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ORIGINAL COMMUNICATION

Prevalence and severity of malnutrition and age at menarche; cross-sectional studies in adolescent schoolgirls in western Kenya

T Leenstra[1,2]*, LT Petersen[3], SK Kariuki[1], AJ Oloo[1], PA Kager[2] and FO ter Kuile[1,2,4]

[1]*Kenya Medical Research Institute, Centre for Vector Biology and Control Research, Kisumu, Kenya;* [2]*Department of Infectious Diseases, Tropical Medicine & AIDS, Academic Medical Centre, University of Amsterdam, the Netherlands; and* [3]*St Mary's Hospital, Mumias, Kenya*

Objective: Nutritional status is an important marker of overall health and linear growth retardation has serious long-term physiological and economic consequences. Approximately 35 and 29% of preschool children in sub-Saharan Africa are stunted and underweight, respectively. There is relatively little information available about the nutritional status in adolescents, the age group with the highest growth velocity after infancy. We conducted a series of cross-sectional surveys to determine the prevalence and main risk groups for malnutrition and to describe the associations between age, sexual maturation and nutritional status in adolescent schoolgirls in western Kenya.
Design: Three cross-sectional surveys; one in Mumias, using random sampling in all schools, and two surveys in Asembo, using a multi-stage random sample design.
Setting: Public primary schools in two different rural malaria endemic areas in western Kenya with high levels of malnutrition in preschool children.
Subjects: In all, 928 randomly selected adolescent schoolgirls aged 12–18 y.
Results: Overall prevalence of stunting and thinness was 12.1 and 15.6%, respectively. Of the total, 2% were severely stunted. Menarche and start of puberty were delayed by approximately 1.5–2 y compared to a US reference population. The prevalence of stunting and thinness decreased with age and mean height for age *z*-scores converged towards the median of the US reference curve. Girls who had not yet started menstruating were more likely to be stunted than the girls of the same age who were post-menarche.
Conclusions: Stunting and thinness are common in young adolescent schoolgirls in these poor rural settings in western Kenya, but the prevalence decreases with age, providing observational support that children catch up on incomplete growth attained earlier in life due to a maturational delay of 1.5–2 y allowing prolonged growth.
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*Correspondence: T Leenstra, Department of Pediatrics/International Health Institute, Brown University, Box G/B 426, Providence, RI 02912, USA.
E-mail: Tjalling-Leenstra@brown.edu
Guarantors: T Leenstra and FO ter Kuile.
Contributors: FO ter K, TL and PAK were responsible for the study design. SKK was responsible for the laboratory work. TL, LP, FO ter K and AJO were responsible for the data collection. TL and FO ter K were responsible for the data analysis and writing of the manuscript, with contributions from all other authors.
[4]Current address: Child and Reproductive Health Group, Liverpool School of Tropical Medicine, Liverpool, UK.
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Introduction

Malnutrition is a prevailing health care problem in the developing world, especially in South-East Asia and sub-Saharan Africa (Stephenson *et al*, 2000). Most studies of malnutrition have focused on children <5 y of age. The fourth report on the world nutrition situation showed that the global scope of malnutrition is still unacceptably high and progress to reduce it is slow (ACC/SCN, 2000). In eastern Africa, 48.1 and 35.9% of the under-5s were estimated to be stunted and underweight, respectively (ACC/SCN, 2000). There is relatively little nutritional information available from adolescents, the age group with the highest growth velocity after infancy. Studies of Ghanaian and Tanzanian schoolchildren aged 7–18 y report 40–60% of girls to be stunted and 30–40% to be underweight (Partnership for Child Development, 1998; Lwambo *et al*, 2000). Although, results were not presented separately for adolescents, studies including adolescents show a trend towards higher height and weight-for-age with increasing age. Studies looking specifically at adolescent girls from the general population suggested a wide range of linear growth retardation ranging from 10 to 47%, with more stunting in the youngest (Brabin *et al*, 1997; Simondon *et al*, 1998).

