

PAPER

Body composition of 4- and 5-year-old New Zealand girls: a DXA study of initial adiposity and subsequent 4-year fat change

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BACKGROUND: Dual-energy X-ray information (DXA) quantitating body fat mass and percentage fat in healthy children of preschool age is scarce.

Objective: To study the initial variability in body composition and subsequent longitudinal changes in absolute fat mass (kg) and relative adiposity (fat percentage) in a sample of contemporary young New Zealand girls.

DESIGN: Cross-sectional study with a longitudinal component.

SETTING: University research unit.

SUBJECTS: A total of 89 Caucasian girls aged 4–5y were recruited by advertisement at baseline and 4-y changes in body composition were evaluated in 23 of these girls.

METHODS: Total body composition was measured by DXA, height and weight by anthropometry.

RESULTS: Baseline values for fat mass varied more than values for lean mass or bone mass. Girls from the upper third of our fat percentage distribution (% fat >19.2%) had more than twice the fat mass (5.34 vs 2.31 kg, $P < 0.001$) of those from the lowest third (% fat <15.4%). The percentage gain in fat mass over 4y (124 (95% CI 90–163)) also exceeded the percentage gain of lean mass (55 (95% CI 51–59)). In data adjusted for age and height, 63.5% of the variance in percentage body fat at time 2 was explained by fat mass at time one.

CONCLUSIONS: In girls, the trajectory of fat gain appears to be established at a young age. Our results support the view that body fatness tracks strongly before puberty. Since preventing the accumulation of excessive fat is preferable to reduction of existing excessive fat stores, it is important to put in place strategies to limit excessive fat gain early in life.

International Journal of Obesity (2003) 27, 410–415. doi:10.1038/sj.ijo.802236

Keywords: prepubertal girls; adiposity; body composition; fat change

Introduction

The rapid increase in childhood obesity, which is currently affecting many countries is of major public health concern.^{1–7} This excessive adiposity is evident in preschool children^{8–10} making it important to know exactly what levels of body fat are present today in youngsters of this age.

Excessive fatness has adverse health effects, even in childhood.¹¹ Obesity in youngsters is associated with

orthopaedic problems, higher blood pressure, raised lipids, altered insulin sensitivity, arterial dysfunction, early signs of cardiovascular disease, psychosocial problems and advanced pubertal maturation.^{12–20} Furthermore, serial measurements of body mass index (BMI) indicate that childhood obesity tracks strongly into adult life^{21,22} where obesity has serious consequences.^{11,23} Thus, curbing early obesity in children has become a health priority.^{3,24}

Until recently, excessive fatness has generally been documented in young children from simple measurements of weight, weight for height or BMI (weight/height²). These methods do not distinguish levels of body fat content separately from lean tissue mass and bone mass. Although underwater weighing does estimate fat stores, this technique

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Received 22 April 2002; revised 24 September 2002;

accepted 25 October 2002

is unsuitable for use in young children²⁵ while bioimpedance²⁶ is unduly influenced by hydration. Skinfold measurements have been widely used to assess adiposity in the past, but are considered to be imprecise.²⁷ Fortunately, the advent of dual-energy X-ray absorptiometry (DXA) enables fat tissue to be quantitated separately from lean tissue with precision and safety in children.^{28,29}

To date, few DXA studies of body composition evaluating large samples of young children of the same gender and ethnicity within a narrow age band have been undertaken. Information concerning longitudinal changes in the body fat and lean mass are even rarer, but are urgently needed.³⁰ The aim of our present study was to measure the body composition of a large group of contemporary New Zealand girls of similar chronological age in order to ascertain the size and variability of their fat stores round the time of entry to school and to quantify prospective changes in body composition after 4 years.

Methods

We report the body composition of 89 New Zealand Caucasian girls aged 4–5 y who were enrolled for studies of bone health and body composition conducted during the last 5 y in our laboratory. Of these, 66 girls participated in cross-sectional studies only. The remaining 23 girls were studied longitudinally exactly 4 y after baseline measurement, when they were aged 8–9 y. Girls were recruited by advertisement. The research was approved by our local hospital Ethics Committee and signed informed parental consent was obtained for every child participant.

