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Patterns of Sexual Dimorphism from Birth to Senescence

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A B S T R A C T

Sexual dimorphism is expressed as median of the female values in percent of the median of the male values, of 4 length measurements, 3 circumferences, and 5 measurements of corpulence respectively fat. Data were obtained from a cross-sectional sample of more than 41.000 German subjects, aged from birth to age 62. The pattern of sexual dimorphism is similar in the length measurements. Girls are shorter at birth, but they increase in length at higher rates than boys and even temporarily overgrow the boys up to age 12. Thereafter, males show an obvious growth advantage leading to some 6 to 9% more length in adult males. In contrast, female circumferences are always smaller, from birth to senescence. Though, the differences between the sexes are low in circumferences, up to age 13, sexual dimorphism increases to 17% in the thoracic circumference at adulthood. Sexual dimorphism in weight and BMI is comparably with that in length measurements while subcutaneous fat and total body fat content are always higher in females. The results highlight that sexual dimorphism develops at different pace in the various components of the body and that it associates with a sex specific growth tempo.

Key words: *sexual dimorphism, biological age, growth-age, adulthood*

Introduction

There is only little sexual dimorphism in humans compared to most non human primates, but it exists already at birth. Girls are born with less body length and body weight compared to boys, but newborn girls already have more subcutaneous fat than boys[1–3]. During childhood and adolescence, sexual dimorphism usually results from different growth velocity in both sexes. In comparison to boys, girls on an average grow and develop faster. They follow the typical human growth curve with a higher tempo and finish their length growth earlier. This leads to a first minor female growth advantage in some measurements around the age of 6 or 7 because already at this age girls may be biologically older compared to boys of the same chronological age and thus may undergo their mid-growth spurt earlier. It often leads, depending on the measurement, to an obvious overgrowth in girls between the age of 9 and 14. At this age, girls are biologically advanced by about 2 years, with an early adolescent growth spurt responding to their biological age. After the adolescent growth spurt the growth velocity decelerates and goes to zero in most, but not in all, dimensions. Now males show a clear growth advantage because of their later and longer lasting growth spurt. This leads to the typical morphological differences between adult females and males. The sexual dimorphism is most distinct at young adult age and decreases during later life.

Whereas these facts are well known for growth age from longitudinal studies[4–9], little is known about the sexual dimorphism within one population during the whole course of life. The present paper offers results of a cross-sectional study from birth to age 60. Cross-sectional studies are not able to highlight individual growth velocity, but they are able to present median anthropometric differences between females and males of the same age, and they are able to record yearly growth increments. By this, they may contribute to a better understanding of the correlations between sex-specific different median developmental velocities and sexual dimorphism at different ages.

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Subjects and Methods

Anthropometric data from a well stratified cross-sectional sample of 41.035 German subjects, aged from birth to age 62 and measured at the late 80th of the 20th century were reanalysed for sexual dimorphism. 12 measurements were included into the study according to Martin and Saller[10]: four length measurements (height, trunk length, leg length, total arm length), three circumferences (head circumference, neck circumference, thoracic circumference), and five measurements of corpulence respectively fat (weight, body mass index, triceps skinfold diameter, subscapular skinfold diameter, total body fat content). The total body fat content was calculated from the triceps and the subscapular skinfold diameter using the age-specific equations of Slaughter et al.[11] and Johnsen[12]. Age- and sex-specific medians of the variables investigated were calculated and smoothed by the LMS-method of Cole[13]. A disadvantage of this sophisticated method is the insufficient fitting of the first and the last values of a succession. Therefore, the raw data at birth were used and the curves were cut at age 60. The anthropometric differences between the two sexes were calculated as differences out of the smoothed sex-specific median curves. The proportional sexual dimorphism (PSD) was calculated as the female median in percent of the male median at the same age: $PSD = 100 \times p50_{female} / p50_{male}$.