Adolescence is the last window of opportunity to implement strategies to correct growth deficits, and knowledge of the main risk factors and risk groups is required to design and target appropriate interventions. It is estimated that at least 25% of women in the developing world have their first child by the age of 19 (Senderowitz, 1995). Teenage pregnancies, where girls haven't reached their full growth potential, have been associated with an increased risk of obstructed labour due to cephalo-pelvic disproportion (CPD), which in turn is associated with an increased risk of peripartum and maternal mortality (Harrison, 1985). Adolescent mothers also have an increased risk of severe anaemia, preterm delivery, still birth, and neonatal death, due to competing nutritional requirements of the developing fetus and growing mother (Naeye, 1981; Brabin & Brabin, 1992; Brabin *et al*, 1998). However, little is known about the determinants of adolescent nutritional status, and the precise mechanisms by which it is linked to other health and social outcomes (de Onis & Habicht, 1996). Assessing nutritional status in adolescents is further complicated by the fact that adolescents in different nutritional settings have different rates of maturation and growth (ie biological age and chronological age are not synchronous) making comparisons of adolescents from developing countries to adolescents from a (too) well nourished reference population problematic (WHO Expert Committee on Physical Status, 1995).

The major part of linear growth retardation occurs in early childhood, though there is evidence that children continue to grow at a slower rate during the school-age years and continue to diverge from reference populations (Norgan, 1995; Stoltzfus *et al*, 1997; Partnership for Child Development, 1998). Whether stunted children have the potential to catch up on linear growth is debated (Martorell *et al*, 1994). In situations where menarche is delayed long enough to allow for a prolonged period of growth, compensatory growth is possible, as was seen in two recent longitudinal studies from rural Africa (Cameron *et al*, 1994; Simondon *et al*, 1998). However, in most developing countries, the period of maturational delay may not be long enough to allow full compensatory growth (Martorell *et al*, 1994). There is some evidence from controlled trials in Nigeria that micronutrient supplementation positively effects linear growth in deficient adolescent girls (Harrison *et al*, 1985).

The aim of this observational study is to add to the limited available information on the nutritional status of adolescents in the developing world. We describe the results of a series of cross-sectional surveys that aimed to determine the prevalence of malnutrition in adolescent schoolgirls in two sites in western Kenya with different malaria endemicity and degrees of malnutrition. We also describe the associations between nutritional status and age and sexual maturation.

Methods and materials

Study area and population

This study was conducted at public primary schools in two areas of western Kenya; Mumias, and Asembo. Mumias (Mumias Division, Kakamega District, Western Province) is one of the most densely populated areas in Kenya and predominantly rural. The predominant ethnic group in the area are the Luhya. Sugarcane is the main cash crop, and has replaced previously grown food crops as maize, beans and cooking bananas. The main rainy seasons are from April to June and from October to November. Malaria transmission is low but perennial with the highest transmission in the rainy seasons (Shililu *et al*, 1998). Malaria is by far the most common diagnosis and cause of death in adults and children admitted to St Mary's Hospital, the local mission hospital (Anonymous, 1997). Infant and under-5 mortality rates are 41/1000 and 53/1000, respectively, and the prevalence of malnutrition in children 12–23 months old, assessed by a mid-upper-arm circumference of <11 cm, is $\sim 35\%$ (Anonymous, 1996).

