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Child undernutrition in affluent societies: what are we talking about?

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In this paper we set out to explore the prevalence of child undernutrition found in community studies in affluent societies, but a preliminary literature review revealed that, in the absence of a gold standard method of diagnosis, the prevalence largely depends on the measure, threshold and the growth reference used, as well as age. We thus go on to explore describe the common clinical 'syndromes' of child undernutrition: wasting, stunting and failure to thrive (weight faltering) and how we have used data from two population-based cohort studies, this paper to explore how much these different 'syndromes' overlap and the extent to which they reflect true undernutrition. This analysis revealed that when more than one definition is applied to the same children, a majority are below the lower threshold for only one measure. However, those with both weight faltering and low BMI in infancy, go on in later childhood to show growth and body composition patterns suggestive of previous undernutrition. In older children there is even less overlap and most children with either wasting or low fat seem to be simply growing at one extreme of the normal range. We conclude that in affluent societies the diagnosis of undernutrition is only robust when it relies on a combination of both, that is decline in weight or BMI centile and wasting.

Undernutrition: Malnutrition: Wasting: Stunting: Failure to thrive

Undernutrition is an intrinsic hazard in pre-school children in all cultures because infants have such high-nutrient requirements due to high rates of morbidity, requirements for growth, relatively inefficient metabolism and dependence on adults for all food. Worldwide, undernutrition has been clearly linked to a substantial increased risk of mortality and morbidity[1] as well as long-term stunting[2] and probably also has metabolic effects stretching into adulthood[3,4]. Thus undernutrition in childhood is clearly an important risk factor. However, what is less clear is how common it actually is in more affluent societies and what causes it in those settings.

Systematic review of the prevalence of undernutrition in affluent societies

We undertook a systematic review of the literature on the recent prevalence of undernutrition in developed societies, searching Medline, Ovid and/or Web of Knowledge for studies published between 2000 and 2011. Countries listed as having a very high human development index as defined by the UN[5] were considered as 'developed or affluent societies'. Studies were included if published in English and if they included prevalence rates and data collection methodology. Keywords used for the search were: children, childhood, malnutrition, undernutrition, thinness, underweight, wasting, stunting, weight faltering, failure to thrive, thinness, growth failure, affluent, developed, prevalence rates, WHO growth charts, low BMI, weight for height, height for age, weight for length, low height and low weight.

The difficulty of carrying out such a study is that there is so much variation between the measures described, the age range covered and the growth reference and thresholds used. However, in recent years several papers have looked specifically at the fit of different populations to the WHO growth standard, whereas others have examined the

Abbreviations: ALSPAC, Avon Longitudinal Study in Pregnancy and Childhood; GMS, Gateshead Millennium Study; IOTF, International Obesity Force.
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prevalence of different International Obesity Task Force (IOTF) BMI categories. Twelve studies were suitable for comparison and were included in the review. The main characteristics of all these studies are described in Table 1. Generally, the prevalence found is dictated by the threshold chosen, so that when the second percentile (−2 SD) is chosen the prevalence of wasting and stunting tends to be in the range of 1–4% and higher when less stringent thresholds such as the fifth percentile are used. It is to be noted that the IOTF thinness threshold tends to generate quite a low prevalence in young children, but these rise substantially into the teens. However, all these thresholds merely identify children as being at the bottom end of the normal range for that measure. What is not clear is the extent to which children below these thresholds are truly undernourished.

How should undernutrition be defined?

One can specify a unifying definition of undernutrition along the same lines as that of obesity, i.e. that the condition represents a net energy deficit, with or without other nutrient deficiencies, but the manifestations of that deficit will vary depending on severity, duration and age of onset. Thus, there can probably never be a single gold standard method of diagnosing childhood undernutrition. Instead, a wide range of different measures and thresholds are used pragmatically, depending on the underlying prevalence of malnutrition in that setting and what can be measured robustly. The result is that there are a range of undernutrition 'syndromes' (Fig. 1) which differ, but can be indicative of undernutrition. The best known of these syndromes – marasmus, nutritional stunting and kwashiorkor – are described predominantly in the developing world; however, failure to thrive, now more appropriately called weight faltering can also be added to this list, which is more commonly described in affluent societies. Each of these syndromes depends on different measures and thresholds. Clearly, these different syndromes are not describing the same clinical condition, but all of them are measuring different potential manifestations of undernutrition (Fig. 1).

