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Gender differences in newborn subcutaneous fat distribution

Abstract The pattern and distribution of subcutaneous fat in term and preterm newborns has been assessed by skinfold thicknesses (ST), describing gender and gestational age variations. Weight, length and ST (triceps, biceps, subscapular and suprailiac) were measured in 4634 neonates (2445 males and 2189 females) aged from 32 to 41 gestational weeks. Central to total skinfold ratio (CTS), (suprailiac + subscapular)/sum of 4 ST, was calculated. Males were heavier and longer than females. The sum of 4 ST and CTS was higher in females at every gestational age (with significant differences from 35 weeks) and also the sum of 4 ST per kg body weight ($P < 0.05$ from 32–33 weeks). Throughout the gestational period, ST increased significantly ($P < 0.0001$) but CTS did not show variations, neither in males nor in females. *Conclusion:* Term and preterm females have a more centralised pattern and more amount of subcutaneous fat than males. Central to total skinfold ratio must be considered as an index of centripetal fat store which is independant of gestational age.

Keywords Fat distribution · Fat mass · Gender differences · Gestational changes · Skinfold thicknesses

Abbreviations BS: biceps skinfold thickness · CTS: central to total skinfold ratio · DXA: dual energy X-ray absorptiometry · FFM: fat-free mass · FM: fat mass · SBS: subscapular skinfold thickness · SPS: suprailiac skinfold thickness · ST: skinfold thickness · ΣST: the sum of the four skinfolds (biceps, triceps, subscapular and suprailiac) · TS: triceps skinfold thickness

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Introduction

In children and adolescents, females have proportionally more fat mass (FM) and less fat-free mass (FFM) than males [18, 22]. These gender-related differences are present even during the first months of life [3, 11]. In newborns, two body composition studies performed recently by dual energy X-ray absorptiometry (DXA) have demonstrated that whole-body fat content is also greater in female infants compared to males [11, 17]. Gender is an independent predictive variable for FM and FFM in preterm and term neonates.

Anthropometric assessment of subcutaneous fat tissue by skinfold thickness (ST) is a fast and noninvasive method that has shown good correlation with the amount of FM in children [23]. The use of ST measurements to predict body fatness specifically in newborns has been recently validated; FM calculated by using ST correlated well with FM values determined by DXA ($R^2 = 0.936$) [20]. Gender differences have been also observed in ST measurements in term and preterm neonates [5, 8, 9, 10]; but, in those studies that have obtained reliable results and performed with an appropriate sample size, only triceps and subscapular ST were considered [5, 9, 10].

As well as for the assessment of subcutaneous fat quantity, ST measurements have been used to evaluate subcutaneous adipose tissue distribution [13, 14]. In childhood, ST ratios and waist circumference measurements have been demonstrated to be highly related to intra-abdominal fat using MRI as a reference method [2, 7]. In children and adolescents, preferential accumulation of adipose tissue in the abdominal or central body regions may predispose to metabolic complications that appear associated with body fatness

[12, 15]. In newborns, there are no data concerning reference values for the relative distribution of fat in the subcutaneous compartment. Perhaps a better knowledge of neonatal body mass composition could help determine relationships between perinatal body fatness and early infant outcome or later development of metabolic disease. For this reason, the aim of the present study was to describe the normal pattern and distribution of subcutaneous fat assessed by four ST at birth, in term and preterm newborn infants, and to analyse their gestational age- and gender-related variations.

Subjects and methods

Subjects

Data collected in this investigation were obtained from 4634 neonates, 2445 males and 2189 females, born in the University Clinical Hospital 'Lozano Blesa', Zaragoza (Spain), with a gestational age ranging from 32 to 41 weeks (Table 1). The sample of term infants ($\geq$37 gestational weeks) comprised all Caucasian singleton neonates born between January 2000 and December 2002 (3 complete years) whose parents were both from Spain. To obtain an appropriated sample size of preterms, we collected data from all Caucasian singletons born between January 1993 and December 2002 (10 complete years), with a gestational age $\leq$ 36 weeks, whose parents were also both from Spain. We compared anthropometric values from preterm infants born in the first half period (1993–1997) with data from infants born in the second half (1998–2002) and there were no statistical differences. Gestational age was expressed in completed weeks from the 1st day of the last menstrual period and confirmed at the first ultrasound examination. Infants of minority ethnic groups were not considered for this study. We also excluded those newborns with major congenital chromosomal or metabolic abnormalities, multiple births, gestational diabetes or other alterations that could affect body composition (oedema, myopathies, etc.).

