

Stature, Maturation Variation and Secular Trends in Forensic Anthropology*

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ABSTRACT: A twentieth-century trend for increased stature has received considerable attention in the forensic literature with regard to its effects on stature estimation, but a secular trend for earlier maturation has received little attention. Current evidence indicates that within populations with similar climatic adaptation, truncation or extension of the same trajectory of ontogenetic allometry accounts for the secular trend and the within-cohort stature variation, as well as the scaling of limb proportion to stature and intralimb proportions. Since secular increase is small compared to interindividual variation, the Trotter and Gleser formulae are still appropriate as long as the 95% confidence intervals are applied. A secular trend for increasing childhood and adolescent obesity is associated with a trend for accelerated skeletal maturation, but does not predict a consistent direction or a quantitative correction for traditional standards. Secular trends for increased stature and earlier maturation are overshadowed by increasing nonsecular intrapopulation variation.

KEYWORDS: forensic science, forensic anthropology, secular trend, stature, maturation, ontogenetic allometry, Ellis R. Kerley

In contrast to the more usual operations of science, i.e., using collections of individual cases to build generalizations, forensic anthropology practice uses generalized observations to arrive at characterizations of individuals. The pitfall in this approach lies in the retained tendency to emphasize the importance of the mean and one standard deviation and to disregard the more extreme values. There is a danger that the central tendencies will acquire a status that distorts natural variation. This variation can be conceptualized as either synchronic (or populational) or diachronic (or secular). While this conceptual dichotomy is often analytically useful, it may obscure an underlying similarity. In casework it may overemphasize concerns, such as secular trends, that in practice need not be treated differently from populational variation. One source of variation that has received attention from forensic anthropologists is the well-recognized secular increase in the stature of North Americans over the last century or so. This secular trend may involve change in body proportions, most frequently a relative increase in leg length, although patterns may differ between sexes and among different populations and subpopulations (1). Based on their studies of males from Trotter's data from the Terry Collection and World War II casualties and more recent data from the Foren-

sic Data Bank, Meadows and Jantz (2) and Ousley and Jantz (3) concluded that because the lower limb bones were positively allometric with stature and because of secular changes in lower limb segment proportions, it is generally inappropriate to use regression formulae based on earlier samples, such as the Terry Collection, to estimate stature in the recently deceased.

But is this secular trend in positive allometry for American white and black males fundamentally any different from the case encountered when dealing with the taller and shorter people that comprise a significant portion of any population cohort? Recent evidence suggests that it is not. Along with their very short stature, the notable body proportions of the African pygmies, with relatively long arms and short legs, had been previously hypothesized to be either a retention of a primitive ape-like trait or the result of a climatic adaptation not shared with neighboring African groups. As part of their anthropometric study of allometry of body proportions and stature in African pygmies, Shea and Bailey (4) analyzed the growth allometric trajectory of Efe pygmies and limb proportions of adult pygmies and adult African nonpygmies. They found that even for populations as disparate in adult stature as pygmies and nonpygmies, the limb length to stature proportions of the nonpygmies fell within the confidence intervals determined from the pygmy growth trajectories. Although the adult pygmies had different stature to limb proportions than adult African nonpygmies, they shared common patterns of growth allometry, one that was truncated in the case of the pygmies. Although the lower limb segment proportions were not investigated, the same ontogenic allometric trajectories were followed by the upper limb segments. Shea and Bailey's analysis strongly suggests that the divergent body proportions of the adult pygmies compared to that of nonpygmy Africans reflect simple growth allometric correlates of final adult size. If this is the case for these two groups, it is unlikely that a different and unknown mechanism needs to be invoked to account for allometric secular trends within a population. Indeed, Shea has elsewhere (5) concluded that with ontogenic scaling the size-shape relationships between adults of different cohorts within a population are of the same nature as those distinguishing shorter from taller.

There is no current reason to assume that secular trend presents a challenge for stature estimation that is substantially different from that involving individuals whose statures are not close to their sample mean. Present evidence supports the theoretical position that systematic variation in limb segment proportions and limb proportions to stature reflect a fundamental growth allometry trajectory that is truncated earlier in shorter individuals and later in taller individuals, and that this principle applies to both synchronic and diachronic variation. In applying Trotter and Gleser formulae to recent cases, special attention needs to be paid to confidence intervals for estimated stature, particularly because taller individuals (i.e.,

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those well above the mean) may be more frequently encountered. Although large recent samples of skeletonized individuals of *known* living or cadaveral stature would be ideal because the presumed higher mean would constrict the average size of the confidence intervals, these are not yet available. For American whites and blacks the Terry Collection formulae should continue to provide good estimates so long as population variation and tibial measurement technique (6) are taken into account.

While there is evidence that secular trend in vertical growth in North America has tapered off (1) as stature approaches asymptote with genetically determined limits, the secular trend for growth in other dimensions shows no such abatement. The increasing adiposity among American adults does not significantly impact forensic osteology, but the secular increase in fatness during the growth period may have significant consequences for human identification. Nutritional status has long been recognized as one of the most important variables governing the tempo of maturation and is seen as the prime factor in the nineteenth and twentieth century decline in the age of menarche and in the worldwide association of lower age at menarche with the higher socioeconomic classes (7). Eveleth and Tanner (7) also noted some increase in the rate of growth with fatness.

