0031-3998/03/5406-0906
PEDIATRIC RESEARCH
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Vol. 54, No. 6, 2003
Printed in U.S.A.

Studies on Human Body Composition during the First 4 Months of Life Using Magnetic Resonance Imaging and Isotope Dilution

ELISABETH OLHAGER, EVA FLINKE, ULF HANNERSTAD, AND ELISABET FORSUM

Department of Molecular and Clinical Medicine, Division of Pediatrics [E.O.], Department of Medicine and Care, Division of Medical Radiology [E.Fl.], Department of Biomedicine and Surgery, Division of Clinical Chemistry [U.H.], Department of Biomedicine and Surgery, Division of Nutrition [E.Fo.], University of Linköping, University Hospital, SE-581 85 Linköping, Sweden

ABSTRACT

Assessing body composition during infancy requires data for the so-called reference infant. Currently available data for this purpose need to be updated and extended using methods based on principles different from those used previously to define the reference infant. Thus, magnetic resonance imaging was applied to full-term healthy boys ($n = 25$) and girls ($n = 21$), 4–131 d old, to estimate adipose tissue volume (ATV) and the amounts of s.c. and non-s.c. adipose tissue (AT). Total body water was estimated using isotope dilution. Total body fat (TBF), fat free weight (FFW) and the degree of hydration in FFW were calculated. Increases in weight, TBF, and FFW with age agreed with current reference data, although when compared with the reference, a slightly more rapid increase in % TBF was observed for boys. The degree of hydration in FFW was 78.9 ± 4.5% ($n = 45$). Both sexes showed significant increases with age in s.c. ATV (14.7 and 13.0 mL/d for boys and girls, respectively) and in non-s.c. ATV (1.58 and 1.26 mL/d, respectively). Subcutaneous ATV was 90.5 ± 1.8% (boys) and 91.1 ± 1.9% (girls) of total ATV. In conclusion, a pronounced increase with age in the amount of AT was demonstrated involving a considerable gain in s.c. fat during early life. Except for % TBF in boys, changes in body composition with age agreed with current reference data. **(*Pediatr Res* 54: 906–912, 2003)**

Abbreviations

- **FFW,** fat free weight
- **TBF,** total body fat
- **TBW,** total body water
- **MRI,** magnetic resonance imaging
- **AT,** adipose tissue
- **ATV,** adipose tissue volume

Much interest has recently been focused on the relationship between early nutrition and the future health of humans (1–3). Poor growth during early life has been associated with disorders such as coronary heart disease, hypertension, and impaired glucose tolerance during adulthood (1), whereas a large weight gain during infancy may act as a risk factor for childhood type 1 diabetes mellitus as well as for obesity later in life (2–4). A relationship between an increased cancer risk and size at birth has also been reported (5). Studies on how the nutritional situation interacts with the growth process during early life in humans are therefore important. In such studies, assessment of body composition, *i.e.* determination of the amount of fat and FFW in the body, becomes of interest. Unfortunately, no true reference method for studies of body composition during infancy is available. Therefore, to make studies in this area possible, data for the so-called reference infant are needed.

In 1982 Fomon *et al.* (6) published their classical body composition model that provided age- and gender-specific data for TBF, FFW, TBW, and the degree of hydration in FFW. The latter is of particular importance, as TBF is often calculated as the difference between body weight and FFW, obtained using direct or indirect estimates of TBW and a value for the degree of hydration in FFW. The Fomon model, which provided data from birth to 10 y of age, was, however, presented as preliminary and crude because it was based on quite a limited data set (6). Butte *et al.* (7) have recently presented data from a longitudinal study where human body composition was studied at 0.5, 3, 6, 9, 12, 18, and 24 mo of age. Their data were in good agreement with Fomon's data for children older than 3 mo, but for younger infants the data reported by Butte *et al.* were different.

Received June 24, 2002; accepted May 14, 2003.

Correspondence: Elisabet Forsum, Department of Biomedicine and Surgery, Division of Nutrition, University of Linköping, S-581 85 Linköping, Sweden; e-mail: elifo@ibk.liu.se

Supported by grants from the Östergötland County Council, Wera Ekström's Fund for Pediatric Research, Crown Princess Lovisa's Fund for Pediatric Research, the Swedish Nutrition Foundation, and the Swedish Research Council (Project No. 12172).