Table 1 Sex and gestational age distribution of newborns

Gestational age (weeks)	Males (n)	Females (n)	Total (n)
32	23	11	34
33	24	16	40
34	53	53	106
35	57	52	109
36	133	101	234
37	136	126	262
38	369	350	719
39	772	729	1501
40	600	500	1100
41	278	251	529
Total	2445	2189	4634

Anthropometric measurements

In each newborn, weight, length and ST were measured using standardised methodology, under similar conditions [19]. Weight (g) was measured with no clothing just after birth by trained nurses. Infant length (cm) was obtained in the first hours of life by two trained nurses with a measuring board. Skinfolds (mm) were obtained within the first 24 h of life by the same trained person. Left ST were measured at four sites to the nearest 0.1 mm with a Holtain skinfold calliper: (1) triceps (TS), halfway between the acromion process and the olecranon process; (2) biceps (BS), at the same level as the triceps, directly above the centre of the cubital fosse; (3) subscapular (SBS), immediately below the tip of the inferior angle of the scapula at an angle of 45º to the vertical; and (4) suprailiac (SPS), immediately above the iliac crest and 1 cm towards the medial line. Measurements were taken three times and the mean was calculated to obtain a final value. Reliability for skinfolds was 95%.

In order to describe subcutaneous body fat distribution, the sum of the four skinfolds (ΣST) (mm) and various ratios were calculated: central to total skinfolds ratio (CTS) using the formula CTS = (SPS + SBS)/ΣST$\times$100, the sum of the four skinfolds per weight unit (ΣST/weight) and central skinfolds per weight unit (SPS + SBS)/weight.

Statistical analysis

Statistical analysis was performed using SPSS for Windows 11.5. Variables were described as mean and standard deviation, by sex and gestational age groups. Comparisons between mean results in males and females at each gestational age were carried out using the unpaired t-test. ANOVA was used to analyse variations between gestational age groups in each sex.

Results

Males were heavier and longer than females but differences were only statistically significant from week 37 (Table 2). Weight and length significantly increased from 32 to 41 weeks in both sexes ($P < 0.0001$).

ST measurements from 32 to 41 weeks of gestation are given in Table 3 and Table 4. SPS and SBS showed higher values in females than in males at all age intervals but these differences were statistically significant from 38 weeks. Females also had higher CTS, ΣST/Weight and (SPS + SBS)/weight ratios at all age intervals (Table 5 and Table 6). These differences were statistically significant from 35, 36, and 32–33 weeks respectively.

Except for the CTS ratio, ST variables and ratios either increased (TS, BS, SPS, SBS, ΣST) or decreased (ΣST/weight, (SPS + SBS)/weight) significantly from 32 to 41 weeks (Tables 1, 2, 3, 4, 5, 6, $P < 0.0001$). The CTS

Table 2 Weight and length from 32 to 41 weeks of gestation: mean, standard deviation (SD), differences between genders analysed using the unpaired *t*-test (*) and variations throughout the gestational period in each sex analysed using ANOVA (**). (*NS* not significant)

Gestational age (weeks)	Weight (g)			Length (cm)		
	Males	Females	*P* *	Males	Females	*P* *
32–33	1805 ± 347	1837 ± 458	NS	42.72 ± 2.38	42.64 ± 2.33	NS
34	2149 ± 344	2113 ± 349	NS	44.68 ± 2.64	44.27 ± 2.17	NS
35	2339 ± 365	2276 ± 348	NS	45.50 ± 2.23	45.48 ± 1.91	NS
36	2595 ± 448	2515 ± 402	NS	47.03 ± 2.24	46.60 ± 2.34	NS
37	3006 ± 465	2778 ± 389	< 0.0001	48.77 ± 2.11	47.53 ± 1.85	< 0.0001
38	3175 ± 419	3047 ± 384	< 0.0001	49.68 ± 1.88	48.76 ± 1.70	< 0.0001
39	3305 ± 386	3196 ± 375	< 0.0001	50.19 ± 1.78	49.56 ± 1.72	< 0.0001
40	3415 ± 399	3326 ± 374	< 0.0001	50.72 ± 1.58	50.09 ± 1.70	< 0.0001
41	3563 ± 404	3390 ± 358	< 0.0001	51.43 ± 1.75	50.35 ± 1.47	< 0.0001
P **	< 0.0001	< 0.0001		< 0.0001	< 0.0001	

Table 3 BS and TS from 32 to 41 weeks of gestation: mean, standard deviation (SD), differences between genders analysed using the unpaired *t*-test (*) and variations throughout the gestational period in each sex analysed using ANOVA (**). (*NS* not significant)