Results

Sexual dimorphism of length is demonstrated in Figure 1. The medians of female measurements are expressed as percent of male values (PSD) are below 100% at birth in height, trunk length, leg length, and total arm length as well as. Girls are born shorter compared to boys, and they have a shorter trunk and shorter limbs. PSD of all 4 length measurements investigated increases annually up to the adolescent growth spurt. The same medians are reached first in leg length, followed by trunk length and height, while arm length remains shorter in girls compared to boys at all ages. Girls have higher medians in leg length between the ages of 2.5 and 12, in height between the ages of 8.5 and 13, and in trunk length between the ages of 8 and 14.5. Sexual dimorphism is first most pronounced in leg length at the age of 10, followed by arm length and height at 11 and at least in trunk length at the age of 12. Thereafter PSD decreases annually with minimum values at young adulthood, where the sex differences in body lengths are profoundly expressed. Sexual dimorphism gradually disappears again in the elderly.

Figure 2 shows sexual dimorphism in head circumference, neck circumference, and thoracic circumference. In contrast to length measurements, circumference measurements are smaller in females compared to males at all ages, yet the differences are low before the age of 13. Later on and up to age 40, a strong sexual dimorphism develops in neck and thoracic circumference. Women of 40 only reach 86% of the male neck circumference and 84% of the male thoracic circumference. Sexual dimorphism in head circumference however stays relatively small. As in length measurements, PSD increases again at older age, and the differences between the sexes gradually disappear in the elderly.

Sexual dimorphism in measurements of corpulence and body fat is shown in Figure 3. Girls are born with 96% of the male weight and 98% of the male body mass index (BMI). The curves of both variables approach 100% indicating absence of sexual dimorphism at the age of 9. Girls have higher medians of weight compared to boys between the ages of 10 and 13, and higher medians of BMI between the ages of 10 and 17. The lowest percent values are reached at the age of 30. At this age median weight of women is only 78% of that of men, and median

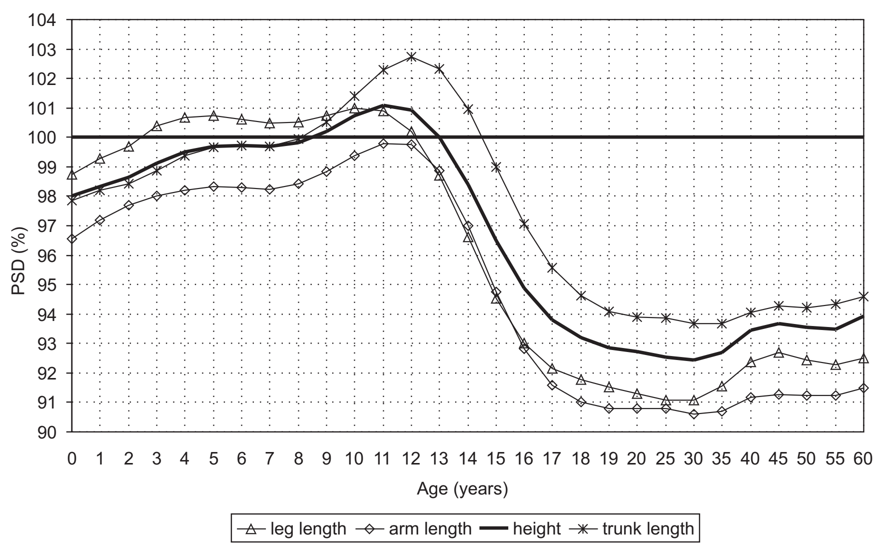

Fig. 1. Sexual dimorphism (PSD) for height, trunk length, leg length, and total arm length calculated as the female median in per cent of the male median at the same age.