Wasting

In recent years, there has been increasing encouragement, particularly from the WHO[6] to use BMI, or weight for height to identify wasting, as the measure most likely to identify children with critically reduced stores who are therefore the most vulnerable. This is a sound approach when seeking to identify acute malnutrition and is likely to be quite specific where the prevalence of undernutrition is high. However, BMI has been less used in more affluent countries until recently, and very little is known about the diagnostic yield of a low BMI or its clinical significance in more affluent settings. One study in Denmark[7] generally found a low concurrence between measures of wasting (BMI below fifth percentile and weight for height less than 80%) and other possible measures of undernutrition. In particular, the Waterlow weight for height criterion tended to identify relatively tall children, suggesting that this particular definition is not at all specific for undernutrition in more affluent communities.

Stunting

Stunting, usually defined simply as low height for age, is also an important measure of nutritional status in undernourished populations. However, it would seem likely that in more affluent communities with a low prevalence of undernutrition, low height would be more likely to reflect constitutional factors or organic disease, rather than low nutrition. Again, this has been little studied; substantial social class gradients for height in UK school children, which are usually presumed to reflect chronic undernutrition, have been described, persisting at least until the 1990s[8,9], but one study of short stature found only limited evidence to suggest nutritional stunting; short children were more likely to be socially deprived, but the socially deprived short children were smaller at birth and had shorter parents[10].

Failure to thrive/weight faltering

In clinical practice in more affluent communities, undernutrition is most commonly identified in younger children via the observation of a slow weight gain pattern, often called 'failure to thrive'. This term has been in use for many years, but with great variability in how it is defined and understood[11]. Many early studies defined it simply on the basis of being or falling below a low centile line. However, this method tends to over-select infants with low birth weight, rather than poor postnatal weight gain. Identifying children on the basis of a fall down the centile chart ('weight faltering' or 'centile crossing'), although more logical, has the limitation that it tends to over-identify large infants, who are merely regressing down towards the mean[7]. In a research context, regression to the mean can be allowed by using conditional weight gain, where a change in SD scores is adjusted for the baseline centile position[12,13].

We have now gathered a substantial body of evidence about the significance of weight faltering identified in this way, with most research done on children in the slowest gaining 5% of various representative populations compared with their birth centile[14–16]. Although only 5% of children, by definition, will drop below this threshold at any one measurement point, about 10% will make a fall of this size at some time in the first year, but only about 5% will show a fall of this size sustained over a number of measurements[15]. The slowest gaining 5% roughly equates to a fall through two centile spaces (1·33 SD) on the UK 1990 growth reference. This chart-based approach can also be adjusted for regression to the mean by applying a different threshold to very large and small children. However, when UK children are compared with the new WHO growth standard, the prevalence of downward centile shifting is much lower, apart from the period immediately after birth[17]. Owing to this mismatch at birth, only the postnatal WHO standard (from age of 2 weeks) was

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Table 1. Evidence in literature about prevalence in affluent countries of different undernutrition indicators

Citation	Location	Growth reference	Threshold used	Ages included (years)	Prevalence found (%)	Variation with age and era
Weight						
De Onis *et al.*[43]	Twenty-first developed countries	WHO	Second*	0–5	1·6 (95% CI 0·8, 3)	
Juliusson *et al.*[44]	Belgium and Sweden	WHO	Second	0–5	0·6	
Wright *et al.*[17]	UK	WHO UK	Second	0–5	0·6–3·6	WHO falls with age. UK stable
					1·8–2·9	
Mei *et al.*[45]	USA	WHO	Second	0–5	1·3–5	Falls with age using both
		US CDC	Fifth			
Length						
De Onis *et al.*[46]	Thirty developed countries	WHO	Second	0–5	6·0 (95% CI 4·1, 8·8)	
Juliusson *et al.*[44]	Belgium and Sweden	WHO	Second	0–5	1·2–1·4	
Mei *et al.*[45]	USA	WHO	Second	0–5	3·9	Falls with age using both
		US CDC	Fifth		3·7	
BMI						
Wang *et al.*[47]		US NHANES	Fifth		3–3·6	
Rolland-Cachera *et al.*[48]	France	US NHANES	Fifth	7–9	3–11	Increased 2–3-fold with age
		US CDC			4–8	
		French			2–6	
Matusik *et al.*[49]	Poland	Polish	Tenth	7–9	6·9	
		French	Third		2·6	
		US CDC	Fifth		4·2	
		IOTF	Thinness†		0	
Vuorela *et al.*[50]	Finland	IOTF	Thinness	2 and 5	1–2·8	
Lissner *et al.*[51]	Sweden	IOTF	Thinness	10–11	5–12	Varied by 4% between cities
Antal *et al.*[52]	Hungary	IOTF	Thinness	7–14	5·9	
		% fat (BIA)	5% M, 10% F		6·7	
Lazzeri *et al.*[53]	Italy	IOTF	Thinness	9	4·6–4·2	Decline in prevalence over years, 2002/4–6
				11	11–10	
				13	9·8–8	
				15	8·8–8·7	
WFH						
Savva *et al.*[54]	Cyprus	US NCHS 1978	Second	2–6	2·8	
Mei *et al.*[45]		WHO	Second	0–5	0·6	Slight fall with age using both
		US CDC	Fifth		3·4	