The Asembo study was conducted in Rarieda Division (Asembo), Bondo District, located on the shores of Lake Victoria in Nyanza Province, western Kenya. The study site and the resident population have been described in detail elsewhere (Bloland *et al*, 1999b; Phillips-Howard *et al*, 2003). Briefly, Asembo comprises an area of 200 km^2 with a widely dispersed culturally homogeneous population (predominantly Luo) of approximately 55 000 people. The main occupation (74%) is in cultivation (maize, sorghum, cassava, millet, vegetables) and limited animal husbandry. The rainfall pattern is bimodal, with the long rains falling between March and May, and the short rains from October to December, though in 1998 there was less rainfall than usual throughout the year and virtually no rain in February 1999. Perennial malaria transmission occurs, since some rain falls in each month (Beier *et al*, 1994). Infant and under-5 mortality are considerably higher than in other parts of Kenya (176/1000 and 275/1000) (McElroy *et al*, 2001). Between 60 and 90% of the children under 5 y are anaemic at any time (Hb $<$ 11 g/dl) (Bloland *et al*, 1999a) and 30 and 20% are stunted or underweight (Kwena *et al*, 2003). No data are available of the nutritional status in adolescents.

There are 58 primary schools in Asembo. Primary school starts at the age of 5 y and teaches children from standard 1 through standard 8. Tuition is charged each trimester and parents decide when their child will start school. If children fail exams or families are unable to pay tuition, they may repeat years, such that some children remain in primary school up to the age of 18 y (Friedman *et al*, 2003).

Asembo was also the site of a large community-based group randomized controlled study on the effect of Insecticide Treated Bed Nets (ITNs) on under-5 mortality (Phillips-Howard *et al*, 2003). Half of 79 villages were randomly assigned to the intervention group and each household received permethrin-treated bednets (ITNs). Results on the effect of bednets on malaria, anaemia and nutritional status in the same adolescent population presented in this paper is presented elsewhere (Leenstra *et al*, 2003).

Study design

Three cross-sectional surveys were conducted. The first survey (Mumias) was conducted between November 1997 (first part of the dry season) and March 1998 (beginning of rain season). Two additional surveys were conducted in Asembo October–November 1998 (tail end of the short rains) and in February–March 1999 (end of the dry season just before the long rains). In Mumias, all six public nonboarding primary schools within an approximate 10 km radius of town were included. In each school, 50 girls aged 12–16 y were randomly selected from the school records. If girls were absent or consent was not obtained, the next girl on the list was selected.

In Asembo, a multistage random sample design was used, with primary schools as the first stage unit and schoolgirls as the second stage unit (Kirkwood, 1998). Prior to randomization, information on the number and size of schools in the study area was obtained from the district education authority. Schools were selected by random sampling proportional to size, ranked by geographical location to allow for equal distribution of the schools over the study area (Bennett *et al*, 1991). In all, 30 girls aged 12–18 y were then randomly selected from 28 school units ($N = 840$) using the computerized list. Schools with less than 30 girls of relevant age were joined with the closest neighbouring school to form one school unit. The cross-sectional survey was originally designed to determine a 25% prevalence of anaemia, within 5% precision and with 95% confidence ($\alpha = 0.05$). The sample size was calculated using Statcalc software in EpiInfo v6 (Centers for Disease Control and Prevention, Atlanta, USA) as 289 assuming simple random sampling and 578 assuming a design effect of 2. A total of 840 girls was randomized to allow for an estimated 30% rate of recent emigrates, absentees and refusals.

Procedures

Each study participant was interviewed by a study nurse using a standardized questionnaire, which included questions on demographics; including age, date of birth, school form/standard and age at menarche (assessed through recall). An age-for-grade score was calculated by taking current age and subtracting the official age for being in the class the schoolgirl was in, to give an indication of late enrolment or a delay in progression through school.

A basic clinical examination was performed; including measurements of height and weight according to standard WHO procedures (WHO Working Group, 1986), and assessment of sexual maturation through a modified Tanner score (breast development only) (Tanner, 1962). Having entered puberty (pubarche) was defined as having breast development stage B2 or more. Weight was measured to the nearest 0.1 kg on a battery-powered digital scale (Seca, Inc, Columbia, MD, USA) and heights to the nearest 0.1 cm using a wooden length-measuring board with sliding head bar (WHO Working Group, 1986). All measurements were taken twice and the average computed.