DOI: 10.1203/01.PDR.0000088064.63106.5E

The data presented by Fomon *et al.* (6) and by Butte *et al.* (7) are based on measurements of the lean body constituents potassium and water. From these data TBF is calculated using a number of assumptions. Fomon's data for TBF are also based on skinfold measurements assuming a linear relationship between percent TBF and truncal skinfolds (6, 7). However, the validity of these results cannot be evaluated because, as indicated above, no true reference method to assess body composition during infancy is available. Therefore, attempts to provide reference body composition data for infants using alternative methods and assumptions are motivated. We have previously described and evaluated a method based on MRI, by which direct estimates of AT and its distribution in the body can be obtained (8). This method can be applied to infants up to at least 4–5 mo of age. In such infants, estimates of ATV using this method were inversely correlated to percentage TBW (8). Consequently, the MRI method represents a new possibility to study the development of AT and body fatness during early infancy. If combined with estimates of TBW, it has the potential to provide information regarding the degree of hydration in FFW.

This article describes a cross-sectional study where the total amount of AT, as well as its distribution between s.c. and non-s.c. AT, is assessed using our MRI method in 46 full-term infants. TBW of these infants was also measured. The results were used to describe body composition development during the first 4 mo of life.

METHODS

Protocol. As soon as an infant entered the study, the day of investigation was scheduled. When deciding this we attempted to cover the age interval between birth and 4 mo of age as completely as possible. The mother collected three urine samples from the infant before the day of investigation. On that day, anthropometric measurements were taken, and the infant was given a dose of stable isotopes and studied by means of the MRI method. The mother collected urine samples from the infant during the following 10 d for estimation of the child's TBW. For infants receiving formula during these 10 d, the amount consumed daily was recorded by the mother.

Subjects. Healthy full-term born infants 4 mo of age or younger and weighing more than 2.5 kg at birth were recruited from mother and child health units in Linköping, Sweden. All infants were studied after receiving informed consent from their parents and approval from the human ethics committee at the University of Linköping. At the time of investigation, all infants except five boys (G, I, K, N, Z) and five girls (m, o, p, r, t) were breast-fed. Infants Z, m, o, p, r, and t were fed formula and infants G, I, K, and N were fed both formula and breast milk. For each of the latter four infants, the amount of formula consumed daily was constant throughout the 10-d urine collection period. Data for 11 of the 46 infants (E, F, G, I, K, M, P, X, g, j, m) have been reported earlier (8).

Assessment of ATV by MRI. ATV was measured by MRI (8) using a Signa, General Electric, 1.5 tesla. The procedure involved the following steps. After being fed, the infant was swaddled using an elastic bandage and fixed in a straight position with a vacuum sack (vac Fix Sac, Scan Flex Medical AB, Täby, Sweden). The scanning procedure started when the infant was asleep, which always occurred without any use of sedative drugs. Starting from C7 of the cervical spine, 16 transaxial images (T_1-weighted, spin echo, repetition time 700 ms, echo time 12 ms, two acquisitions, matrix 512 × 256, 8-mm thick) were taken during a period of 6 min. The head was not included in the scan. The images were evenly distributed over the body, *i.e.* for a particular infant the distance between adjacent images was always the same. In the images, AT was white in contrast to other tissues that were gray or black. The AT area in the images was assessed using a computer program in which the exact criteria were defined by the observer, and which allowed separation of s.c. from non-s.c. AT by manually tracing the appropriate AT area. The sum of AT areas in all images in one scan was multiplied by the distance between the images to obtain ATV. The data reported in this article represent the average of two AT area evaluations that were carried out on two different occasions by the same observer. On each occasion scans from all infants (including E, F, G, I, K, M, P, X, g, j, m) were arranged in a randomized order, which was changed for the second occasion. Precision based on the two evaluations was 1.7, 1.6, and 8.7% for total, s.c., and non-s.c. ATV, respectively.

Calculation of TBF. Procedures to calculate TBF from ATV using figures for AT composition have been published for adults (9, 10) as well as for infants (11). In the latter study, AT from 17 boys and 5 girls between 1 and 5 mo were found to contain 0.67 ± 0.07 g fat/mL. Reported values for the fat content in AT from newborn full-term infants are slightly lower (12, 13). We have selected the figure 0.456 g/mL (12) to represent the fat content of AT at birth and assumed a linear increase in the fat content of AT during the first 30 d of life until a level of 0.67 g/mL was reached. Thus, for infants below 30 d of age, TBF (g) was calculated as: [0.456 + (0.67–0.456)/30 × age in days] (g/mL) × total ATV (mL). For infants older than 30 d, TBF (g) was 0.67 (g/mL) × total ATV (mL).