BIA, bioelectrical impedance analysis; CDC, Centre for Communicable Diseases 2000; IOTF, International Obesity Task Force 2000; NCHS, National Centre for Health Statistics 1978; NHANES, National Health and Nutrition Examination Survey 1991; UK 1990; WFH, weight for height.
*Second percentile assumed to correspond to −2 SD.
†Roughly corresponds to −2 SD in pooled reference data.

Table 2. Prevalence and concurrence of different definitions used in Gateshead Millennium Study (GMS) and Avon Longitudinal Study in Pregnancy and Childhood (ALSPAC) cohorts

		GMS				ALSPAC			
		13 months		8 years		7 years		11 years	
Measure	Definition	%	*n*	%	*n*	%	*n*	%	*n*
Wasting	BMI < −2 SD UK–WHO growth standard	0·6	5	1·3	8	1·3	99	2·0	144
	BMI < −1·33 SD UK–WHO growth standard	3·8	33						
Stunting	Length/height < −2 SD UK–WHO growth standard	0·7	6	1·7	10	1·2	93	0·7	53
	Length/height < −1·33 SD UK–WHO growth standard	4·5	38						
Sustained weight faltering	Slowest 5% conditional weight on gain since birth (internally standardised) on more than two occasions in first year[15].	6·0	51						
BMI fall	Fifth centile for change in BMI SD between 7 and 11 years (internally standardised)							5	303
				Mean	SD	Mean	SD	Mean	SD
Lean Z-score	Lean mass measured by bio electrical impedance adjusted for height age and gender[42]			−0·16	1·00	0·00	0·93	0·03	1·05
Fat Z-score	Fat Z-score mass measured by bio electrical impedance adjusted for height age and gender[42]			0·49	0·74	−0·01	0·86	−0·04	1·11
Adiposity index	Summary of Z-score for skinfolds, waist and fat[39]			−0·10	2·0				
				%	*n*	%	*n*	%	*n*
Low fat	Fifth centile fat Z-score (internally standardised)					5·0	386	5·0	363
Low lean	Fifth centile lean Z-score (internally standardised)					5·1	391	5·0	363

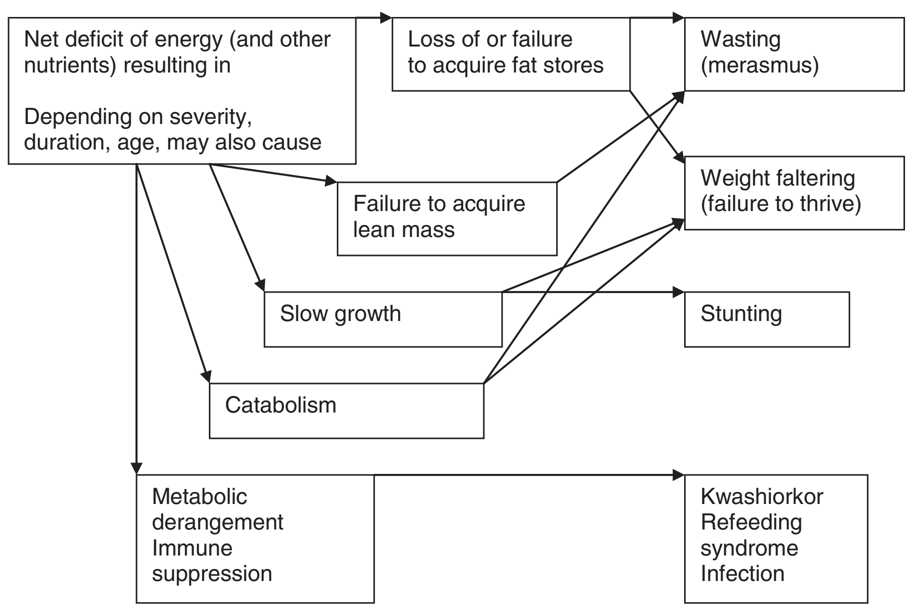

Fig. 1. Impact of undernutrition on growth and resulting undernutrition 'syndromes'.

actually implemented in the UK,[18] but the prevalence of weight faltering from birth when compared with the UK-WHO standard has not yet been described.

