Coll. Antropol. 39 (2015) 3: 601–609
Original scientific paper

Subcutaneous Adipose Tissue Topography in Long-Term Enterally Fed Children and Healthy Controls

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A B S T R A C T

In the context of enteral feeding in children the influence on growth and the question of fat resorption is of great interest. We, therefore, measured the thickness of subcutaneous body fat in a sample of long-term enterally fed toddlers and healthy controls. In 33 long-term enterally fed toddlers (10 girls, 23 boys) and 275 healthy controls (128 girls, 147 boys) subcutaneous body fat was measured by means of the optical device Lipometer. All participants were divided into three age groups (infants, toddlers and children). The height (p=0.014, –11.7 cm, –12.5%) and weight (p=0.012, –3.0 kg, –21.9%) of long-term enterally fed female toddlers were significantly lower than healthy controls, while male enterally fed toddlers had lower values in all anthropometric measures compared to healthy controls: height (p=0.003, –8.0 cm, –8.4%), weight (p<0.001, –3.5 kg, –24.8%), BMI (p=0.004, –1.3 BMI), Z-score BMI (p=0.001, –1.2 Z-score BMI), upper arm circumference (p<0.001, –1.6 cm, –10.1%) and waist circumference (p<0.001, –6.2 cm, –12.5%). Tube fed toddlers showed a similar body fat distribution when compared to healthy controls, but demonstrated significantly lower values of anthropometric measurements. The results indicate that long-term enterally fed children have ample fat stores but lack physical development.

Key words: *body composition, body fat distribution, lipometer, subcutaneous adipose tissue topography, gastrostomy, enteral feeding*

Introduction

An increasing number of infants and children with complex medical conditions and neurological impairments survive because of advances in enteral nutrition technologies[1,2]. Tube feeding can provide a temporary means of improving the child's nutritional status and growth during a medical crisis or when the nutritional needs cannot be met through oral intake[2]. In the context of enteral feeding in children the influence on growth and the question of fat resorption is of great interest. Food refusal and feeding disorders are common in the pediatric population[3–5].

Nevertheless, very few studies have investigated the body composition and subcutaneous adipose tissue distribution of cognitively normal tube-fed children. While some studies have investigated the body composition of tube-fed children with cerebral palsy[6–12], there is no information about the specific body fat distribution of children who are nourished by tube on a long-term basis. Moreover, very little is known on the topic of fat deposition of this clinical sample[13,14] leaving the body composition and body fat distribution of long-term enterally fed children more or less unexplored.

There exists a variety of different methods to assess subcutaneous body fat in children[15–20]. The most widely used technique to obtain subcutaneous body fat and its distribution is via skinfold callipers. A more sophisticated method is using the optical device Lipometer (EU patent no. 0516251) which enables a precise, noninvasive, quick and safe measurement of a mono-layer of subcutaneous

Received for publication August 26, 2013

adipose tissue at any given site of the human body[21,22]. The Lipometer allows the determination of the subcutaneous fat distribution of an individual. Fifteen well-defined body sites are normally specified providing the so-called subcutaneous adipose tissue topography of a subject[23,24].

In a prior study, subcutaneous adipose tissue topography was determined in 275 healthy children and the deviations of their subcutaneous body fat with respect to age and gender have been presented by our working group[25]. We, therefore, used the subcutaneous adipose tissue topography of these healthy children along with similar measures in long-term tube fed toddlers to investigate the following:

i) are there any differences in subcutaneous adipose tissue topography between long-term enterally fed toddlers and healthy controls,

ii) is there an intercorrelation between the 15 subcutaneous adipose tissue body sites measured and whether a meaningful reduction of data is possible by means of factor analysis and,

iii) are there differences in subcutaneous adipose tissue patterns between tube fed toddlers and under-, normal- and overweight controls.

It has been stated that long-term enterally fed children tend to be short and show relatively low body mass index (BMI) but have fat levels within normal limits[14]. We therefore hypothesize that enterally fed children will have similar subcutaneous adipose tissue depositions to healthy control children.

Subjects and Methods

Healthy subjects

Two hundred and seventy five healthy children (128 girls and 147 boys) aged between 0 and 7 years were recruited from several schools, kindergartens, infant daycare centers and the University Clinic for Pediatrics and Adolescent Medicine in Graz (260,000 inhabitants), Austria.

Tube-fed subjects

The 33 long-term enterally fed toddlers (10 girls and 23 boys) with an age range from 1–5 years consisted of patients from the local University Clinic for Pediatrics and Adolescent Medicine, which took part in a specialized tube weaning program [26–28]. Table 1 indicates their main diagnostic characteristics according to ICD–10 (International Statistical Classification of Diseases and Related Health Problems 10th Revision)[29] (Table 1).

A written informed consent was obtained from the parents before participation. This study was approved by the ethics committee of the Medical University, Graz (EK-number 20–415 ex 08/09). The procedures were in accordance with the Declaration of Helsinki and the local ethics committee recommendations.

