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Anthropometric characteristics of children living in food-insecure households in the USA

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Abstract

Objective: This study provides information on food insecurity and child malnutrition in a technologically advanced nation.
Design: Population-based study using multistage probability cluster sampling design to collect survey data. Multivariable regression models were used to determine associations between food security status and various malnutrition indices.
Setting: We used a national sample from the US National Health and Nutrition Examination Survey 2011–2014.
Participants: The anthropometric and demographic data sets of 4121 children <7 years old were analysed for this study.
Results: Food-insecure infants younger than 6 months had shorter upper arm length (–0·4 cm, $P = 0{\cdot}012$) and smaller mid-upper arm circumference (–0·5 cm, $P = 0{\cdot}004$); likewise those aged 6 months–1 year had shorter upper arm length (–0·4 cm, $P = 0{\cdot}008$), body length (–1·7 cm, $P = 0{\cdot}007$) and lower body weight (–0·5 kg, $P = 0{\cdot}008$). Food-insecure children younger than 2 years were more likely to be underweight (OR: 4·34; 95 % CI 1·99, 9·46) compared with their food-secure counterparts. Contrariwise, food-insecure children older than 5 years were more likely to be obese (OR: 3·12; 95 % CI 1·23, 7·96).
Conclusions: Food insecurity associates with child growth deficits in the USA. Food-insecure infants and young children are generally smaller and shorter, whereas older children are heavier than their food-secure counterparts, implying a double burden of undernutrition–overnutrition associated with child food insecurity. Child food and nutrition programmes to improve food insecurity should focus on infants and children in the transition ages.

Keywords
Food insecurity
Child undernutrition
Child growth
Wasting
Childhood obesity

To date, there is a dearth of data on anthropometric characteristics of children living in food-insecure households in developed countries. We provide some of such data from a pre-pandemic era to aid future comparison. Food insecurity, characterised by limited access to enough food for an active healthy life, has been associated with impaired child growth in previous studies[1–3]. In the USA, about 7·1 % of households with children (26·1 million adults and 11·2 million children) were food insecure in 2018 which shows a decline from the 9·9 % (33·3 million adults and 15·8 million children) reported in 2013[1].

Food-insecure children experience malnutrition which can result in minor or major physical growth faltering depending on the severity of food deficits. Before birth, undernutrition can result in intrauterine growth retardation which can cause small-for-gestation age or low birth weight (LBW). Undernutrition among children presents as growth failure, underweight, wasting and stunting[2–7]. Traits of food-insecure children mirror those of undernourished children including aggression, anxiety, attention deficit, depression, irritability, food allergy, frequent hospitalisation, learning disability and nutrients deficiencies[4,8–15]. Neonates

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who experienced intrauterine growth retardation or small-for-gestation age undergo catch-up growth which is associated with rapid accretion of body fat mass, body girth and visceral fat mass[16–20]. They may experience changes in body composition and phenotype usually associated with incapacity and disease later in life[17,21–26]. Diseases such as anaemia, arthritis, asthma, cancer, coronary artery disease, dyslipidaemia, food allergy, hypertension, obesity, osteoporosis and type 2 diabetes mellitus are reported possible sequelae of food insecurity[2–4,17,20–22,26,27].

Even though the clinical symptoms of undernutrition in developing countries are often overt because of elevated severity, these symptoms are often covert in developed countries[2,28]. The large number of food-insecure children in the USA warrants analysis of its associations with childhood physical growth faltering because of its largely indiscernible but damaging health effects[4,17,22,24,25,28].

By virtue of the rapid growth of children, physical growth deficits can be detected using established anthropometric standards[5,29–33]. Anthropometric indices that are typically used to assess physical growth in children include: (1) body weight-for-age (for assessing underweight), (2) body weight-for-height (for wasting, overweight and obesity), (3) height-for-age (for stunting), (4) mid-upper arm circumference (MUAC) (for wasting and overweight), (5) BMI-for-age percentiles (for underweight, overweight and obesity), (6) head circumference (for brain growth) and (7) chest:head circumference ratio (for general growth failure)[2,3,5,29,31,34]. Common surrogates for estimating height are upper arm length and leg length[34–36].

