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Body composition in children based on anthropometric data

A presentation of normal values

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Abstract Knowledge of the body composition in terms of fat and fat-free mass is used in paediatrics to estimate a child's nutritional status. To obtain the fat content or protein content sophisticated techniques exist. These techniques are often difficult to apply in daily practice. An anthropometric approach is therefore relevant because of its simplicity. In this study skinfold thicknesses and mid-upperarm circumference are presented as reference values and used to derive the fat-free mass fraction of the body and the arm muscle area.

Conclusion Despite the shortcomings of an anthropometric approach in estimating the fraction of fat-free mass or protein content, its simplicity makes the method of calculating these fractions on skinfold thicknesses and mid-upperarm circumference valuable to apply in daily paediatric practice.

Key words Body composition · Fat-free mass · Mid-upperarm circumference · Muscle area · Skinfold

Abbreviations *MUAC* mid upperarm circumference

Introduction

To estimate a child's nutritional status weight is commonly used; but weight as an isolated measurement provides little information. It should, at least, be related to height as in the weight for height index. However, the weight for height index provides no information about body composition i.e. the distribution of fat and fat-free mass. Knowledge about this distribution is important since, to a certain extent, it indicates the ability to withstand stress, starvation and disease [1]. There are several methods to determine the distribution of fat and fat-free mass e.g. under water weighing, bioelectrical impedance and stable isotope labelled water dilution [6]. In general these methods are time consuming, expensive or difficult to apply. Therefore, in clinical paediatric practice a simple method based on skinfold thickness measurements is preferred. From skinfold thicknesses the total body fat content is estimated assuming a relation between total body fat content and fat content located subcutaneously [3, 5, 7–9, 14, 15, 22, 23, 27, 29, 30, 32, 33, 36, 39]. Since the subcutaneous tissue layer is not of uniform thickness several skinfold measurements are taken to estimate the fat mass [13, 26].

Estimation of the fraction of fat-free mass involves three densities: the total body density, the density of fat mass and the density of fat-free mass. The total body density, D, is estimated from the skinfolds as $D = a - b \log \Sigma s_i$, where the four skinfolds, s_i, are taken at biceps, triceps, subscapular and supra-iliacal sites. The parameters a and b depend on age and sex and are based on the work of Durnin and Rahaman [8] and Durnin and Womersley [9]. Extrapolation over the age range [0–18 years] is described and validated by Weststrate and Deurenberg [38]. The density of fat mass, D_f, is constant: 0.9 kg/l [11, 28]. The density of fat-free mass, D_{ff}, depends on age and sex. The value D_{ff} is based on the experimental observations by Fomon et al. [12] and Garrow [16].

The fraction of fat-free mass is expressed as

$$\left(\frac{1}{D}-\frac{1}{D_f}\right)\left(\frac{1}{D_{ff}}-\frac{1}{D_f}\right)^{-1}$$

Apart from the fat content another aspect of nutritional status can be considered: the protein content. As an indicator of the protein content the muscle mass of the upperarm is estimated. The muscle area in the sagital plane of the mid-upperarm is computed based on mid-upperarm circumference (MUAC) and the average of the biceps and triceps skinfold thicknesses, s [4, 15, 17, 24, 25].

$$\frac{\pi}{4}\left(\frac{MUAC}{\pi}-s\right)^{2}$$

In this paper normal values are presented for the four skinfolds thicknesses and the arm circumference of a Dutch reference population. Based on the above mentioned expressions the fraction of fat-free mass and the arm muscle area are calculated and graphically presented such that they are easy to apply in daily paediatric practice.

Material and methods

Reference population

The reference population consisted of 2351 healthy Dutch children (1105 girls and 1246 boys) uniformly distributed over the first 18 years of life. They were measured in a cross-sectional growth study known as the Oosterwolde Study [18, 20]. Oosterwolde is a municipality centrally situated in the northern-most part of The Netherlands. The Oosterwolde Study provides reference data for 20 anthropometric measurements and describes the body proportions of children at all ages. The study was carried out from 1979 to 1980. The youngest group, age-range birth to 4 years, was measured at infant health centres. The older group was measured both at kindergarten and at different types of schools, so as to cover all socio-economic levels of the population. In 1990 the study was repeated in the same population for a number of measurements [19]. Although there was a significant difference for height, no such differences were found for weight and arm circumference. In the second Oosterwolde study, the skinfolds were not repeated.