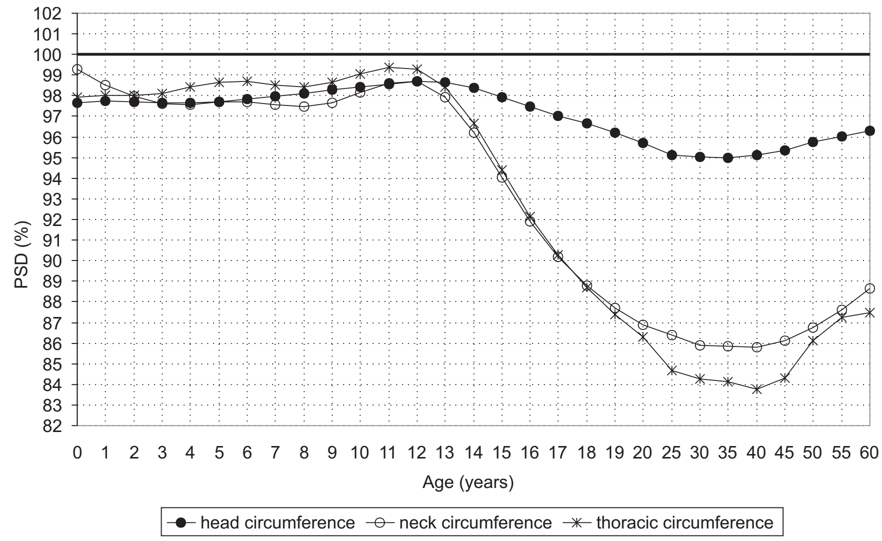

Fig. 2. Sexual dimorphism (PSD) for head circumference, neck circumference, and thoracic circumference calculated as the female median in per cent of the male median at the same age.

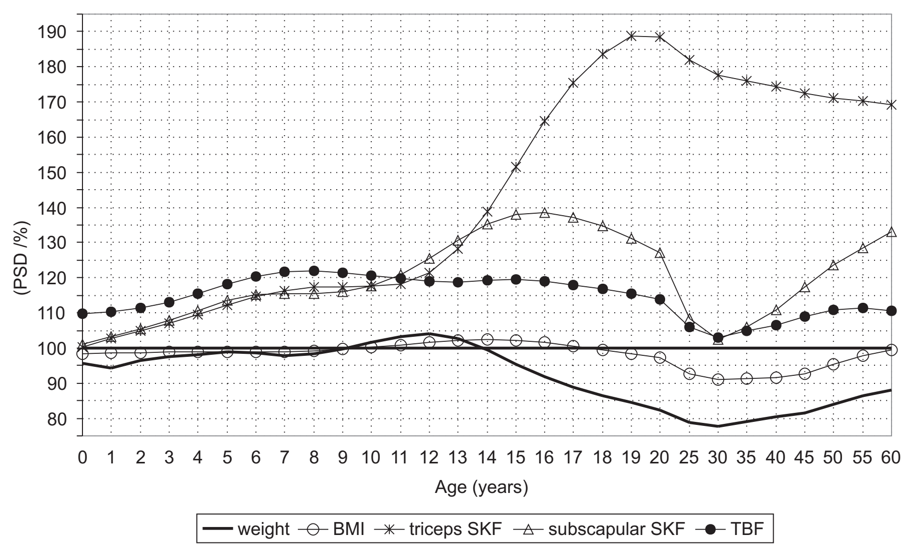

Fig. 3. Sexual dimorphism (PSD) for weight, body mass index (BMI), triceps skinfold diameter (triceps SKF), subscapular skinfold diameter (subscapular SKF) and total body fat content (TBF) calculated as the female median in per cent of the male median at the same age.

BMI is only 91 %. Sexual dimorphism of weight and BMI decreases in the elderly. Body fat differs from all other measurements. Females have more subcutaneous fat and higher total body fat content compared to males at all ages. Sexual dimorphism is more expressed in measurements of body fat than in the other physical signs investigated. High medians of subcutaneous fat are characteristic for the female sex. Young adult women nearly reach 190% of the triceps skinfold diameter of young adult men, and women of 60 still hold 170% of the male median. Compared to the triceps skinfold diameter, subscapular skinfold diameter and percentage of total body fat content do not differ so much between the sexes. Females only have some 10 to 20% more total body fat content than males with a minimum sexual dimorphism at the age of 30. At the same age the sexual dimorphism of the subcutaneous skinfold diameter is also low in contrast to the triceps skinfold diameter.