Assessment of TBW. Urine samples were taken using a baby urine collector (Coloplast A/S, Copenhagen, Denmark). An accurately weighed dose containing 0.08 g of ^2H_2O and 0.24 g of $H_2{}^{18}O$/kg body weight was given to the infant through a nasogastric tube and flushed through with 2–5 mL of water. To estimate TBW, urine samples were collected 4–6 h after dosing (39 infants) as well as on d 1, 3, 8, and 10 after dosing (44 infants). For infant s, the only postdose sample obtained was collected 4 h after dosing. The time (date and time of day) of sampling was always noted. Urine samples were transferred to glass vials with internal aluminum-lined screw-cap sealing and kept at 4°C until sample collection was finished. They were then placed at −20°C and kept there until analyzed. For infants E, F, G, I, K, M, P, X, g, and m, isotope enrichment in dose and urine samples was analyzed at the Department of Clinical Physiology, University of Uppsala, using a mass spectrometer (SIRA Series II, VG Isogas Ltd., Middlewich, UK) as described previously (8). Dose and urine samples from the remaining infants were analyzed in our own laboratory using a mass spectrometer (Deltaplus XL, Thermo Finnigan

AB, Dreieich, Germany) fitted with a $CO_2/H_2/H_2O$ equilibrium device. The analytic procedure described by Thielecke and Noah (14) was followed, except that equilibration time was 180 and 840 min for H_2 and CO_2, respectively. Deuterium and oxygen dilution spaces (N_D and N_O, respectively) were calculated from the zero-time enrichments obtained from the exponential isotope disappearance curves that provided estimates for the rate constants for ^2H and ^{18}O, respectively. For boys, N_D/N_O was 1.03 ± 0.02 ($n = 25$) and for girls 1.03 ± 0.01 ($n = 20$). In both laboratories, the masspectrometric response was standardized using Vienna standard mean ocean water as well as standards 304 A and B (for ^{18}O) and 302 A and B (for ^2H) obtained from the International Atomic Energy Agency, Vienna. A linear response was confirmed for both isotopes for each set of samples analyzed. Analytical precision in the measurement range, for results expressed as mol fraction, was 0.58 ppm (Uppsala), 0.44 ppm (Linköping) for ^2H and 0.49 ppm (Uppsala), 0.15 ppm (Linköping) for ^{18}O. For infant s, N_D and N_O were calculated using the plateau method after correction for the amount of isotope lost during 4 h, assuming $k_O = 0.275$ and $k_D = 0.229\ 24\ h^{-1}$. These figures represented the average of the appropriate values as obtained from infants p, q, r, t, and u. TBW was calculated as the average of N_D divided by 1.04 and N_O divided by 1.01 (15).

FFW and the degree of hydration in FFW. FFW (g) was body weight (g) minus TBF (g) and the degree of hydration in FFW was calculated as [TBW (g)/FFW (g)] × 100.

Anthropometry. The infants were weighed naked on an electronic baby scale (Tanita Corp., Tokyo, Japan) to the nearest 5 g. Crown–heel length was measured to the nearest centimeter on a length board.

Statistics. Values are expressed as means ± SD. The data were analyzed using PC statistical software Minitab (release 12, Minitab Inc., State College, PA, U.S.A.). Correlation and regression analysis was performed as described by Kirkwood (16). Precision (%) was calculated using the following formula:

$$100 \times \frac{\sqrt{\dfrac{\sum(a-b)^2}{2n}}}{\dfrac{\sum(a+b)}{2n}}$$

where a and b are duplicate estimates of the variable under investigation, and n is the number of duplicates.

RESULTS

Subjects. At birth, boys were 51 ± 2 cm tall and weighed 3645 ± 430 g ($n = 25$). The corresponding figures for girls were 50 ± 3 cm and 3515 ± 520 g ($n = 21$). The gestational age at birth for the infants was 40.0 ± 1.3 wk. Table 1 shows weight-for-age, length-for-age, and weight-for-length z scores at the time of investigation for the boys and girls in the study as obtained using two different U.S. growth references (17, 18). Obviously, when compared with these references our infants tended to be heavy and tall but slightly light for their length.

Degree of hydration in FFW. Tables 2 and 3 show TBW and age of all infants in the study. Using data from 45 of these infants, the degree of hydration in FFW was calculated to be 78.9 ± 4.5%, CV = 5.7% [79.2 ± 3.6% for boys ($n = 25$), 78.5 ± 5.6% for girls ($n = 20$)]. The regression equation relating this variable (y) to age in days (x) was: $y = -0.0137 \times +79.7$ and its correlation coefficient (0.11) was nonsignificant.