The girls were weighed (electronic balance, Model 169N Tanita Corp., Tokyo, Japan) and measured (Harpender stadiometer, Holtain Ltd, Crosswell, Crymych, UK) without shoes in light clothing. BMI was determined as weight in kilograms divided by height in metres squared. Subjects were also classified as having high adiposity if their percentage fat values were greater than those estimated to correspond with high BMI values,³¹ as recently proposed by the International Obesity Taskforce.³² Tanner staging of pubertal development was self-assessed³³ in older girls using standard pictures and descriptions of breast development as described previously.³⁴ Metal objects (watches, jewellery, buckles) worn by the children were removed and body composition was measured by one operator using the same Lunar DPX-L scanner (Lunar Corporation, WI, USA) by procedures described elsewhere.³⁵ Total body scans were analysed with software package 1.35. The long-term stability of our DXA scanner was monitored by measuring phantom tissue blocks daily and a Hologic spine phantom 3 times per week. Measurements were stable throughout the study period. Our *in vivo* DXA precision values (coefficients of variation in adults) are (%): fat percentage (2.4%), fat mass (2.5%), lean mass (1.1%) and bone mineral content (BMC, 1.5%), respectively. Similar

repeatability is obtained from *in vivo* repeat scan measurements performed on children.²⁹

Statistical analysis was performed with STATA (StataCorp Stata Statistical Software Release 7, Stata Corporation 2001, College Station, TX, USA) data being log-transformed where appropriate. Raw data are presented in Tables 1 and 4 as means and s.d.'s. The tertile cutpoints for relative adiposity (percentage body fat) at baseline for the whole study population were determined and the girls were then subdivided from these into three groups having Group 1 = low (<15.4%), Group 2 = medium (>15.4% <19.1%) or Group 3 = high (>19.2%) initial percentage fat values. Data were analysed by ANOVA and when $P < 0.05$ Tukey's test was applied to ascertain levels of statistical difference between different groups.

Results

Table 1 shows the characteristics of the study population at baseline. Total fat mass values varied widely. Although the girls were only 4 or 5 y of age, we found that there was a 10-fold difference between the lowest and highest values for fat mass. This compared with a four-fold difference for percentage fat values, and only an approximately two-fold difference for bone mineral content and lean mass between the minimum and maximum values for these variables.

Although the group of 23 girls who were studied prospectively were 3 months older ($P < 0.04$) at baseline than the 66 girls studied only once at baseline, these groups did not differ in weight or BMI or percentage fat after adjusting for age ($P > 0.05$). Thus, we feel that these 23 girls studied again after 4 y were satisfactorily representative of the greater group. As expected, all 23 girls grew substantially and their adiposity increased with age. Although only six of these girls (all from group 3) had percentage fat values indicating overweight or obesity at baseline, nine subjects met these criteria four years later (Table 2). Moreover, we found that fat mass expanded considerably more in 4 y than other tissues, although all times 1 and 2 measurements were highly correlated (Table 3).

The increases in fat mass and percentage fat tended to be most pronounced in girls with high initial adiposity, although this was not true for every individual (Figures 1 and 2). Nevertheless, the average fat mass gain was three times higher in group 3 girls than in those from group 1 (Table 4). We found, by logistic regression, in a model adjusting for age and height at time 2 that 63.5% of the variance in percentage body fat at time 2 was explained by fat mass at time one. By 8–9 y of age, girls drawn from the highest group of initial adiposity weighed more, had higher BMI values, more body fat and a higher fat percentage than girls from group 1 (low initial adiposity). However, despite a 12 kg total average weight difference, the lean mass and BMC values of these older groups did not differ.

Table 1 Characteristics of the 89 girls grouped according to their baseline total body fat percentage

