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The growth and nutritional status of healthy Asian children aged 4–40 months living in Sheffield

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Detailed anthropometric measurements were made on 169 healthy children aged between 4 and 40 months during a comprehensive study of the diet and nutritional status of Asian children (of Pakistani and Bangladeshi origin) living in Sheffield. These measurements were used to describe the growth profile of these apparently healthy children and to compare this with both international and UK reference data. The distribution of values for most anthropometric measurements was close to the UK reference data although both boys and girls tended to be slight of build, and girls tended to have relatively smaller head circumferences. Nevertheless, it was concluded that their growth and nutritional status over this age range can be evaluated using standard (UK) growth charts.

Nutritional status: Anthropometry: Asian children

'A child's growth reflects, better than any other single index, his state of health and nutrition' (Eveleth & Tanner, 1976). The weight and length-for-age of Asian children raised in Britain have been shown by Warrington & Storey (1988) to be similar to those of social-class-matched white British children. Nevertheless, small stature in the Asian child is often attributed to ethnic variation, whereas in a white child from the same background of socioeconomic disadvantage the euphemism 'constitutional small stature' may be preferred. We wished to study the growth and nutritional status of a group of healthy Asian children in the 12 months or so following the commencement of weaning, which is recognized to be a critical period.

A cross-sectional study of the diet, biochemical Fe status, and protein–energy nutritional status of 169 healthy Sheffield Asian children aged 4–40 months was undertaken. A stratified sampling design was used to ensure smooth distribution by age and sex. The results of detailed anthropometric measurements are used to describe the growth profile of these apparently healthy children.

METHODS

Recruitment of healthy subjects

Random sampling was excluded by paucity of information on the size of the study base. Data from Sheffield Central Child Health (CH) records were used, in a feasibility study, to estimate the size and geographical location of the Asian child population. The families of

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Table 1. *Values for weight, crown–heel length (CHL) and head circumference (HCirc) and weight and length standard deviation (SD) scores* of eighty-two healthy Asian boys grouped by age from 4 to 40 months*

(Mean values and standard deviations)

Age group (months)	No. of subjects		Wt (kg)	CHL (mm)	HCirc (mm)	SD scores		
						Wt:age	L:age	Wt:L
4–< 6	6	Mean	6·8	644	418	−0·2	−0·2	−0·2
		SD	1·12	30·7	13·1	1·11	1·3	0·92
6–< 9	17	Mean	8·3	702	441	−0·2	−0·03	−0·3
		SD	1·22	33·7	12·3	1·39	1·28	0·87
9–< 12	8	Mean	9·8	745	458	0·3	0·3	0·1
		SD	1·32	29·8	10·7	1·3	0·89	1·22
12–< 15	12	Mean	9·8	769	464	−0·6	0·01	−0·6
		SD	1·15	22·1	11·2	1·18	0·85	1·42
15–< 18	11	Mean	11·5	820	476	0·2	0·3	0·1
		SD	1·19	40·5	17·6	0·96	1·21	1·13
18–< 21	9	Mean	11·4	842	471	−0·2	0·4	−0·4
		SD	1·58	37·6	13·7	1·27	1·21	1·43
21–< 24	6	Mean	11·2	846	467	−0·8	−0·5	−0·7
		SD	1·80	55·7	15·1	1·45	1·76	0·90
24–< 30	10	Mean	12·6	887	474	−0·3	−0·1	−0·3
		SD	2·66	40·5	21·3	1·90	1·05	1·9
⩾ 30	5	Mean	13·1	920	480	−0·5	−0·4	−0·4
		SD	2·12	71·7	19·1	1·44	1·92	1·07

* Calculated with reference to data from the World Health Organization (1983).

490 (80%) of the 615 Asian children eligible at that time in the whole city were concentrated in five areas served by ten CH and general practitioner (GP) clinics. These areas were targeted for recruitment of all (with the proviso of age stratification within the selected age range) Asian children. With the collaboration of health visitors, the parents of 338 eligible children were approached at a clinic or home visit and requested to participate. Of 195 initial recruits 169 (87%, which represents 50% of those originally approached) agreed to anthropometric measurement and 120 (35% and 62% of those respectively approached and recruited) successfully completed a weighed dietary assessment.

Staff and training

Anthropometric measurements and supervision of weighed dietary inventories were undertaken by three specifically recruited and trained British Asian link workers (LW) supervised by two research dietitians or the clinician. Staff training included instruction in technical anthropometry by an auxology technician (Mrs M. Pickering) followed by practice under supervision in paediatric out-patient clinics. After initial calibration of the equipment, replicated measurements on the same (volunteer) subjects were used to estimate interobserver variability.