TABLE 1
MAIN DIAGNOSIS OF 10 FEMALE AND 23 MALE LONG-TERM ENTERALLY FED TODDLERS ACCORDING TO ICD-10 (INTERNATIONAL STATISTICAL CLASSIFICATION OF DISEASES AND RELATED HEALTH PROBLEMS 10th REVISION)

		ICD-10 Diagnosis	Number of children
1.	D61.0	Diamond-Blackfan-Syndrome	1
2.	D80.9	Leucocyte-Adhesion-Deficiency	1
3.	F98.2	Feeding Disorder	3
4.	P07	Short Gestation And Low Birth Weight	15
5.	Q04.0	Agenesis Of Corpus Callosum	1
6.	Q40.1	Congenital Hiatus Hernia	1
7.	Q79.0	Congenital Diaphragmatic Hernia	1
8.	Q87.0	Pierre-Robin-Syndrome	2
9.	Q87.0	Goldenhar-Syndrome	1
10.	Q87.1	Cornelia-de-Lange-Syndrome	1
11.	Q87.2	VACTERL-Association	1
12.	Q87.8	Costello-Syndrome	1
13.	Q90	Down's Syndrome	2
14.	Q99.9	Chromosomal Abnormality, Unspecified	2

This data set was divided into three age groups (infant: 0–1 years; toddler: 1–5 years; child: 5–7 years) for each sex according to definitions used previously[30].The body length of infants was obtained by a standardized measurement device (SECA®, Hamburg, Germany). The height of toddlers and children was measured using a stadiometer (SECA®-220, Hamburg, Germany). The body weight of infants was determined by a RAUCH scale (RAUCH®-WPT20D, Graz, Austria). The toddlers and children were weighed on a SECA scale (SECA®-803, Hamburg, Germany). The body mass index (BMI kg/m^2) was calculated and the Z-score BMI was calculated according to Cole's LMS method[31–34]. Upper arm and waist circumference were measured with an insertion tape (KAWE®-REF E-43971, Asperg, Germany). Upper arm circumference was taken from the right arm at the midpoint between the acromion and the olecranon, while the arm was in a stretched position. Waist circumference was determined at the midpoint between the iliac crest and the lower ribs measured at the sides. All anthropometric parameters were measured once.

Measurement of subcutaneous adipose tissue topography

The thicknesses of subcutaneous adipose tissue layers (in mm) were measured by the Lipometer device at 15 specified body sites from 1 (at the neck) to 15 (at the calf) on the right side of the body rendering the subcutaneous adipose tissue topography. The subcutaneous adipose tissue topography rebuilds the body fat distribution pattern of an individual with good precision[35–39]. Please, simply refer to the literature. There is a lot of information about the Lipometer one can find in Pubmed.

Subcutaneous adipose tissue topographies of infants were determined while held on the lap of their primary caretaker, whereas toddlers and children were measured in a standing position. Due to the small sensor head of the Lipometer the whole set of 15 body sites could be measured even in infants.

Some of the 15 measured body sites are situated in the same body region (e.g. on the arms: triceps, biceps) and consequently they might exhibit similar fat development. To investigate the summed subcutaneous adipose tissue topography information of complete body regions (e.g. arms, trunk, etc.), additional variables were calculated by summarizing the corresponding body sites:

Arms = biceps + triceps;

Trunk = neck + upper back + lateral chest + front chest;

Abdomen = upper abdomen + lower abdomen + lower back + hip;

Legs = front thigh + lateral thigh + rear thigh + inner thigh + calf;

Total= Arms + Trunk + Abdomen + Legs;

Notably, to give information about the total amount of subcutaneous fat in healthy children all 15 subcutaneous adipose tissue layers were summed (total subcutaneous adipose tissue).

Statistics

Statistical analysis was carried out using SPSS 16.0 for Windows (SPSS, Chicago, IL, USA). The normal distribution of the variables was examined by the Kolmogorov-Smirnov and Shapiro-Wilk tests. Differences in the distribution of variables between tube-fed toddlers and healthy controls were tested by the Student's t-test for independent samples (for normally distributed variables) and the non-parametric Mann-Whitney U-Test for two independent samples (if variables were not normally distributed).

A correlation matrix was calculated to investigate to what degree the 15 subcutaneous adipose tissue topography body sites are intercorrelated.

To test the adequacy of our sample for factor analysis the measure of sampling adequacy (MSA) by Kaiser-Meyer-Olkin[40] was applied. MSA ranges from 0−1 and should be higher than 0.8[41]. MSA $\leq$ 0.5 is regarded as unacceptable;

MSA $\geq$ 0.8 is meterious; MSA $\geq$ 0.9 is excellent[42].

To accept a factor as statistically meaningful a minimum eigenvalue of 1.0 was used.