Fat percentage group	Group 1	Group 2	Group 3	ANOVA ^b
	Low (n=30)	Medium (n=30)	High (n=29)	
Overweight ^a (n)	0	0	11	
Obese ^a (n)	0	0	6	
Age (y)	5.1 (0.5) 4.0–5.8	5.0 (0.6) 4.1–5.9	5.2 (0.6) 4.1–5.9	NS
Height (cm)	110.4 (6.6) 98.5–126.0	109.7 (6.1) 98.8–124.0	113.4 (7.7) 99.0–131.0	NS
Weight (kg)	18.3 (2.4) 14.5–25.0	19.1 (1.8) 16.2–22.2	22.7 (4.2)*** 16.6–36.0	0.001
BMI (kg/m ²)	15.0 (1.0)** 13.3–16.8	15.9 (0.9) 14.2–17.6	17.5 (1.6)*** 15.3–21.0	0.001
BMC (g)	590 (109) 379–860	613 (94) 426–779	683 (111)*** 379–899	0.004
Lean mass (kg)	14.5 (1.9) 11.4–19.6	14.5 (1.5) 12.1–17.3	15.7 (2.1)* 12.3–20.6	0.025
Fat mass (kg)	2.3 (0.5)** 1.4–3.6	3.1 (0.4) 2.5–3.9	5.3 (2.3)*** 3.1–14.3	0.001
Fat %	13.2 (1.7)** 9.4–15.4	17.2 (1.1) 15.5–19.1	23.8 (5.4)*** 19.5–40.5	0.001

Results are means (s.d.) minimum–maximum.

^a% fat values above those expected at BMI cutpoints recommended by IOTF for girls aged 4 or 5 years (overweight=20–26% and obese >26%).³¹

^bData log-transformed for analysis, NS= $P > 0.05$ by ANOVA.

*= $P < 0.05$ vs group 1.

**= $P < 0.05$ vs group 2 (Tukey's test).

Table 2 Distribution of high percentage fat at time 2 in the 23 girls who were studied longitudinally

Adiposity group at Time 1 ^a	Percentage fat at time 2 ^b		
	Healthy (<27%) (n=14)	Overweight (27–36.9%) (n=4)	Obese (>37%) (n=5)
Group 1 (<15.4%) (n=7)	7	0	0
Group 2 (15.4–19.2%) (n=7)	5	1	1
Group 3 (>19.2%) (n=9)	2	3	4

^aFrom percentage fat values describing our tertile distribution at baseline.

^bThe cutpoints used to denote girls aged 9 y as overweight or obese were taken from Taylor *et al.*³¹

At baseline, all girls were prepubertal (Tanner breast stage 1), whereas by the end of the study some had commenced pubertal development. As anticipated, pubertal status tended to be more advanced in girls from the top initial adiposity group than in those from other groups, although the numbers were too small for this trend to attain statistical significance.

Table 3 Relative gain in body composition variables as a percentage of their baseline values^a in the 23 girls studied longitudinally and strength of the associations between measurements at times 1 and 2

	Mean 4-year gain %	95% CI	r values ^b
Height (cm)	19	18–21	0.952
BMI (kg/m ²)	19	12–26	0.697
Fat %	31	17–46	0.764
Lean mass (kg)	55	51–59	0.936
Weight (kg)	69	59–79	0.825
BMC (g)	77	70–84	0.914
Fat mass (kg)	124	90–163	0.808

^aAll data were log-transformed for analysis.

^bCorrelations between values at times 1 and 2.

Discussion

Our observational study shows that, in contemporary New Zealand girls, a wide variation in body fat mass is already present by the age of 5 y. Importantly, our results establish that higher adiposity subsequently tracks in these young girls, so that youngsters with high initial fat percentage have a greater likelihood of showing greater adiposity 4 y later than those who were initially leaner. Fat mass at five appears to be a strong determinant of weight and fatness at 9 y of age. This is a concern, given the rapid rises in adiposity currently being documented among preschool children in much of the

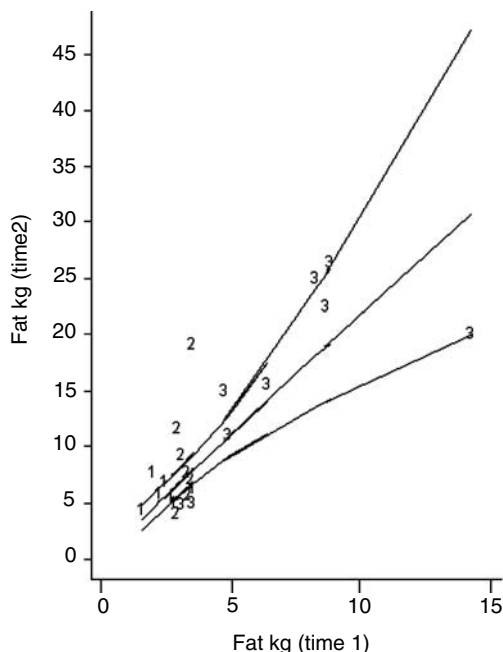


Figure 1 Fat mass values at baseline (time 1) and 4 years later (time 2) in the 23 girls studied prospectively. Numbers indicate baseline fat percent group. Lines show mean values and 95% confidence intervals of the regression line.