Anthropometric measurements were made in the child's home by pairs of workers, usually a LW plus the dietitian or the clinician. A total of eleven anthropometric measurements were undertaken on each child (the mean of three skinfold estimates was considered as one measurement). Children were weighed naked in a basket weighing (beam)

Table 2. *Values for weight, crown–heel length (CHL) and head circumference (HCirc) and weight and length standard deviation (SD) scores* of eighty-seven healthy Asian girls grouped by age from 4 to 40 months*

(Mean values and standard deviations)

Age group (months)	No. of subjects		Wt (kg)	CHL (mm)	HCirc (mm)	SD scores		
						Wt:age	L:age	Wt:L
4–< 6	17	Mean	6·0	621	400	−0·3	−0·2	−0·3
		SD	1·05	28·1	14·9	1·12	0·78	0·80
6–< 9	9	Mean	7·4	679	427	−0·1	0·4	−0·5
		SD	0·45	26·5	6·7	0·60	0·67	1·05
9–< 12	10	Mean	8·57	727	435	−0·4	0·2	−0·5
		SD	0·67	30·6	9·9	0·63	0·97	0·93
12–< 15	10	Mean	8·8	749	441	−0·9	−0·1	−0·8
		SD	1·35	46·6	11·7	0·79	1·4	0·74
15–< 18	15	Mean	10·2	800	456	−0·3	0·2	−0·4
		SD	1·01	33·7	16·2	0·79	0·98	0·69
18–< 21	6	Mean	10·1	823	461	−0·8	0·2	−1·1
		SD	0·8	25·2	16·6	0·65	0·64	0·65
21–< 24	6	Mean	10·96	839	468	−0·6	−0·4	−0·4
		SD	1·25	18·9	18·9	0·98	0·74	1·51
24–< 30	8	Mean	11·6	854	467	−0·6	−0·9	−0·1
		SD	1·47	18·0	16·1	1·09	0·37	1·31
⩾ 30	6	Mean	13·7	934	469	−0·2	−0·3	0·02
		SD	2·82	54·2	15·2	1·67	1·35	1·18

* Calculated with reference to data from the World Health Organization (1983).

balance with a range of 0–12·0 kg with 10 g minimum scale difference (Weylux Supreme, H. Fereday & Sons Ltd, Shaftesbury Works, 45 Holloway Road, London). For children weighing > 12·0 kg, a portable adult balance was used (Weylux 424). Body length was measured using an infant measuring table with 1 mm minimum scale difference (Holtain Ltd, Crymych, Dyfed). Upper and lower body segment lengths were estimated from crown–heel and crown–rump (upper segment) length. Arm length, mid-upper-arm circumference, thigh, calf, and thoracic and head circumferences were also measured using a metal tape with 1 mm minimum scale difference (Harpenden anthropometric tape; Holtain). The mean of three measurements of subscapular and triceps skinfold thickness (using Holtain skinfold calipers) was used to estimate trunk and limb skinfold fat respectively.

Reference standards

Values for the weight and length of each child were referred to the World Health Organization (WHO; 1983) database and also expressed as standard deviation (SD) scores i.e. in terms of their standard difference from the mean weight and length (or weight-for-length) of a reference child of the same age and sex (WHO, 1983). Measurements were also used to estimate subcutaneous body fat using the geometric model of Dauncey *et al.* (1977), and also compared with the body composition of the 'reference infant' (Fomon, 1967). Length, weight and circumferential measurements are also compared with values for English (Tanner & Whitehouse, 1970; Freeman *et al.* 1995) and Indo-Mediterranean children (an inclusive anthropological term applied to inhabitants of the near East and the Indian subcontinent by Eveleth & Tanner, 1976). Other aspects of the methodology have

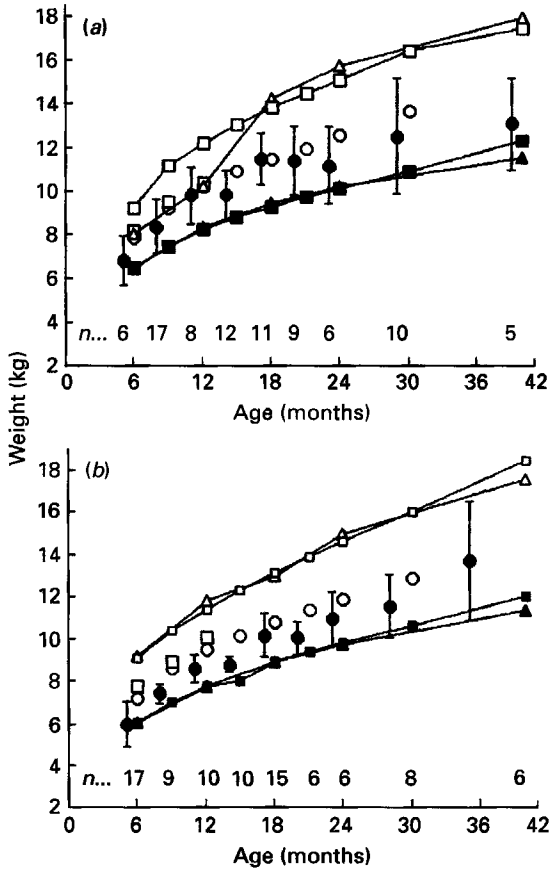

Fig. 1. Body weights of (a) Asian boys (n 82) and (b) Asian girls (n 87) aged 4–40 months living in Sheffield (●), compared with the World Health Organization (1983) reference mean (○), Sheffield reference data (R. G. Carpenter, unpublished results) (□), the 97th (—△—) and 3rd (—▲—) centiles of previous UK reference data (Tanner & Whitehouse, 1970) and the 97th (—□—) and 3rd (—■—) centiles of the current UK reference data (Freeman *et al.* 1995). Values from the present study are means with their standard deviations represented by vertical bars.

been described previously (Duggan *et al.* 1991, 1992). After approval of the study protocol by the Medical Ethics Committee of the Northern General Hospital, Sheffield, the study was carried out during the 12-month period February 1989 to January 1990.

