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A longitudinal study of lean and fat areas at the arm

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Summary. Using biceps and triceps skinfolds and upper arm circumference, areas of fat and lean tissue at the arm can be approximately determined based on a cylindrical assumption. Based on the first Zürich growth study a longitudinal analysis of estimated fat and lean areas is undertaken. Area may often be a more meaningful parameter than width in development, due to the increasing width of the limbs stretching the layer of fat. When comparing these quantities with the body mass index, correlations in boys were higher for lean area than for fat area, and about equally high for both measures in girls (around 0·8 beyond age 10). The primary goal of this investigation was to quantify the development of lean and fat arm areas from birth to adulthood, and to assess sex differences in this respect. The comparison with results obtained earlier from radiographic data is of particular interest, since such data can rarely be obtained any more, and overall this comparison can be considered encouraging. Lean area develops slowly until the onset of puberty, girls showing a slightly smaller value than boys. The pubertal spurt is very impressive in boys and moderate in girls, timed to age of peak height velocity in both sexes. Fat area changes only minimally in boys older than 16 months, and increases steadily in girls until age 16. The respective velocity curve shows a systematic up and down until age 5, when a gradual increase to a prepubertal fat spurt starts. It is interrupted by a trough in velocity—much more accentuated in boys—at puberty, and followed by a postpubertal fat spurt. When studying subgroups of subjects with a relatively high or relatively low adult body mass index, the heavy group differed relatively more in terms of fat area than lean area. Girls heavy as adults increase their fat area consistently more from about 5 years onwards. Boys later heavy show a qualitatively different pattern in puberty, with accentuated pre- and postpubertal fat spurts, but also a strong trough to a negative velocity in between.

1. Introduction

When assessing overweight or nutritional status for clinical or research work, simple measures such as the body mass index weight/height^2 or some reference value of weight have been popular. Ideally, one would like to distinguish at least the two compartments fat and lean mass, and this in the whole body, and if possible also the regional distribution. Malina (1980) gives an excellent overview of how to estimate whole-body fat and lean mass. These techniques have, however, certain disadvantages regarding inherent assumptions and ease of application, and provide estimates of whole-body composition only. A method used early for regional investigation of the extent of bone, muscle and fat is radiography (see below). For ethical reasons its application has largely disappeared in normal subjects.

The measurement of skinfolds is a simple and common method to quantify fat and its distribution. During development a decrease of skinfolds may be due to a real loss of fat tissue, or due to the increase of limb circumference stretching the ring of fat, or both. Thus, it might be of interest to compute an estimate of area of limb fat, based on skinfold and circumference measurements by making a cylindrical assumption for the fat layer (Malina 1980, Himes, Roche and Webb 1980, Frisancho 1981). This allows further computation of an estimate of the area of lean tissue, comprising muscle and bone. While this approach works for limbs in general, it is applied here to the upper arm only. According to Himes *et al.* (1980), fat area correlates better with absolute fat weight than skinfolds, and about equally well with relative fat weight, the latter obtained by density measurements. Estimates of mid-arm lean area correlate highly with measurements from CT scans, and skinfold measurements also correlate well with width of fat from radiographic data (Malina 1980), giving more validity to computing fat and lean area as described above.

Radiography used to be a classical tool to study body composition in terms of bone, muscle and fat. A popular site in early studies was the widest part of the calf (Stuart, Hill and Shaw 1940, Reynolds 1944). Fat tissue was measured additionally at mid-arm in the Harpenden Growth Study, and the analysis of these data by Tanner, Hughes and Whitehouse (1981) led to substantial insight: after aligning the data to peak height velocity they identified a pubertal spurt (PS) for muscle width in both sexes which was much stronger for boys. Its timing was later than for peak height velocity and roughly coincident with sitting height. In such a longitudinal analysis the velocity of width of arm fat showed a dip at puberty which reached negative values in both sexes, but more so for boys. For reasons given above, fat area need not necessarily decrease given width decreases. The results obtained by Johnston and Malina (1966) in a cross-sectional study pointed in the same direction as those of Tanner *et al.* (1981). An interesting finding was that the width of the fat layer was larger in early maturers and more so for boys.

In this paper we quantify the development of fat and lean arm areas from birth to adulthood, based on skinfold and circumference measurements. The fact that similar radiographic data can no longer be obtained, lends additional interest to such an investigation. Since radiographic data are expected to be superior to anthropometric data, one question to be investigated is whether skinfold and circumference measurements enable results similar to those reported in the literature for radiographic data. Advantages of this investigation are the quality of the longitudinal data of the Zürich growth study and the availability of advanced statistical techniques. Apart from analysing the prepubertal and pubertal developmental pattern in lean and fat tissue, we want to describe relevant sex differences in this respect. The computation of structural average distance and velocity curves is the main methodological tool which was successful for analysing linear growth (Gasser, Kneip, Binding, Prader and Molinari 1991) as well as growth of weight, circumferences and skinfolds (Gasser, Ziegler, Kneip, Prader, Molinari and Largo 1993). An analysis performed on subgroups of children who later became heavy or light adults should give information on how and when a surplus in lean and fat tissue builds up for those later heavy. Apart from giving no indication of body composition, the body mass index suffers from other weaknesses which have been discussed by Garn, Leonard and Hawthorne (1986) and by Gasser, Ziegler, Seifert, Prader, Molinari and Largo (1994a) and Gasser, Kneip, Ziegler, Molinari, Prader and Largo (1994b).