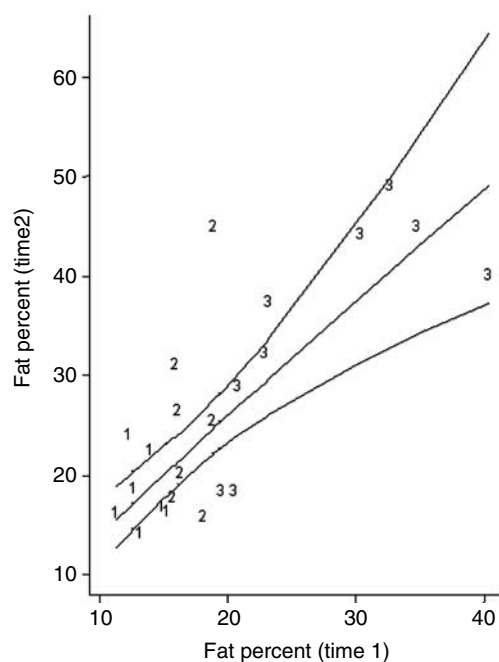


Figure 2 Fat percentage values at baseline (time 1) and 4 years later (time 2) in the 23 girls studied prospectively. Numbers indicate baseline fat percentage group. Lines show mean values and 95% confidence intervals of the regression line.

developed world.^{8–10} If we are to curb the epidemic of obesity affecting New Zealanders, there is an urgent need to put in place strategies to limit excessive early gain of excessive fat in young girls.

It is not perhaps generally appreciated that even at a young age, differences in the total body fat content make a larger contribution to the differences in body weight observed in girls of the same height and age than do differences in their lean mass and bone mass. This is evident from our results. In 4- and 5-y-old girls, the variation in fat mass at baseline was greater than that observed for either lean mass or bone mass. Thus, at baseline, girls in the high adiposity group had twice the body fat mass of those in the low group (5.3 vs 2.3 kg), although the mean values for lean mass in these groups differed by approximately only 1 kg and their average bone mineral content by only 93 g. Accordingly, the wide difference in the average fat percentage values in these groups (23.8 vs 13.2%) was mostly because of variations in fat mass. A similar picture was present in the older girls, where variation in absolute fat mass explained most of the 12 kg weight difference of girls in the high and low adiposity groupings.

Relative adiposity is expected to increase during growth.^{36,37} However, our longitudinal measurements show that girls who have acquired a high fat percentage by the age of five generally continue to gain large amounts of body fat mass over 4 y. These results provide strong support for the view that body fatness tends to track strongly from a young age in girls.

Although current measurements of adiposity or BMI from a representative sample of children are not available for the whole country, recent research indicates that high levels of overweight and obesity are present in New Zealand youngsters today.⁵ At baseline, our 89 girls had a mean BMI of 16.1: this was significantly higher ($P < 0.03$) than the mean BMI value of 15.8 in 435 girls aged 5 y, from a cohort of children born in 1972–73 from the same city.³⁸ The 23 girls we studied longitudinally increased their BMI by 18% in 4 y, which was substantially greater than the BMI rise of only 3.8% (95% CI 2.9–4.6) recorded between 5 and 9 y of age in the earlier Dunedin birth cohort study.³⁸ These comparisons provide striking evidence for the view that many prepubertal New Zealand children are fatter now, and are gaining fat faster, than those born 30 y ago.

Previous evidence for tracking of adiposity in childhood has been based on methods which do not distinguish gains in fat mass from gains in lean mass and bone mass.³⁹ Our study is one of the first with the ability to quantitate fat mass separately from lean mass to have yet been undertaken in young prepubertal children. Strengths of our study design include the use of DXA to quantitate body fat and examination of a large sample of children of the same gender and the same ethnicity. Chronological age was limited to a very narrow range, but we placed no restrictions for study entry on weight or height; all healthy children being eligible to participate. In addition, our longitudinal measurements, although limited to only 23 girls, were made at a precise time interval and were measured directly: they were not estimated by extrapolation. However, we acknowledge that because the present study sample was recruited