Discussion

Differences in human body size and body proportions within populations are well known for various age groups, but little is known about the whole age range from birth to senescence. In several animal species, sexual dimorphism may be viewed as a response to selection for fecundity. Guegan et al.[14] evaluated the hypothesis that the extent of sexual dimorphism in human populations, which is relatively small compared to non human primates, also results from the interaction between fertility and size-related obstetric complications. Observations about a markedly increase of sexual dimorphism of many anthropometric parameters at puberty in association with the development of sexual maturation support this hypothesis. There is a high correlation between sex hormones and the sex-specific development of the physique. Jaffe et al.[15] found already the regulatory mechanisms of growth hormone secretion to be sexually dimorphic. Different approaches have been undertaken to analyse sexual dimorphism. Some more or less sophisticated indices like the index of androgyny were developed to quantify anthropometric differences between the two sexes[10]. Loesch et al.[16] offered a general score between the poles »maleness« and »femaleness«. The present results support the opinion of al-Haboubi et al.[17] that sexual dimorphism develops at different pace in the various parts and compartments of the body and therefore, should be estimated separately for different body measurements. Lovich & Gibbons[18] published a review of techniques for quantifying sexual size dimorphism. They recommend an index based on the mean size of the larger sex divided by the mean size of the smaller sex resulting in positive values when females are larger and negative values in the opposite case. In this paper a similar approach is used. The median of the female sex is expressed as percentage of the median of the male sex.

Adult height is associated with the age at adolescent growth spurt[19]. A late growth spurt means high final height. The age at the onset of the adolescent growth spurt seems to be influenced also by socio-economic conditions in a sex-specific way. Valenzuela[20], Holden & Mace[21] and Spencer[22] found a larger sexual dimorphism in height in poor countries or in populations where women contributed less to food production. This corresponds to the results presented in this paper. The amount of sexual dimorphism in the German population signalises good living conditions. The pronounced sexual dimorphism in circumferences at adulthood is well known. Head circumference is an exception. Here the highest PSD is no more than 95%. Hajnis[23], Henneberke & Prahl-Andersen[24], and Joffe et al.[25] published similar results. They argue that the postnatally growth of the head is completed to about 95% at the age of 5. A small adolescent growth spurt was found only in boys, but not in girls. The higher total body fat content in females at all ages is well known. The results given here highlight especially the PSD of subcutaneous fat at triceps. Webster-Gandy et al.[26] found a significantly larger percentage body fat already in 5 to 7 years old children, but no different fat patterning in the two sexes. This agrees also with the results given above. The large sexual dimorphism in subcutaneous fat distribution with a high degree of fat accumulation at the upper arm at adult age is a result of a larger change in fat distribution in boys compared to girls at puberty, while girls hold better their prepubertal fat pattern. He et al.[27] found similar postpubertal sex-specific changes in fat distribution by age in different populations.

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OBRASCI SPOLNOG DIMORFIZMA OD ROĐENJA DO STAROSTI

S A Ž E T A K

Spolni dimorfizam izražava se u kao medijan vrijednosti za žene u postotku medijana vrijednosti za muškarce, za 4 mjerenja dužine, 3 mjerenja obujma i 5 mjerenja debljine, odnosno masti. Podaci su dobiveni iz presječnog uzorka od više od 41,000 njemačkih subjekata, od rođenja do 62. godine. Obrazac spolnog dimorfizma pokazuje sličnost u dužini mjerenja. Djevojčice su niže kod rođenja, ali rastu u dužinu u većoj mjeri nego dječaci te privremeno prerastaju dječake do 12. godine. Zatim muškarci pokazuju očitu prednost u rastu koja vodi povećanju dužine u odraslih muškaraca od 6 do 9%. Za razliku od toga, ženski obujam se smanjuje od rođenja do starosti. No, razlike među spolovima su smanjene u obujmu do 13. godine, a spolni dimorfizam se povećava do 17% u torakalnom obujmu u odrasloj dobi. Spolni dimorfizam težine i BMI može se usporediti s mjerama dužine, dok su potkožno masno tkivo i sadržaj ukupne tjelesne masnoće uvijek veći kod žena. Rezultati pokazuju da se spolni dimorfizam razvija različitom brzinom u različitim dijelovima tijela te je povezan sa spolno specifičnom brzinom rasta.