2. Subjects and methods

2.1. Subjects and measurements

In an internationally coordinated study (Falkner 1960), initiated in 1954, participation of 321 children could be obtained for the Zürich sample. In this investigation, $n = 112$ girls and $n = 120$ boys, with rather complete measurements from infancy to adulthood, enter into the analysis. For further details the reader may consult the papers by Gasser, Kneip, Ziegler, Largo and Prader (1990) or Prader, Largo, Molinari and Issler (1989).

Measurements were taken at 1, 3, 6, 9, 12, 18 and 24 months and then annually until age 9 for girls and age 10 for boys; then $\frac{1}{2}$-yearly intervals started. This was again changed to yearly measurements, when the annual increment in height was less than 0·5 cm. Techniques of measurement are described in Prader *et al.* (1989) and briefly in Gasser *et al.* (1993).

When approximating the arm by a cylinder, upper arm circumference (UAC) and skinfolds can be used to obtain area of fat and of lean tissue traditionally based on triceps skinfold (TRI):

$$\mathrm{LA} = (\mathrm{UAC} - \pi \times \mathrm{TRI})^2/4\pi$$
$$\mathrm{FA} = \mathrm{UAC}^2/4\pi - \mathrm{LA}$$

where:

LA = area of lean tissue
FA = area of fat tissue.

A somewhat better approximation accounting to some extent for an irregular layer of fat can be obtained by using the average value of biceps (BIC) and triceps skinfolds when computing LA.

$$\mathrm{LA} = (\mathrm{UAC} - \pi \times (\mathrm{TRI} + \mathrm{BIC})/2)^2/4\pi$$

The latter formula is used primarily in this paper.

2.2. *Statistical methods*

The structural average growth curve for distance, velocity and acceleration is described in Gasser *et al.* (1990) and for the mathematically oriented reader in Kneip and Gasser (1992). First, individual growth curves are transformed from a chronological to a developmental age scale by an alignment procedure which is continuous in time. This transformation is based on characteristic ages in individual development, with age of maximum velocity or age of maximum acceleration during puberty being examples. Here, the individual characteristic ages of height growth have been used. After transforming individual age scales to a common 'maturational' age scale, individual growth curves (be it distance or velocity) are averaged, and the average is then slightly smoothed.

In order to obtain a better understanding of the mechanisms leading to a high or a low level of adult lean mass, or of adult fat, the following procedure was adopted (Gasser *et al.* 1994b): the sample was divided into three subsamples of equal size having a low, middle or high body mass index as adults. The two extreme groups were then further analysed and compared. According to the previous paper the two subgroups can also be considered as subgroups of rather lean and rather fat subjects. The high index group has a body mass index above 21·7 kg/m^2 (boys) and 21·1 kg/m^2 (girls) and the low index subjects lie below 19·6 kg/m^2 (boys) or 19·1 kg/m^2 (girls). Thus, the middle group has a narrow range, which should not be interpreted as the basis of a normal range.

3. Results

Table 1 shows means and standard deviations for fat and lean area after birth and when reaching adulthood. Adult males reached much higher values for lean tissue and females for fat tissue, and these sex differences were statistically highly significant. Differences were small at 4 weeks, and significant for fat only, but nevertheless

Table 1. Area (cm^2) of fat and lean tissue at upper arm at 4 weeks and when reaching adulthood for $n = 120$ boys and $n = 112$ girls; p-values from Wilcoxon tests for statistical significance of sex differences.

Variable	Age	Boys $\bar{x}$	Boys s	Girls $\bar{x}$	Girls s	p-values
Area fat (cm^2)	4 Weeks	2·2	0·5	2·4	0·5	0·009
	Adults	7·8	3·4	11·6	4·9	<0·0001
Area lean (cm^2)	4 Weeks	6·1	1·0	6·0	1·1	– n.s.
	Adults	55·7	9·3	40·2	5·5	<0·0001

pointed in the same direction. The increase in lean tissue till adulthood was relatively more impressive than the one for fat, which, on the other hand, had a higher relative variability from the beginning.