Table 4 Changes (4 y) in anthropometry and final body composition, and pubertal status of 23 girls studied longitudinally grouped by their baseline fat percentage status

Baseline fat % grouping	Group 1 Low (n=7)	Group 2 Medium (n=7)	Group 3 High (n=9)	ANOVA ^a
Height gain (cm)	21.1 (2.2)	23.6 (2.4)	22.4 (2.4)	NS
Weight gain (kg)	11.9 (1.3)	14.3 (6.3)	18.2 (7.5)	NS
BMI gain (kg/m ²)	2.3 (1.1)	3.0 (3.6)	3.9 (2.9)	NS
Lean mass gain (kg)	8.6 (0.9)	7.9 (1.2)	9.1 (1.7)	NS
Fat mass gain (kg)	2.9 (1.3)	5.6 (4.9)	8.8 (6.0)	NS
Fat percentage gain	4.5 (4.1)	8.3 (9.4)	7.0 (7.1)	NS
BMC gain (g)	452 (49)	472 (115)	559 (150)	NS
Age (y)	9.2 (0.6)	9.2 (0.5)	9.3 (0.5)	NS
Height (cm)	137.3 (7.7)	137.1 (4.9)	140.2 (8.9)	NS
Weight (kg)	31.2 (3.4)	33.8 (6.0)	43.4 (11.4) ^b	0.031
BMI (kg/m ²)	16.5 (0.8)	18.0 (3.4)	21.8 (4.0) ^b	0.009
Lean mass (kg)	23.9 (3.0)	23.0 (2.3)	25.7 (4.1)	NS
Fat mass (kg)	5.39 (1.2)	8.8 (5.0)	15.7 (8.0) ^b	0.009
Fat %	17.9 (3.6)	25.4 (9.9)	34.3 (11.2) ^b	0.005
BMC (g)	1051 (213)	1109 (179)	1273 (248)	NS
Tanner 1,2,3 (n)	6,1,0	5,2,0	3,4,2	

Results are means (s.d.); Tanner=Tanner breast stages of pubertal development.

^a=Data log-transformed for analysis; NS= $P > 0.05$ by ANOVA.

^b= $P < 0.05$ vs group 1 (Tukey's test).

from volunteers, it is not a true representative random sample of the population. We did not attempt to measure energy intake or energy expenditure in the study children. Nor did we collect any information concerning parental obesity status, fetal health or birth weight, which influence child adiposity.^{40,41} We are merely reporting the observed changes in body fat and are not attempting to identify mechanisms responsible for child to child differences in fat gain.

At five, small girls with high adiposity frequently do not look overfat. Accordingly, parents often fail to notice the problem. However, by 9 y of age, excessive adiposity in the same children is generally all too evident. Our results establish that 4- and 5-y-old girls with high initial relative adiposity tend to maintain a considerably higher trajectory of fat gain, than girls who were leaner at baseline. Nevertheless, it is reassuring to note that not every child with high initial adiposity gained large amounts of fat. Thus, although worsening adiposity is more likely as childhood advances, it is not an inevitable consequence of having a high fat percentage at 5 y of age. Whether or not excessive adiposity becomes more severe over time will depend on the balance each child achieves between their energy intake and their energy expenditure. Our longitudinal measurements indicated that girls from the low percentage fat group were gaining on average 2 g fat per day, whereas those from the high percentage fat group were accumulating about 6 g fat daily.

Parents need to know throughout growth whether or not their child is too heavy. We believe that this information would encourage the adoption of strategies to limit excessive fat gain. An opportune time to provide this information

would be when the child starts school. Although measurements of percentage fat yield the best information regarding excess fatness, these are not as accessible as measurements of weight and height. Thus, it seems reasonable to advocate that children should be weighed and measured carefully then, so that BMI status can be determined and the parents told where their child ranks on the BMI growth charts. This would facilitate early identification of children having elevated BMI values and may encourage families to adopt lifestyle changes to limit excessive fat gain. If the current obesity epidemic is to be curbed, it is desirable that sensible eating patterns and regular physical activity patterns should be put in place for all children during their early years when the seeds of adult obesity are being sown.

Acknowledgements

We thank all the participants and their families for their willing cooperation and interest in our study. This work was supported by the Health Research Council of New Zealand, and the Otago Medical Research Foundation.

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