Only children of Caucasian parents were included in this study and children suspected of being growth retarded due to one of the following causes were excluded from the reference population: intra-uterine growth retardation, growth retardation of endocrine origin, chromosomal abnormalities and syndromes, growth retardation resulting from constitutional skeletal diseases, growth retardation due to systemic insufficiencies, chronic infections, parasitic infestations and emotional deprivation.

Method of measurement

The measurements of skinfold thicknesses were taken at four sites: biceps and triceps skinfold thicknesses midway between elbow

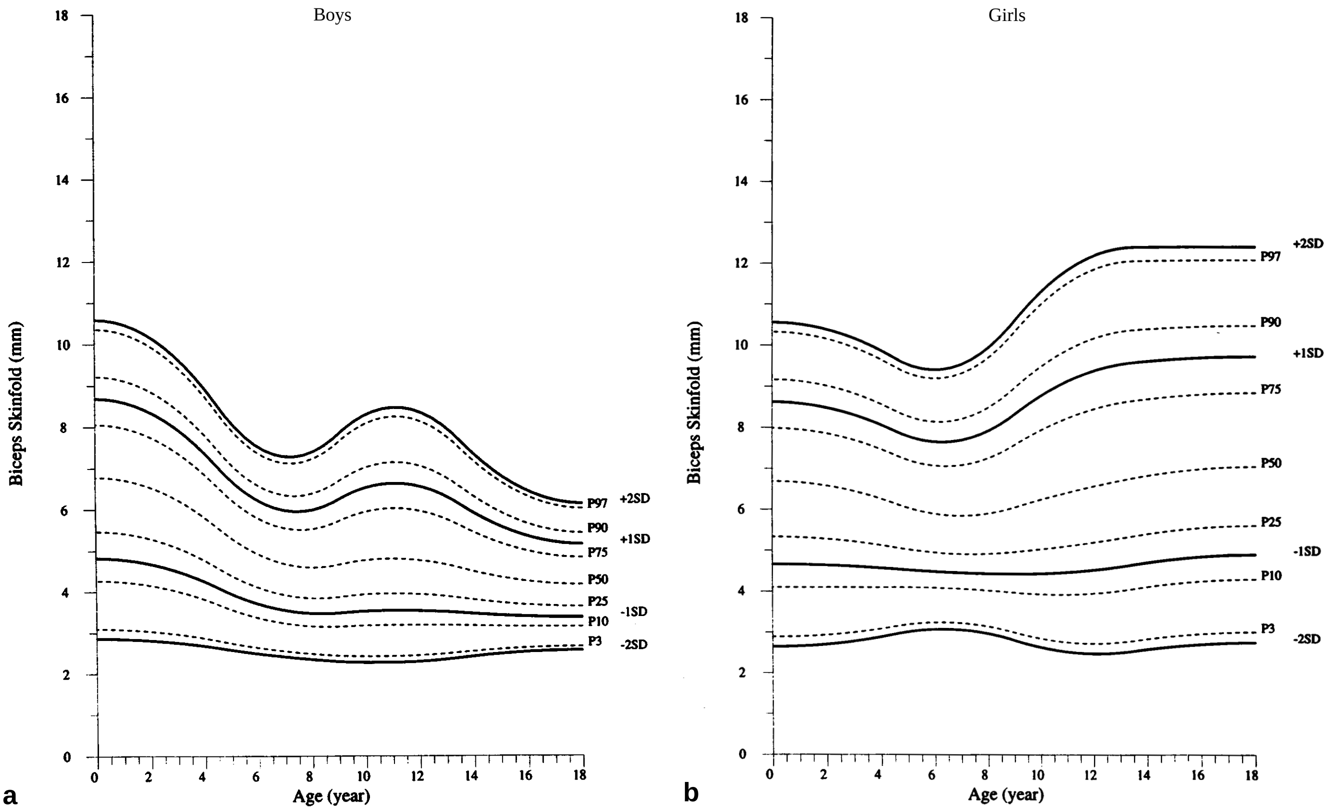


Fig. 1a, b Normal values for the biceps for boys (**a**) and girls (**b**). The *dotted lines* depict the percentiles P_3, P_{10},...,P_{97}. The *solid lines* depict the transformed standard deviations