Factor values were calculated by factor analysis as additional variables for all subjects of our data set. The obtained factor values for an individual were used as coordinates in a factor plot, providing the condensed information of subcutaneous body fat distribution in a two-dimensional diagram.

Results

Table 2a shows the demographic and anthropometric characteristics, as well as the subcutaneous adipose tissue topography measurements of the 10 female long-term enterally fed toddlers and 54 healthy controls. Additionally, the measurements of the four body regions (arms, trunk, abdomen, legs), and the total subcutaneous adipose tissue topography are presented. The anthropometric data showed significant differences of height (p=0.014) and weight (p=0.012) between the female tube fed toddlers and the control group. Female enterally fed toddlers were 11.7 cm (–12.5%) shorter and their body mass was 3.0 kg (–21.9%) lower compared to healthy controls.

Apart from 10-hip (p=0.048) and 13-rear thigh (p=0.049), no significant differences of subcutaneous adipose tissue topography measurements between the female enterally nourished toddlers and their healthy controls could be found. Body regions of arms, trunk, abdomen, legs and the total subcutaneous adipose tissue did not significantly differ between the two groups.

The results of the 23 male long-term tube fed toddlers and their 66 healthy controls are presented in Table 2b. In all anthropometric parameters male enterally fed toddlers had significantly lower values compared to their healthy controls: height (p=0.003), weight (p<0.001), BMI (p=0.004), Z-score BMI (p=0.001), upper arm circumference (p<0.001) and waist circumference (p<0.001). In absolute values, enterally fed boys were 8.0 cm (–8.4%) shorter and 3.5 kg (–24.8%) lighter. Male tube-fed toddlers showed significantly decreased values of subcutaneous adipose tissue thickness measurements in 2-triceps (p=0.010, –1.5 mm), 4-upper back (p=0.038, –0.6 mm) and 9-lower back (p=0.010, –2.2 mm). There were no significant differences of the body regions (arms, trunk, abdomen, legs) and the total subcutaneous adipose tissue topography between the clinical group and controls.

The correlation matrix of all 308 children for the 15 body sites (not shown in this paper) provided correlation coefficients between +0.31 and +0.87. Especially, body sites situated in the same area, e.g. on the trunk (4-upper back, 5-front chest, 6-lateral chest, 7-upper abdomen and 8-lower abdomen) showed a stronger (r=+0.67 to r=+0.87) intercorrelation, while body sites situated on areas of great anatomical distance yielded lower correlations (e.g. r = 0.31 for 9-lower back and 15-calf). On the legs, the body sites (11-front thigh, 12-lateral thigh, 13-rear thigh, 14-inner thigh and 15-calf) showed high correlation coefficients between +0.64 and +0.84.

An MSA value of 0.94 was obtained, indicating excellent adequacy of the dataset for factor analysis. Two factors were extracted (Factor 1: eigenvalue = 9.4, percent of variation = 63.0; Factor 2: eigenvalue = 1.6, percent of variation = 10.5). The rotated factor matrix (Table 3)

TABLE 2a
DEMOGRAPHIC, ANTHROPOMETRIC AND SUBCUTANEOUS ADIPOSE TISSUE CHARACTERISTICS OF THE 10 LONG-TERM ENTERALLY TUBE FED AND 54 HEALTHY FEMALE TODDLERS (MEDIAN (MIN-MAX))