Figure 1 gives rank correlations between fat and lean area on one side and the body mass index (weight/height^2) on the other side, computed separately for each age. Correlations for lean tissue became high after about age 9, in particular for boys. Fat showed almost the same correlations as lean tissue for girls, but lower ones for boys. Interestingly, correlations were higher for fat area than for the sum of biceps and triceps skinfolds. Correlations of the two areas with the adult value of the body mass

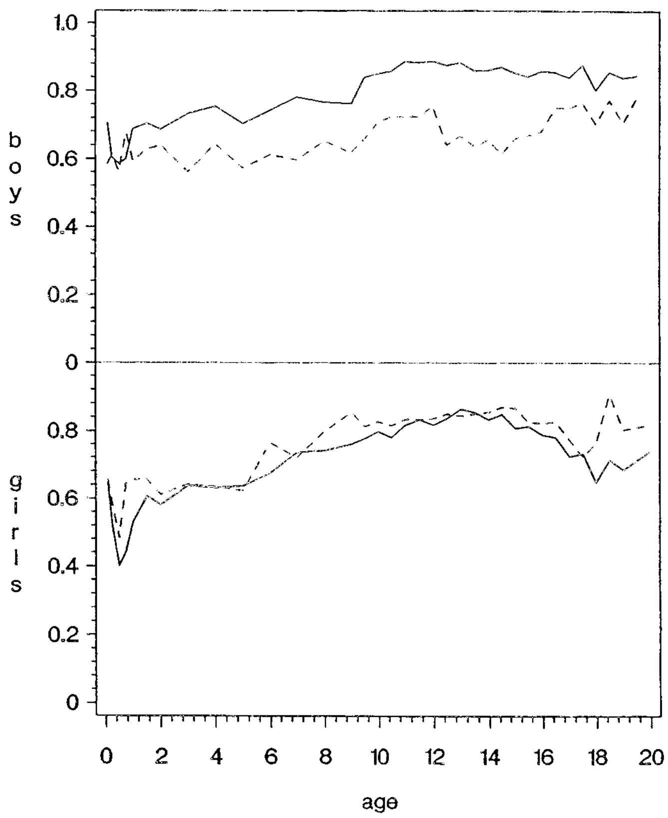

Figure 1. Rank correlations between lean area (solid line) and fat area (dashed line) with body mass index weight/height^2 at same age. Girls below, boys above.

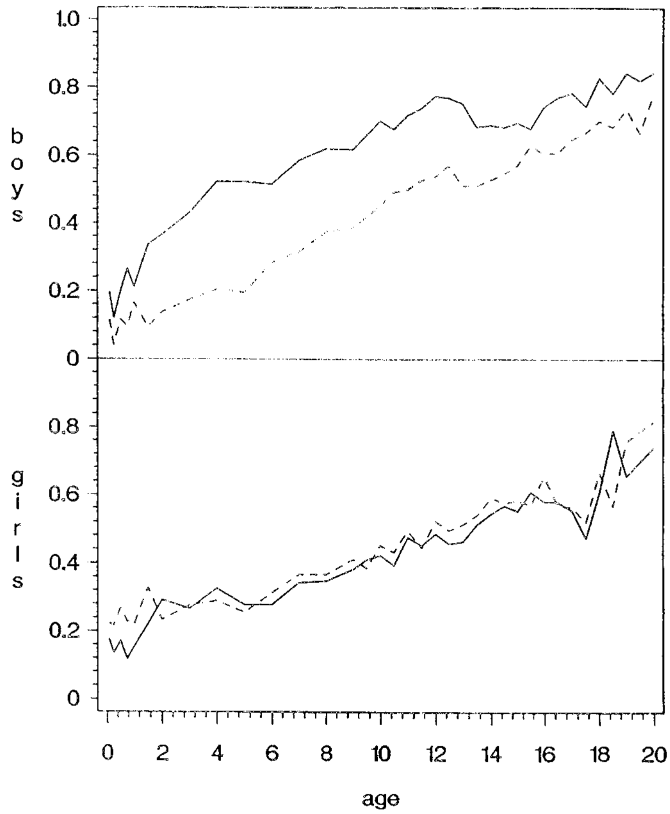

Figure 2. As in figure 1, but depicting correlations with adult body mass.

index are depicted in figure 2. Correlations for fat area increased slowly, similarly for both sexes, while lean tissue reached much higher correlations at an earlier age for boys only. Correlations for fat and lean areas with adult values increased almost linearly from 0·2 after birth to 0·7 for girls, while correlations of lean tissue for boys were above. These correlations were very similar to those obtained earlier for triceps skinfolds.