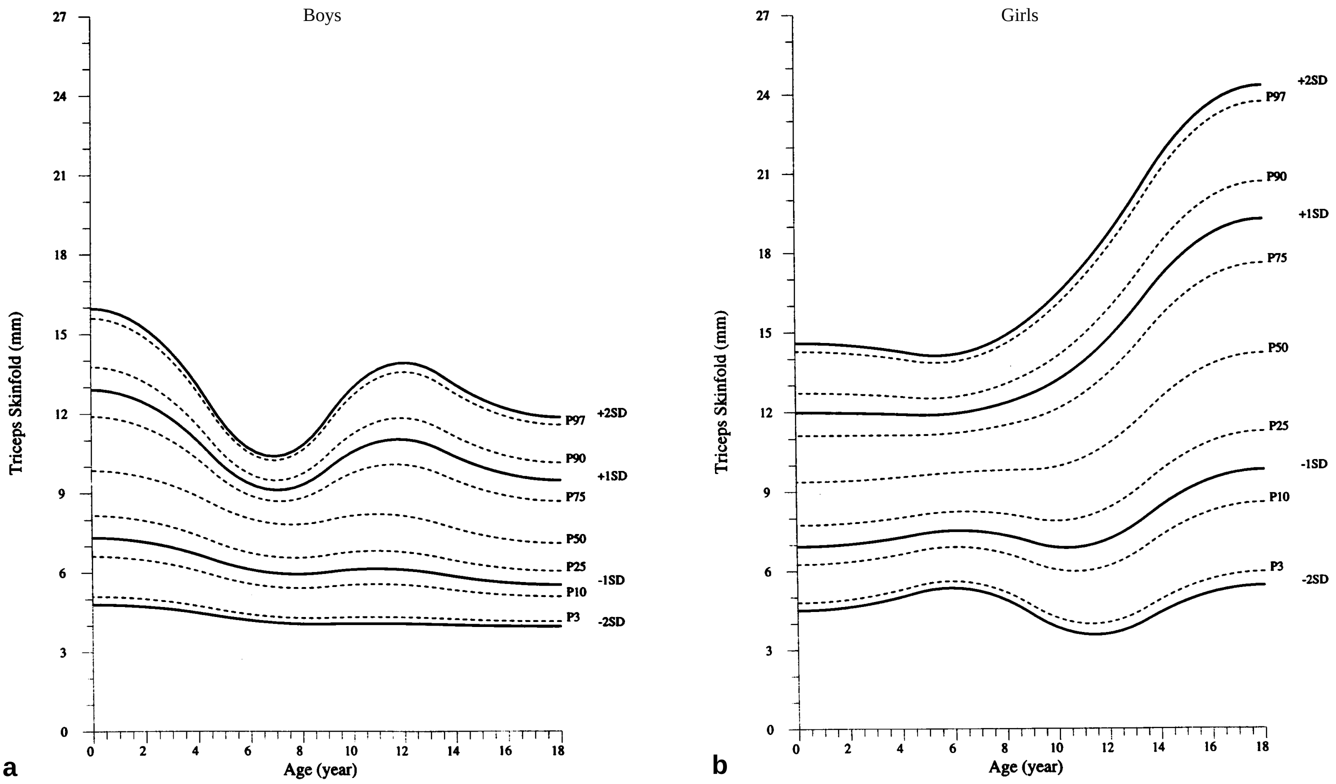


Fig. 2a, b Normal values for the triceps skinfold thickness for boys (**a**) and girls (**b**). The *dotted lines* depict the percentiles P_3, P_{10},...,P_{97}. The *solid lines* depict the transformed standard deviations