Data from the first two National Health and Nutrition Examination Surveys (NHANES I and II) collected 1963 to 1970 and 1976 to 1980 generally show no obvious trends for African American and Euro-American boys or girls (7); however, recent data from the NHANES III survey, conducted from 1988 to 1994, show dramatic increases in overweight and obesity in American children, especially African American adolescents (8). One study (8) in Philadelphia found the secular trend for increasing prevalence of overweight and obesity over the last two to three decades to be particularly alarming among underprivileged urban black adolescents. Similar high rates of childhood obesity have been reported recently for other U.S. minorities and a high-poverty rural white community (9). Thus, it appears that for the U.S., the recent secular trend for increased prevalence of overweight is accelerated in low socioeconomic groups, in contrast to the developing countries.

These trends for increased weight are paralleled by clinical signs of earlier maturation. For instance, Bogin's 1988 volume (10) states that breast development begins at an average age of about eleven years for American girls of European descent. A 1997 study (11) reported on a large clinical survey in which the mean ages for onset of breast development were 9.96 years for white girls and 8.87 years for black girls. At age eight 48.3% of black girls and 14.7% of white girls had begun development. Another study (12) reported that in a cohort of nine- and ten-year-old girls 64% of black girls had begun pubertal development compared to 33% of white girls and claimed that these differences were related to racial differences in obesity.

The question of concern to forensic anthropologists is to what extent do skeletal indicators of maturation follow those of the soft tissues. Is attaching a chronological age to a stage of skeletal maturation becoming increasingly unreliable? From the standpoint of secular trends based on clinical surveys of living children, the answer is equivocal. For instance, one study (13) found that 1990s' U.S. children matured considerably earlier than expected by the 1960s Tanner-Whitehouse standards based on not-so-well-off U.K. children. Another study (14) found that the Greulich-Pyle standards, based on economically well-off U.S. children in the 1930s, were not applicable to today's black girls, who are more skeletally advanced, but black boys and white boys and girls did not show the same trends.

From the forensic point of view, problems associated with secular trend for earlier maturation may be overshadowed by other sources of variation and error in assessing skeletal age. Assessment of skeletal age for a single individual can vary significantly with the criterion used for the same skeletal area, and between the hand-wrist and knee areas (15). But the luxury of choice of method and skeletal area may elude the caseworker, who is constrained by the elements available for analysis. Even more disquieting are recent results showing high variation and lack of consistency among maturity indicators when applied to test skeletons of known age (16). Another source of variation may be ethnicity not directly tied to socioeconomic status. It appears that East Asian children and adolescents may be skeletally advanced with respect to standards based on white children (7,17,18).

It is well-established that much of the variation in the rate and extent of individual growth and maturation is due to environmental factors, such as nutrition, stress, illness, living conditions, and psychosocial circumstances (10). The dramatic effects of adverse environment on skeletal maturation were reported by Lampl and Johnston (19) for a sample of Mexican children. Using Greulich-Pyle standards young children were underassessed by 1 to 3 years and had skeletal age 95% confidence intervals of 4 to 8 years. Impoverished immigrant children may well display parallel effects.

It must be remembered that published standard deviations and confidence intervals apply only when children come from the same strata of society as those on whom the standards are based. But the poorer segments of society live more dangerous and more unsupervised lives, and thus environmentally stressed children are apt to be overrepresented in the count of unidentified deceased. In some cases these children may be advanced in growth and maturation, and in other cases significantly delayed. The implication is that variability is increasing and largely unpredictable for an individual case. Bioarchaeologists and paleoanthropologists have had to contend with this sort of dilemma for years, but they have also recognized the problem. Forensic anthropologists, for whom missing the mark has different consequences, would be well advised to augment their ranges of estimated errors. When profiling unidentified remains, the age range encompassing ± 2 standard deviations should be considered the bare minimum, and Clegg and Aiello's recent study (16) suggests that, even for children, many indicators should be used and that dental age may not always be the gold standard. Law enforcement officials should be aware that tighter estimated age ranges are not the sign of more expert analysis, but instead may be inappropriately removing too many missing children from consideration.

Extremes of environmental stress may extend well into the adult years. Although famine is not a significant concern in North America, the self-imposed "starvation" of eating disorders and malnutrition associated with drug abuse are not negligible. In the absence of standards of growth and maturation, it is difficult to get a handle on clear signals of normality and variability. However, there are hints that metabolic and physical stressors can strongly retard the normal pace of skeletal morphological change. For instance, in a previous study (20) evaluating cast methods for estimating age from the *symphysis pubis*, 11 of 116 male pubis pairs were significantly underestimated for age using both methods. Nine of the eleven had abnormalities that had warranted notes at autopsy, including such disparate conditions as extremes in body weight, alcoholism, and physical disability. While the effects of stressors on the aging processes of adult skeletons have yet to be characterized, they should be taken into account when the circumstances of a case point to their presence.

Webb and Suchey (21) stressed variability in age of epiphyseal union of the anterior iliac crest and medial clavicle in a large multiracial sample of males and females autopsied in the late 1970s. They noted an especially high variability for American black females. Moreover, they had specifically excluded from the total male and female sample those with a history of disease and physical affliction, including Down's syndrome. Since such cases can and do appear in casework, the total range of maturational variability may be even larger than that noted by Webb and Suchey. The continued collection of data for the forensic data bank should help to define the parameters of modern variability.

From the point of view of forensic anthropology the effects of secular trends for increased stature and earlier skeletal maturation on estimates of stature and age, while real, are small and often inconsistent contributors to the noise of population variation. Other, nonsecular, sources of variability, such as physical, environmental, and life-style stressors, can impact both stature and pace of maturation and must be taken into account, and the extremes of variation should not be dismissed.

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