Age was calculated from the reported date of birth after verification against school records. If the day of birth was unknown (40%), the 15th day of the month was used. If month of birth was unknown (31%), the midpoint of the year of birth was taken as date of birth. Body mass index (BMI) was calculated as weight/(height^2) and thinness defined as BMI below the 5th percentile for that age using the NHANES I reference population (WHO Expert Committee on Physical Status, 1995). The new CDC (2000) reference population was used to obtain BMI-for-age *z*-scores (Kuczmarski *et al*, 2000). Height-for-age and weight-for-age *z*-scores were obtained using the 1978 CDC/WHO normalized version of the 1977 NCHS reference curves (Dibley *et al*, 1987). Stunting and severe stunting were defined as height-for-age *z*-scores less than 2 and 3 standard deviations below the median of this reference population, respectively (WHO Expert Committee on Physical Status, 1995). The EpiNut program in Epi2000 was used to calculate all *z*-scores.

Statistical analysis

Data were analysed using SAS (the SAS system for Windows, version 8.01, SAS Inc) and SUDAAN software (SAS callable version, release 7.5.6, Research Triangle Institute). Variance estimates took into account the correlation among observations taken from the same school. The design specification in SUDAAN was with replacement. To maintain the assumption of an equal probability sample, data from Asembo was weighted to obtain clusters of equal size to adjust for nonresponders (Bennett *et al*, 1991). Because the study design of the Mumias survey was not proportional to size, its analysis was weighted by school-size. Differences between proportions were compared by χ^2-test. Normally distributed continuous data were compared by Student's *t*-test. Data not conforming to a normal distribution were compared by the Wilcoxon–Mann–Whitney U-test and the Kruskal–Wallis one-way analysis of variance. Correlations were assessed by Pearson's or Spearman's rho where appropriate. A multivariate logistic regression model (proc logistic in SUDAAN) was used to explore determinants of thinness and stunting.

Two sided *P*-values < 0.05 were considered statistically significant.

Median age at menarche and pubarche, and their 95% fudicial limits were estimated with *status quo* data using probit analysis in SAS, assuming a normal distribution (Eveleth & Tanner, 1990; WHO Expert Committee on Physical Status, 1995). Maturational delay was defined as the difference between median age at menarche of the reference population and the estimated median age at menarche of the study population. To correct for differences in maturation between the reference and study population, the prevalence of stunting and thinness is also reported after adjusting for maturational delay (WHO Expert Committee on Physical Status, 1995). Adjustment was done by subtracting the maturational delay in the study population from each individual's age and recalculating the *z*-scores with this adjusted age.

Ethical clearance and informed consent

The school-based studies were approved by the ethical committee of the Kenya Medical Research Institute (KEMRI) and the Academic Medical Centre, University of Amsterdam. Parents–teachers meetings were held in each school to create awareness of the planned study. Written consent was obtained from the parent–teacher association of each school and the individual student and her parents.

Results

In Mumias, 300 girls were enrolled. In total, 10 were subsequently excluded because, further analysis using date of birth revealed they were less than 12 y of age, despite the reported age. In the two Asembo surveys, 669 of 840 randomized (79.6%) were enrolled. The remaining had moved out of the study area or were absent on the day of survey ($N=55$), or consent was not given ($N=116$). A further 21 were younger than 12 y of age and were excluded. Thus, 938 girls contributed to the final data set, including 290 from Mumias and 648 from Asembo. Their characteristics are given in Table 1.

All girls knew their year of birth, but almost a third of the girls did not know their month of birth and age was approximated as described in the methods. Observed standard deviations for height-for-age and weight-for-age *z*-score distributions were 1.14 and 1.17, respectively, indicating that the quality of the data was good (WHO Expert Committee on Physical Status, 1995).

Descriptive statistics

Overall, 15.6% had a BMI < 5th percentile for their age; 18.3% in Asembo and 7.8% in Mumias. Overall, 12.1 and 2.0% were stunted and severely stunted, respectively; 10.8 and 1.6% in Asembo and 15.6 and 3.4% in Mumias. In total, 36 girls (3.9%) were classified as being both thin and stunted.