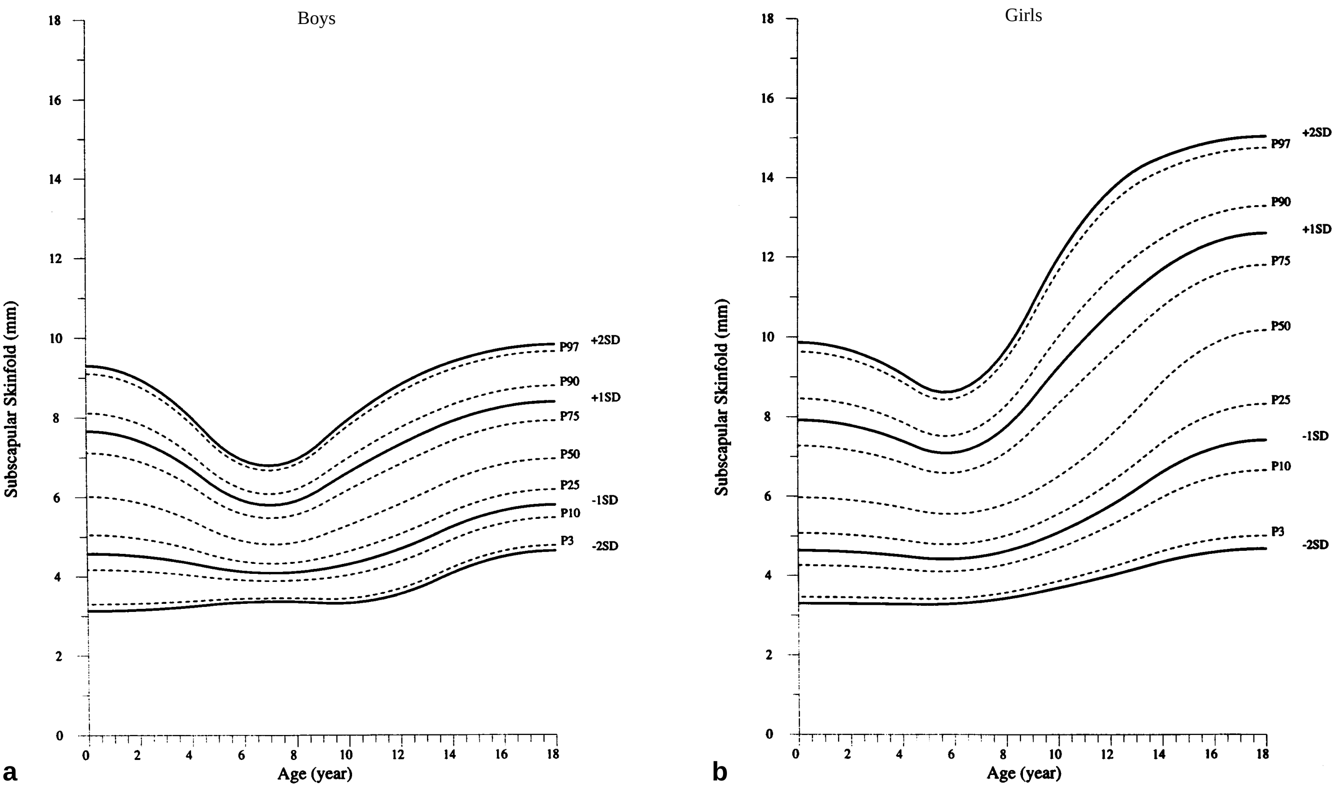


Fig. 3a, b Normal values for the subscapular skinfold thickness for boys (**a**) and girls (**b**). The *dotted lines* depict the percentiles P_3, P_{10},...,P_{97}. The *solid lines* depict the transformed standard deviations