The National Center for Health Statistics of the Centers for Disease Control and Prevention has established anthropometric standards for US children, whereas the WHO has done the same for children globally[31,33]. The availability of anthropometric standards applying *Z*-scores and percentile cut-offs, as well as rapid assessment tools, has enabled inexpensive assessment of malnutrition in children and adults[31,33]. In this study, we examine anthropometric data of children living in food-insecure households to determine whether the extent of food insecurity experienced in the USA associates with malnutrition. Knowledge of the critical ages where food insecurity has the most profound influence is useful to child nutrition programmes.

Methods

Data sources and participants

Data for this study were from the continuous US National Health and Nutrition Examination Survey (NHANES) 2011–2014[37]. The final composite data set comprised 4121 children, specifically 2110 boys and 2011 girls, aged 7 years or younger. Children in this age range were included in the study to obtain adequate span of age range for analysis while obviating confounding by the growth spurt of adolescence. Inclusion criteria were availability of data on age, anthropometry, gender, household food security status and race/ethnicity. The food-insecure children lived in households whose poverty:income ratio, a ratio of household income to the federal poverty threshold provided by the United States Bureau of the Census, was <1·0.

In this study, protocols involving human subjects were approved by the Ethics Review Board of the National Center for Health Statistics, Centers for Disease Control and Prevention (Protocol Nos. 2011-17)[38]. Written parental consent and child assent were obtained from all participating households[38]. The NHANES data sets analysed for the present study had been de-identified and released for public use[38].

Food security status and categories

During the NHANES 2011–2014, a nationally representative sample of about 45 000 households were surveyed. Based on responses to the ten-item child food security survey module of the US Census Bureau's Current Population Survey, children in the participating households were assigned to one of four food security categories: (1) food secure, (2) marginal food security, (3) low food security and (4) very low food security which are the categories used in this study[1]. Food-secure children were from households that reported no indications of food access issues or food limitations. Those in the marginal food security category had one or two reported indications, typically of anxiety over food sufficiency or anxiety over food shortage with little or no indication of adverse changes in diets or food intake. Those in the low food security category reported reduced quality, variety or desirability of diet, but not reduced quantity of food intake. Participants in very low food security reported multiple indications of disrupted eating patterns, reduced quality, variety, desirability of diet and food intake[1].

Anthropometric data

Available child anthropometric data analysed for this study were birth weight, body length, BMI, height, weight, head circumference, MUAC and upper arm length[37]. The anthropometric measurements were done by trained technicians who followed the NHANES Mobile Examination Centers' approved protocols[36]. Measurements were linked to an integrated survey information system which enabled flawless data transmission and storage[36]. For more than three decades, the NHANES anthropometric data sets have been used to assess physical growth and body weight of the US civilian population[36,39,40]. The detailed procedures for the anthropometric measurements are provided in chapter 3 of the anthropometric procedures manual, published elsewhere[36].

Data analysis strategy

We applied a two-pronged approach to ascertain associations between child malnutrition and food security status. In the first approach, we used linear regression models to test whether significant differences in growth rates of children exist between food security categories. Because certain anthropometric indices are unreliable in young children, and not all are applicable to older children, the NHANES anthropometric data tend to be age-dependent. For instance, birth weight is measured shortly after birth, body length is measured up to 2 years, height from 2 years and older, BMI from 2 years and older, head circumference is up to 1 year and MUAC from 2 months and older[29–31,33,41,42]. Consequently, some of the analyses were restricted to applicable age-dependent data.

In the second approach, *Z*-scores of applicable anthropometric indices were computed based on the Centers for Disease Control and Prevention/National Center for Health Statistics child growth standards for US children[5,29,31,33,43]. Prevalence of malnutrition was determined based on *Z*-scores. The Anthro-for-PC software for survey anthropometric data analysis version 3.2.2 (WHO, 20 Avenue Appia, 1211 Geneva 27, Switzerland) was used to calculate *Z*-scores for all children aged < 6 years. *Z*-scores calculated included weight-for-age – for assessing underweight, height-for-age – for assessing stunting and weight-for-height – for assessing wasting, overweight or obesity[31,33]. Moderate underweight, stunting and wasting were defined as a *Z*-score ≤ −2 SD, whereas severe forms were defined as a *Z*-score ≤ −3 SD of the Centers for Disease Control and Prevention/National Center for Health Statistics growth standards[5,29,31,33,44]. Overweight was defined as a *Z*-score ≥ +2 SD, whereas severe overweight (obesity) was defined as *Z*-score ≥ +3 SD[29–33]. We applied anthropometric cut-offs of BMI and MUAC to calculate likelihood ratios for wasting, overweight and obesity using multinomial logistic regression analyses. The MUAC clinical cut-offs applied were: severely underweight or wasted (MUAC < 11·5 cm) and moderately underweight (MUAC < 12·5 cm)[29,32,33]. A BMI-for-age value greater than the 95th percentile was categorised as obese (severe overweight)[8,29–31,33,42,45]. Participants with birth weight < 2·5 kg were deemed LBW[29,30,33].