Table 1 Demographic and nutritional characteristics of 938 adolescent schoolgirls from western Kenya

Characteristics	*Mumias (Nov '97 and Mar '98)*	*Asembo 1 (Oct–Nov '98)*	*Asembo 2 (Feb–Mar '99)*	*Asembo Overall*	*Overall*
Number of study participants	290	312	336	648	938
Age; median (inter-Q range)	13.7 (13.0, 14.7)[a]	14.3 (13.3, 15.4)	14.2 (13.0, 15.2)	14.2 (13.2, 15.3)	14.1 (13.1, 15.1)
Menstruating; No. (%)	91 (32.2)	101 (32.3)	110 (32.4)	211 (32.3)	302 (32.2)
Median age at menarche; median (95% fiducial limits)	14.6 (14.4, 14.9)	15.1 (14.9, 15.3)	15.0 (14.9, 15.2)	15.1 (14.9, 15.2)	15.0 (14.9, 15.1)
Median age at start of puberty (>B2); median (95% fiducial limits)	11.7 (10.4, 12.3)	12.4 (11.8, 12.7)	12.2 (11.7, 12.5)	12.2 (11.8, 12.5)	12.1 (11.7, 12.3)
Maturity rating (breast development); median (inter-Q range)	3 (2, 3)	3 (2, 4)	3 (2, 4)	3 (2, 4)	3 (2, 4)
BMI-for-age <5th percentile; No. (%)[b]	22 (7.8)[a]	60 (19.0)	57 (17.7)	117 (18.3)	139 (15.6)
Height-for-age *z*-score; mean (95% CI)[c]	−0.95 (−1.15, −0.75)	−0.68 (−0.80, −0.55)	−0.75 (−0.87, −0.62)	−0.71 (−0.80, −0.62)	−0.77 (−0.86, −0.68)
Height-for-age *z*-score < −2SD; No. (%)	45 (15.6)	32 (10.9)	37 (10.8)	69 (10.8)	114 (12.1)
Height-for-age *z*-score < −3SD; No. (%)	10 (3.4)	3 (1.2)	7 (2.0)	10 (1.6)	20 (2.0)
Thin and stunted; no. (%)	12 (4.3)	8 (2.6)	16 (4.9)	24 (3.8)	36 (3.9)

[a]Significant difference between Mumias and both Asembo surveys ($P<0.05$).
[b]NHANES I reference data (Must *et al*, 1991a, b).
[c]Normalized NCHS (1977) reference data (<18 y only) (Dibley *et al*, 1987).

Mean height-for-age *z*-scores are presented in Table 1 and the crude nonage standardized anthropometric measures in Table 2. No differences in thinness and stunting were seen between the two Asembo surveys, conducted in different seasons with different food availability and malaria transmission (Table 1). The prevalence of thinness was appreciably higher in Asembo than in Mumias; odds ratio 2.67 (1.83, 3.88). The prevalence of stunting in Mumias was higher than in Asembo; odds ratio 1.52 (0.84, 2.74). Only five girls (0.6%) (four in Asembo [0.7%] and one in Mumias [0.3%]) and were classified as overweight (BMI > 85th percentile). In Asembo, median age at menarche was 15.1 y (95% fiducial limits; 14.9–15.2), and median age at the start of puberty (breast development stage B2) 12.2 y (95% fiducial limits; 11.8–12.5). Maturational delay in Mumias was 6 months shorter. Overall, only 26 girls (2.8%) were in the correct class for their age according to the governments criteria from the Ministry of Education. Median age-for-grade score (see methods) was 4 (interquartile range: 3–5), suggesting either a high frequency of late enrolment in school, a high frequency of repeating school years or both (Partnership for Child Development, 1999).

