In rural Gambia, do adolescents have increased nutritional vulnerability compared to adults?

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# **Abstract**

Adolescents may be particularly susceptible to malnutrition due to the energy and nutrient costs of the pubertal growth spurt. The aim of this study was to compare differences in selected markers of nutritional status between adolescents and adults in rural Gambia.

The Keneba Biobank collects cross-sectional data and samples for all consenting individuals resident in the West Kiang region of The Gambia. For this study, participants between the ages of 10 and 40 years (y) were selected (*n* = 4201, female 2447). Height, body mass index, body composition, haemoglobin concentration, fasting glucose concentration and blood pressure were compared using linear regression models adjusting for age, parity, season of measurement and residence, across three age groups: early adolescent (10-14.9y), late adolescent (15-19.9y) and adult (20-39.9y).

Adolescents, particularly early adolescent girls and boys, were shorter, lighter and leaner than adults. By late adolescence differences were smaller, particularly in girls where, notably, the prevalence of overweight, hypertension and impaired fasting glucose was low. Given the importance of maternal health for reproductive outcomes and intergenerational health, the results of the study, albeit with limited biomarkers available, indicate adolescent girls are no more compromised than adult women or males from the same population.

# **Introduction**

In 2011, the population of adolescents aged 10-19 years in the world was 1.2 billion. 1 In sub-Saharan Africa, 30-35% of the population are aged 10-24 years. 2 Adolescent growth and timing of puberty are important determinants of adult and intergenerational health and non-communicable disease risk. 3, 4 Clearly at a time of rapid growth the energy and nutrient requirements of an individual increase substantially. As such, adolescents may be particularly susceptible to malnutrition due to the energy and nutrient costs of the pubertal growth spurt and, for girls, the increased demands for iron after menarche. Adolescent health and nutrition are closely linked to offspring birth outcomes and can therefore also have important long-term (intergenerational) effects. The most recent reports of pubertal timing in Gambian girls from a rural, subsistence farming population (the same population where the current study was based), were that the median age at menarche was 14.9 years. 5, 6 In boys, puberty is delayed even more than in girls, with age at peak height velocity (APHV) an indicator of the pubertal growth spurt, being reported as 16.1 ± 0.12 years. 5, 7 In comparison, the APHV in a contemporary cohort of South African adolescents was 11.4(0.7) and 14.2(1.1) in girls and boys respectively; 8 similar timings were reported in two UK birth cohorts. 9, 10

The Gambia has high neonatal mortality (29.9 per 1,000) and maternal mortality (706 per 100,000), as well as a high rate of adolescent pregnancy. 11 In rural areas in 2010, 58.6% of girls were married before the age of 18 years, contributing to an adolescent birth rate of 161 per 1,000 (age-specific fertility rate, 15-19 years). 12 The effects of adolescent pregnancy may be compounded by the relatively delayed pubertal development of Gambian children. 13

In 2012, the Keneba Biobank was established to build on the existing Kiang West Demographic Surveillance System (KWDSS) and historical longitudinal cohorts studied in the region. The aim of the Biobank was to collect phenotypic data, biological samples and to perform some analytical tests on the population which relies primarily on subsistence agriculture, with yield fluctuating heavily across the year. In 2013, the average life expectancy at birth in the Kiang West Longitudinal Population Study was reported as 73.5 and 65.3 years in females and males respectively. 14 The wet season, lasting from July to October, is a hungry period because stored staple foods from the previous year’s harvest are near depleted. At the same time, adults have an increased workload in preparation for the current year’s harvest. These factors lead to reduced maternal weight gain during pregnancy and reduced birth weight. 15 Furthermore, there are ongoing effects in later life, such that children born during the wet season have increased mortality from the age of 15 years onwards. 16 Of the 36 villages in the Kiang West region, three have been the sites of longitudinal studies and demographic surveys since the 1950s. These ‘core’ villages (Keneba, Manduar and Kantong Kunda) have benefited from improved access to health care, including antenatal clinics, since 1977. 14, 17

Despite wide acknowledgement of the importance of adequate nutrition status for adolescent growth, few data are available, particularly from low and middle income countries. There is therefore a need to better understand the determinants of nutritional status among adolescents, to improve their own current and subsequent health and the health of their children. The aim of the current study was to compare differences in selected markers of nutritional status, height, body mass index, haemoglobin, blood pressure and body composition, between male and female adolescents and adults in rural Gambia, to assess whether adolescent nutritional vulnerability exists at the population level.