Girls	Tube		Controls		Significance	
N	10		54			
Age (years)	2.5	(1.1–4.5)	2.8	(1.1–5.0)	n.s.	†
Height (cm)	82.0	(70.0–104.0)	93.7	(73.5–125.0)	p=0.014	†
Weight (kg)	10.7	(7.1–18.2)	13.7	(8.1–24.6)	p=0.012	†
BMI (kg/m^2)	15.3	(13.9–17.0)	15.5	(12.4–21.6)	n.s.	†
Z-score BMI	–0.7	(–1.5–1.0)	–0.2	(–2.5–3.3)	n.s.	†
Upper arm (cm)	15.3	(12.9–17.6)	15.6	(12.5–19.3)	n.s.	†
Waist (cm)	44.3	(37.4–57.9)	48.2	(39.4–55.3)	n.s.	†
Subcutaneous adipose tissue topography						
1-neck	2.9	(1.7–10.0)	3.3	(0.9–13.3)	n.s.	*
2-triceps	9.5	(7.1–14.9)	8.8	(3.3–13.9)	n.s.	†
3-biceps	4.9	(3.5–7.3)	4.4	(1.7–13.1)	n.s.	*
4-upper back	2.6	(0.9–10.3)	2.5	(1.2–11.3)	n.s.	*
5-front chest	5.7	(1.4–14.1)	5.0	(0.9–13.7)	n.s.	†
6-lateral chest	1.9	(0.9–11.6)	1.9	(0.9–8.5)	n.s.	*
7-upper abdomen	3.4	(1.1–13.5)	2.6	(0.6–18.9)	n.s.	*
8-lower abdomen	6.5	(1.1–18.0)	4.7	(1.3–21.4)	n.s.	*
9-lower back	6.7	(1.4–22.0)	5.6	(1.1–15.8)	n.s.	*
10-hip	10.3	(4.2–21.4)	7.0	(2.1–34.1)	p=0.048	*
11-front thigh	9.0	(6.6–16.9)	7.7	(2.8–24.8)	n.s.	*
12-lateral thigh	7.7	(5.8–13.4)	8.4	(2.8–30.5)	n.s.	*
13-rear thigh	8.6	(5.1–15.1)	6.9	(1.7–18.2)	p=0.049	†
14-inner thigh	8.9	(7.5–15.2)	7.8	(2.1–15.4)	n.s.	*
15-calf	5.9	(3.0–7.4)	5.2	(1.4–20.5)	n.s.	*
Body regions						
Arms	14.5	(10.6–22.2	13.2	(5.9–26.7)	n.s.	†
Trunk	13.2	(5.9–32.8)	13.2	(5.7–46.8)	n.s.	*
Abdomen	28.1	(10.7–71.0)	22.1	(8.6–90.2)	n.s.	*
Legs	37.5	(33.8–66.8)	35.2	(14.6–108.6)	n.s.	*
Total	98.0	(72.2–191.8)	85.0	(38.7–268.2)	n.s.	*
Factors						
Factor 1	–0.12	(–1.12–3.42)	–0.16	(–1.25–2.52)	n.s.	*
Factor 2	0.44	(–1.25–1.23)	–0.00	(–1.99–4.72)	n.s.	*

*Mann-Whitney U-Test ($p<0.05$), †Student's t-Test for Independent Samples ($p<0.05$)

shows the loadings for these two factors for all body sites, e.g. the body site 1-neck is stronger related to Factor 1 (0.658) than to Factor 2 (0.459). Factor 1 includes the upper body sites from 1-neck to 9-lower back, while Factor 2 corresponds to all body sites of the legs (11-front thigh to 15-calf). The body site 10-hip is related to Factor 1 and Factor 2. Therefore, an »upper body factor« (Factor 1) and a »leg factor« (or »lower body factor«) (Factor 2) were suggested by this analysis. The factor value plot (Figure 1) shows the clustering of these body sites to two clusters: the upper body cluster and the leg cluster, situated at different positions in the diagram. The factor value plot pro-

TABLE 2b
DEMOGRAPHIC, ANTHROPOMETRIC AND SUBCUTANEOUS ADIPOSE TISSUE CHARACTERISTICS OF THE 23 LONG-TERM ENTERALLY TUBE FED AND 66 HEALTHY MALE TODDLERS (MEDIAN (MIN-MAX))

Boys	Tube		Controls		Significance	
N	23		66			
Age (years)	2.6	(1.1–4.8)	2.9	(1.1–5.0)	n.s.	†
Height (cm)	87.0	(70.0–110.0)	95.0	(74.5–118.0)	p=0.003	†
Weight (kg)	10.6	(7.9–16.5)	14.1	(9.2–25.0)	p<0.001	†
BMI (kg/m^2)	14.8	(11.9–17.6)	16.1	(10.3–20.4)	p=0.004	*
Z-score BMI	–1.0	(–3.7–0.6)	0.2	(–5.6–2.4)	p=0.001	*
Upper arm (cm)	14.4	(12.2–18.6)	16.0	(11.7–20.0)	p<0.001	†
Waist (cm)	43.3	(36.4–53.6)	49.5	(38.0–60.8)	p<0.001	†
Subcutaneous adipose tissue topography						
1-neck	3.1	(0.9–5.7)	2.6	(1.0–10.4)	n.s.	*
2-triceps	6.6	(1.1–12.0)	8.1	(2.3–15.5)	p=0.010	†
3-biceps	3.4	(1.1–7.9)	4.1	(1.6–11.4)	n.s.	*
4-upper back	1.6	(0.7–7.1)	2.2	(0.8–18.4)	p=0.038	*
5-front chest	3.4	(0.8–14.7)	4.1	(1.3–15.2)	n.s.	*
6-lateral chest	1.8	(0.8–8.0)	1.7	(0.6–7.5)	n.s.	*
7-upper abdomen	2.4	(1.0–15.5)	2.4	(1.0–14.9)	n.s.	*
8-lower abdomen	4.2	(1.1–15.1)	3.0	(1.1–15.7)	n.s.	*
9-lower back	3.6	(0.7–14.1)	5.8	(1.0–16.6)	p=0.010	*
10-hip	4.5	(1.3–16.1)	7.2	(1.6–17.5)	n.s.	*
11-front thigh	6.7	(1.9–12.6)	6.9	(2.1–17.3)	n.s.	†
12-lateral thigh	7.9	(2.6–16.6)	7.5	(2.2–13.3)	n.s.	*
13-rear thigh	7.2	(1.9–10.2)	6.4	(2.0–14.4)	n.s.	†
14-inner thigh	7.1	(2.0–13.8)	7.3	(1.4–17.7)	n.s.	†
15-calf	4.6	(1.6–8.8)	5.2	(1.2–11.7)	n.s.	†
Body regions						
Arms	10.1	(3.5–17.8)	12.2	(5.7–23.9)	n.s.	†
Trunk	10.0	(4.8–32.1)	11.3	(5.0–46.3)	n.s.	*
Abdomen	17.4	(4.6–55.3)	19.8	(6.6–59.5)	n.s.	*
Legs	31.9	(10.7–59.4)	34.1	(9.7–60.4)	n.s.	†
Total	68.0	(29.6–164.6)	76.4	(33.0–176.5)	n.s.	*
Factors						
Factor 1	–0.41	(–1.25–2.33)	–0.34	(–1.11–3.95)	n.s.	*
Factor 2	–0.05	(–1.87–1.03)	–0.11	(–2.04–1.82)	n.s.	†