There is considerable evidence to suggest that weight faltering does reflect some degree of undernutrition. We have found moderate evidence of reduced dietary intake in children in the slowest gaining 5% [19–21]. Weight faltering infants show their slowest weight gain pattern in the early weeks of life, with a slower recovery pattern after the age of a year[22], suggesting that this was not a natural growth trajectory. In our trial of primary care-based intervention those children receiving the intervention showed more catch up in weight and were also taller when followed-up at age four, further suggesting that some of the children had reversible nutritional stunting[22]. What is less clear is why these children are undernourished. A consistent finding in various cohorts has been a lack of association of weight faltering with deprivation [15,23,24]. Although weight

Table 3. Prevalence of downward centile crossing from birth to ages 4, 8 and 12 months in Gateshead Millennium cohort, compared with UK–WHO growth standard, broken down by centile position at birth

	Centile at birth					
	Below ninth		Ninth to ninety-first		Above ninety-first	
	n	%	*n*	%	*n*	%
Birth to 4 months						
Crossing at least						
One centile	3	2·9	114	18·2	45	69·2
Two centiles	2	1·9	19	3·0	24	36·9
Three centiles	1	1·0	4	0·6	8	12·3
Total	105		626		65	
Birth to 8 months						
Crossing at least						
One centile	0		41	8·6	33	60·0
Two centiles	0		8	1·7	12	21·8
Three centiles	0		1	0·2	6	10·9
Total	71		475		55	
Birth to 12 months						
Crossing at least						
One centile	0		49	8·0	30	47·6
Two centiles	0		12	1·9	12	19·0
Three centiles	0		1	0·2	6	9·5
Total	95		616		63	

faltering is very likely to be a manifestation of poverty in poorer societies, the lack of association in the UK will reflect the British welfare system that particularly assists families with young children. There is some association with abuse and neglect, but it is important to realise that this is still seen only in a minority of weight faltering children[25,26]. Similarly, only between 5 and 10% will have any symptoms or signs of underlying disease[14]. Some evidence of differences in maternal feeding behaviour and appetite and eating behaviour as well as decreased energy intake at meals[31] have been found in the infant[27–30]. Thus, the majority of children showing a weight faltering pattern have no observable disease or evidence of neglect. Although this may reflect an inherently low appetite, another possible explanation for this is that not all these children are in fact undernourished.

The many possible anthropometric indicators of undernutrition are selected simply on the basis that they are at the bottom end of the normal range for that characteristic, so all are likely to be non-specific. However, if a child truly is undernourished one would expect that more than one of these indicators would be low. Olsen *et al.*[7] proposed that infants with both wasting and weight faltering were most likely to be truly undernourished, but she was not able to test the validity of this in individual infants or in older children.

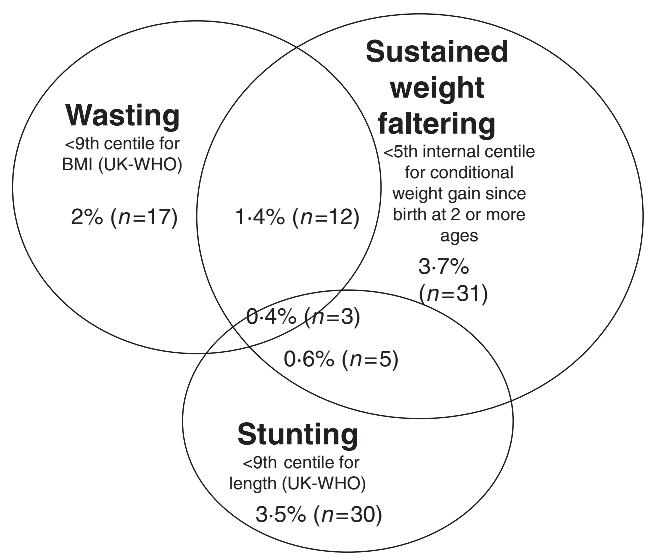

Fig. 2. Concurrence of wasting, weight faltering and stunting in infancy (Gateshead Millennium Study, GMS) cohort.

Aims

We therefore set out to define the true recent prevalence of undernutrition in infancy and childhood in the UK by using two existing UK datasets in order to describe: The prevalence of weight faltering (centile crossing) in UK infants when compared with the combined UK–WHO growth standard; The prevalence of overlap between different anthropometric indicators of undernutrition; The characteristics in later childhood of infants with one or more different anthropometric indicators of undernutrition.