# **Methods**

## Participants

The Keneba Biobank was established in 2012 and to September 2015 cross-sectional data and samples for over 9000 consenting individuals had been collected. The Biobank sampling and measurements were conducted in the field, with visits scheduled to ensure even distributions of recruitment by village and season. Biobank samples are linked to the Kiang West Demographic Surveillance System via the KWDSS unique identifiers (DSS), which provides information on age, parity and family structure for every individual who has been resident in Kiang West since 2004, based on three-monthly surveillance of the population. DSS survey and Biobank recruitment methods, and information of the database structure and data flow are detailed in Hennig et al. 14

For this study, participants between the ages of 10 and 40 years (y) were selected (*n* = 4,201; female 2,447). These were divided into three age groups for comparison: “early adolescent” (10 – 14.9 y), “late adolescent” (15.0 – 19.9 y) and “adult” (20 – 39.9 y). Adolescents were split into two groups as per UNICEF recommendations. 1

Parity was obtained from the DSS. It is possible that some older children may not have been included in this count, if they have not lived in the Kiang West region at any time since the initiation of the DSS in 2004. Since almost all early-adolescent girls were nulliparous, this age group was excluded from any analysis involving parity as a predictor. Very few late-adolescent girls had had two or more children, so comparisons between age groups were made using parity as a binary variable, comparing subjects who had had at least one child to those who had not. Direct data concerning lactation were not available as part of the information collected by the Biobank. Instead, the DSS was used to determine whether a subject had had a child within the two years preceding the Biobank visit, and to confirm whether that child was alive at the time of the mother’s Biobank visit. If both these conditions were true, and due to the very high rates of breastfeeding in this population, the mother may have been lactating. Pregnancy in the last two years is therefore reported in Table 1 as a marker of high rates of pregnancy and breastfeeding in this population.18

## Anthropometry

Weight and height were collected using standard protocols and using regularly validated equipment. Body Mass Index (BMI) was computed at weight (kg) / height squared (m2). Height and BMI were converted to z-scores (height-for-age, HAZ; BMI-for-age, BAZ) using the WHO growth references. 19 The reference centiles attain adult values at the age of 19. Since adolescent growth in The Gambia is known to be delayed relative to reference populations, the centiles for 19-year-olds were also applied to all participants over the age of 19, so that adult values can be compared to those of adolescents. 13 Stunting, underweight and overweight were defined as per WHO definitions: stunting, HAZ < -2; underweight, BAZ < -1.65 (below the 5th percentile); overweight, BAZ > 1.04 (above the 85th percentile). At the age of 19 years, the 5th percentile of BMI is close to 18 kg/m2, the threshold normally used to define underweight in adults, so the same cut-offs are used in all age groups.

## Body composition

Body composition was measured by bioimpedance using a Tanita BC-418 MA Segmental Body Composition Analyser (Tanita Corporation, Amsterdam, the Netherlands). The outcome used in this study was body fat expressed as a percentage of total body mass. Fat %-for-age z-scores (FAZ) were calculated using reference centiles based on a European population that was measured using the same model of bioimpedance analyser. 20 Low body fat was defined as FAZ < -2.05 (below the 2nd percentile) and high body fat as FAZ > 1.04 (above the 85th percentile), as recommended by. 20

## Haemoglobin

Haemoglobin concentration was measured from fasting venous blood samples as part of a full blood count using a Boule Medical Medonic M-series 3-part Haematology Analyser (Boule Diagnostics AB, Sweden). Age-specific cut-offs were used to defined define mild anaemia, as recommended by: 18 11.5 g/dl up to 11.99 years; 12.0 g/dl up to 14.99 years; 12.0 g/dl after age 15 years (female); 13.0 g/dl after age 15 years (male). Moderate and severe anaemia were defined using thresholds of 11 and 8 g/dl, respectively (in males and females of all ages).