*Mann-Whitney U-Test (p<0.05), †Student's t-Test for Independent Samples (p<0.05)

vides the maximum of information of measured body fat distribution in a two-dimensional diagram.

After calculating the factor values of all 308 children, the three defined age groups (infant, toddler, child) of healthy girls (Ig, Tg, Cg) and boys (Ib, Tb, Cb) as well as the female (Tgt) and male (Tbt) long-term enterally fed toddlers were depicted in a factor value plot (Figure 2). Table 4 presents the factor values of the 275 healthy controls divided into three age groups (infant, toddler, and child) for each sex. There were no significant differences of Factor 1 values between the three defined age groups for healthy girls and boys, while Factor 2 values in both

TABLE 3
ROTATED FACTOR MATRIX OBTAINED BY FACTOR ANALYSIS

	Factor 1	Factor 2
Body sites		
1-neck	0.658	0.459
2-triceps	0.565	0.410
3-biceps	0.593	0.467
4-upper back	0.854	0.188
5-front chest	0.790	0.411
6-lateral chest	0.857	0.153
7-upper abdomen	0.868	0.268
8-lower abdomen	0.794	0.428
9-lower back	0.743	0.350
10-hip	0.597	0.610
11-front thigh	0.380	0.859
12-lateral thigh	0.370	0.817
13-rear thigh	0.215	0.854
14-inner thigh	0.408	0.794
15-calf	0.181	0.821

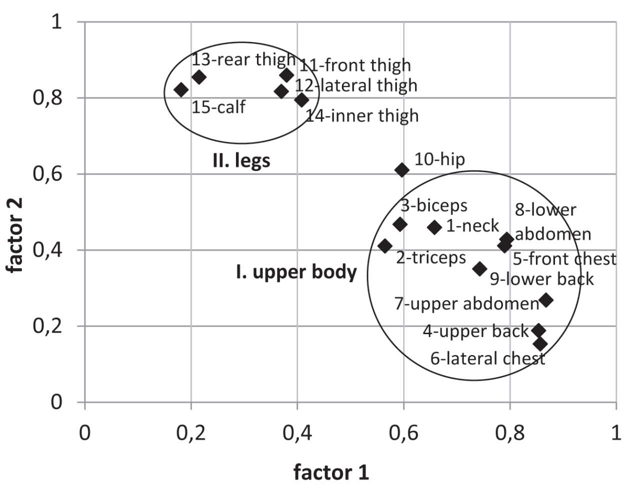

Fig. 1. Factor value plot for 15 body sites, providing two clusters: a leg cluster including all five body sites of the legs, and an upper body cluster, containing the body sites from neck to lower back, whereas the body site hip is related to both clusters.

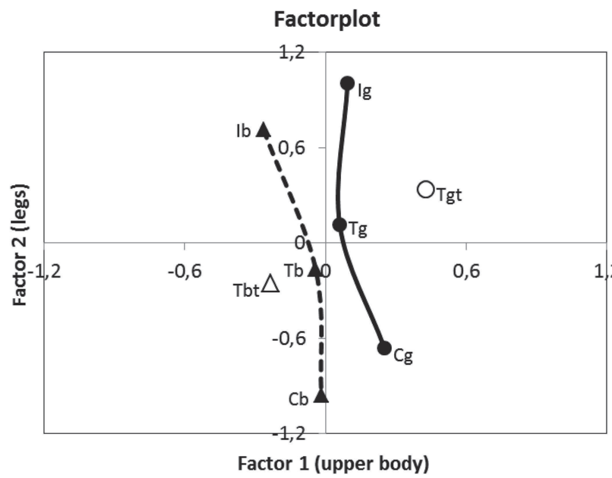

Fig. 2. Factor value plot of 275 healthy controls divided into three age groups (I=infant, T=toddler, C=child (128 girls: Ig, Tg, Cg and 147 boys: Ib, Tb, Cb)) and 33 long-term enterally fed toddlers (10 girls: Tgt and 23 boys: Tbt), showing decreasing factor values of Factor 2 (legs) from infancy to childhood. For example: Ig=infant, girl; Tgt=toddler, girl, tube.

sexes differed significantly ($p<0.001$) between the age groups (Table 4, Figure 2).