The NHANES uses complex multistage probability cluster sampling design to select households that together are representative of the state-level and national-level non-institutionalised US civilian population[1]. In conformity with this design, Mobile Examination Centers sampling weights assigned to participants were applied in the analyses. To enable application of Mobile Examination Centers sampling weights, the STATA 14.2 statistical software (STATA Corporation, College Station, Texas) was used for analysis[46]. The NHANES 2011–2014 consists of two waves, 2011–2012 and 2013–2014; therefore, the Mobile Examination Centers sample weights were halved and applied during analyses[8,46]. To improve sample size and hence sensitivity, the low and very low food security categories were combined into one category as food insecure[8].

The following age groups were used to coincide with some life stages of children: <6 months (infants), 6 months–1 year (weaners), 2–3 years, 4–5 years (school entry) and 6–7 years (schoolers)[47]. Within each age group, the applicable anthropometric indices of food-insecure children were compared with their food-secure counterparts. Initially, descriptive statistics were calculated for each anthropometric measure stratified by age group and food security category. Proportions that were below or above clinical cut-offs were compared using Pearson's χ^2 test of independence and multinomial logistic regression analysis. Multiple linear regression analysis was used to examine continuous data. In the regression analyses, statistically significant differences in the continuous variables between food security categories were tested using the design-based Student's *t* test components. During the regression analysis, race/ethnicity and sex were controlled as potential confounders[8,47,48]. The food-secure children were treated as the referent, food security status as the independent variable and the anthropometric measures as the outcome variables. In all analyses, statistical significance was tested at $P < 0·05$.

Results

Among the 4121 children meeting inclusion criteria, 65·3 %, 13·7 % and 21·0 % were in the food secure, marginal food security and food-insecure categories, respectively, due to oversampling during the NHANES[8,49]. Table 1 shows characteristics of the participants. In general, some of them were overweight (4·0 %) or obese (2·6 %). The prevalence of obesity among food-insecure children (6·9 %) was significantly higher than among their food-secure counterparts (2·8 %) ($P = 0·003$). In general, some of the children were moderately underweight (0·5 %), moderately wasted (0·6 %) or moderately stunted (0·4 %) (Fig. 1).

The anthropometric values of the children show noticeable differences indicative of malnutrition (Table 2). Food insecurity among those aged 6 months–1 year was associated with significantly less body weight ($P = 0·009$), body length (−1·7 cm, $P = 0·007$) and upper arm length ($P = 0·010$) compared with their food-secure counterparts (Table 2). Food-insecure children younger than 6 months had significantly shorter upper arm length ($P = 0·018$) and smaller MUAC ($P = 0·006$) (Table 3). The difference remained significant after adjusting for covariates (Table 4). However, these deficits in the anthropometric values disappeared by age 3 years, and by age 6 years, food-insecure children had amassed greater BMI and arm circumference than their food-secure counterparts. Among the marginal food security category, children aged 2–3 years had significantly greater body weight ($P = 0·001$), height ($P = 0·028$), BMI

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Table 1 Background characteristics of children aged <1 month to 7 years by food security status

	Food secure*			Marginal food security			Food insecure			Total		
	n	%		*n*	%		*n*	%		*n*	%	
Sex category												
Boys	1195	51·2		336	53·4		579	53·9		2110	51·2	
Girls	1215	48·8		308	46·6		488	46·1		2011	48·8	
Race/ethnicity												
Black	565	52·8		206	18·1		323	29·2		1094	14·5	
Mexican	653	48·8		238	17·9		441	33·3		1332	25·3	
White†	1192	75·3		200	10·8		303	13·9		1695	60·2	
		Mean	SE‡		Mean	SE‡		Mean	SE‡		Mean	SE‡
Age (months)	2410	43·47	0·87	644	42·58	1·32	1067	44·31	1·17	4121	43·60	0·55
Birth weight (kg)	2381	3·12	0·02	637	3·09	0·04	1054	3·08	0·03	4072	3·11	0·01
Household income§	2228	2·83	0·11	596	1·38	0·07	998	0·99	0·03	3822	2·25	0·10

*NHANES sampling weights were applied during the analyses.
†White includes multiracial and small racial groups.
‡SE is standard error linearised per Taylor series linearisation.
§Income was expressed as poverty:income ratio (PIR) provided by the US' Bureau of the Census.