RESULTS

Precision of measurement

The magnitude of interobserver error between LW was estimated by comparing replicated measurements on volunteers. The means, irrespective of units, of repeated observations by the three LW, i.e. full anthropometry on nine children, were compared. There was no significant difference between means and no evidence of systematic under- or over-measurement by any of the three observers. Interobserver variation in crown–heel length measurement (critical to nutritional assessment in terms of weight-for-body-length) on these children was separately compared and there was no significant systematic difference between observers. All weight measurements at home were double-checked and length

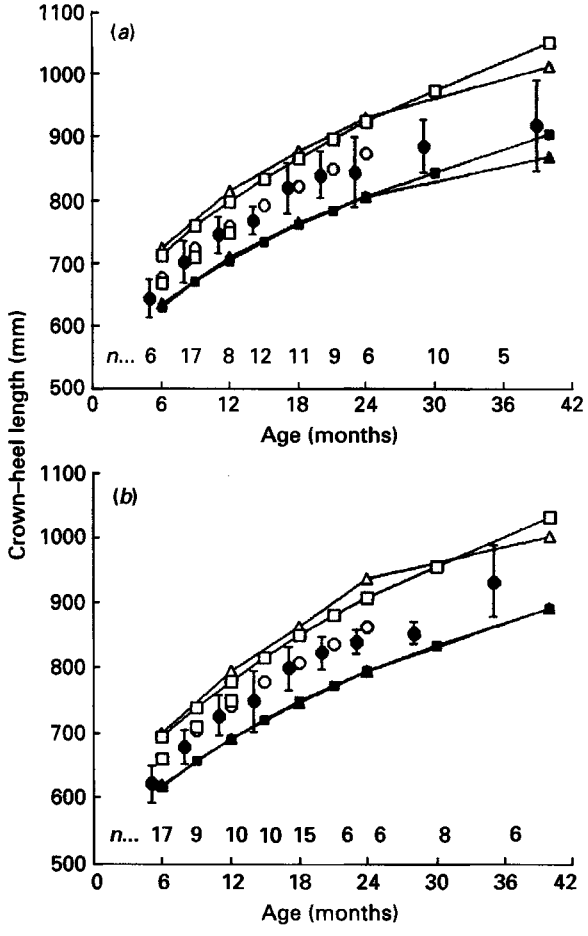

Fig. 2. Crown–heel lengths (mm) of (a) Asian boys (n 82) and (b) Asian girls (n 87) aged 4–40 months living in Sheffield (●), compared with the World Health Organization (1983) reference mean (○), Sheffield reference data (R. G. Carpenter, unpublished results) (□), the 97th (—△—) and 3rd (—▲—) centiles of previous UK reference data (Tanner & Whitehouse, 1970) and the 97th (—□—) and 3rd (—■—) centiles of the current UK reference data (Freeman *et al.* 1995). Values from the present study are means with their standard deviations represented by vertical bars.

measurements made by LW were rechecked opportunistically by the clinician. Paired crown–heel and crown–rump length measurements on forty-seven and forty children respectively which had been repeated by the clinician were compared by Student's t test and by Wilcoxon's paired signed rank test; there was no significant difference between measurements made by LW and the clinician.

The dietary intake and the biochemical Fe status (120 and 138 respectively) of these children have been separately reported (Duggan *et al.* 1991, 1992). The mean weight and length of the 169 children (eighty-seven girls and eighty-two boys) grouped according to age are illustrated in Tables 1 and 2 and compared (Figs. 1 and 2) with international and British reference values for the weight and length of boys and girls (Tanner & Whitehouse, 1970, 1978; WHO, 1983; Freeman *et al.* 1995) and with Sheffield data from R. G. Carpenter (unpublished results). Minor adjustment to allow for age difference between study and reference data has been made to these and all subsequent figures. Tables 1 and