The structural average distance curve for lean tissue showed a steady increase until puberty, when a sharp sex-dependent increase occurred (figure 3). The lean area was always higher for boys, except during the PS of girls when girls reached the level of boys, but did not surpass it. The structural average velocity curve (figure 4) allows more detailed conclusions: a sharp drop in infancy to a minimum at 1·7 years was followed by a gradual increase, very similar for boys and girls. There was no solid evidence of a mid-growth spurt. The PS peaked at 12·8 years and 14·2 years, respectively. Peak lean velocity was higher by about 60% for boys, for whom velocity almost quadrupled compared to childhood values. Fat area increased from 2 cm^2 to about 7 cm^2 for boys and 6·8 cm^2 for girls in the first 6 months, the only instance where boys had a slightly larger fat area (figure 3). Thereafter boys experienced little change apart from a biphasic wave in puberty. Girls increased their area markedly from 7 years onwards until age 16, with little change to follow. Again, the structural average

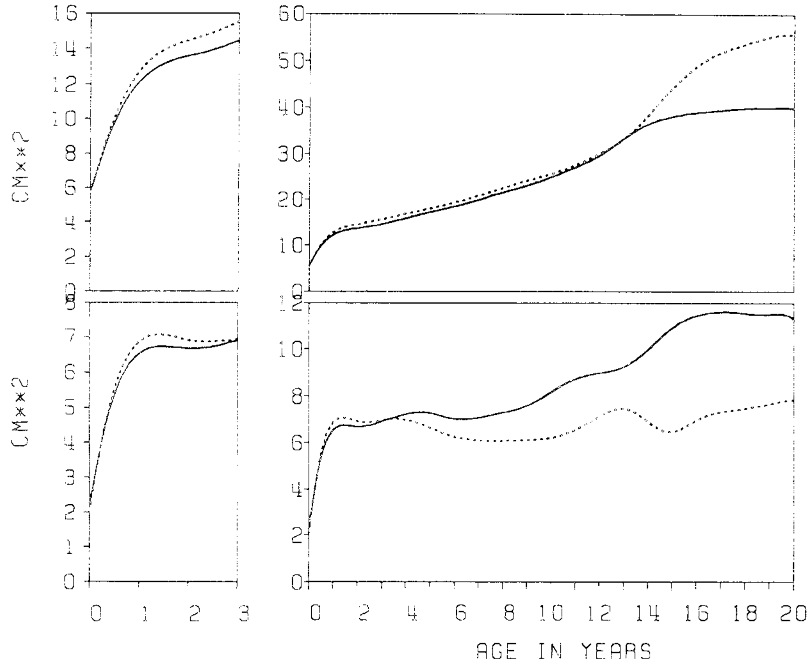

Figure 3. Structural average distance curves for girls (solid line) and for boys (dashed line) of lean area (above) and of fat area (below).

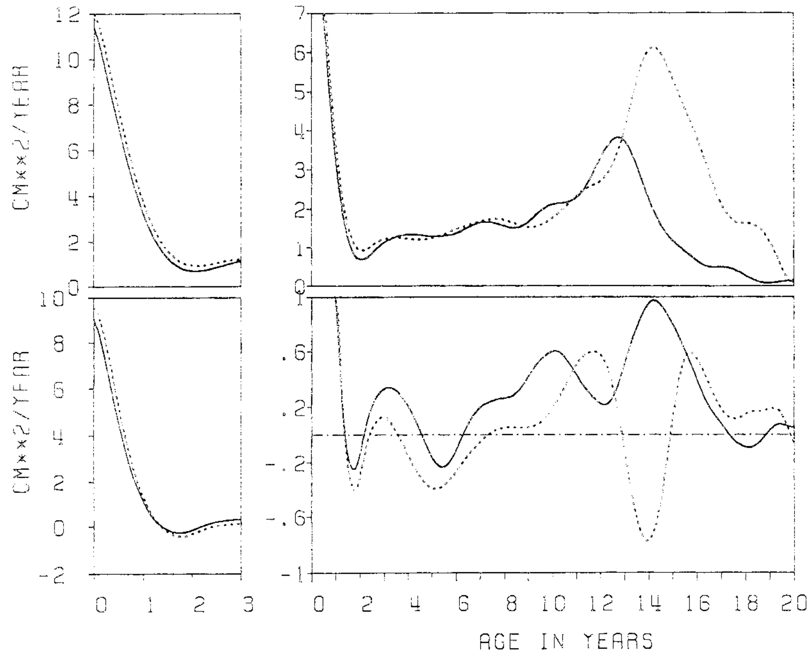

Figure 4. As in figure 3, but depicting structural average velocity curves.

velocity curve yields a more detailed quantification of dynamic processes (figure 4): the general pattern was similar for both sexes, with a sharp fall to a slightly negative minimum at 1·6 years followed by an increase and a further decrease to a negative minimum at 5·5 years. From this age onwards, velocity increased to a prepubertal fat spurt, followed by a drop to a minimum at the age of the PS and a further postpubertal fat spurt. Sex differences were quite accentuated: girls had a velocity higher by about 1 cm^2/year from 3 years until their prepubertal fat spurt. Then they showed a much smaller non-negative trough in velocity at the age of the PS, and a more intense postpubertal fat spurt.