## Blood pressure

Blood pressure was measured using an Omron 705-CPII. For subjects aged 18 years or over, hypertension was defined as systolic blood pressure (SBP) ≥ 140 mm Hg and/or diastolic blood pressure (DBP) ≥ 90 mmHg. 21 For subjects under the age of 18, hypertension was defined according to US guidelines for children and adolescents. 22

*Fasting glucose*

Fasting glucose was measured from a venous blood sample using a Roche Diagnostics Accu Check (London, UK). A fasting glucose concentration of 6.1 mmol/l or more was considered indicative of impaired fasting glucose (IFG). 23

## Statistical analysis

Statistical analysis was carried out in R version 3.3.2, 24 including the following packages: dplyr version 0.5.0 for data manipulation and ggplot2 version 2.2.1 for plotting. 25, 26 Continuous outcome variables were HAZ, BAZ, FAZ, haemoglobin concentration, and systolic and diastolic blood pressure. These were compared across the three age groups using linear regression. Residence of the core village of Keneba, Manduar and Kantong Kunda was included as a binary predictor. Season of measurement was also included as a binary predictor, comparing the wet (hungry) season lasting from July to October against the dry season. For female participants, the analysis was repeated twice: first for all participants, then limited to nulliparous women. To test whether age differences depended on village of residence or season, interactions were added to the initial models. These were non-significant in all cases and so not reported or included. Coefficients for the age-group terms in the unadjusted models were near-identical to those in the models adjusted for season and village and so only the adjusted models are included in the results. For each model, QQ plots were inspected to check for normality of the residuals.

Comparisons between the adolescent groups and adults are given in Table 2. Coefficient estimates are shown with [95% confidence intervals] and are considered significant if *p* < 0.05.

# **Results**

Descriptive statistics for each age group are shown in Table 1. Continuous variables are summarised as means ± standard deviations and categorical variables as percentages. The distributions of the anthropometric outcome variables across age groups are illustrated in Figure 1. Between 20% and 29% of respondents in each age group were from the core villages of Keneba, Manduar and Kantong Kunda, and there was an even distribution across months of the year for data collection across the age groups. Many late adolescent girls (20%) had had at least one child, and a majority of adult women (63%) had had at least three children. For 52% of adult women, the most recent child had been born within the last two years, suggesting that they might have been lactating at the time of the visit. 18

Stunting was common among adolescent boys (25%) and among early adolescent girls (14%). Underweight was common among adolescent boys (early 46%, late 48%), adult men (20%) and adolescent girls (early 38%, late 12%), but adult women were more likely to be overweight (14%). Low body fat was common among late adolescent boys (16%) and girls (10%), and among adult men (25%), whereas high body fat was common among adult women (24%). Anaemia was common in all age groups and both sexes (from 22% in adult men to 58% in adult women), but this was rarely severe. Hypertension and impaired fasting glucose were rare.

## Female (all)

Adolescent girls in both age groups were shorter and had lower BMI and fat percent than adult women, relative to the reference populations. They also had lower blood pressure (lower SBP in early adolescence, lower DBP in both age groups), but higher haemoglobin concentration. Residency in the core villages was associated with a higher BMI. Fat percent, haemoglobin and blood pressure were lower during the wet season, but height was greater.

## Female (nulliparous)

When considering only nulliparous women, results remained very similar to those in the complete female group. Exceptions were that the difference in fat percent was no longer significant in early adolescence, SBP was significantly lower in late adolescence, and there was no longer an effect of core village residence on BMI.

## Male

Adolescent boys were shorter and had lower BMI than adult men, relative to the reference population. Fat percent was lower in early adolescence but not in late adolescence. Haemoglobin concentration and blood pressure were lower in both adolescent groups than in adults. Core village residence was associated with increased BMI and fat percent. During the wet season, BMI, fat percent, haemoglobin and blood pressure were all lower than during the dry season.