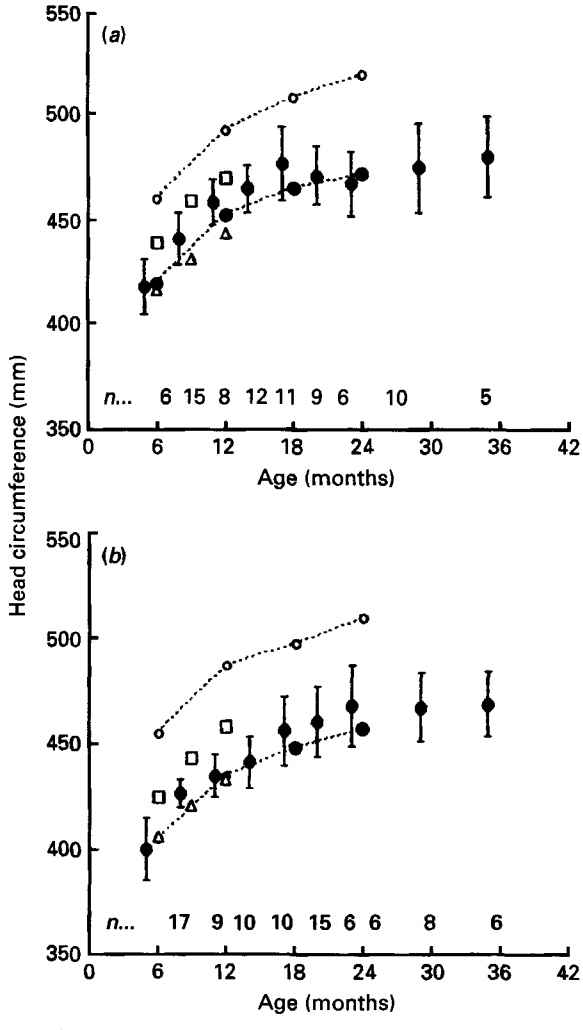

Fig. 3. Occipitofrontal circumference values (mm) for (a) Asian boys (n 82) and (b) Asian girls (n 87) aged 4–40 months living in Sheffield (●), compared with the 97th (--○--) and 3rd (--●--) centiles of previous UK reference data (Tanner & Whitehouse, 1970), Indian reference data (Eveleth & Tanner, 1976) (△) and Sheffield reference data (R. G. Carpenter, unpublished results) (□). Values from the present study are means with their standard deviations represented by vertical bars.

2 and Figs. 1 and 2 illustrate a trend, more marked with respect to weight increment, towards growth faltering in older boys and girls. When data from different age groups, expressed as SD scores (calculated using the simple WHO (1983) method and referring to the multi-ethnic WHO (1983) reference data) for weight- and length-for-age, were compared using Student's t test, the apparent trend for growth faltering proved to be insignificant. A trend for children to be relatively light for attained body length is evidenced by a significantly higher SD score for length-for-age than for weight-for-age (mean SD scores −0·3 (SE 0·092) and 0·0 (SE 0·084) for weight- and length-for-age respectively; t 4·1; $P < 0·001$; analysis of data on 169 pairs). The trend persisted when data on boys and girls were analysed separately.

Head circumference measurements are also illustrated in Tables 1 and 2 and in Fig. 3 in

Table 3. *Upper:lower body-segment values in 169 healthy young Asian children (eighty-two boys and eighty-seven girls)**

(Mean values and standard deviations)

Age group (months)		Crown–rump (mm)		Leg length (mm)		Body segment ratio	
		Boys	Girls	Boys	Girls	Boys	Girls
4–< 6	Mean	421	400	224	223	0·7	0·6
	SD	18	26	11	15	0·01	0·01
	n	6	17	6	17	6	17
6–< 9	Mean	448	433	246	254	0·6	0·6
	SD	26	20	15	16	0·02	0·02
	n	15	9	15	9	15	9
9–< 12	Mean	467	450	277	278	0·6	0·6
	SD	26	21	29	24	0·03	0·03
	n	8	10	8	10	8	10
12–< 15	Mean	481	461	286	288	0·6	0·6
	SD	17	29	23	21	0·02	0·02
	n	12	10	12	10	12	10
15–< 18	Mean	501	482	318	319	0·6	0·6
	SD	24	20	26	25	0·02	0·02
	n	11	15	11	15	11	15
18–< 21	Mean	496	497	335	347	0·6	0·6
	SD	33	25	8	37	0·01	0·02
	n	15	12	15	12	15	12
21–< 24	Mean	522	506	349	365	0·6	0·6
	SD	28	15	16	18	0·01	0·01
	n	10	8	10	8	10	8
⩾ 24	Mean	537	546	388	383	0·6	0·6
	SD	55	25	33	33	0·03	0·01
	n	5	6	5	6	5	6

* Body-segment length was estimated by difference, from crown–heel and crown–rump measurements.

which observations on boys and girls are separated for comparison with longitudinal data on English and Indian infants.

The upper and lower body-segment lengths and the relative body-segment ratio are illustrated separately for boys and girls in Table 3. A trend for male infants to have a comparatively longer upper body segment (greater sitting height ratio) than girls was not significant (Mann–Whitney *U* test). Upper (and lower) segment length values are compared with reference data on white British and Indian children in Fig. 4. Inspection of available data on body segment ratio suggests a close approximation to the relatively shorter legged white British than to the Indian child (Eveleth & Tanner, 1976).

Body size was further described by circumferential measurements of thorax, mid-upper arm, mid-thigh and mid-calf (Table 4). Visual comparison of mean values for these variables with available reference data on white British and Indo-Mediterranean children (Eveleth & Tanner, 1976) suggests that the thoracic circumference of the Sheffield Asian child lies midway between the UK reference and narrower Indian reference means. Visual comparison of the distribution of values for the mid-upper-arm circumference suggests that they lie midway between UK and Iraqi reference means. Mid-thigh circumference measurements are reported without reference to other studies, and mean mid-calf circumference lies close to the UK reference mean (Eveleth & Tanner, 1976).