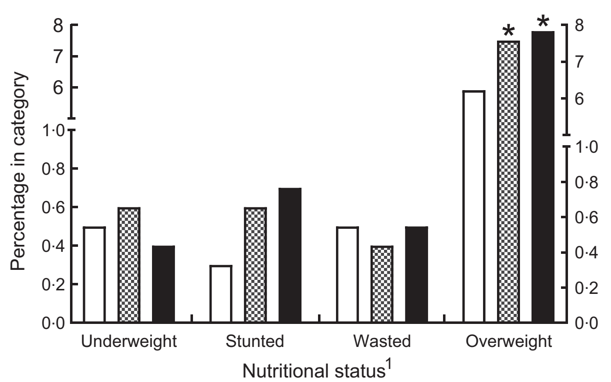

Fig. 1 Percentage of participants that fall in various categories of malnutrition by food security category. □, Food secure; ▨, Marginal; ■, Food insecure

($P = 0·001$) and MUAC ($P = 0·001$) than their food-secure counterparts.

Based on MUAC cut-offs, in general, food-insecure children were more likely to be moderately underweight (OR: 4·08; 95 % CI 1·97, 8·44) or severely underweight (OR: 5·09; 95 % CI 1·34, 19·35) compared with their food-secure counterparts (Table 4). Further analysis showed that food-insecure children younger than 2 years were more likely to be underweight (OR: 4·34; 95 % CI 1·99, 9·46). Conversely, food-insecure children older than 5 years were more likely to be obese (OR: 3·12; 95 % CI 1·23, 7·96). These observations indicate a double burden of undernutrition–overnutrition among food-insecure children.

Figure 1 shows proportions of the children who were underweight, stunted or wasted within each food security category assessed using Centers for Disease Control and Prevention/National Center for Health Statistics *Z*-score benchmarks. Compared with food-secure children, there appeared to be a greater prevalence of stunting among the marginal food security and food-insecure children, but proportions were inadequate for reliable test of statistical significance. The prevalence of overweight/obesity among the children in the marginal food security (7·8 %, $P = 0·001$) and food insecure (7·9 %, $P = 0·001$) categories was significantly higher than the food-secure category (5·8 %) (Fig. 1).

Overall, a high proportion of the children were born having LBW (12·1 %). Categorically, the prevalence of LBW was: food secure, 11·9 %; marginal food security, 11·8 % and food insecure, 12·8 %. Food security status did not significantly associate with LBW.

The patterns of MUAC growth among marginal food security and food-insecure children were conspicuously irregular compared with their food-secure counterparts (Fig. 2). Among marginal food security and food-insecure children, there were conspicuous dips in the MUAC at age 4–5 years (indicated with the letter 'ϕ' on Fig. 2), but upper arm length remained unchanged (Fig. 3). The MUAC of food-insecure children aged below 6 months lagged their food-secure counterparts, but this lag disappeared by age 1 year. Similarly, food-insecure children below age 1 year had significantly shorter upper arm length, but this difference disappeared by age 3 years (Table 4, Fig. 3).

Discussion

In the current study, although generally the prevalence of stunting, underweight and wasting was below the 20 %, 10 % and 5 % cut-offs, respectively, at which public health intervention is mandated, disparity in the prevalence rates was significantly associated with food security status[43,47,50]. The associations between food insecurity and anthropometric values differed between infants, weaners and older children. The shorter upper arm length and

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Table 2 Anthropometric values of children by food security status