Gestational age (weeks)	BS (mm)			TS (mm)		
	Males	Females	*P* *	Males	Females	*P* *
32–33	2.31 ± 0.63	2.32 ± 0.63	NS	2.59 ± 0.58	2.72 ± 0.62	NS
34	2.42 ± 0.69	2.53 ± 0.78	NS	3.07 ± 0.70	3.17 ± 0.72	NS
35	2.61 ± 0.62	2.52 ± 0.58	NS	3.25 ± 0.61	3.25 ± 0.68	NS
36	2.77 ± 0.79	2.83 ± 0.87	NS	3.44 ± 0.84	3.41 ± 0.90	NS
37	3.46 ± 0.91	3.22 ± 0.70	0.015	4.05 ± 0.98	3.82 ± 0.85	0.049
38	3.47 ± 0.83	3.59 ± 0.88	NS	4.03 ± 0.85	4.17 ± 0.84	0.020
39	3.61 ± 0.89	3.61 ± 0.84	NS	4.21 ± 0.84	4.25 ± 0.81	NS
40	3.63 ± 0.83	3.61 ± 0.88	NS	4.23 ± 0.83	4.30 ± 0.86	NS
41	3.68 ± 0.77	3.74 ± 0.80	NS	4.26 ± 0.88	4.49 ± 0.94	0.004
P **	< 0.0001	< 0.0001		< 0.0001	< 0.0001	

Table 4 SPS and SBS from 32 to 41 weeks of gestation: mean, standard deviation (SD), differences between genders analysed using the unpaired *t*-test (*) and variations throughout the gestational period in each sex analysed using ANOVA (**). (*NS* not significant)

Gestational age (weeks)	SPS (mm)			SBS (mm)		
	Males	Females	*P* *	Males	Females	*P* *
32–33	1.73 ± 0.52	2.04 ± 0.72	0.034	2.49 ± 0.56	2.81 ± 0.76	0.048
34	2.20 ± 0.67	2.34 ± 0.87	NS	2.89 ± 0.80	3.17 ± 0.94	NS
35	2.30 ± 0.63	2.43 ± 0.65	NS	3.03 ± 0.64	3.17 ± 0.72	NS
36	2.53 ± 0.75	2.69 ± 0.83	NS	3.25 ± 0.78	3.37 ± 0.88	NS
37	3.15 ± 0.85	3.16 ± 0.79	NS	3.77 ± 1.01	3.78 ± 0.93	NS
38	3.17 ± 0.76	3.37 ± 0.83	< 0.0001	3.69 ± 0.80	4.03 ± 0.99	< 0.0001
39	3.32 ± 0.76	3.40 ± 0.76	0.047	3.92 ± 0.90	4.09 ± 0.88	0.0001
40	3.35 ± 0.74	3.47 ± 0.83	0.011	3.95 ± 0.85	4.19 ± 0.91	< 0.0001
41	3.43 ± 0.78	3.69 ± 0.82	0.0002	3.94 ± 0.79	4.25 ± 1.00	0.0001
P **	< 0.0001	< 0.0001		< 0.0001	< 0.0001	

ratio did not show variations throughout this gestational period (Table 5).

Discussion

Neonatal body composition assessment is useful in evaluating fetal growth, nutritional status and general infant outcome. ST is a fast and relatively noninvasive in vivo method to quantify subcutaneous fat store, and requires only simple technology and careful training. In newborns, ST measurements show a good correlation with FM [20]; and have less inter- and intra-observer variability than other morphometric indices [4].

It has been recently demonstrated that ST measurements and whole-body fat content measured by DXA are greater in female newborns compared with males [5, 8, 9, 10, 11, 17]. In preterm and term infants, there are limited data available on the amount and relative distribution of subcutaneous body fat and whether gender may influence the pattern of subcutaneous fat store throughout pregnancy [5, 8, 9, 10]. Our study has shown gender and gestational age variations of subcutaneous fat distribution. Female infants not only had greater ST measurements but also larger CTS values in every gestational age group, with significant differences from 35 weeks. The CTS ratio is used as an index of the central pattern of adiposity distribution

Table 5 ΣST and CTS from 32 to 41 weeks of gestation: mean, standard deviation (SD), differences between genders analysed using the unpaired *t*-test (*) and variations throughout the gestational period in each sex analysed using ANOVA (**). (*NS* not significant)