## Pooled females and males

Sex differences in adult HAZ were not significant, but men had lower BMI, lower fat percent, higher haemoglobin concentration and higher SBP than women. The differences among age groups were significantly different between the sexes, for all outcomes except DBP. There were also significant sex differences in the effects of core village residence on fat percent, and in the effect of season of measurement on BMI and fat percent.

# **Discussion**

## In a population-based study of over 4000 individuals from a rural, subsistence farming population, susceptible to malnutrition, this work has shown that towards the end of growth and in early-mid adulthood, there is low prevalence of stunting, overweight and obesity and in risk factors for cardiometabolic disease and anaemia. Males remain lighter and leaner than females, but overall there were no significant differences between females and males for the markers of health assessed.

## There were greater differences with age in BAZ and FAZ among boys than among girls, which is consistent with the more delayed pubertal development of boys compared to girls. This is in contrast to previous reports of nutritional vulnerability in adolescent girls but is possible due to an increased sensitivity of males to environmental challenges. 1, 5, 7, 8 27 However, due to known delays in pubertal development in this population, these results cannot necessarily be interpreted as a signal of nutritional vulnerability. 13 Growth references are created according to chronological age, which is the simplest, globally consistent, assessment of an individual’s age. However, it is well-recognised that chronological age is limited as a reflection of maturity, particularly when delayed or precocious puberty occurs due to an underlying chronic disease or, as it the case in the current population, due to environmental constraint. As such it is difficult to determine whether a low HAZ or BAZ, is due to a physiological deficit in growth or due to delayed puberty, and in-turn the subsequent impact on final height or body composition. Previous work from The Gambia indicated the longer growth period and later puberty in the Kiang West population allow some ‘catch-up’ of height growth. 13 In agreement with this, the results of the current cross-sectional study suggest that delayed puberty is the likely reason for the observations of group differences in growth. Most particularly for HAZ, where z-scores are almost zero in the adult group indicating the longer and slower growth period in this population does not, at the population level, impair final adult height. Similarly for girls BAZ, FAZ z-scores are close to zero by the end of growth. To confirm these observations, longitudinal studies and/ or more direct assessment of pubertal stage or maturity, such as bone ageing or Tanner staging, are required. 8, 28 Regardless, the impact of later or slower pubertal growth on increased risk of future disease, is well-described in higher income populations, showing later pubertal growth to be associated with higher risk of cardiovascular and musculoskeletal disease. 9, 10, 29 In LMICs less is known about the impact of pubertal timing on linear and somatic growth during adolescence or on final height, weight and future health outcomes. 30 In the COHORTS collaboration, a greater BMI gain during childhood and adolescence was associated with poorer markers of cardiometabolic health. Similarly, recent data from the Vellore cohort in India showed that greater height and weight gain relative to height were associated with increased risk of a poor cardiovascular disease profile in adulthood. 31

One surprising finding was the impact of village of residence within this rural community on both BAZ and FAZ, with higher values observed in residents of the three ‘core’ villages. This finding probably reflects a combination of the closer proximity to the MRC Keneba *c*linic and the impact of the MRC on the economy in this area (through direct employment and also indirectly). 17 The observation draws parallels with recent work from the Urban Gambian population where the odds of being stunted were increased if a child's parents had been born in a rural region. 27

In addition to the importance of adolescent growth for health of the individual, there are also impacts for intergenerational health. Younger maternal age (≤ 19 years) is a risk factor for a range of adverse pregnancy outcomes including low birthweight, preterm birth and childhood stunting at two years of age. 32 As adolescence represents a period of nutritional vulnerability, it is easy to assume that these adverse outcomes are a consequence of nutritional constraint during this time. However, we have published elsewhere that the literature on the nutritionally mediated pathways underpinning the links between young maternal age and poor intergenerational and long-term health is sparse. 4 The data presented here suggest that, even in a rural sub-Saharan African context, where seasonally driven food insecurity creates a high risk of undernutrition in childhood, 33 adolescent girls are no more susceptible to nutritional vulnerabilities than adolescent boys or older females and males, at least for the limited number of nutritional status biomarkers assessed. However, as this analysis was cross sectional in nature and did not include a cohort of pregnant adolescent girls we are unable to comment on how pregnancy would impact on nutritional status.