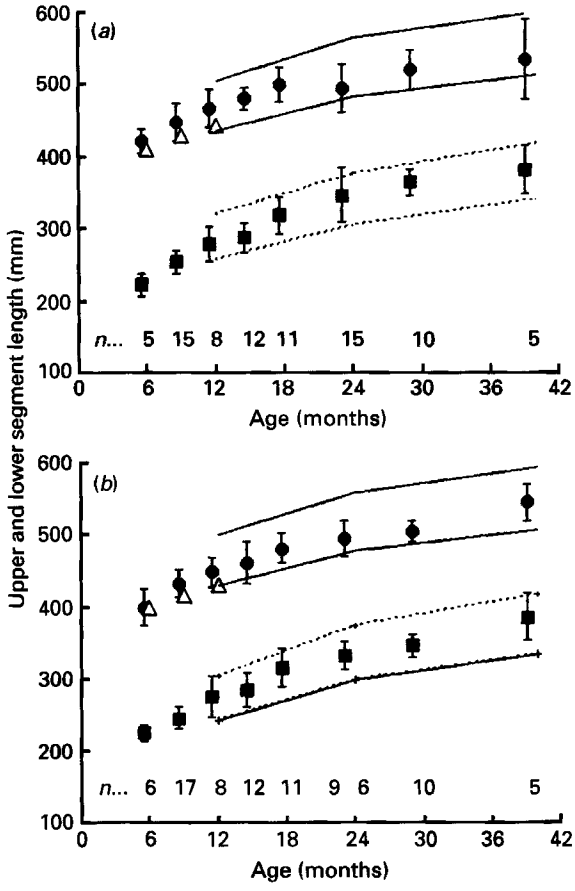

Fig. 4. Upper (●) and lower (■) body segment measurements (mm) estimated, by difference, from crown–heel and crown–rump measurements, for (a) Asian boys (n 82) and (b) Asian girls (n 87) aged 4–40 months living in Sheffield, compared with the 97th and 3rd centiles (——, upper segment; – – –, lower segment) of UK reference data (Tanner & Whitehouse, 1978) and with Indian reference data (Eveleth & Tanner, 1976) (△). Values from the present study are means with their standard deviations represented by vertical bars.

Visual comparison of mean triceps and subscapular skinfold thickness (illustrated in Table 5 and Figs. 5 and 6) with UK reference data (Tanner & Whitehouse, 1970) suggests that mean subscapular skinfold thickness lies close to the UK 25th centile whereas the mean triceps skinfold thickness lies closer to the UK 10th centile (Tanner & Whitehouse, 1970). Changes in body composition with increasing age were further studied using the geometrical model of Dauncey *et al.* (1977) to approximate the volume and thereby the weight of subcutaneous fat (Table 5). Our estimate of the percentage of body weight contributed by subcutaneous fat is similar to that reported for Cambridge children by Dauncey *et al.* (1977) and also to values for the 'reference male infant' which are based on a completely different calculation (Fomon, 1967). A trend for boys aged between 12 and 24 months to be plumper than girls (Table 5) proved to be statistically non-significant (analysis of unpaired data on the percentage of body weight due to subcutaneous fat using Wilcoxon's rank test).

Table 4. *Thorax, mid upper arm, mid thigh and mid calf circumference measurements (mm) for 169 healthy Asian children living in Sheffield (eighty-two boys and eighty-seven girls)*

(Mean values and standard deviations)

Age group (months)		Thorax		Mid upper arm		Mid thigh		Mid calf	
		Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
4–< 6	Mean	420	412	134	139	204	219	157	167
	SD	28	29	12	14	19	28	15	14
	n	17	6	17	6	17	6	17	6
6–< 9	Mean	440	451	136	147	222	236	170	171
	SD	12	28	10	19	18	24	13	20
	n	9	15	9	15	9	15	9	15
9–< 12	Mean	459	487	142	155	241	248	181	190
	SD	31	27	12	12	22	15	37	13
	n	10	8	10	8	10	8	10	8
12–< 15	Mean	467	483	138	147	213	250	163	183
	SD	32	41	15	12	23	30	14	21
	n	10	12	10	12	10	12	10	12
15–< 18	Mean	482	509	149	156	253	260	185	188
	SD	22	35	12	14	22	19	13	23
	n	15	11	15	11	15	11	15	11
18–< 21	Mean	477	481	144	155	247	261	178	188
	SD	16	20	7	16	21	27	13	10
	n	6	7	6	7	6	7	6	7
21–< 24	Mean	488	489	148	148	260	248	188	185
	SD	9	27	15	13	23	22	15	15
	n	6	9	6	9	6	9	6	9
24–< 30	Mean	485	520	147	157	250	274	183	200
	SD	18	40	9	17	20	43	16	27
	n	8	9	8	9	8	9	8	9
⩾ 30	Mean	493	502	150	154	269	266	194	187
	SD	32	20	11	15	31	20	16	20
	n	7	5	7	5	7	5	7	5

DISCUSSION

These results indicate that Asian boys and girls living in Sheffield follow closely international, national and local reference parameters for weight and length (WHO, 1983; Freeman *et al.* 1995; and R. G. Carpenter, unpublished results) although they appear to be relatively slight of build. Nevertheless, somatic (thoracic) circumference lies closer to the UK than to the Indian reference values whereas head circumference lies closer to Indian reference values.

These data are also of interest because they illustrate body size during early childhood of a recently migrated community. Available demographic data on the families indicate that the majority of parents were first-generation immigrants; 76% of men were born in Pakistan and 17 and 10% respectively born in Bangladesh or Britain; 72, 18 and 7% of women were born in the three respective countries. Husbands were older than wives and tended to have spent longer in Britain. The mean ages of 143 women and 123 men were 33·5 (SD 9·48) and 27·9 (SD 5·67) years (t 5·77, unpaired data); 78% men had lived in Britain for > 10 years compared with 31% women (data from 154 couples). Virtually all heads of households were men, and unions appeared in all cases to be formal marriages.