Factor 1 is related to upper body subcutaneous adipose tissue topography: The load for Factor 1 of healthy girls is above average in all three age groups (Ig, Tg, Cg). In healthy boys, however, Factor 1 values are below average in all three defined age groups (Ib, Tb, Cb). Factor 2 values (»leg factor«) of female controls are above average in infants (Ig) and in toddlers (Tg) and below average in children (Cg). Factor 2 values of male controls are above average in infants (Ib) and below average in toddlers (Tb) and in children (Cb). In healthy girls and boys Factor 1 values remain more stable from infancy to childhood, whereas Factor 2 values decrease to about the same amount from one age group to the next age group in both sexes. In general, healthy girls showed higher factor values of Factor 1 and Factor 2 in all age groups compared to boys (Figure 2, Table 4).

In female long-term enterally fed toddlers (Tgt) Factor 1 and Factor 2 values were above average, while Factor 1 and Factor 2 values in male tube fed toddlers (Tbt) were below average (Figure 2). Comparing tube fed toddlers with healthy controls for each sex no significant differences of Factor 1 and Factor 2 values could be found (Table 2a, Table 2b).

Finally, the 275 healthy controls were divided into three subgroups (underweight, normal weight and overweight controls) according to BMI-percentiles[31,32] (Table 5). The loads for the factors of the three age groups (infant, toddler, child) of underweight (Igu, Tgu, Cgu), normal weight (Ig, Tg, Cg) and overweight (Igo, Tgo, Cgo) girls, of underweight (Ibu, Tbu, Cbu), normal weight (Ib, Tb, Cb) and overweight (Ibo, Tbo, Cbo) boys, and the female (Tgt) and male (Tbt) long-term enterally fed toddlers are shown in a factor value plot (Figure 3).

The load of the »upper body factor« (Factor 1) of underweight girls (Igu, Tgu, Cgu) and boys (Ibu, Tbu, Cbu) was below average in all three age groups. There is a reduction of Factor 2 values between age group infant and age group child in both underweight sexes.

TABLE 4
FACTOR VALUES (X±SD) OF 275 HEALTHY GIRLS AND BOYS DIVIDED INTO THREE AGE GROUPS

	Infant (0–1 year)		Toddler (1–5 years)		Child (5–7 years)	
Girls						
N	36		54		38	
Age (years)	0.6 ± 0.2	***	3.0 ±1.2	†††	6.2 ±0.6	‡‡‡
Height (cm)	69.3 ± 5.0	***	94.6 ± 12.0	†††	118.6 ± 5.6	‡‡‡
Weight (kg)	7.8 ± 1.3	***	14.1 ± 3.2	†††	21.6 ± 3.2	‡‡‡
BMI (kg/m²)	16.1 ± 1.7		15.6 ± 1.6		15.4 ± 1.9	‡
Z-score BMI	0.1± 1.5		–0.1 ± 1.0		–0.2 ± 1.0	
Factor 1	0.09 ± 0.98		0.06 ± 0.83		0.25 ± 1.24	
Factor 2	1.00 ± 0.81	***	0.12 ± 0.96	†††	–0.66 ± 0.49	‡‡‡
Boys						
N	44		66		37	
Age (years)	0.6 ± 0.2	***	2.9 ±1.2	†††	6.0 ± 0.6	‡‡‡
Height (cm)	69.4 ± 4.5	***	95.0 ± 12.1	†††	120.3 ± 6.1	‡‡‡
Weight (kg)	7.9 ± 1.5	***	14.7 ± 3.8	†††	23.0 ± 5.7	‡‡‡
BMI (kg/m²)	16.3 ± 1.6		16.1 ± 1.9	†	15.7 ± 2.7	‡‡‡
Z-score BMI	–0.3 ± 1.5		0.1 ± 1.4		–0.1 ± 1.1	
Factor 1	–0.26 ± 0.53		–0.04 ± 1.02		–0.02 ± 1.20	
Factor 2	0.71 ± 0.94	***	–0.17 ± 0.78	†††	–0.96 ± 0.57	‡‡‡

*p<0.05, **p<0.01, ***p<0.001 – age group infant versus age group toddler
†p<0.05, ††p<0.01, †††p<0.001 – age group toddler versus age group child
‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001 – age group infant versus age group child