There is limited comparable data reporting population-level trends in markers of nutritional status across females and males in this age range. A recently published review presenting data on global and regional trends in the nutritional status of young people highlighted that “while national-level data for children under 5 have been largely collected, over- and undernutrition data for adolescents are mostly unavailable and tend to have smaller sample sizes.” 3 Indeed, in this same review and using recent estimates from the WHO’s Global School-Based Health Survey (GSHS) of underweight prevalence by WHO region and for the age groups 13-15 years, 16-17 years and 13-17 years, only 16/59 counties listed had comparable data across the early- to late-adolescent period. 3 Where data were available, there was limited evidence of differential vulnerability by age group, at least for underweight (< -2SD from median for BMI). However, for the previously discussed reasons, there is a need to extend the use of HAZ, WAZ and BAZ to include other biomarkers in order to gain a full and in-depth reflection of the underlying nutritional vulnerabilities in the population.

In the current study, for measures of nutritional status other than height and BMI, fewer and less consistent associations were observed for trends between age groups. Of note, our data do highlight that particularly within the late-adolescent group, females were in relatively good nutritional and metabolic health with no impaired glucose control, little hypertension and low rates of moderate and severe anaemia. Haemoglobin concentration was higher in adult men than in adolescent boys, but this relationship was reversed among women and girls. Lower haemoglobin concentrations of adult women may be indicative of insufficient recovery between multiple pregnancies, but the difference was still evident when the analysis was limited to nulliparous females. Blood pressure increased with age from early to late adolescence, and from late adolescence to adulthood. This increase was greater among males than among females, though none of these increases indicated high rates of hypertension in the populations. Blood pressure was lower during the wet (hungry) season than during the dry season, and there was no difference between the core villages and other villages. No differences were found for fasting glucose concentrations.

The strengths of the current study include the relatively large size of the cohort, with contemporary data, and focused on a population susceptible to nutritional challenges. Limitations have been discussed but briefly include: the limited availability of biomarkers; lack of detailed socioeconomic status, lack of assessment of maturational status and cross-sectional data do not allow underlying aetiology to be determined. Further, the reliance on published reference data and cut-offs, often generated from contrasting populations, and the use of different references and cut-offs between age groups may introduce some inherent errors into the data as presented.

In conclusion, in older adolescent females and males from rural Gambia there is little evidence to suggest that, in comparison to adults from the same population, prevalence of anaemia, stunting, overweight and obesity differs. Overall these data indicate good cardio-metabolic health in this population. High rates of anaemia across the ages indicate nutritional vulnerability at a population level. The data from girls and boys in early adolescence, although indicative of higher levels of undernutrition, is limited in its interpretation due to the aforementioned issues caused by the known delay in puberty in the Kiang West Population which can create an artefactual exaggeration of differences from reference populations. 5, 6, 13 These results may not be applicable to populations at different stages of nutrition, social and economic transition. Moving forwards work should include direct assessment of a maturational marker or pubertal status, and nutritional status and dietary intake and markers of socioeconomic status to further define the concept of nutritional vulnerability in adolescents. Such measurements would include assessment of micronutrient status for nutrients such as zinc, iron, sodium, vitamin D, folate and vitamin A. 34 Clearly, adolescence remains an important period of an individual’s life course and is an important determinant of adult and intergenerational health. It is important to extend the work to other settings, and to continue to monitor the current population which is in nutritional, social and economic transition, to fully understand the impact of adolescence in future non-communicable disease risk.

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SEM, KAW: study design, data interpretation, drafting and producing final version of manuscript

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AP, AMP: drafting and approval of final version of manuscript

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**Figure legends**

Figure 1: Height-, BMI- and fat %-for-age z-scores by age group and sex. Boxplots showing the median (thick horizontal line), interquartile range (height of box) and sample size (width of box), superimposed on violin plots showing the distribution. The dashed horizontal line indicates a z-score of zero, representing the median in the international reference data.