Data from the Gateshead Millennium Study (GMS) were used to examine the prevalence of weight faltering in infancy, its concurrence with wasting and stunting and the growth and anthropometric outcome for children meeting these different definitions at age 8 years. Data from the Avon Longitudinal Study in Pregnancy and Childhood (ALSPAC) were then used to examine the concurrence of wasting and stunting with body fat in mid childhood.

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Table 4. Growth and body composition outcomes at age 8 years for children with wasting and weight faltering at age 13 months (all values apart from adiposity score are SD scores adjusted for age and gender)

	No wasting, weight faltering or stunting			Stunting only			Wasting only			Weight faltering only			Weight faltering plus wasting†		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Weight	0·53	1·08	495	−0·94***	−1·20	24	−0·55***	0·87	14	−0·36***	0·93	21	−1·52***	1·29	5
BMI	0·52	1·09	495	0·03*	1·08	24	−0·55***	0·93	14	−0·09*	0·84	21	−1·52***	1·50	5
Adiposity score	−0·08	2·09	384	0·31	1·51	18	−1·00	1·81	14	−0·28	1·17	15	−1·23	2·05	3
Lean mass (BIA)	−0·11	0·98	494	−0·34	1·14	23	−0·74*	1·09	14	−0·40	0·76	21	−1·57**	1·04	5
Height	0·27	0·98	497	−1·52***	0·72	24	−0·31*	0·96	14	−0·49***	0·85	21	−0·86**	0·66	5
Mid-parental height‡	−0·01	0·78	466	−1·00***	0·74	20	−0·28	1·00	13	−0·56**	0·85	18	−0·15	1·17	5

BIA bioelectrical impedance.
***$P<0·001$; *$P<0·01$; ** t-test compared to those with no wasting, weight faltering or stunting.
†One case with all three characteristics: Wt −2·39, BMI −2·5, adiposity −1·98, lean −2·4, height −1·07, mid-parental Z-score −1·17.
‡Mean of maternal and paternal height SD score.

Data sets used in the analysis

The Gateshead Millennium Study

The GMS birth cohort was established to examine infant eating behaviour prospectively and relate this to subsequent growth and weight gain[32]. The study aimed to recruit all babies shortly after birth to Gateshead resident mothers in pre-specified recruiting weeks between June 1999 and May 2000. We successfully recruited 1029 babies, 81 % of those eligible. Baseline socio-demographic data were collected in the first interview and this was followed by four postal questionnaires in the first year (6 weeks, 4, 8 and 12 months) and a health check at age 13 months, where research nurses measured weight and length and collected parental heights and weights also. At age 8 years anthropometry, bioelectrical impedance and skinfolds were performed on approximately 600 children. All measures were collected by the research staff[32]. Ethical approval for all phases of the study was granted by Gateshead and South Tyneside Local Research Ethics Committee.

The Avon Longitudinal Study in Pregnancy and Childhood

ALSPAC[33] is a prospective study of 14 541 pregnancies resulting in 13 988 children alive at one year. Women were enrolled on the basis of an expected date of delivery between 1 April 1991 and 31 December 1992, and place of residence within three health districts of the former county of Avon, UK. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee and Local Research Ethics Committees. For this analysis, we drew on anthropometry and bioelectrical impedance data collected between the ages of 7 and 11 years, which were available for about 7000 children at both age points[34].

Analytical methods

All the growth and body composition data were expressed as SD scores compared with external standards when available or internally standardised (Table 2). Height/length, weight and BMI were compared with the combined UK–WHO standard, which comprises the WHO standard from age 2 weeks to 4 years[35] and the UK 1990 reference at birth[36] and from 4 to 20 years[37,38]. In the GMS cohort the influence of initial centile was explored by categorising birth weight into those below the ninth centile ($< -1·33$ SD), above ninety first ($> +1·33$ SD) and the remainder (ninth–ninety-first centile). Centile crossing was explored by calculating the number of children dropping by one (0·67 SD) or more centile spaces between birth and 4, 8 or 12 months. In infancy the overlap between low measures was explored the using the ninth centile ($-1·33$ SD) for length and BMI, as few children were below the second centile. At age 8 years an Adiposity Index was generated for each child based on a factor analysis of all the available adiposity measures (bioelectrical impedance analysis skinfolds and waist)[39]. In the ALSPAC cohort BMI fall was identified by calculating individual change in BMI Z-score