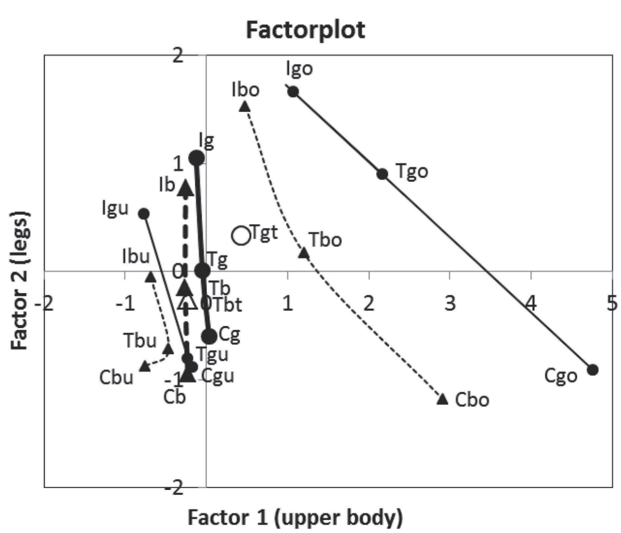

Fig. 3. Factor value plot of 30 underweight (13 girls: Igu, Tgu, Cgu and 17 boys: Ibu,Tbu,Cbu), 216 normal weight (103 girls: Ig, Tg, Cg and 113 boys: Ib, Tb, Cb) and 29 overweight controls (12 girls: Igo, Tgo, Cgo and 17 boys: Ibo, Tbo, Cbo) divided into three age groups (I=infant, T=toddler, C=child) and 33 long-term enterally fed toddlers (10 girls: Tgt and 23 boys: Tbt), showing differences of factor values between the subgroups of underweight, normal weight and overweight controls, sex-specific differences for each group and decreasing factor values of Factor 2 from infancy to childhood in all subgroups. For example: Igu=infant, girl, underweight; Ig=infant, girl, normal weight; Igo=infant, girl, overweight; Tgt=toddler, girl, tube.

Factor 1 values in normal weight girls were slightly below average in infants (Ig) and in toddlers (Tg) and slightly above average in children (Cg). Factor 1 values in normal weight boys were slightly below average in all age groups (Ib, Tb, Cb). Both sexes in the normal weight group demonstrated decreasing Factor 2 values from one age group to the next.

In overweight girls and boys Factor 1 values were above average in all three age groups (Igo, Tgo, Cgo, Ibo, Tbo, Cbo). There is an increase of Factor 1 values in overweight girls and overweight boys from one age group to the next age group, whereas Factor 2 values decrease to about the same amount in both overweight sexes from infancy to childhood.

Female enterally fed toddlers (Tgt) demonstrated higher values of Factor 1 and Factor 2 than underweight and normal weight toddlers (Tgu, Tg), but lower values than overweight controls (Tgo). Male tube fed toddlers (Tbt) showed higher values of Factor 1 and Factor 2 than underweight toddlers (Tbu), but compared to normal weight toddlers (Tb) the Factor 1 value was slightly higher in the male tube fed sample than in normal weight controls. The Factor 2 value was again slightly lower in enterally nourished toddlers than in normal weight controls. Factor 1 and Factor 2 values were lower in the male clinical group (Tbt) compared to overweight controls (Tbo) (Figure 3).

TABLE 5
RATES OF UNDERWEIGHT (<10.PERCENTILE), NORMAL WEIGHT (10.–90. PERCENTILE) AND OVERWEIGHT (>90. PERCENTILE) IN THE SAMPLE OF 128 GIRLS AND 147 BOYS DIVIDED INTO THREE AGE GROUPS (INFANT, TODDLER, CHILD)

	Infant (0–1 year)	Toddler (1–5 years)	Child (5–7 years)
Girls	36	54	38
<10. Percentile	2	5	6
10.–90. Percentile	30	43	30
>90. Percentile	4	6	2
Boys	44	66	37
<10. Percentile	6	8	3
10.–90. Percentile	35	47	31
>90. Percentile	3	11	3

Discussion

In this study the subcutaneous adipose tissue topography of 33 long-term enterally fed toddlers (10 girls, 23 boys) is described for the first time. The results of the subcutaneous adipose tissue measurements are presented at three levels: 15 body sites, four body regions (arms, trunk, abdomen, legs) and total subcutaneous adipose tissue.

Female enterally fed toddlers showed significantly lower values of height (–12.5%) and weight (–21.9%) compared to healthy controls and only subcutaneous adipose tissue measurements of the body sites 10-hip (p=0.048) and 13-rear thigh (p=0.049) slightly reached statistically significance (Table 2a), but it makes no sense to talk about p-values of 0.048 and 0.049 for the given number of studied subjects. Furthermore, these differences were not confirmed on the level of the four body regions and the level of total subcutaneous body fat.