For the subgroups having a high or a low body mass index as adults we have tabulated some elementary statistics (table 2). The mean area of lean tissue in adulthood was increased by about 1/4 (girls) and 1/3 (boys) in the high compared to

Table 2. Area (cm^2) of fat and lean tissue at upper arm at 4 weeks and when reaching adulthood.

	Body mass index	Age	Area fat (cm^2) $\bar{x}$	Area fat (cm^2) s	Area lean (cm^2) $\bar{x}$	Area lean (cm^2) s
Boys	High	4 Weeks	2·3	0·5	6·4	1·0
		Adult	10·6	3·9	64·9	7·7
	Low	4 Weeks	2·2	0·5	5·9	1·0
		Adult	5·5	1·3	47·7	6·0
Girls	High	4 Weeks	2·5	0·6	6·2	1·2
		Adult	16·2	5·5	45·1	5·3
	Low	4 Weeks	2·3	0·5	5·8	1·1
		Adult	8·1	2·0	35·8	3·0

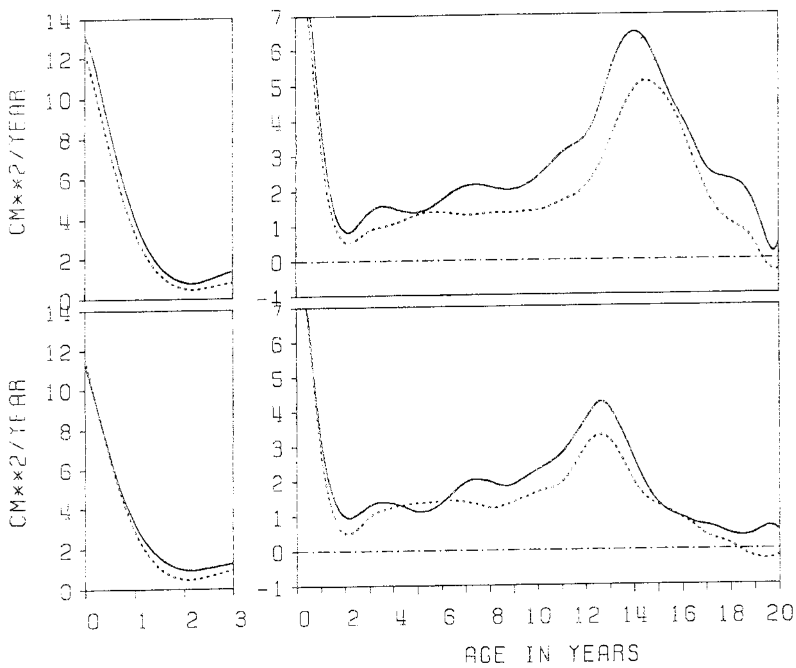

Figure 5. Structural average velocity curves for lean area for subgroup of heavy adults (solid line) and light adults (dashed line). Boys above, girls below.

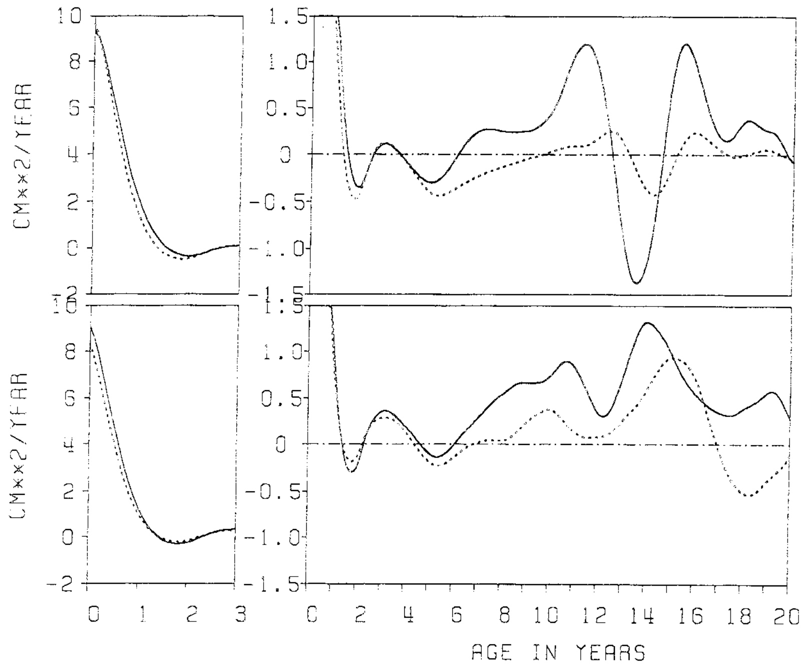

Figure 6. As in figure 5, but depicting fat area.