Table 1. *Weight-for-age, length-for-age, weight-for-length* z *scores at the time of investigation calculated using older 17 as well as more recent 18 U.S. reference data for boys and girls in the study*

	Boys ($n = 25$)	Girls ($n = 21$)
Older reference data		
Weight-for-age z score	0.43 ± 0.79	0.53 ± 1.01
Length-for-age z score	0.71 ± 0.81	1.09 ± 1.00
Weight-for-length z score	−0.08 ± 0.89	−0.71 ± 0.89
More recent reference data		
Weight-for-age z score	0.34 ± 0.85	0.24 ± 0.82
Length-for-age z score	0.72 ± 0.82	1.62 ± 1.05
Weight-for-length z score	−0.52 ± 1.04	−1.10 ± 0.96

Values are mean ± SD.

Body weight, TBF, FFW, and ATV in relation to age. Tables 2 and 3 show body weight, TBF, and age of boys and girls in the study. Figure 1*A* shows FFW and TBF for the boys in the study together with the corresponding data for the reference boy as reported by Fomon *et al.* (6). The corresponding data for the girls in the study are shown in Figure 1*B*. The linear relationships between weight in grams (y) and age in days (x) (y = 30.7x + 3628 for boys and y = 24.9x + 3477 for girls) were significant for boys [$r = 0.86$ ($p < 0.001$)] and for girls [$r = 0.90$ ($p < 0.001$)]. Furthermore, significant linear relationships between FFW in grams (y) and age in days (x) were found for boys (y = 18.6x + 3143, $r = 0.86$, $p < 0.001$) and for girls (y = 13.8x + 3052, $r = 0.81$, $p < 0.001$). The linear relationships between TBF in grams (y) and age in days (x)—y = 12.1x + 485, $r = 0.83$, $p < 0.001$ (boys) and y = 11.1x + 424, $r = 0.93$, $p < 0.001$ (girls)—were also significant. According to these relationships, daily increases in body weight, FFW, and TBF for boys were 30.7, 18.6, and 12.1 g, respectively, during the first 4 mo of life. The corresponding figures for girls were 24.9, 13.8, and 11.1 g. Fomon's reference boy and girl gained 29.3 and 24.5 g of body weight, 18.4 and 15.2 g of FFW, and 10.8 and 9.3 g of TBF, respectively, during the corresponding period of infancy.

Tables 2 and 3 show TBF in percentage of body weight and age of boys and girls in the study. Figure 2*A* shows TBF in percentage of body weight in relation to age for boys compared with the corresponding figures for Fomon's reference infant (6). The corresponding data for the girls in the study are shown in Figure 2*B*. When compared with Fomon's reference boy, the body fat content for the boys in our study tended to increase slightly more rapidly. The corresponding increase for our girls, however, agreed well with that of the reference girl.

Tables 2 and 3 show total ATV, s.c. ATV in percent of total ATV, and age of boys and girls in the study. Figure 3, *A* and *B*, shows the amounts of s.c and non-s.c. ATV in relation to age for boys and girls in the study. Obviously, s.c. ATV increases rapidly with age in both sexes. The linear relationship between s.c ATV in milliliters (y) and age in days (x) for boys was y = 14.7x + 790, $r = 0.79$, $p < 0.001$, and for girls it was y =

Table 2. *Age, weight, length, TBW, total ATV, s.c. ATV, and TBF at the time of investigation of the boys in the study*

Infant	Age (d)	Weight (g)	Length (cm)	TBW (g)	Total ATV (mL)	s.c. ATV (% of total ATV)	TBF (g)	TBF (% of body weight)
A	4	3505	53	2384	935	86.1	453	12.9
B	7	3550	55	2491	716	89.9	362	10.2
C	10	3790	52	2666	860	89.5	453	12.0
D	11	4425	55	3126	1333	89.9	712	16.1
E	19	3700	52	2517	945	89.7	559	15.1
F	28	3825	52	2549	945	92.8	620	16.2
G	31	4940	55	3235	1453	92.3	974	19.7
H	43	5300	60	3246	1676	91.7	1123	21.2
I	46	5240	59	3333	1699	89.8	1138	21.7
J	46	5145	60	3233	1650	89.8	1106	21.5
K	54	5330	57	3038	1691	90.7	1133	21.3
L	55	4865	58	3149	1668	93.0	1118	23.0
M	56	5420	59	3305	2064	92.3	1383	25.5
N	64	5295	57	3442	2001	92.8	1341	25.3
O	73	6800	63	3999	2432	91.2	1629	24.0
P	75	7660	62	4225	2957	90.6	1981	25.9
Q	76	5480	62	3621	1667	90.8	1117	20.4
R	76	5930	66	3649	1853	91.2	1242	20.9
S	89	6150	64	3499	2366	88.0	1585	25.8
T	92	6450	63	3762	2502	90.2	1676	26.0
U	98	7160	65	4122	2876	91.7	1927	26.9
V	104	6325	65	3777	2310	87.6	1548	24.5
X	107	7070	62	3680	2787	91.4	1867	26.4
Y	108	7550	67	4108	3259	91.5	2184	28.9
Z	117	5590	63	3770	1383	87.2	927	16.6
Mean	60	5460	59	3357	1841	90.5	1206	21.1
SD	35	1240	5	536	708	1.8	510	5.1