Table 5. *Adiposity of 169 healthy Asian children living in Sheffield (eighty-six girls and eighty boys*) as assessed by subscapular and triceps skinfold thicknesses (mm) and estimated total subcutaneous fat expressed as a percentage of total body weight†*

(Mean values and standard deviations)

Age group (months)		Subscapular skinfold (mm)		Triceps skinfold (mm)		Estimated total subcutaneous fat (% total body wt)	
		Girls	Boys	Girls	Boys	Girls	Boys
4–< 6	Mean	7·5	7·3	8·5	8·6	22·2	20·5
	SD	1·4	1·3	1·3	1·0	3·5	4·7
	n	17	6	17	6	17	6
6–< 9	Mean	7·2	8·1	7·9	8·5	18·4	20·1
	SD	1·8	2·7	2·2	3·2	6·0	7·0
	n	9	14	9	14	9	14
9–< 12	Mean	7·4	7·3	8·2	9·0	19·1	19·8
	SD	2·0	1·4	1·9	2·6	5·6	4·4
	n	10	8	10	8	10	8
12–< 15	Mean	6·2	7·5	6·9	8·3	14·7	18·9
	SD	1·4	2·1	1·7	1·9	4·5	4·9
	n	10	12	10	12	10	12
15–< 18	Mean	6·8	7·7	7·0	8·9	16·1	19·8
	SD	1·7	2·0	1·4	2·0	4·7	5·9
	n	15	11	15	11	15	11
18–< 21	Mean	7·1	6·9	7·6	7·9	18·2	17
	SD	1·6	1·4	1·3	2·1	4·8	3·7
	n	5	9	5	9	5	9
21–< 24	Mean	7·4	7·1	7·8	8·5	18·1	19·9
	SD	1·7	0·2	2·7	1·3	6·4	5·1
	n	6	6	6	6	6	6
24–< 30	Mean	6·1	7·5	8·6	9·1	16·8	20·1
	SD	1·7	0·1	2·6	1·8	5·3	3·2
	n	8	9	8	9	8	9
⩾ 30	Mean	6·7	6·9	8·0	9·4	16·6	19·7
	SD	1·3	0·2	1·3	2·2	3·1	6·1
	n	6	5	6	5	6	5

* Discordant number of observations explained by non-acceptance by children and parents of the skinfold calipers.

† Using the geometric model of Dauncey *et al.* (1977).

Consanguinity was almost universal. Nearly half (sixty of the 135 fathers who provided information) were unemployed and two thirds (66%) of mothers were functionally illiterate. The mean birth weight was 3·10 (SD 0·56) kg for girls and 3·19 (SD 0·61) kg for boys (data available for sixty-seven girls and seventy boys). Height measurement was permitted by eighty-three mothers and forty-one fathers. The mean values for maternal and paternal height, 1·562 (SD 0·0583) m and 1·651 (SD 0·0812) m respectively, are close to the reference mean height of Pakistanis (about 1·56 m and 1·68 m for women and men respectively; visual inspection of data from several studies cited by Eveleth & Tanner, 1976).

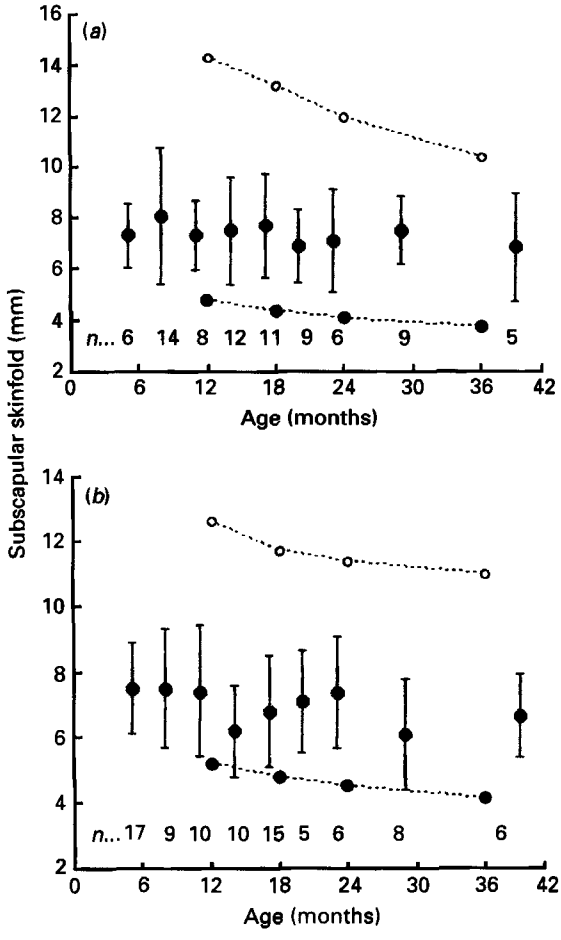

Fig. 5. Subscapular skinfold thickness values (mean of three measurements in each case) for (a) Asian boys (*n* 80) and (b) Asian girls (*n* 86) aged 4–40 months living in Sheffield (●), compared with the 97th (--○--) and 3rd (--●--) centiles of UK reference data (Tanner & Whitehouse, 1970). Values from the present study are means with their standard deviations represented by vertical bars.