the low index group. The average fat area differed, however, by a factor of 2. After birth small differences occurred, pointing in the same direction. Most of the adult difference in lean tissue was due to a higher velocity from 6 years until puberty and to a higher and broader PS (figure 5). The period in the rising phase to the pubertal peak contributed more to the difference between the heavy and the light subgroups than the period just following. For boys, but not for girls, the heavy group experienced its PS earlier by $\frac{1}{2}$ year. Structural average velocity curves of stature showed a similar maturational pattern, heavy boys being earlier by $\frac{1}{2}$ year but not girls. From 5 years until the start of the prepubertal fat spurt, later heavy boys or girls had a higher velocity in fat area (figure 6). For boys, pubertal changes were much different for heavy and light subjects: for the heavy ones a strong prepubertal and a strong postpubertal fat spurt emerged, which were both small in subjects becoming light adults. However, the decrease in velocity during puberty was also much more accentuated for heavy subjects. As for lean tissue, heavy boys passed somewhat earlier through this pubertal pattern. For girls the general pattern of fat velocity for the two subgroups did not differ as much, except that ups and downs were a bit more accentuated in heavy subjects. A markedly higher velocity level prevailed in the high index group through most ages.

4. Discussion

As anticipated, the area of arm fat is in many ways a more meaningful quantity than the width of biceps and triceps skinfolds. The structural average curves bring out a clearer pattern than the one identified for the two skinfolds separately (Gasser *et al.* 1993). Whereas boys had a decrease in both skinfolds after infancy—suggesting a loss of fat—the area stays roughly at the same level of 7–8 cm^2 beyond 2 years. Since area is in some ways a more meaningful quantity than width, one might also expect better correlations. On the other hand, they might also be worse, since area is inheriting variability from two skinfold and one circumference measurements. Furthermore, the area can only be calculated approximately, based on some idealized assumptions. It is then not surprising to see some correlations improved and others stay the same. A further advantage of computing an approximate fat area is that an estimate of the area of lean tissue—muscle and bone—becomes available.

Correlations of fat and lean tissue with the body mass index are of about equal size for girls, and for boys markedly higher for lean tissue. This is true for correlations at the same age and with the adult value of weight/height^2. This is attributed to the fact that lean tissue makes up a larger percentage of body mass for boys. Unfortunately, correlations of fat area at some age with the respective adult value are of moderate size up to later childhood, similar to skinfolds themselves.

Let us first discuss the development of lean area: our distance curves are in good qualitative agreement with the results obtained by Tanner *et al.* (1981) for muscle width radiographically, whereas the figures of Johnston and Malina (1966) for muscle width are somewhat discrepant: they show a gradual drift between boys and girls, whereas Tanner's and our results show the same almost linear development until puberty, boys having respectively slightly more lean muscle tissue. (The higher value of boys starts as early as $\frac{1}{2}$ year.) After just reaching boys' size in puberty, girls fall back decisively when boys reach puberty. This is underlined by the velocity curve of lean area, which shows a low prepubertal level in both sexes and a moderate PS in girls and a very strong one in boys, with a peak velocity almost four times as high as velocity in childhood. These findings agree with those obtained by Tanner *et al.* (1981) based on radiographically determined muscle width, and where comparable also with Forbes (1972) based on estimates of whole-body lean mass. The PS of lean area is of a remarkable duration. The timing of the PS of lean area is almost coincident with the one of stature for our data, whereas Tanner *et al.* (1981) identified for muscle width a slightly later age, coincident with the pubertal peak of sitting height. Compared to the normative values for lean area of Frisancho (1981) there is a substantial difference for girls, but not for boys; whereas our value was around 40 cm^2 from 17–20 years, his was around 33 cm^2. In order to clarify this point we recomputed areas based on triceps skinfolds only, as done by Frisancho. Our young adult value then dropped to about 37 cm^2, diminishing the difference to some extent.

Fat area shows a different developmental pattern from fat width (Tanner *et al.* 1981), obtained radiographically. For both measures, the two sexes begin to diverge around 4 years. Whereas width falls for boys almost continuously from a maximum of 16 mm at 3 years to about 8 mm at late teens, the area shows little change after 16 months, when 7 cm^2 were reached. The lowest value is reached at 8 years with 6·1 cm^2, the highest at 20 years with 7·8 cm^2. Fat width for girls shows a drop to about 14 mm at age 7, then to rise steeply to 22 mm reached at age 18. The area, on the other hand, rises almost continuously from a value of 6·7 cm^2 at 16 months to a value of 11·8 cm^2 at age 16, after which age the fat area stays roughly constant. The results of Johnston and Malina (1966) are qualitatively different, because their widths of fat develop roughly the same in both sexes from 6 to 12 years, both showing a modest increase. Differences arise only afterwards. The normative values of Frisancho (1981) show an age pattern for sex differences in fat area similar to ours, but his values are higher, except in infancy and early childhood. This difference is accentuated for girls and does not disappear, when recomputing areas based on triceps skinfolds only, as done by Frisancho (1981). Such a finding puts once more in question the use of purely statistical norms, as, say, opposed to criterion-oriented norms for quantities measuring soft tissue.