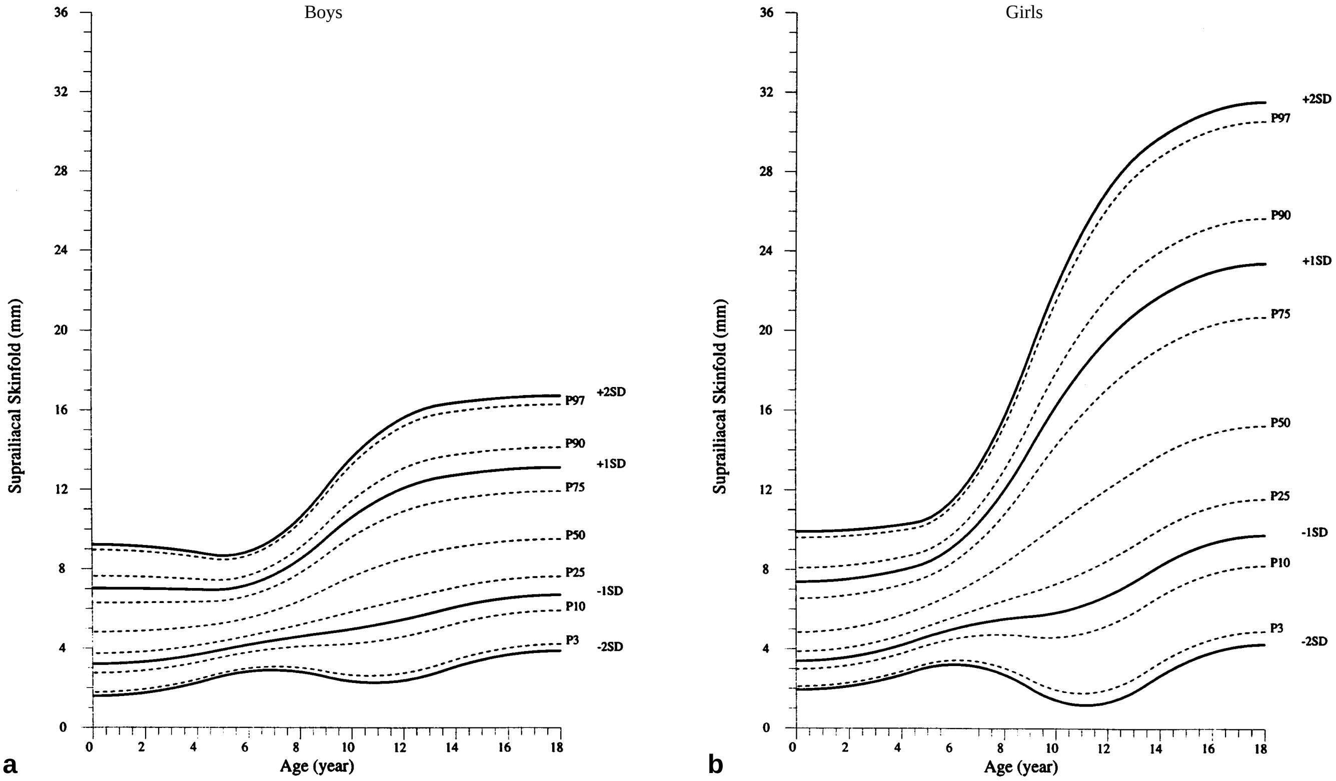


Fig. 4a, b Normal values for the supra-iliacal skinfold thickness for boys (**a**) and girls (**b**). The *dotted lines* depict the percentiles P_3, P_{10},...,P_{97}. The *solid lines* depict the transformed standard deviations