Gestational age (weeks)	ΣST (mm)			CTS (%)		
	Males	Females	*P* *	Males	Females	*P* *
32–33	8.96 ± 1.93	9.91 ± 2.39	NS	47.24 ± 3.93	48.70 ± 4.14	NS
34	10.61 ± 2.51	11.23 ± 3.02	NS	47.87 ± 3.73	48.80 ± 4.16	NS
35	11.20 ± 2.06	11.38 ± 2.34	NS	47.55 ± 3.18	49.17 ± 3.02	0.007
36	12.01 ± 2.80	12.31 ± 3.22	NS	48.28 ± 3.24	49.03 ± 3.08	0.015
37	14.45 ± 3.38	13.99 ± 2.89	NS	47.87 ± 3.01	49.48 ± 3.05	< 0.0001
38	14.33 ± 2.86	15.18 ± 3.07	0.0001	47.64 ± 3.12	48.71 ± 3.09	< 0.0001
39	15.08 ± 2.89	15.37 ± 2.77	0.047	48.04 ± 3.25	48.76 ± 3.30	< 0.0001
40	15.17 ± 2.77	15.58 ± 2.91	0.017	48.17 ± 3.06	49.15 ± 3.47	< 0.0001
41	15.33 ± 2.74	16.18 ± 2.99	0.0007	48.13 ± 3.19	49.06 ± 3.52	0.001
P **	< 0.0001	< 0.0001		0.135 (NS)	0.128 (NS)	

Table 6 ΣST/weight and CTS/weight ratios from 32 to 41 weeks of gestation: mean, standard deviation (SD), differences between genders analysed using the unpaired *t*-test (*) and variations throughout the gestational period in each sex analysed using ANOVA (**). (*NS* not significant)

Gestational age (weeks)	ΣST/weight (mm/kg)			CTS/weight (mm/kg)		
	Males	Females	*P* *	Males	Females	*P* *
32–33	5.06 ± 1.03	5.54 ± 0.86	NS	2.38 ± 0.47	2.66 ± 0.49	< 0.05
34	4.94 ± 0.85	5.37 ± 1.44	NS	2.37 ± 0.48	2.63 ± 0.80	< 0.05
35	4.83 ± 0.83	5.03 ± 0.86	NS	2.29 ± 0.42	2.47 ± 0.44	< 0.05
36	4.63 ± 0.80	4.88 ± 0.95	< 0.05	2.23 ± 0.40	2.40 ± 0.46	< 0.01
37	4.81 ± 0.88	5.09 ± 0.83	< 0.01	2.30 ± 0.45	2.51 ± 0.42	< 0.001
38	4.53 ± 0.81	4.98 ± 0.83	< 0.0001	2.15 ± 0.40	2.43 ± 0.43	< 0.0001
39	4.53 ± 0.73	4.83 ± 0.75	< 0.0001	2.18 ± 0.38	2.35 ± 0.39	< 0.0001
40	4.46 ± 0.72	4.70 ± 0.78	< 0.0001	2.14 ± 0.36	2.31 ± 0.41	< 0.0001
41	4.31 ± 0.67	4.77 ± 0.78	< 0.0001	2.07 ± 0.35	2.34 ± 0.42	< 0.0001
P **	< 0.0001	< 0.0001		< 0.0001	< 0.0001	

because it is positively related to thoracic and abdominal subcutaneous fat [14].

Traditionally, a more central distribution of subcutaneous fat has been a peculiar characteristic of male body composition pattern at different ages (prepubertal, pubertal and postpubertal) [6, 24]; but in preterm and term female newborns, surprisingly, central subcutaneous fat was proportionally greater than in males. As suggested by other authors [5, 9], sexual differences in size and body composition might be caused by androgenic steroids or other hormonal factors that are increased in male fetuses and could stimulate their growth. Therefore, the total amount of fat store and its distribution may be indirectly related to the growth rate of FFM in the last weeks of gestation. As pointed out in other studies [5, 9], this fact could be related to the better outcomes seen in female neonates because they can use fat stores as energy reserve or against heat loss in the first days of life.

The assessment of newborn fat distribution and its gender variations may be also used to investigate possible relations about early life body composition and long-term development of metabolic alterations. It has been proved that early growth during the perinatal period may influence the development of insulin resistance, obesity or cardiovascular disease during adolescence and adulthood [16, 21]. Among others, high levels of adiposity and insulin resistance have been found in adults and adolescents with intrauterine growth restriction or malnutrition during the 1st year of life [1, 16].

In conclusion, we have found that term and preterm female infants have a pattern of subcutaneous adipose tissue more centralized than males, as well as more amount of subcutaneous body fat assessed by ST. While ST measurements increase with gestational age, the degree of central subcutaneous adiposity (CTS) does not vary significantly from 32 to 41 weeks, neither in male nor in female newborns. Therefore, CTS must be considered as an index of centripetal fat store that is not gestational age dependent. Separately in both sexes, ST measurements and CTS ratio could be used to determine the pattern of subcutaneous fat distribution in newborns. The assessment of the amount and distribution of fat mass in the neonate should be taken into account with regard to perinatal growth, early infant outcome and later development of metabolic alterations or diseases.

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