Table 3. *Age, weight, length, TBW, total ATV, s.c. ATV, and TBF at the time of investigation of the girls in the study*

Infant	Age (d)	Weight (g)	Length (cm)	TBW (g)	Total ATV (mL)	s.c. ATV (% of total ATV)	TBF (g)	TBF (% of body weight)
a	6	4460	54	3054	1415	90.4	706	15.8
b	7	3050	52	2202	557	90.8	282	9.2
c	7	3470	55	2337	762	87.4	386	11.1
d	11	4710	57	3178	1599	90.1	855	18.2
e	11	4045	54	2342	1204	92.9	643	15.9
f	15	4035	55	2556	1070	89.2	602	14.9
g	22	3980	52	2505	1021	94.1	626	15.7
h	26	3515	54	2342	953	89.5	611	17.4
i	44	3790	53	2775	1166	91.7	781	20.6
j	57	4875	58	—	1209	92.8	810	16.6
k	61	4910	58	3125	1804	90.6	1209	24.6
l	65	5180	61	3316	1711	91.7	1146	22.1
m	73	5640	58	3149	2175	91.6	1457	25.8
n	73	4400	61	2608	1566	89.1	1049	23.8
o	75	5460	67	3669	1674	92.2	1122	20.5
p	81	5190	60	2776	1708	94.1	1144	22.0
q	90	5590	61	3199	2433	92.0	1630	29.2
r	90	5700	61	2981	2592	94.4	1737	30.5
s	95	5930	64	3373	2036	89.7	1364	23.0
t	116	6730	65	3875	2554	91.5	1711	25.4
u	131	7185	69	4284	2808	88.2	1881	26.2
Mean	55	4850	59	2982	1620	91.1	1036	20.4
SD	39	1075	5	555	632	1.9	464	5.7

—, Missing value.

$13.0x + 761$, $r = 0.87$, $p < 0.001$. The corresponding relationship for non-s.c. ATV was $y = 1.58x + 78.6$, $r = 0.81$, $p < 0.001$ (boys) and $y = 1.26x + 72.4$, $r = 0.76$, $p < 0.001$ (girls). For both sexes, ATV in relation to body weight (mL/kg, y) increased with age (days, x); boys: $y = 253 + 1.22x$, $r = 0.70$ ($p < 0.001$); girls: $y = 253 + 1.28x$, $r = 0.72$ ($p < 0.001$). This increase did not differ significantly between boys and girls. The proportion of total ATV present as s.c. ATV was