Structural analysis velocity curves of fat area lead to an interesting pattern, qualitatively similar for both sexes: there is a sharp drop of velocity in infancy to a negative minimum at $1\frac{1}{2}$ years. The loss of fat may be associated with spending relatively less time and effort in eating and drinking, compared to the first year. It is followed by an increase and a further dip at $5\frac{1}{2}$ years reaching negative velocity. This can be attributed to the biceps (Gasser *et al.* 1993) but otherwise lacks an explanation. The gradual increase in velocity after this age culminates in a prepubertal fat spurt. A trough coincident with peak height velocity is followed by a postpubertal fat spurt, a pattern also described in Tanner *et al.* (1981) for radiographically obtained fat width. One might speculate about the trough in velocity that—as a supplement to nutritional intake—fat deposits are resolved when demand is highest for building up muscles in boys; in girls velocity is diminished, but still positive, in line with the different balance between fat and lean in body composition. Sex differences in development are such that velocity is slightly higher for boys up to $1\frac{1}{2}$ years; after that age the level is consistently higher for girls until the prepubertal fat spurt. The trough during puberty is much more accentuated in boys, and leads to a loss of fat only for them. For width, Tanner *et al.* (1981) found a loss in both sexes. Combining these results it seems that part of the decrease in width is due to the fact that the radius of lean tissue becomes larger. Girls also have a much larger postpubertal fat spurt than boys. Let us note in conclusion that area of fat yields a clearer pattern in terms of structural average velocity curves than single skinfold (Gasser *et al.* 1993).

Given that radiographic data can scarcely be obtained nowadays, anthropometric data are an attractive alternative to obtain regional estimates of tissue composition. A common opinion is that the quality of such measurements is inferior, but the present study demonstrates that meaningful and rather detailed information can be obtained from lean and fat area estimated from skinfolds and circumferences. The agreement with results obtained from radiographic data is good.

As in a previous paper (Gasser *et al.* 1994b) we have formed subgroups of rather light or rather heavy subjects with respect to the adult body mass index. The analysis of these subgroups should provide information concerning the mechanisms and timing of overweight accumulation, and how this evolves in terms of fat and lean tissue. The present analysis supports our earlier claim that these subgroups can also be considered as groups of rather thin or rather fat adults: while the adult lean area is also increased in the high index group, the fat area is almost doubled. Boys and girls show a different development: later heavy females have a consistently higher velocity in fat area from 6 years well into puberty compared to later light females, without much difference in the velocity pattern. The postpubertal fat spurt is of about equal size in the two subgroups, but differences rise again after age 17. Boys, in contrast, show a markedly different pattern after about age 10: males who are lean as adults never win or lose much in fat area. Those later fat have marked ups and downs before, during and after puberty. Accentuated pre- and postpubertal fat spurts are interrupted by a strongly negative velocity minimum at about age of peak height velocity. In a way, naturally occurring events become exaggerated and render an impression of instability of regulation. Eventually, there are a number of non-developmental, psychosocial factors influencing the level of fat, such as diet, physical activity, stress, disease, etc.

The higher instability in the pattern of average fat velocity for boys heavy as adults, may be tentatively interpreted as follows: to accumulate a substantial amount of fat is natural for girls, leading to an estimated average percentage of fat to weight of 25% (Holliday 1986). For boys it is natural to accumulate a small amount of fat (estimated to be 12% in adulthood), and factors other than biological ones become relatively more important, leading to a greater instability for fat subjects. Evidently, an analysis at an individual level is necessary to obtain sound results in terms of tracking and stability of lean and fat tissue (Roche and Baumgartner 1988).

We have found a slightly earlier pubertal spurt for the heavier boys but not for girls. This is consistent with the results of Johnston and Malina (1966) that early maturers—in particular boys—have a larger fat width.

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Zusammenfassung. Bei Annahme eines zylindrischen Modells lassen sich aus den Hautfaltendicken am Bizeps und am Trizeps sowie aus dem Armumfang die Fettfläche und die Fläche der fettfreien Masse am Arm näherungsweise bestimmen. Auf der Basis der Daten aus der ersten Züricher Longitudinalstudie werden die Veränderungen der Fettfläche und der Fläche der fettfreien Masse unter longitudinalem