Measure	Food secure†			Marginal food security				Food insecure				Total		
Body weight (kg)	*n*	Mean	SE‡	*n*	Mean	SE	*P*-value	*n*	Mean	SE	*P*-value	*n*	Mean	SE
<6 months	219	6·38	0·11	65	6·78	0·20	0·08	106	6·15	0·12	0·142	390	6·38	0·08
6 months–1 year	515	10·68	0·09	128	10·77	0·21	0·878	189	10·33	0·18	0·009*	832	10·63	0·07
2–3 years	548	14·81	0·13	155	15·72	0·24	0·001*	269	14·90	0·20	0·768	972	14·99	0·11
4–5 years	457	19·60	0·24	133	19·74	0·33	0·985	212	19·94	0·42	0·696	802	19·69	0·18
6–7 years	526	25·48	0·30	137	26·46	0·57	0·573	244	26·90	0·50	0·115	907	25·91	0·23
Length (cm)§														
<6 months	218	61·22	0·38	64	62·40	0·57	0·089	106	60·58	0·47	0·298	388	61·24	0·30
6 months-1 year	508	78·51	0·34	127	78·27	0·67	0·502	189	77·24	0·49	0·007*	824	78·24	0·25
Standing height (cm)§														
2–3 years	524	95·34	0·34	150	96·55	0·37	0·028*	253	94·71	0·35	0·207	927	95·40	0·24
4–5 years	457	110·00	0·35	132	110·36	0·56	0·606	211	109·44	0·70	0·325	800	109·94	0·28
6–7 years	527	123·21	0·36	136	122·94	0·57	0·492	246	122·95	0·46	0·419	909	123·12	0·27
Upper arm length (cm)														
<6 months	137	12·70	0·09	48	12·65	0·19	0·766	69	12·33	0·15	0·018*	254	12·60	0·07
6 months–1 year	498	15·82	0·10	123	15·78	0·18	0·495	188	15·55	0·14	0·010*	809	15·76	0·08
2–3 years	495	19·39	0·09	141	19·58	0·10	0·193	247	19·31	0·08	0·408	883	19·40	0·07
4–5 years	433	22·51	0·10	126	22·70	0·16	0·419	200	22·47	0·20	0·648	759	22·53	0·08
6–7 years	516	25·52	0·09	133	25·63	0·16	0·954	242	25·71	0·15	0·618	891	25·58	0·08

†The food secure category was the referent.
‡SE is linearised standard error per Taylor series linearisation. Mean values are weighted per the NHANES sampling weights.
§Anthropometric indices not showing all five age groups are age-specific.
*Significantly different from the food-secure category, $P<0·05$.

Table 3 Body girth indices of children by food security status

	Food secure†			Marginal food security				Food insecure				Total		
Measure	*n*	Mean	SE‡	*n*	Mean	SE	*P*-value	*n*	Mean	SE	*P*-value	*n*	Mean	SE
BMI (kg/m^2)§														
2–3 years	522	16·30	0·08	64	16·83	0·18	0·001*	253	16·71	0·17	0·004*	839	16·47	0·08
4–5 years	457	16·08	0·13	128	16·16	0·22	0·83	211	16·54	0·18	0·124	796	16·20	0·09
6–7 years	527	16·65	0·16	136	17·33	0·29	0·205	246	17·78	0·26	0·001*	909	16·98	0·13
MUAC (cm)‖														
<6 months	137	14·00	0·10	48	14·21	0·18	0·416	69	13·52	0·19	0·006*	254	13·93	0·09
6 months–1 year	498	15·43	0·06	123	15·56	0·17	0·317	188	15·25	0·11	0·128	809	15·42	0·05
2–3 years	494	16·41	0·09	140	16·83	0·16	0·001*	247	16·57	0·11	0·154	881	16·51	0·07
4–5 years	433	17·77	0·13	126	17·66	0·20	0·381	202	17·87	0·20	0·98	761	17·78	0·09
6–7 years	515	19·35	0·14	133	19·86	0·28	0·352	240	20·04	0·24	0·049*	888	19·57	0·11
Head circumference (cm)§														
<6 months	219	40·98	0·18	64	41·43	0·28	0·253	106	40·60	0·21	0·203	389	40·96	0·16
6 months–1 year	40	44·07	0·26	15	44·01	0·27	0·875	18	44·26	0·27	0·765	73	44·10	0·21

†The food secure category was the referent.
‡SE is linearised standard error per Taylor series linearization. Means values are weighted per the NHANES sampling weights.
§Anthropometric indices not showing all five age groups are age-specific.
‖MUAC is mid-upper arm circumference, assessed from age 2 months and older.
*Significantly different from the food-secure category, $P<0·05$.

