aim of this study is to find the most suitable estimation method for archaeological skeletal material from Central Europe, and to record the diachronic changes considering factors such as social status, biological welfare and environmental conditions.

2. Material and methods

- LB measurements (after Martin 1928) of 1.002 individuals (561 males, 441 females) from 12 archaeological sites (France, Germany, Switzerland; 4th–7th c. AD); means of LB measurements of 21.600 individuals (13.900 males, 7.700 females) from 149 sites from Central Europe (5500 BC–19th c. AD) were collected.
- Twelve traditional and new estimation formulas were compared **(fig. 1)**; as a benchmark, the mean of all methods was computed.
- The LB proportions (femorotibial, femorohumeral and humeroradial index) were calculated and compared to the reference series.
- The diachronic development of mean stature was calculated and linked to well known proxies for paleoclimate: Schmidt & Gruhle, 2003; Reimer et al. 2004; Vinther et al. 2005.
- Individual's stature *vs.* wealth, social status, age-at-death were compared by t-test.

3. Results and discussion

Compared to the mean from all estimations the different formulas show a significant variability:

- **Pearson, 1899:** ♂ -2.3cm, ♀ -2.5 cm.
- **Breitinger, 1938 & Bach, 1965:** ♂ +0.7 cm, ♀ +2.1 cm
- **Telkkä, 1950:** ♂ -0.5 cm, ♀ -2.0 cm.
- **Trotter & Gleser, 1952 „white":** ♂ +2.3 cm, ♀ +2.2 cm.
- **Trotter & Gleser, 1952 „negro":** ♂ -2.3 cm, ♀ -1.4 cm.
- **Olivier et al., 1978:** ♂ -0.2 cm, ♀ +0.9 cm.
- **Sjøvold, 1990:** ♂ +0.5 cm, ♀ +1.5 cm.
- **Feldesman et al., 1990:** ♂ +3.6 cm, ♀ +0.9 cm.
- **Formicola & Franceschi, 1996:** ♂ -0.3 cm, ♀ -1.1 cm.
- **Raxter et al., 2008:** ♂ -2.8 cm, ♀ -2.4 cm.
- **Vercellotti et al., 2009:** ♂ +2.4 cm, ♀ +0.1 cm.
- **Maijanen & Niskanen, 2009:** ♂ +0.5 cm, ♀ +1.0 cm.
- **mean from Pearson, 1899 and Trotter & Gleser 1952, „white" and „negro":** ♂ -0.9 cm, ♀ -0.5 cm.

Fig. 1. Methods of stature estimation used and deviation from the mean estimation (12 archaeological series, 1002 individuals, Central Europe, 4th – 7th c. AD).

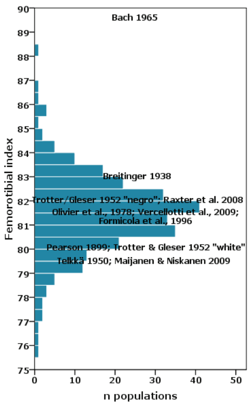

Fig. 2. Femorotibial index of European archaeological populations (n=149; x=81.6, sd=1.8) in comparison to the reference series of stature estimation methods.

The estimated stature differs within few centimetres. This well-known effect is caused by the different LB proportions of the reference series, which makes the choice of an "ideal" estimation method challenging. Most of the populations are closer to the proportions of Pearson 1899, Trotter & Gleser 1952 „negro" and Trotter & Gleser 1952 „white", making this methods still suitable for Central Europeans, while the reference series used by Bach 1965, Telkkä 1950 and Olivier et al. 1970 (females) match only to few populations **(fig. 2)**.

Stature estimations made by the Fully-method (Schmidt et al., 2007) or by in-situ measurements of the skeleton (e.g. Petersen, 2005) show again, that estimations after Pearson 1899 or after a combination of Pearson 1899, Trotter & Gleser 1952 „white" and „negro" give the most accurate results with low systematic bias between males and females.

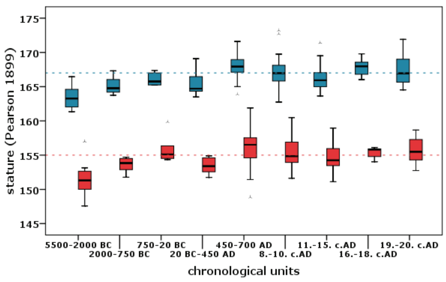

Fig. 3. Stature estimation after Pearson 1899 for males (blue) and females (red) of 149 Central European populations, chronologically grouped. The dotted horizontal lines indicate the mean for males (c. 167 cm) and females (c. 155 cm).