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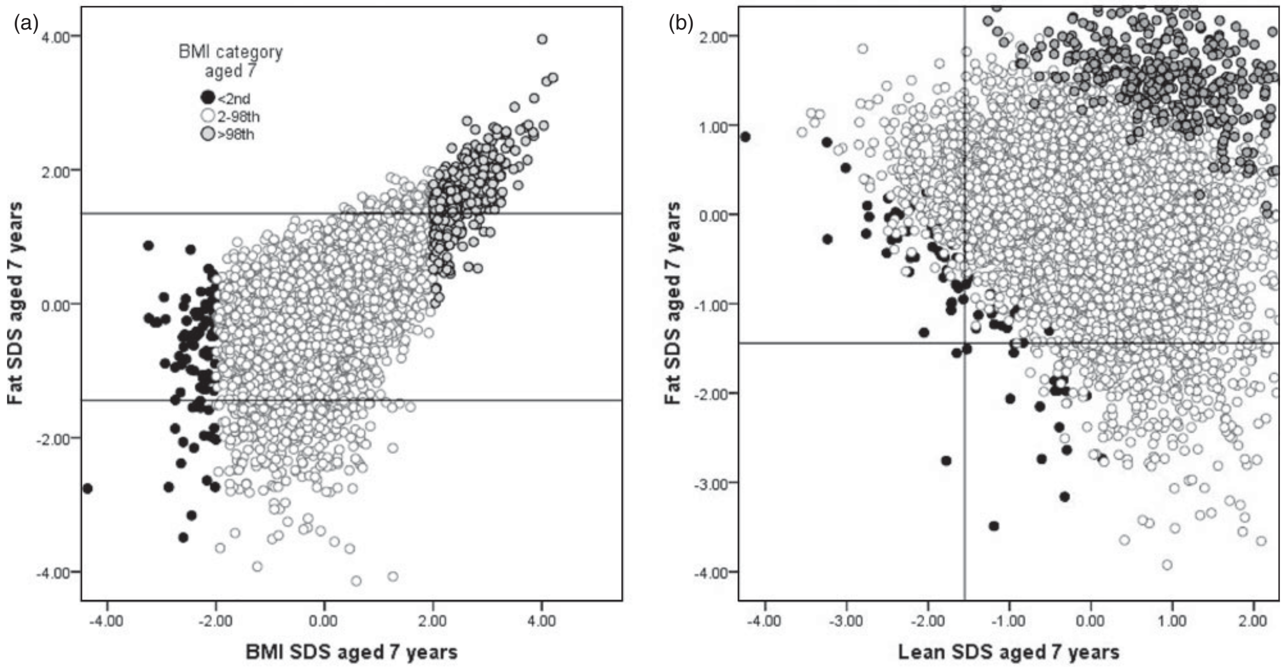

Fig. 3. Scatter plots at age 7 years (ALSPAC cohort) of (a) BMI Z-score (SDS) against fat Z-score and (b) lean Z-score against fat Z-score; filled black dots = BMI below second percentile, clear dots = 2nd–98th percentile, grey-filled dot = BMI above 98th percentile.

between ages 7 and 11 years and then identifying the lowest fifth percentile for that change.

Results

Prevalence and concurrence of different definitions in Infancy

In the GMS cohort the prevalence of centile crossing compared with the UK–WHO growth standard is shown in Table 3. As expected, rates are much higher in those infants who were initially large. Only between 1·7 and 3 % of initially average children crossed two centile spaces (1·33 SD) compared with about 5 % when compared with the UK 1990 reference (Table 3).

Over the first year sustained weight faltering was seen in 6 %; the prevalence of wasting or stunting at age 13 months (BMI or length below the second centile compared with the WHO standard) was low, with only five children (0·6 %) being wasted and six stunted (0·7 %). None were both wasted and stunted, but a substantial proportion (4/5 of the wasted children; 3/6 of the stunted children) had also shown sustained weight faltering. There were 3·8 and 4·5 %, respectively with BMI or height below ninth centile (−1·33 SD). The overlap between weight faltering and those with BMI or length below ninth centile is shown in Fig. 2. Although about two-thirds in each group showed that characteristic in isolation, children with low BMI showed a 6–7-fold increased risk of weight faltering compared with those without (30 % *v.* 4·5 %), whereas children with length less than ninth centile had a nearly 5-fold increased risk of weight faltering (20 % *v.* 4·7 %).