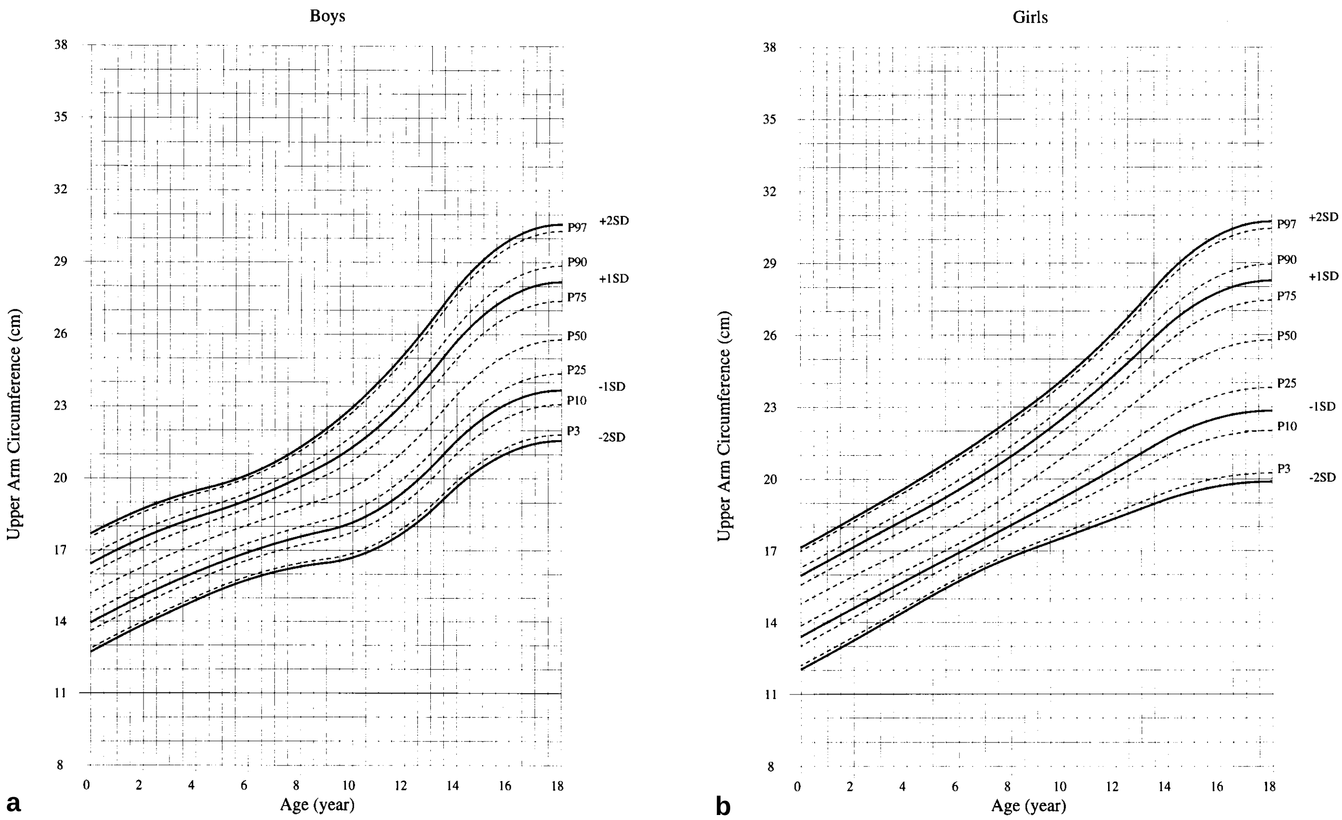


Fig. 5a, b Normal values for the MUAC for boys (**a**) and girls (**b**). The *dotted lines* depict the percentiles P_3, P_{10},...,P_{97}. The *solid lines* depict the transformedstandard deviations

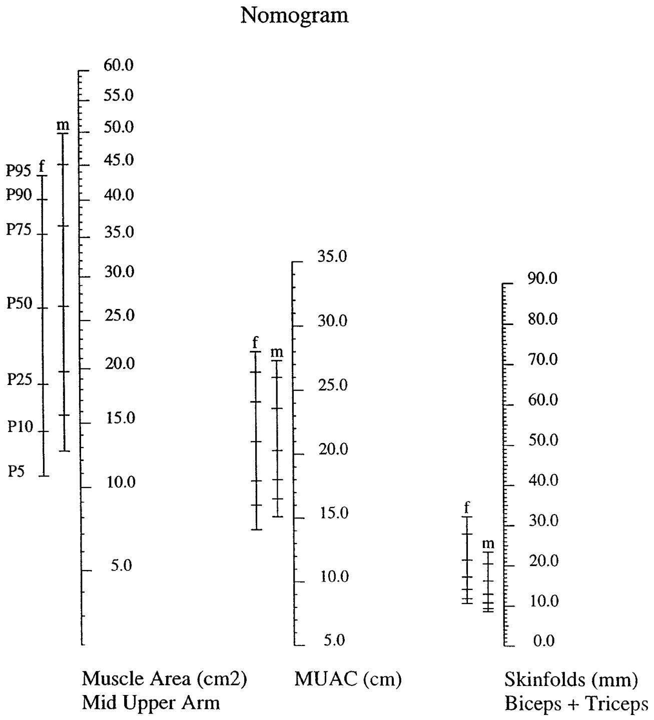


Fig. 6 Nomogram for arm muscle area in terms of skinfold thickness and MUAC. The arm muscle area is found by reading the value where the line through the values of skinfold thickness (left) and MUAC (mid) of an individual intersects with the right-vertical line. The *vertical bars* left of the axes represent the distribution of the Oosterwolde population in terms of percentiles: boys (M) on the right, girls (F) on the left

and shoulder in the mid-biceps region, the subscapular skinfold thickness at the lower tip of the scapula and the supra-iliacal skinfold thickness over the iliac crest. Measurements are taken by grasping the subcutaneous tissue between thumb and forefinger, shaking it gently to exclude underlying muscle tissue and stretching it just far enough to permit the jaws of the caliper to impinge on the tissue. Since the jaws of the caliper compress the tissue, the caliper reading is postponed for 2 s. The caliper used is from Holtain-Harpenden [10]. Only the left side of the body is used conform the protocol of the International Biological Programme [37].