Age and sexual maturation

The prevalence of thinness and stunting decreased markedly with age and sexual maturation (Table 3). BMI-for-age *z*-scores and height-for-age *z*-scores were significantly associated with age (Spearmans rho [*P*-value]; 0.25 [$P<0.001$] and 0.34 [$P<0.001$] for BMI and height, respectively) and with sexual maturation (Kruskal–Wallis one-way analysis of variance; $P<0.001$ and 0.001). The mean *z*-scores of height-for-age converged towards the US reference median with age and the corresponding prevalence of stunting decreased

Table 2 Anthropometric measurements* of 938 adolescents schoolgirls from western Kenya, stratified by age

Age	*N*	*Height (cm)*	*Weight (kg)*	*BMI*
12	214	147.3 (146.0, 148.6)	35.4 (34.4, 36.3)	16.2 (16.0, 16.5)
13	250	151.6 (150.4, 152.7)	38.9 (37.8, 40.0)	16.9 (16.6, 17.2)
14	228	156.7 (155.7, 157.7)	43.8 (42.5, 45.0)	17.8 (17.4, 18.2)
15	157	160.4 (159.4, 161.3)	47.5 (46.3, 48.7)	18.5 (18.1, 18.9)
16	74	160.7 (159.3, 162.1)	51.7 (50.4, 53.0)	20.0 (19.5, 20.5)
17 + 18	15	162.2 (159.6, 164.8)	56.4 (54.0, 58.9)	21.4 (20.6, 22.3)

*Mean (95% CI).

Table 3 Demographic factors associated with thinness and stunting in adolescent schoolgirls from western Kenya[a]

	Thin (BMI for age < 5th percentile)[b]		*Stunted (Height for age z-score < −2sd)*[c]	
Factors	*n (%)*	*Odds ratio (95% CI)*	*n (%)*	*Odds ratio (95% CI)*
Cross-sectional survey				
Mumias	22/290 (7.8)	0.39 (0.28, 056)	45/290 (15.6)	1.52 (0.80, 2.90)
Asembo 1	60/312 (19.0)	1.09 (0.63, 1.88)	32/310 (10.9)	1.00 (0.53, 1.90)
Asembo 2	57/335 (17.7)	Reference	37/334 (10.8)	Reference
Age (y)				
12	45/214 (20.8)	Reference	50/214 (22.8)	Reference
13	42/249 (19.2)	0.95 (0.52, 1.73)	44/249 (17.8)	0.72 (0.44, 1.19)
14	34/228 (15.9)	0.72 (0.36, 1.43)	13/228 (6.3)	0.22 (0.10, 0.51)
15	15/157 (10.1)	0.38 (0.18, 0.82)	6/157 (3.5)	0.13 (0.04, 0.37)
16 +	3/89 (3.0)	0.10 (0.02, 0.44)	1/86 (1.0)	0.03 (0.00, 0.29)
Maturity rating (Tanner breast development)				
1	53/149 (36.4)	Reference	52/149 (33.5)	Reference
2	45/233 (21.8)	0.59 (0.32, 1.08)	41/233 (18.1)	0.41 (0.22, 0.75)
3	28/305 (9.8)	0.20 (0.12 . 0.32)	19/305 (6.5)	0.13 (0.07, 0.24)
4	10/132 (7.9)	0.14 (0.05, 0.35)	0/132 (0)	—
5	1/114 (0.8)	0.01 (0.00, 0.10)	1/111 (0.8)	0.02 (0.00, 0.11)
Menstruation				
Premenarche	126/625 (21.2)	Reference	105/625 (16.6)	Reference
Postmenarche	12/302 (4.0)	0.15 (0.07, 0.30)	5/299 (1.7)	0.09 (0.03, 0.25)

[a]Odds ratios, obtained by logistic regression, adjusted for survey and clustering in schools.
[b]NHANES I reference data (Must *et al*, 1991a, b).
[c]normalized NCHS (1977) reference data (< 18 y only) (Dibley *et al*, 1987).