Methodological problems

The general applicability of these findings depends on the degree to which the sample was representative of Asian children living in Sheffield. There were considerable methodological obstacles. First, the size of the study base was uncertain; second, it was difficult to anticipate the level of both recruitment and compliance. Extrapolation from the 1980 census data in which ethnic origin *in sensu strictu* had not been recorded (Bussue & Drew, 1988) resulted in estimates of 10000 and 1000 people born in Pakistan and Bangladesh respectively (i.e. exclusive of British-born Asians). Speculation about the probable demographic distribution resulted in an estimate of 500–600 children eligible by age and ethnicity. Inspection of birth records confirmed that 615 babies with 'Asian' names had been registered in Sheffield during a representative 18-month period. Noting that 80% of these names were concentrated in an area served by ten clinics we considered that targeting, with the intention of recruiting all eligible children registered at these clinics, was justified.

The 338 families with eligible children who were located and approached approximated

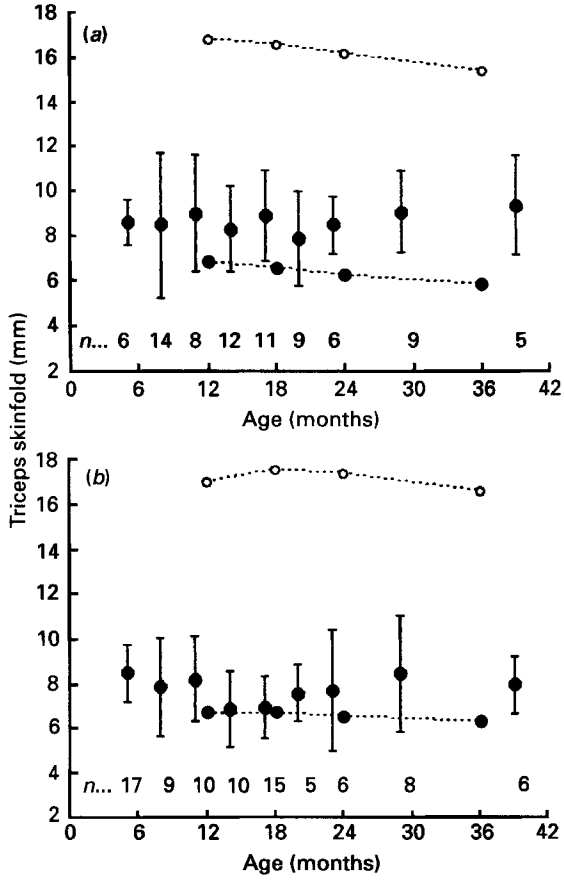

Fig. 6. Triceps skinfold thickness values (mean of three measurements in each case) for (a) Asian boys (n 80) and (b) Asian girls (n 86) aged 4–40 months living in Sheffield (●), compared with the 97th (--○--) and 3rd (—●—) centiles of UK reference data (Tanner & Whitehouse, 1970). Values from the present study are means with their standard deviations represented by vertical bars.

70% of the original estimate of 490 eligible children in the target area. Failure to recruit all eligible children was due to a number of factors: first, the imposition of age stratification; and second, difficulty in accessing potential subjects. After repeatedly finding no one at home in a number of eligible households, the family was assumed or reported to have moved away or to be visiting Pakistan. Half of the 338 families approached agreed to participate, often postponing agreement for further consultation with the family head. Thereafter 87% of the recruits (50% of those approached) complied with anthropometric measurement. A similar method of targeting ethnic minority children, i.e. by selection of electoral wards with a high proportion of inhabitants born in the New Commonwealth, continent of Asia, was employed by Rona & Chinn (1986). By targeting the inner city, however, we inevitably excluded middle-class families.

Standard methods of random sampling (relatively straightforward for studying schoolchildren; Rona & Chinn, 1986) would clearly have been impossible, and recruitment by letter or telephone was not feasible. Adverse factors included a high rate of functional illiteracy, scarcity of telephones, inaccessibility by public transport, protracted overseas visits and requests by health visitors that certain vulnerable families be excluded. Within

these constraints, and aware of a possible bias towards the exclusion of both vulnerable and better-off children, we regard the sample as reasonably representative of Asian children living in Sheffield.

Compliance, which is known to be affected by sociocultural factors, was higher for anthropometry than for blood sampling or the weighed dietary inventory (Duggan *et al.* 1991, 1992), although a few children refused to sit in the basket scales. For the few who weighed more than their range, weight was estimated directly (or by difference from the combined weight of mother and baby) on an adult balance. No estimate of subcutaneous fat mass is available for the three children who objected to the application of skin calipers. Continual processing of anthropometric data, to calculate SD scores, facilitated the identification and rechecking of outlying readings.

Allowance had been made, in constructing figures, for the inevitable differences between cross-sectional and (mixed) longitudinal and cross-sectional measurements. With this proviso, the length and weight attained by these children appear to be in reasonable accord with WHO, UK and Sheffield reference values. The data have recently been referred to the large body of cross-sectional data on which new stature and weight reference curves will be based (Freeman *et al.* 1995; T. J. Cole, personal communication). The Asian data were seen to lie largely within the normal range of both old and new UK reference standards, and of a recent Sheffield data set (R. G. Carpenter, unpublished results). They are also comparable with growth patterns of north Indian children (unpublished results on 'well-off' Delhi children attributed to Banik, and cited by Eveleth & Tanner, 1976). British Asian schoolchildren (Rona & Chinn, 1986) had been noted to be close in height to 'well-off' Indians, i.e. taller than a general Indian reference group.