Upperarm circumference is measured to the nearest millimeter with a fibreglass reinforced tape with the left arm hanging relaxed. The measurement is taken midway between the tip of the acromion and olecranon process.

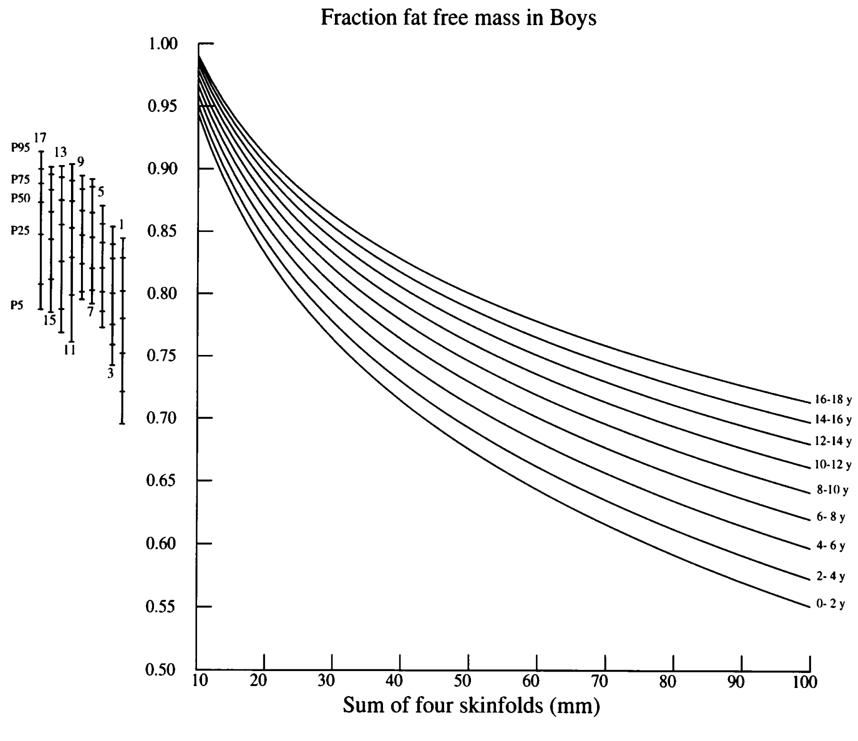
Construction of percentiles

The distribution of the skinfold thicknesses for each age is non-symmetrical. Therefore, for the construction of percentiles the following method was applied. After sorting the n measurements of the population in ascending sequence of age, a moving frame consiting of 100 individuals is considered starting with index number 1,2,3..., n–99. For each frame the percentiles P_{25}, P_{50} (modus) and P_{75} are computed. Based on these values the data are transformed to a symmetrical distribution. Next, all other percentiles are computed and transformed back. Cubic spline approximation is used to smooth the calculated percentiles.

Results

In Figs. 1–5 reference curves of the biceps, triceps, subscapular and suprailiacal skinfold thicknesses and reference curves of the mid-upperarm circumference are depicted for boys and girls.

Fig. 7 Age dependent relation between fat-free mass and sum of four skinfolds in boys. The *horizontal axis* denotes the sum of the skinfolds at biceps, triceps, subscapular and supra-iliacal sites. The *vertical axis* denotes the fraction fat- free mass. Multiplication of this fraction with the actual weight gives the fat- free mass. To use the graph find the sum of skinfolds at the horizontal axis and look up until the curve of the child's age class is crossed. From this intersection point draw a horizontal line to the left until you meet the vertical axis and find the fraction fat-free mass. Continue the horizontal line until the 90% confidence interval of the child's age class is reached. Each interval is trivially divided by the percentiles P_5, P_{10}, P_{25} P_{50}, P_{75}, P_{90} and P_{95}