Male tube fed toddlers demonstrated significantly lower values in all anthropometric parameters in comparison to controls (height (–8.4%), weight (–24.8%), BMI, Z-score BMI, upper arm circumference (–10.1%) and waist circumference (–12.5%)). Though they showed significantly lower values of subcutaneous adipose tissue thicknesses in three of the fifteen body sites (2-triceps (–18.5%), 4-upper back (–27.3%) and 9-lower back (–37.9%)), again the enterally fed sample did not confirm any significant differences on the level of the four body regions (arms, trunk, abdomen, legs) and on the level of total subcutaneous body fat when compared to their controls (Table 2a, Table 2b, Figure 2).

Overall, these results indicate for both sexes a comparable subcutaneous adipose tissue topography and body fat distribution of long-term enterally fed children and healthy controls. Furthermore, Factor 1 and Factor 2 values were not significantly different between the two groups (Table 2a, Table 2b and Figure 2). Consequently, these results confirm our hypothesis of no significant differences of subcutaneous adipose tissue topography between long-term tube fed toddlers and healthy controls.

In this study we have confirmed previous results which indicated that long-term enterally fed children tended to be shorter and have relatively lower BMI´s but have fat levels in the normal range[14]. In general, tube fed children of both sexes showed reduced anthropometric values but demonstrated subcutaneous adipose tissue topography and total subcutaneous adipose tissue values within normal limits, when compared to healthy controls. It seems as if long-term enterally fed children have ample fat stores but lack in physical development, which could be also related to their underlying medical conditions (Table 1).

In our study the 15 subcutaneous adipose tissue thicknesses were moderately intercorrelated (r = +0.31 to r = +0.87). Body sites situated on the same area (e.g. on trunk or legs) showed the highest mutual correlations. Previous findings in a sample of 980 healthy girls and boys aged 7–19 years demonstrated higher correlation coefficients from +0.52 to +0.91[43]. As in the aforementioned study[43] of 980 girls and boys our study found two overall factors (Factor 1=upper body, Factor 2=legs), which confirms the previous findings.

Differences of subcutaneous adipose tissue topography between tube-fed, underweight, normal weight and overweight controls were also found in this study. Generally, the normal weight groups of girls and boys were situated in the center of the factor plot (Figure 3), on the left side with lower factor values we found the underweight groups, and on the right side providing higher factor values the overweight groups were located. Tube fed toddlers of both sexes were located closer to their normal weight controls, than to under- or overweight toddlers, which confirms again (in the context of underweight, normal weight and overweight) the previous findings[14], that long-term enterally fed children have fat levels in the normal range.

Our study is the first to be able to generate basic documentation of anthropometry and exact subcutaneous adipose tissue topography of long-term enterally fed toddlers compared to healthy controls and to describe subcutaneous adipose tissue topography differences between tube fed, underweight, normal weight and overweight controls.

Acknowledgement

The Lipometer is used exclusively for research without commercial interest. Therefore there are no conflicts of interest and funding to declare.

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TOPOGRAFIJA POTKOŽNOG MASNOG TKIVA KOD DUGOROČNO ENTERALNU HRANJENE DJECE I KONTROLNE SKUPINE

SAŽETAK

U kontekstu enteralne prehrane u djece, utjecaj na rast i pitanje resorpcije masti je od velikog interesa. Mi smo, stoga, izmjerili debljinu potkožnog masnog tkiva na uzorku od dugoročn enteralno hranjene male djecu i kontrolne skupine. U 33 dugoročn enteralnuo hranjene male djece (10 djevojčica, 23 dječaka) i 275 zdravih ispitanika (128 djevojaka, 147 mladića) razina potkožnog masnog tkiva je mjerena pomoću optičkog uređaja Lipometer. Svi sudionici su bili podijeljeni u tri dobne skupine (dojenčad, malu djecu i djecu). Visina (p=0,014, –11.7 cm, –12,5%) i masa (p=0,012, –3.0 kg, –21,9%) dugoročno enteralno hranjene ženske male djece bile je značajno niža od kontrolne skupine, dok su enteralno hranjene muška mala djeca imala niže vrijednosti u svim antropometrijskim mjerama u odnosu na kontrolnu skupinu: visina (p = 0,003, –8.0 cm, –8,4%), težina (p<0,001, –3.5 kg, –24,8%), BMI (p = 0,004, –1.3 BMI), Z-indeks BMI (p=0,001, –1,2 Z-indeks BMI), opseg nadlaktice (p<0,001, –1.6 cm, –10,1%) i opseg struka (p<0,001, –6,2 cm, –12,5 %). Mališani hranjeni s cijevi su pokazali sličnu raspodjelu tjelesne masti u odnosu na kontrolnu skupinu, ali su pokazali značajno niže vrijednosti antropometrijskih mjerenja. Rezultati pokazuju da dugoročno enteralno hranjena djeca imaju dovoljno masnih naslaga, ali nemaju tjelesni razvoj.