- Concerning the diachronic trend a 2.5 cm increase of the mean stature from Neolithic Period (5500 – 2000 BC) to Bronze Age (2000 – 750 BC) was observed, followed by smaller changes **(fig. 3).** The 50%-spans around the median are mostly overlapping with previous and following periods.
- The intrapopulation variability is ± 4.5 cm (std.dev.).
- Early Medieval populations (450-700 AD) exhibit the highest stature from prehistory to modern times **(fig. 3).** This is in concordance to other studies (Koepke & Baten 2005 fig. 2-3; Giannecchini & Moggi-Cecchi, 2008) and could be read as a result of high genetic exchange caused by migration period (ca. 375-450 AD), but also as a reflection of good living conditions after the end of Roman Empire (more rural live, low population density).
- The comparison with usual proxies for the development of past climate like $\delta^{18}O$, $\delta^{14}C$ or tree-ring growth **(fig. 4-6)** shows no correlation between climate and stature, indicating that economic and social factors had been of more importance to prehistoric societies than environmental conditions. This is in concordance with previous studies (e.g. Koepke & Baten 2005; Giannecchini & Moggi-Cecchi, 2008).

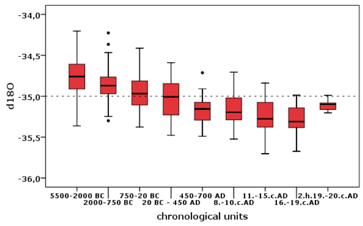

Fig. 4. Boxplot of $\delta^{18}O$ in Greenland ice cores (mean of GRIP, NGRIP and GISP2; chronology after GICC05), aggregated to the same chronological units as fig. 3. The dotted horizontal line indicates the overall mean (-34.92‰) from 5500 BC to 2000 AD. Higher values indicate warmer temperature on northern hemisphere (Vinther et al., 2005).

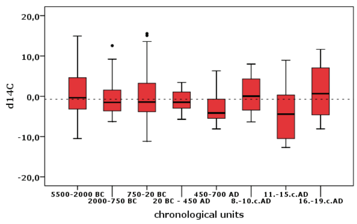

Fig. 5. Boxplot of detrended residuals of $\delta^{14}C$-concentration in atmosphere (after IntCal04), aggregated to the same chronological units as figs. 3-4. The dotted horizontal line indicates the overall mean (-0.74‰) from 5500 BC to 1850 AD (i.e. ends with industrial revolution). Higher values are usually interpreted as times of lower sun activity with few sunspots (Reimer et al., 2004).

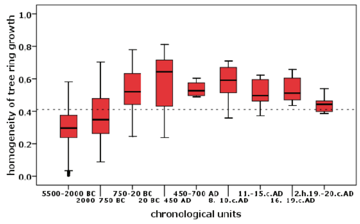

Fig. 6. Homogeneity of tree ring growth in Central Europe (after Schmidt & Gruhle 2003), aggregated to the same chronological units as figs. 3-5. The dotted horizontal line indicates the overall mean (0.41) from 5500 BC to 2000 AD. Higher values show a more homogeneous growth of trees, caused by continental climate (cold & dry), lower values indicate a more individual growth of trees, caused by atlantic climate (mild & wet) (Schmidt & Gruhle, 2003).

- Individuals buried with rich grave goods are slightly taller than their poorer counterparts (mean of 7 series: +2.7 cm males, +1.2 cm females), but the difference never reaches statistical significance. There is no significant correlation between age-at-death and stature, wherefore the thesis *„the short die young"* (Kemkes-Grottenthaler 2005) could not be verified for that historic period.

Conclusions

The present study indicates that the Pearson's stature estimation is the optimal method for Central European archaeological populations. The results from the various stature estimation methods differ significantly, therefore only estimations acquired by the same method should be compared. The diachronic differences (ca. 7000 years) in stature are small, whereas the inter- as interpopulation variability is greater. Stature does not correlate with climatic changes, it is more dependent on social and economic factors.

References

[for the traditional formula of stature estimation see the overviews of e.g. ***RAXTER et al.*** *2008 or* ***SIEGMUND*** *2010].*

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