Table 4 Difference, prevalence and likelihood to have abnormal anthropometric measures by food security status

	Food secure† (*n* 2077)		Marginal food security (*n* 570)		Food insecure (*n* 946)		Total (*n* 3593)
Percentage moderately underweight: MUAC < 12·5 cm‡	0·4		0·3		1·2		0·5
Likelihood to be moderately underweight (adjusted OR)	1·0	Ref§	1·09	0·28–4·22	4·08*	1·97–8·44	
Percentage severely underweight: MUAC < 11·5 cm	0·1		0·1		0·3		0·1
Likelihood to be severely underweight (adjusted OR)	1·0	Ref	1·10	0·13–4·45	5·09*	1·34–19·35	
Percentage obese: BMI > 95th percentile	2·8		5·6		6·9*		4·1
Likelihood to be obese, (adjusted OR)	1·0	Ref	1·82	0·93–3·55	2·12*	1·27–3·54	
Low birth weight (%)‖	11·9		11·8		12·8		12·1
		β-coefficient	95 % CI	*P*-value	*β*-coefficient	95 % CI	*P*-value
Upper arm length (cm)							
<6 months (*n* 254)	Ref	–0·05	–0·46, 0·22	*P* = 0·772	–0·40	–0·71, –0·09	*P* = 0·012*
6 months-1 years (*n* 809)		–0·12	–0·39, 0·29	*P* = 0·483	–0·41	–0·72, –0·11	*P* = 0·008*
2–3 years (*n* 883)		0·12	–0·15, 0·40	*P* = 0·376	–0·13	–0·38, 0·13	*P* = 0·319
4–5 years (*n* 759)		0·14	–0·22, 0·49	*P* = 0·440	–0·08	–0·38, 0·21	*P* = 0·577
6–7 years (*n* 891)		–0·02	–0·41, 0·38	*P* = 0·940	0·07	–0·24, 0·39	*P* = 0·655
MUAC (cm)	Ref						–
<6 months (*n* 254)		0·17	–0·23, 0·57	*P* = 0·401	–0·53	–0·89, –0·17	*P* = 0·004*
6 months–1 years (*n* 809)		0·13	–0·22, 0·38	*P* = 0·315	0·17	–0·06, 0·40	*P* = 0·134
2–3 years (*n* 883)		0·41	0·16, 0·66	*P* = 0·001*	0·17	–0·06, 0·40	*P* = 0·157
4–5 years (*n* 759)		0·18	–0·61, 0·24	*P* = 0·389	0·01	–0·35, 0·35	*P* = 0·969
6–7 years (*n* 891)		0·28	–0·31, 0·87	*P* = 0·351	0·46	0·01, 0·93	*P* = 0·048*

*Significantly different from the food-secure category, $P < 0·05$.
†NHANES sampling weights were applied in all analysis. β-coefficients and OR have been adjusted for sex and race/ethnicity.
‡MUAC is mid-upper arm circumference, assessed from age 2 months and older.
§The food-secure category was the referent.
‖Birth weight < 2·5 kg.

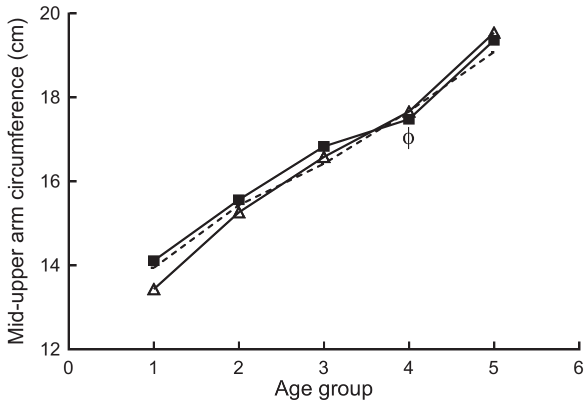

Fig. 2 Trends in mid-upper arm circumference of children aged 2 months–7 years categorised by food security status. - -, Food secure; ■, Marginal; △, Food insecure