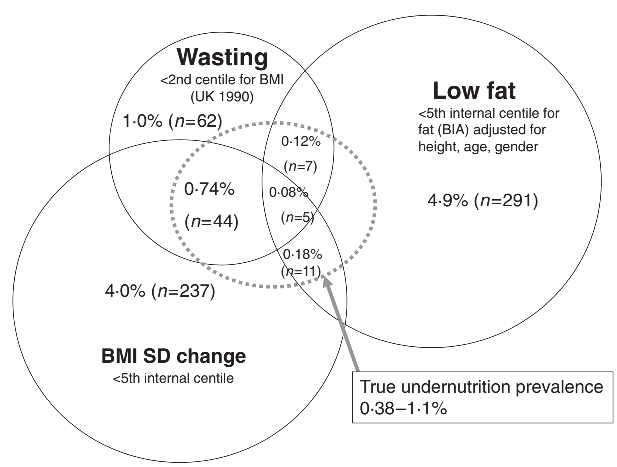

Fig. 4. Concurrence of low BMI and fall in BMI with low body fat at age 11 years (ALSPAC cohort). Percentages are as a proportion of all children measured. BIA, bioelectrical analysis.

Characteristics in later childhood of infants with one or more indicators of undernutrition

We examined the growth and body composition characteristics of children who had been below one or more of these thresholds in infancy at age 8 years (Table 4). Children with low BMI in infancy but without low length or weight faltering had anthropometry well within the normal range at age 8 years, but did have relatively low adiposity and lean mass. Children who showed weight faltering only had both adiposity and lean mass close to average; their mean height Z-score was significantly lower, but close to their mid-parental Z-score. In contrast, the few children who had shown both weight faltering and wasting had

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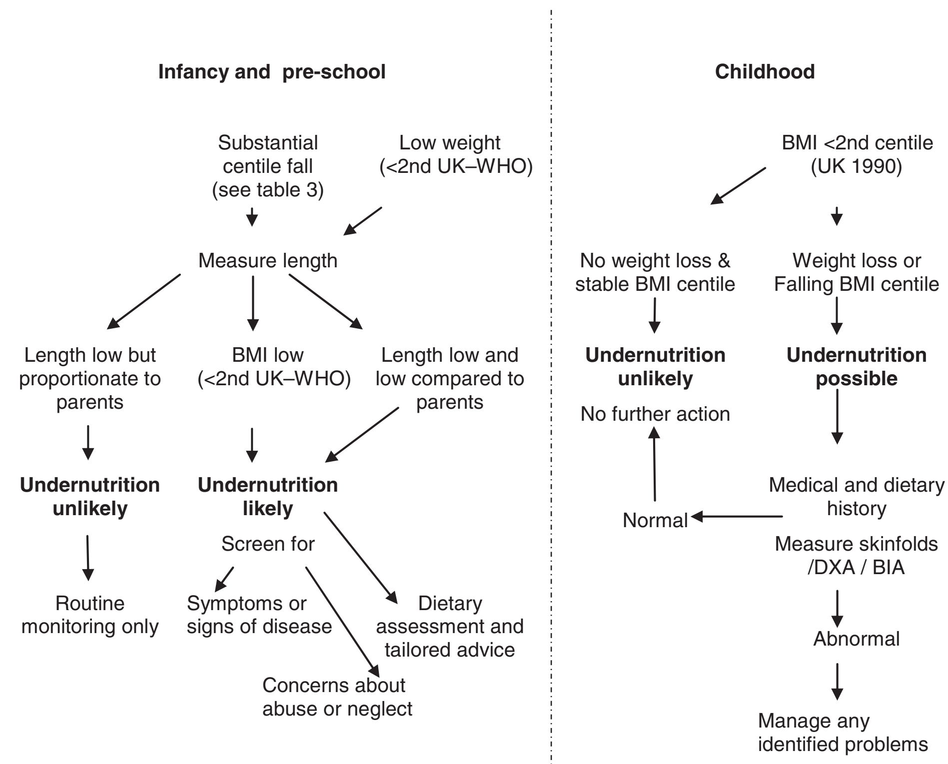

Fig. 5. Proposed algorithms for identification and assessment of possible undernutrition in infancy and childhood. BIA, bioelectrical analysis; DXA, dual energy X-ray absorptiometry.

much lower weight, BMI and lean mass, although only a relatively low adiposity. They were also the shortest group and yet their average mid parental Z-score was well within the normal range. Owing to attrition there was no follow up data for the five children with both stunting and weight faltering and only one of the three children with all three characteristics, who was very thin at age 8 years, but not short relative to the parents (Weight −2·39, BMI −2·5, adiposity −1·98, lean −2·4, height −1·07, mid parental Z-score −1·17).