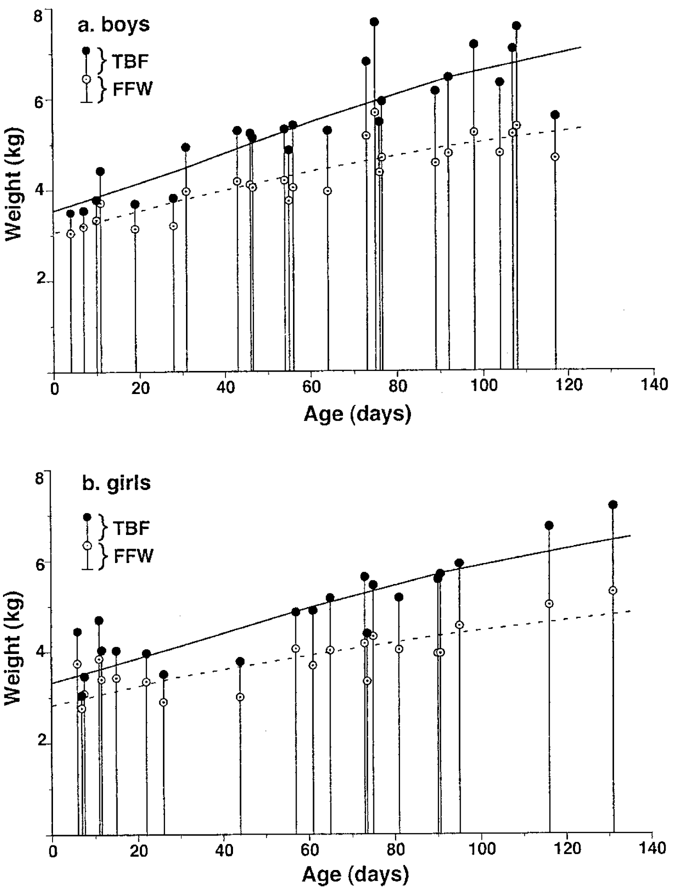

Figure 1. TBF and FFW *vs* age of infants in the study. *Dotted* and *solid lines* represent the growth of the reference infant (6) in FFW and FFW + TBF, respectively. (*A*) boys, $n = 25$; (*B*) girls, $n = 21$.

90.5 ± 1.8% (boys) and 91.1 ± 1.9% (girls). No significant relationship between percentage of total ATV located s.c. and age was found for boys or girls or for the sexes combined.

DISCUSSION

The average birth weight of our infants was slightly higher than the corresponding figure for the reference infant whereas the observed relationships between weight and age corresponded well to the weight gains of the reference boy and girl (6). The frequency of breast-feeding among our infants was high and similar to that of contemporary Swedish infants (19). At the time of investigation, our infants tended to be heavy and tall but slightly light for their length when compared with reference data for U.S. infants (17, 18). Nevertheless, it is reasonable to consider our data as complements to existing reference data for infants below 4 mo of age.

We have previously shown that our MRI procedure can estimate ATV with good precision and with a relative validity, *i.e.* it is possible to arrange the infants in a study in a specific order with respect to the amount of ATV they contain as long as all images in the study are evaluated using criteria defined by one observer (8). This requires that the scans from all infants are evaluated at least twice, and that each time they are presented to the observer in a randomized order, as was done in the present study where results for infants E, F, G, I, K, M, P, X, g, j, and m were arranged in the same order as that reported previously (8). However, although our estimates of ATV have good precision and a relative validity, the possibility that they may be slightly biased cannot be excluded, as there is no true reference method available to evaluate measurements of this kind.

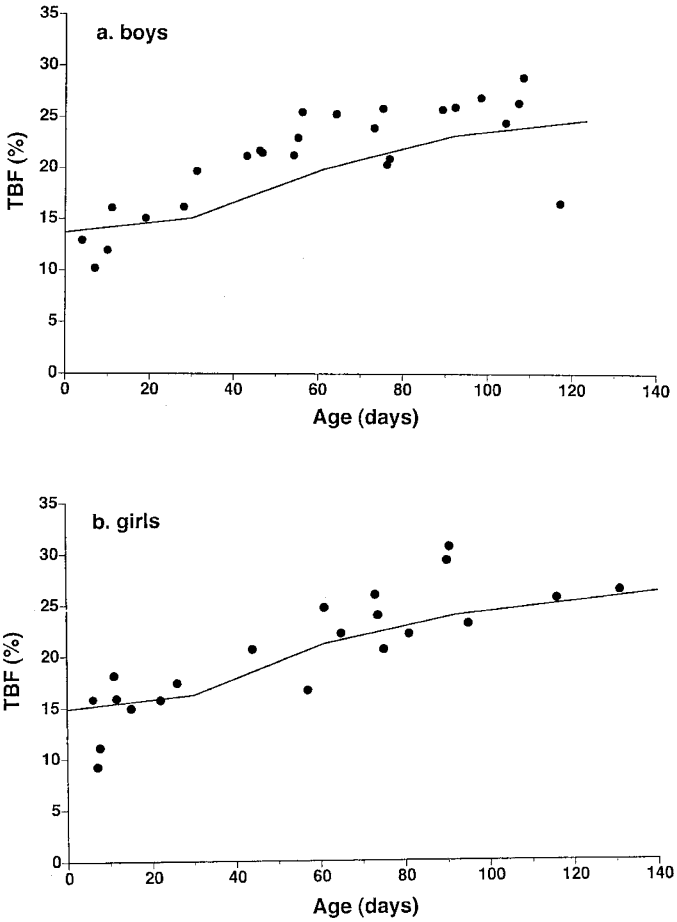

Figure 2. TBF in percentage of body weight *vs* age of infants in the study. *Solid lines* represent the fat content of the reference infant (6). (*A*) boys, $n = 25$; (*B*) girls, $n = 21$.