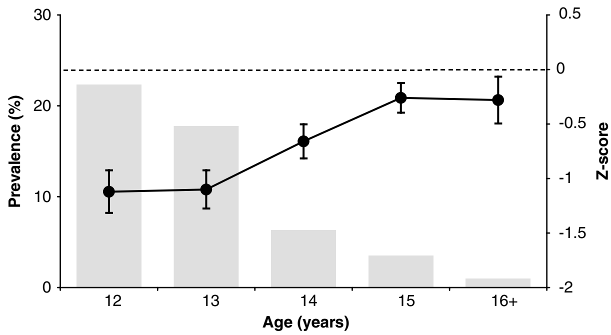

Figure 1 Measures of linear growth by age in 934 adolescent schoolgirls from western Kenya. Bars represent prevalence of stunting (height-for-age *z*-score <-2 s.d.); Circles and error bars represent mean height-for-age *z*-score and its 95% confidence interval. Horizontal dashed line represents reference median height-for-age. Height-for-age *z*-scores and prevalences were calculated using 1978 CDC/WHO reference data (Dibley *et al*, 1987).

(Figure 1). A similar relationship between height-for-age *z*-scores and sexual maturation was seen (data not shown). A third of all girls (32.2%) had passed menarche and thinness and stunting were rare in these girls compared to premenarcheal girls (Table 3).

Age at menarche and age at pubarche in this population were markedly delayed relative to the median ages for these maturational events in the NCHS/WHO reference population (WHO Expert Committee on Physical Status, 1995). In Asembo and Mumias there were approximate delays of 2 and 1.5 y, respectively. When height-for-age *z*-scores were adjusted for this maturational delay (see Methods and materials) the overall prevalence of stunting was only 1.0%.

Girls relatively late to start menstruating (girls equal to or older than the estimated median age at menarche and not menstruating) had significantly lower height-for-age z-score than girls having gone through menarche relatively early (girls younger than the estimated median age at menarche and menstruating) (*t*-test mean difference = −0.36 [−0.63, −0.10]). This difference was apparent even after adjusting for age (adjusted mean difference [95% CI]; −0.47 [−0.86, −0.08]). Additionally, girls late to start menstruating were more likely to be classified as thin (crude odds ratio [95% CI]; 5.37 [1.22, 23.76]), even after adjusting for age (adjusted odds ratio [95% CI]; 9.30 [2.00, 43.33]). The same was true for BMI-for-age *z*-scores (*t*-test mean difference [95% CI]; −0.85 [−1.12, −0.58], adjusted mean difference [95% CI]; −0.92 [−1.23, −0.61]).

Discussion

In this sample of schoolgirls aged 12–18 y, we found that malnutrition was prevalent in young girls, but relatively uncommon in older adolescents; overall 20.0 and 20.1% of the younger girls (12–13 y) and 11.6 and 4.3% of the older girls (14–18 y) could be classified as thin (low BMI) or stunted, respectively. Severe stunting was rare (2%). Furthermore, mean *z*-scores for height-for-age tended to converge towards the median of the US reference curve in older girls and prevalence of thinness and stunting decreased with age. The prevalence of stunting in adolescent girls was approximately a third of that found in children under 5 y from the same study area in Asembo (Kwena *et al*, 2003). The prevalence of stunting was lower than the prevalence reported in one other study in African adolescent girls using the same reference data (Simondon *et al*, 1998).

The median age at menarche and median age at start of puberty (Tanner B2), obtained using the *status quo* method (Eveleth & Tanner, 1990), were delayed relative to that of the NCHS/WHO reference population (WHO Expert Committee on Physical Status, 1995) by approximately 2 y in Asembo and 1.5 y in Mumias. Similar delays have previously been described in undernourished adolescents and the decline in age at menarche in developed countries has been attributed to secular changes in welfare (Dreizen *et al*, 1967; Eveleth & Tanner, 1990; Cameron *et al*, 1993; Simondon *et al*, 1997; Chowdhury *et al*, 2000).