Aspekt analysiert. Die Fläche könnte unter entwicklungsbiologischem Aspekt häufig ein bedeutungsvollerer Parameter sein als die Breite, da bei wachsender Breite der Extremitäten die Fettschicht gedehnt wird. Ein Vergleich dieser Parameter mit dem Body Mass Index zeigt, daß die Korrelationen bei Jungen mit der fettfreien Fläche größer waren als mit der Fettfläche und bei Mädchen für beide Maße etwa gleichgroß (etwa 0·8 für 10jährige und ältere Mädchen). Das primäre Ziel dieser Untersuchung war, die Entwicklung der fettfreien Armfläche und der Fettfläche des Arms von der Geburt bis ins Erwachsenenalter unter besonderer Berücksichtigung der Geschlechtsunterschiede zu analysieren. Ein Vergleich der Ergebnisse mit früheren Ergebnissen auf der Basis röntgenologischer Daten ist von besonderem Interesse, da solche Daten kaum noch erhoben werden können. Die Ergebnisse des Vergleichs können insgesamt als ermutigend angesehen werden. Die fettfreie Fläche entwickelt sich bis zum Beginn der Pubertät sehr langsam, Mädchen weisen etwas geringere Werte auf als Jungen. Der puberale Spurt ist bei Jungen stark ausgeprägt und moderat bei Mädchen; in beiden Geschlechtern steht er zeitlich mit dem Auftreten des maximalen Körperhöhenspurts in Zusammenhang. Während sich die Fettfläche bei Jungen nach dem 16. Lebensmonat kaum verändert, steigt sie bei Mädchen bis zum Alter von 16 Jahren stetig an. Die entsprechende Geschwindigkeitskurve zeigt bis zum Alter von 5 Jahren ein systematisches Auf und Ab, danach beginnt ein gradueller Anstieg bis zu einem präpuberalen Fettspurt. Er wird zum Zeitpunkt der Pubertät von einem Tal in der Geschwindigkeit unterbrochen, das bei Jungen deutlich stärker betont ist. Es schließt sich ein postpuberaler Fettspurt an. Bei Analyse von Teilstichproben, die auf der Basis eines relativ hohen bzw. relativ niedrigen Body Mass Index im Erwachsenenalter gebildet wurden, zeigt sich, daß die 'schwere' Gruppe sich im Hinblick auf die Fettfläche relativ stärker unterschied als in der fettfreien Fläche. Bei Mädchen, die als Erwachsene einen hohen BMI aufweisen, nimmt die Fettfläche vom Alter 5 Jahre an deutlich stärker zu. Jungen, die später einen hohem BMI aufweisen, zeigen während der Pubertät ein qualitativ anderes Fettzunahmemuster mit betonten prä- und postpuberalen Fettspurts sowie einem deutlichen Tal mit negativer Geschwindigkeit dazwischen.

Résumé. En utilisant les plis cutanés bicipital et tricipital ainsi que la circonférence du bras et en appliquant un modèle de type cylindrique, on peut approximativement déterminer les surfaces de graisse et de tissu maigre du bras. Une analyse longitudinale des estimations de ces surfaces a donc été développée, sur la base de la première étude de croissance de Zurich. Les surfaces peuvent souvent être un paramètre plus adéquat que les diamètres dans les études de développement, car l'accroissement de largeur des membres étire la couche graisseuse. Quant on les compare avec l'indice de masse corporelle, les corrélations rencontrées chez les garçons sont plus élevées pour la surface maigre que pour la surface grasse; elles sont à peu près d'intensité analogue chez les filles (autour de 0·8 après 10 ans). Le premier objectif de ce travail est de quantifier le développement des surfaces maigre et grasse depuis la naissance jusqu'à l'âge adulte et de décrire les différences sexuelles de ce développement. La comparaison avec les résultats obtenus antérieurement par radiographie est d'un intérêt particulier car de telles données sont très difficiles à obtenir désormais, et surtout parce que cette comparaison donne des résultats encourageants. La surface maigre s'accroit lentement jusqu'au début de la puberté, les filles présentant des valeurs un peu plus petites que celles des garçons. Le pic pubertaire est très marqué chez les garçons, modéré chez les filles et en phase avec l'âge du maximum de vélocité de la croissance staturale dans les deux sexes. La surface graisseuse change à peine chez les garçons après l'âge de 16 mois, alors qu'elle augmente régulièrement chez les filles jusqu'à 16 ans. Les courbes respectives de vitesse montrent des oscillations verticales jusqu'à 5 ans, lorsque commence l'accroissement graduel de graisse prépubertaire. Celui-ci est interrompu par une dépression de la vitesse à la puberté—beaucoup plus marqué chez les garçons—et suivi par un pic d'accroissement graisseux post-pubertaire. Lorsqu'on étudie des sous-groupes de sujets avec un indice de masse corporelle adulte relativement élevé ou relativement bas, le groupe le plus lourd diffère relativement plus en terme de surface graisseuse que de surface maigre. Les filles devenues des adultes lourdes, accroissent leur surface graisseuse de façon régulière et consistante depuis l'âge de cinq ans. Les garçons qui deviennent ultérieurement lourds, montrent un schéma qualitativement différent au cours de la puberté, avec des pics d'accroissemnent graisseux pré- et post-pubertaires accentués, mais aussi une dépression forte jusqu'à une vélocité négative pendant l'intervalle.