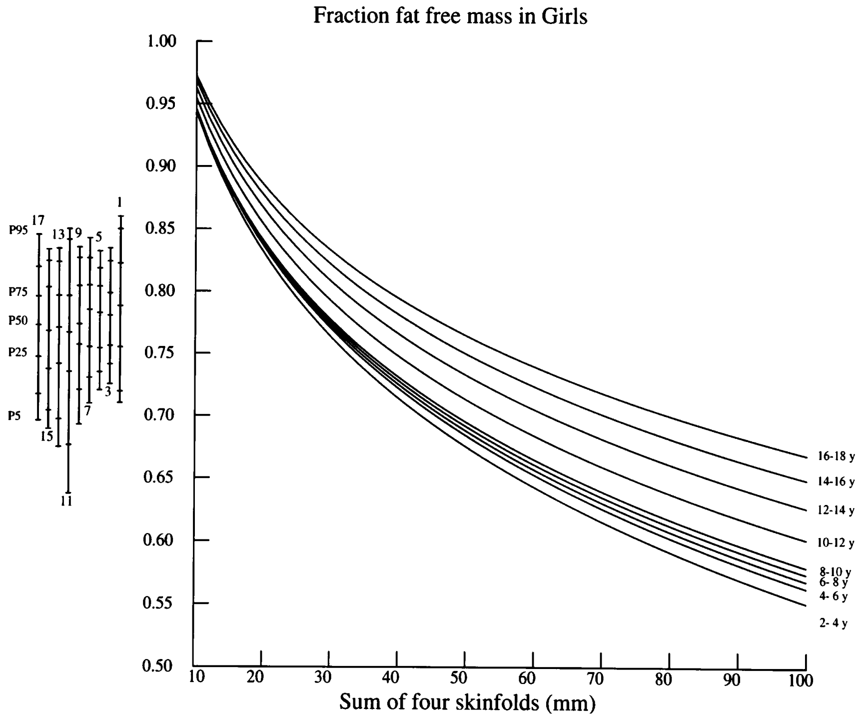


Fig. 8 Age dependent relation between fat-free mass and sum of four skinfolds in girls

In Fig. 6 a nomogram for arm muscle area in terms of skinfold thickness and mid-upperarm circumference is depicted. Also indicated is the distribution of the reference population in terms of percentiles for boys and girls.

Figures 7 and 8 depict the normal values for the age and sex dependent fraction of fat-free mass based on the sum of four skinfolds. Also indicated is the distribution of fraction of fat-free mass of the reference population in terms of percentiles for boys and girls at different ages.

Discussion

There are several reasons to be interested in body composition. Knowledge of the fat content may be of importance in the choice of treatment, in the effect of medication [2], in the estimation of the degree of malnutrition [21], etc. The use of weight or body surface to quantify the dose in a prescription is less effective when not considering fat-free mass. In this paper normal values are presented for the separate measurements but also a nomogram for muscle area and a graph for the fat-free mass are given which are easy to use. This kind of presentation makes it possible to estimate muscle area and fat-free mass even in field work. It may be of help for the paediatrician's daily practice as well as for the health worker in developing countries. Some caution must be made. First, skinfolds measurements are not very reproducible. Measuring errors are more dominant than in most other anthropometric measurements. Repeated measurements in our study show a variation with standard deviation of 0.5 mm (biceps), 1.1 mm (triceps), 0.7 mm (subscapular) and 0.6 mm (supra-iliacal). By averaging four skinfolds this problem is reduced [31]. Second, the use of theoretically defined prediction equations introduces a simplification by reduction of the parameters which are involved. For example, a child suffering from congestive heart failure may show a drastic increase in weight due to water retention only. The skinfold thicknesses of this patient do not change. Following the graph in Fig. 5 this means that the fraction of fat-free mass remains the same. Since the weight is increased it follows that also the fat mass increased violating that the weight gain consisted purely on water. The results of the estimation of the fraction of fat-free mass depends on the method used. In the case of the child presented above the use of labelled water will differ drastically from the use of skinfold thicknesses. In fact no gold standard exists. The presented model is validated by Weststrate [38] for 68 children, aged 7–10 years. This study indicated that predicted body density differed on average less than 1% from measured body density. In addition, predicted body density was highly correlated with measured body density: $r = 0.73$ for girls ($n = 33$) and $r = 0.77$ for boys ($n = 35$).

In the nomogram for arm muscle area in terms of skinfold thickness and mid-upperarm circumference the distribution of the reference population in terms of percentiles is given. These percentiles are age independent and give the frequency of occurence of a combination of the two measurements for the reference population. Age is implicitly involved in the MUAC and skinfold thickness. This method only roughly indicates the protein content of the body. Precise validation is not possible.

Despite the shortcomings of an anthropometric approach in estimating the fraction of fat-free mass or protein content, its simplicity makes the method valuable to apply in daily paediatric practice.

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