In this population, girls who were relatively late to start menstruating were more malnourished than girls of the same age who started menstruating early. In most girls, menarche comes approximately a year after peak height velocity and coincides with the last part of the adolescent growth spurt. Maturational delay in undernourished children, has been shown to provide an opportunity for catch-up growth (Cameron *et al*, 1994; Martorell *et al*, 1994; Simondon *et al*, 1998). The trend towards higher height-for-age *z*-scores with age and sexual maturation seen in this population, is similar to that reported from cross-sectional studies published earlier (Partnership for Child Development, 1998; Lwambo *et al*, 2000). On the assumption that age-related patterns in cross-sectional data reflect patterns of longitudinal growth, this gives observational support to the phenomenon of catch-up growth. When the prevalence of stunting was adjusted for maturational delay, allowing for a comparison with the reference population excluding average effects that accompany differences in maturational rate (WHO Expert Committee on Physical Status, 1995), only 1.0% of girls were classified as being stunted, suggesting potential for complete catch-up growth within the 1.5–2-y period of maturational delay.

There were differences in mean height-for-age and BMI-for-age between the two study sites. The distinct ethnic (genetic) makeup of each area is a possible explanation for these differences. Other possible explanations are the difference in maturation (∼6 month difference in median age at menarche) between the two study areas, genetic imprinting during foetal development (Golden, 1994), or differences in nutritional conditions and other factors affecting linear growth during the preschool years (the main period in which linear growth retardation occurs), such as malaria (ter Kuile *et al*, 2003).

No seasonal differences between the two Asembo surveys were seen, which suggests that the seasonality of potential key determinants of nutritional status such as differences in food availability, energy expenditure and infectious diseases, may have been smaller at the time of study than reported from other studies in developing countries (Ferro-Luzzi *et al*, 1994; Benefice *et al*, 2001; Tetens *et al*, 2003). Similar to our study, a recent study of nutritional status in preschool children in a different part of Kenya also found no seasonal weight change (Kigutha *et al*, 1995).

The prevalence of thinness in this study is likely to overestimate the true prevalence of functional malnutrition because the US reference data used for our analyses have been reported to be markedly skewed towards higher values when compared to other well nourished (European) populations (WHO Expert Committee on Physical Status, 1995). Moreover, a recent study evaluating the use of the NCHS reference data in populations of different ethnic background concluded that use of these curves led to a misleadingly high prevalence of thinness in an otherwise well-off group of Indian adolescent boys (de Onis *et al*, 2001). Studies specifically looking at anthropometric measures and their functional outcomes would be needed to establish more valid cut-offs.

Several design related limitations should be considered when interpreting the results of this study. Because of the selected sample of school attendees, generalizations of our findings to the adolescent population overall, must be made with caution. No attempt was made to identify randomized children absent from school on the day of survey (6.5% of randomized girls eg due to illness, domestic duties, care for ill siblings or failure to pay school fees), or to evaluate children who do not attend school at all. Studies from Ghana and Tanzania have shown marked health differences between children who attended school and those of the same age who did not (Beasley *et al*, 2000; Fentiman *et al*, 2001). A contemporary prospective school-based study of younger children from the same area suggested that girls are more likely to drop out of school than boys (Friedman *et al*, 2003). Girls may drop out of school because of teenage pregnancy or if they become orphaned. The study sample is thus potentially biased towards healthier girls, possibly with higher socio-economic status, potentially resulting in an underestimation of the proportion of girls with (severe) malnutrition. Furthermore, the cross-sectional design makes any inference of growth patterns over time difficult. We cannot rule out that selective dropout of malnourished girls is, at least in part, responsible for the age-related decline in malnutrition.

We conclude that stunting and thinness are common in young adolescent schoolgirls in these poor rural settings in western Kenya, but that prevalence decreases with age, providing observational support that children catch up on incomplete growth attained earlier in life due to a maturational delay of 1.5–2 y allowing prolonged growth.

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