The procedure used in this study to calculate TBF from ATV is likely to be more correct than using 0.66 g fat/mL throughout infancy, as previously suggested (11). It should be pointed out, however, that the present calculation is based on assumptions that there is a linear increase in the fat content of AT with age during the first month of life and that the fat content of AT remains at the level 0.67 g fat/mL during the following 3 mo. These assumptions are based on results obtained by means of chemical analysis of AT of infants at various ages and it should be noted that comparatively few such results are available in the literature. Our procedure to calculate TBF from ATV may therefore need modification when more data on infant AT composition becomes available.

Our data demonstrate that the main part of the fat retained in the infant body during the first 4 mo of life is located subcutaneously, and that this period of life is associated with considerable growth in s.c. AT. This new finding is of interest, because at birth and in the newborn period the human is one of

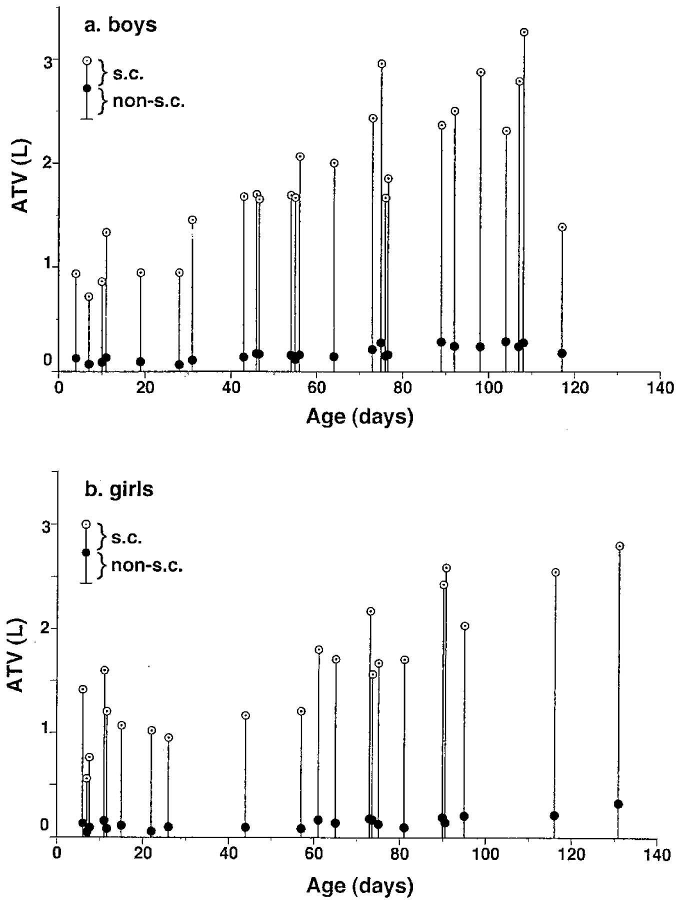

Figure 3. Subcutaneous and non-s.c. ATV *vs* age of infants in the study. (*A*) boys, $n = 25$; (*B*) girls, $n = 21$.

the fattest species on record (20). This can be reconciled with the finding by Sohlström *et al.* (10) that excess body fat tends to be stored subcutaneously in adult women. It has been suggested that AT in human infants serves as insulation to compensate for hairlessness, but support for this hypothesis is weak (20). It is more widely accepted that the role of body fat is to serve as an energy store (20, 21), presumably in preparation for future needs, such as during weaning. In addition, knowledge regarding the location of body fat is important when anthropometric methods based on caliper measurements are being developed. It has been suggested (11, 22) that one reason for the lack of accuracy of such methods is that the caliper is unable to measure non-s.c. AT.

When compared with the infants studied by Butte *et al.* (7) as well as with Fomon's reference infant (6), our infants were slightly heavier at birth. However, as shown in this study, in relation to age, their weight was comparable to Fomon's reference data. When compared with this reference, the infants studied by Butte *et al.* (7) tended to grow more rapidly. Despite these differences it is relevant to compare body composition data for our infants to the corresponding data provided by Butte *et al.* (7) and by Fomon *et al.* (6). Thus, with the exception of a slightly more rapid increase in percentage TBF for boys, the changes in body composition as estimated by the MRI method are similar to the corresponding changes described by Fomon *et al.* (6) for the reference infant throughout the first 4 mo of life. However, according to Butte *et al.* (7), the increase in TBF between 0.5 and 3 mo of age is much more pronounced, and a peak is reached at 3–4 mo when TBF is as high as 30%. At this age the infants in our study as well as those studied by Fomon *et al.* (6) contained only about 25% TBF. With respect to the degree of hydration in FFW, our results are slightly lower than those reported by Fomon *et al.* (6) or Butte *et al.* (7). This may be related to the fact that our estimates of ATV do not include the head. Furthermore, it should be pointed out that we have no specific reason to suspect that the accuracy of our estimate of the degree of hydration in FFW is influenced by the age of the infant. With respect to the precision of this estimate, the following comments are relevant. In their study on infants, Butte *et al.* (7) found the CV of estimates of the degree of hydration in FFW to be only 1–2%, and in a study on children 8–12 y of age, Wells *et al.* (23) found that the biologic variation in the degree of hydration of FFW is quite small. Therefore, it is likely that the biologic variation in the degree of hydration in FFW is also small during infancy. If this is the case, the obvious explanation for the comparatively large variation in our estimate of the degree of hydration in FFW is that the fat concentration in AT varies between individual infants not only in analyzed AT biopsies (11) but also at the whole body level. This explanation is interesting because it gives rise to several questions regarding the significance of this variation for the possibilities to identify and prevent obesity early in life. However, the procedures used to assess the degree of hydration in FFW are different in the studies by Wells *et al.* (23) and by Butte *et al.* (7). Therefore, it is not presently