The study protocol did not include a Caucasian 'control' group. In the first place, international and local experience indicates that differences in body size will, at this age, be better explained by health and socioeconomic factors than by ethnic variation (Eveleth & Tanner, 1976; Warrington & Storey, 1988). Second, it would have been impossible to control for confounding variables such as family structure, sibling number, and sensitive factors such as consanguinity.

In comparison with international and British reference data (WHO, 1983; Tanner & Whitehouse, 1970; Freeman *et al.* 1995), Asian children living in Sheffield appeared to be light for attained body length. In a climate which tends to stereotype ethnic attitudes to childrearing we noted no influence of sex on SD scores for weight- and length-for-age. Comparison of birth-weight records with the measured weights of infants < 6 months of age suggests a satisfactory early rate of weight gain. The low prevalence of stunting in older toddlers is also an indirect indicator of good nutrition and health during infancy.

It was of interest to consider the possibility of ethnic variation in less frequently compared variables such as head circumference, body segment ratio and skinfold thickness. Ethnic variation in body proportions (Martorell *et al.* 1988) and in the range and distribution of body fat has been observed in older, but not in younger, American children (Flynn *et al.* 1970). The distribution of values for several variables was compared with available reference data on UK (white) and Indo-Mediterranean children, using measurements on ('well-off') North Indian and Iraqi children (Eveleth & Tanner, 1976) in the absence of data from Pakistan or Bangladesh. Mean head circumference, especially in girls < 12 months, appeared to be closer to reference mean values for Indian than English infants (Eveleth & Tanner, 1976; R. G. Carpenter, unpublished results) although the mean values for both sexes (in the 6–24 month age range were close to the 10th centile of the Gairdner & Pearson (1988) standards (which are based on longitudinal data). By contrast, values for upper and lower body-segment length and ratio appear to be closer to white British than to Indo-Mediterranean reference values (Eveleth & Tanner, 1976). A recent

secular trend towards longer legs is recognized in white UK children (J. Wales, personal communication).

The slender habitus of the children in comparison with the 1970 UK reference data is evidenced by the relatively small thoracic circumference and lower mean values for circumferential measurements of mid-upper arm and calf respectively. However, Asian children living in Sheffield appeared to be more stocky in body than Indo-Mediterranean infants (Eveleth & Tanner, 1976), but with similar values for mid-upper arm circumference (Shakir, 1975).

There is little information on the adiposity of very young children. The triceps and subscapular skinfold measurements are in reasonable agreement with available reference data (Eveleth & Tanner, 1976; Dauncey *et al.* 1977). Two trends are of interest. First, inspection of data on subscapular and triceps skinfold thickness (Figs. 5 and 6) suggests that Asian boys and girls may have plumper bodies and more slender limbs than UK reference children. Second, similar comparison of measurements of skinfold thickness and estimates of adiposity suggests that whereas UK white girls are plumper than boys (Eveleth & Tanner, 1976; Dauncey *et al.* 1977). Asian boys in Sheffield are plumper than girls. This non-significant trend towards a sex effect was not (see above) supported by analysis of weight-for-length SD scores.

To what extent might family migration have affected the body size and shape of these children? In many cases migration is associated with an increase in size of the genetic pool but there is evidence (Modell & Kuliev, 1992) that a high level of consanguinity persists in Punjabi (Mirpuri) immigrants to Britain. The rural–urban migration implicit in moving to Sheffield directly from Pakistan or Bangladesh is associated with the acquisition of urban benefits likely to offer an indirect nutritional advantage, for example primary child health services and clean water supply. (The possible influence of dietary, demographic and socioeconomic change is to be addressed separately.) The majority of these children would be classified in UK as socially disadvantaged; nevertheless, their length and weight appear to be closer to those of 'well-off' than 'poor' Indian children. They have longer legs than their Indian peers, and sturdier chests, but there appears to be no effect of migration on head size.

The appropriateness of referring measurements made on individuals from an ethnic minority to reference growth charts based on a different (majority) ethnic group remains a matter for debate. Powerful arguments in favour of the development of reference charts appropriate to an ethnic group or a defined subpopulation have been offered by Goldstein & Tanner (1986) and by van Loon *et al.* (1986). On the other hand the present data and those of Warrington & Storey (1988), indicate that the vast majority of healthy Asian toddlers would, in practice, be well served by local and/or national growth charts. The observation by Rona & Chinn (1986) that the mean heights of both inner city white and Asian schoolchildren lay below the fiftieth but above the tenth centile of the reference sample tends to support this conclusion.

Furthermore, even when the use of centile charts based on an elite group or 'imported' standards is inappropriate, the rate of growth is capable of comparison with that of a reference group (Goldstein & Tanner, 1986). By this token we observe that although our results support the suggestion (Eveleth & Tanner, 1976) that Asian infants have a smaller head circumference than Europeans, the pattern of increment in head circumference with age is sufficiently close to local standards for these to be used in the evaluation of both boys and girls.

In summary these children appear to follow reference patterns of weight gain and linear growth. They are slighter of habitus with smaller heads during infancy than English babies. Nevertheless we conclude that their growth and nutritional status can be evaluated using

standard UK growth charts, including the recently published cross-sectional stature and weight reference curves for the UK (Freeman *et al.* 1995). Finally if present marriage patterns persist into the next generation, there may be an opportunity to assess how far secular trends in growth, in a community which has migrated, may be explained by dietary changes alone.

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