Prevalence and concurrence of different definitions in Childhood

In the ALSPAC Cohort, by definition, about 5% of the cohort had low lean and fat indices at each age. At age 7 years, 1·3% were wasted and 1·2% stunted, whereas at age 11 years, 2·0% were wasted but only 0·7% were stunted. The concurrence between a low BMI and a relatively low fat index was surprisingly small. Only a minority of children with a BMI below the second percentile (21%) had a fat Z-score below the fifth percentile (Fig. 3(a)), but over half (52%) were below the fifth percentile for lean Z-score (Fig. 3(b)). When one also examines the concurrence of low fat and wasting with a fall in BMI at age 11 years (see Fig. 4) it can be seen that the degree of concordance is low. Nearly half the wasted children had shown a fall in BMI, but only 13 (12%) wasted children had low fat and only five of these had also shown a fall in BMI.

Discussion

These findings suggest that in affluent societies, although individual thresholds and measures may identify children with undernutrition, all are highly non-specific, so that no single measure can be used as anything more than a trigger for further concern. We found a similar overlap of weight faltering with both low BMI and shortness to that described by Olsen *et al*. in Denmark[7], but we were able to show additionally that infants with both weight faltering and a BMI below the ninth centile went on in childhood to be shorter on average, despite having parents of average height and to have relatively low lean and fat mass. However, the majority with low BMI had not weight faltered, and vice versa and these children showed little difference from the rest of the cohort at follow up. This suggests that about two-thirds of children with either sustained weight faltering or low BMI are probably sufficiently nourished and simply showing a variant growth pattern. It is to be noted that those children with weight faltering only were relatively short at follow up, but not more so than their parents, suggesting that they may have been 'catching down' to their true genetic centile.

The proportion with 'true' wasting or stunting at age 13 months, when defined as a BMI or length below the second centile compared with the WHO standard was low with only 1·3% in total being in either category, and two-thirds of these children had also weight faltered. However, if one also accepts that children with both relatively low BMI and weight faltering are truly undernourished, this would suggest a prevalence for significant undernutrition

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in infancy in an affluent community of about 2%. In contrast, in the ALSPAC cohort, studied in childhood, there was much less overlap. Most children with wasting (BMI<second centile) did not have low fat, although nearly half had shown a significant fall in BMI in the preceding years. A great majority of children with low fat were neither wasted nor had shown a BMI SD change. This is in keeping with the earlier work, which similarly found that a low BMI is more closely related to low lean than fat[40] and this was acknowledged when the IOTF definition of thinness was proposed[41]. This would tend to suggest that the only children who show wasting with low fat or with a decline in BMI SD should be considered to be truly undernourished. This would give a maximum prevalence of undernutrition in mid-childhood of just over 1%, but this could be as low as 0·4% if one considered that a BMI change and wasting were only significant if they also coincided with low fat. This suggests that using a low BMI as a population marker for undernutrition may be inappropriate in affluent countries, as a majority of children with a low BMI or low fat appear to be simply growing at one extreme of the normal range.

The strength of the GMS analysis was the opportunity to follow these infants on into childhood, but it was limited by the relatively small number remaining, particularly in the group with both weight faltering and low BMI or low length. Ideally, body composition would have been measured in infancy itself, but in practice there are few viable measures of body composition in infancy, although skinfolds compared with the new WHO standard now offer considerable promise for future studies. A strength of the ALSPAC cohort was the opportunity to examine both the concurrence with body fat as measured by BIA and the trend in BMI over time. No field measures of body composition can be entirely relied on, but we have previously shown that BIA is a valid measure of lean mass[42] and the close concurrence of fat Z-score and BMI at the top of the range suggests that on average it is also a valid measure of fat mass. A limitation is that both data sets used are now relatively old, both having been collected around the turn of the Millennium and only included British children. Thus these analyses are an example of the applicability of the combination of indicators rather than necessarily a reflection of the current actual prevalence.

Conclusions

This suggests that, amid justifiable concern about overnutrition in childhood, true undernutrition will still be found in affluent societies in infancy, though in most cases this is likely to be mild. However, it appears to be much rarer in childhood. Although a low value for height or BMI may reflect undernutrition in populations with a high prevalence of undernutrition, in more affluent societies these measures will always be more likely to detect healthy children who are simply at the lower end of the normal range. The implication for clinicians is that undernutrition only becomes likely when a child shows both a decline in weight or BMI and low absolute BMI (wasting) and this should influence the clinical algorithms followed (see Fig. 5). The implications for research are that studies in affluent societies that rely on single measures will greatly overstate the true prevalence of undernutrition in childhood.

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