Table 4. *TBW of boys and girls and the degree of hydration in FFW of infants at birth, at 14 d, and at 3 mo of age as obtained in this study and in the studies by Butte* et al. *7 and Fomon* et al. *6*

	Birth	14 d	3 mo
TBW (%)			
Boys			
Present study*	70.2	68.3	57.5
Butte *et al.*	†	73.9	56.5
Fomon *et al.*	69.6	69.0‡	61.4
Girls			
Present study§	68.4	66.7	57.4
Butte *et al.*	†	73.2	55.6
Fomon *et al.*	68.6	68.1‡	60.9
Degree of hydration in FFW (%)‖			
Present study¶	79.7	79.5	78.4
Butte *et al.*	†	82.9	81.1
Fomon *et al.*	80.6	80.6‡	80.0

* Values obtained using the linear relationship between % TBW (y) and age (d) (x) for all boys in the study <96 d of age: $y = 70.2 - 0.138\times$, ($n = 20$) $r = 0.82$, $p < 0.001$.

† Values not available.

‡ Average of values at birth and at 1 mo of age.

§ Values obtained using the linear relationship between % TBW (y) and age (d) (x) for all girls in the study <96 d of age: $y = 68.4 - 0.120\times$, ($n = 18$) $r = 0.65$, $p < 0.01$.

‖ Values represent data for boys and girls combined.

¶ Values obtained using the linear relationship between degree of hydration in FFW (%) (y) and age (d) (x): $y = -0.0137x + 79.7$, ($n = 45$), $r = 0.11$, NS.

possible to definitely conclude that the biologic variation in the degree of hydration in FFW is small also during infancy.

Some relevant points with respect to estimates of the degree of hydration in FFW as obtained in our study as well as in the studies by Butte *et al.* (7) and by Fomon *et al.* (6) are summarized in Table 4. At 14 d of age the degree of hydration in FFW, as reported by Butte *et al.* (7), tends to be higher than the corresponding figures found in the present study or by Fomon *et al.* (6). Table 4 also demonstrates that at 14 d of age, percentage TBW of the infants studied by Butte *et al.* (7) was higher than comparable figures obtained in the present study or by Fomon *et al.* (6). In a study on alternative approaches for calculating TBW, Davies and Wells (15) compared the so-called plateaux method to the so-called back extrapolation method using procedures apparently similar to those used by Butte *et al.* (7). Davies and Wells (15) observed that the former method produced higher values than the latter, which is of is of relevance inasmuch as Butte *et al.* (7) used the plateaux method in their 14-d-old infants and the back extrapolation method for older infants. The latter method, also used in the present study, has been shown to produce values for TBW in close agreement with data for Fomon's reference infant (15). These methodological comments are relevant, because an overestimation of TBW will result in an overestimation of the degree of hydration in FFW.

CONCLUSION

In conclusion, we have demonstrated a pronounced increase in ATV during the first 4 mo of extrauterine life in boys as well as in girls that involves a considerable gain in s.c. fat. We have also provided data on the degree of hydration in FFW as well as on body weight and body composition during this period of life. Our data have been obtained using MRI, a method that is independent of the methodology previously used to obtain body composition data for the reference infant. Nevertheless, with the exception of a slightly more rapid increase in percentage TBF for boys, our data confirm corresponding data previously published by Fomon *et al.* (6).

Acknowledgments. The authors thank the parents and infants who participated in the study; Karin Boström, Margareta Jönsson, and Christine Rosén for help with subject recruitment; Eva Sjödahl for laboratory assistance; and Olle Eriksson for statistical advice.

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