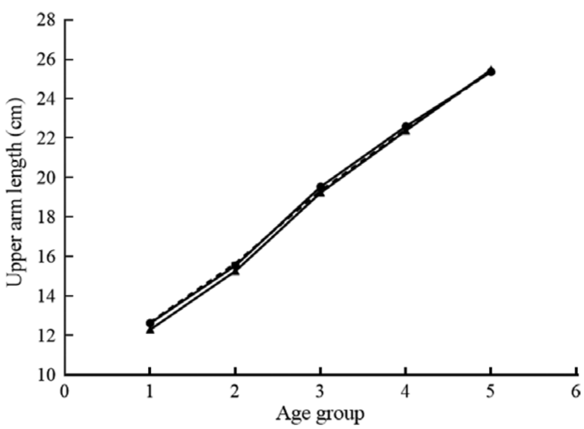

Fig. 3 Trends in upper arm length of children aged 2 months–7 years categorised by food security status†. --, Food secure; ◆, Marginal; ▲, Food insecure

MUAC of food-insecure infants are indicative of undernutrition. At this age of rapid growth, nutritional deficit could engender growth deficit such as observed in younger food-insecure children. Even though an inferior MUAC value can be indicative of either chronic or acute undernutrition, it is often indicative of the latter[29,33,43,49]. However, we reasoned that the concurrent decreases in both MUAC and upper arm length values of food-insecure infants are indicative of chronic undernutrition in this age group.

The MUAC deficit among food-insecure infants had disappeared by age 1 year, whereas the deficit in upper arm length had disappeared by age 3 years. This indicates that MUAC recovered faster than upper arm length. The disappearance of the growth deficit and the upward trend in upper arm length manifest the phenomenon of catch-up growth among food-insecure children. There is ample evidence that catch-up growth early in life associates with markers of adult diseases including excess body fat mass, obesity and visceral adiposity[16–20]. These changes associate with adverse health outcomes and metabolic syndromes severally reported[2–4,17,20,22–27,51]. Due to previously reported associations of childhood food insecurity with poor health in adulthood, and the apparent incidence of accelerated growth among food-insecure children, we assert that childhood food insecurity is a marker of poor health later in life[2–4,17–21].

Food-insecure children at age 6 months–1 year had lesser body weight, body length, upper arm length and MUAC than their food-secure counterparts. This observation warrants attention because most children are weaned or introduced to complementary foods at this stage, a transition accompanied by financial and resources constraints. It is a transition from breast milk to the purchasing of weaning foods while enduring food insecurity. The fact that significant growth faltering occurred at this weaning period is an indication of inadequate nutritional intake.

In general, we observed a positive association between food insecurity and BMI among those aged 2 years or older. Within each age group, BMI increased as the intensity of food insecurity increased, and by age 6 years, food-insecure children already had BMI and MUAC higher than their food-secure counterparts. Children 2–3 years in the marginal food security category were heavier, taller and larger than their food-secure counterparts. These are in households that experience anxiety about food shortage but not necessarily food shortage or hunger. Research reports indicate that households that experience anxiety about food shortage or hunger may adopt coping strategies associated with increased energy intake while decreasing energy expenditure[51–54]. This could be a reason why a higher prevalence of overweight and obesity was observed among marginal food security and food-insecure children even at this tender age. Casey *et al.*[48] had observed similar associations among 3–5-year-old food-insecure children.

Compared with food-secure children, there was a conspicuous dent in the MUAC growth pattern of marginal food security and food-insecure children at age 4–5 years. This drop in MUAC is indicative of acute weight loss, a consequence of sudden onset of energy deficit, at this school entry age[2,4,5,28,32]. We interpreted this observation as an incidence of acute undernutrition because the upper arm length did not decrease within this age group[50]. We reasoned that the lower MUAC at the school entry age could be contributed by increased energy demand.

A limitation of this study, like other cross-sectional studies, is that cause–effect relationships could not be established so no causal inferences can be claimed. Like other population-based studies, not all variables could be controlled in this analysis, so the application of the outcome should be done with vigilance. However, the large sample size used, and the control of some potential confounders facilitated reliable estimates of associations and enabled generalisability of findings.

In conclusion, the extent of food insecurity experienced in the USA, although may not associate with severe undernutrition, is associated with minor chronic and acute onsets of malnutrition. There is a divergent association between child malnutrition and food insecurity. Whereas food-insecure infants and weaning-age children appear smaller and shorter, older food-insecure children appear heavier, suggestive of a double burden of undernutrition–overnutrition associated with childhood food insecurity. It is recommended that child food and nutrition programmes place emphasis on the transition ages.

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