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TITLE

An analysis of the nutrition status of neighboring Indigenous and non-Indigenous populations in Kanungu District, Southwestern Uganda: close proximity, distant health realities

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ABSTRACT

Objectives. Malnutrition is a persistent health concern throughout the world. Globally, Indigenous peoples experience poorer health outcomes compared to their non-Indigenous neighbours. Despite this, malnutrition among Indigenous populations is poorly understood. This analysis estimated the prevalence, and modeled possible determinants of, moderate acute malnutrition (MAM) and severe acute malnutrition (SAM) for Indigenous Batwa and non-Indigenous Bakiga of Kanungu District in Southwestern Uganda. We then characterize possible mechanisms driving differences in malnutrition.

Methods. Retrospective cross-sectional surveys were administered to 10 Batwa communities and 10 matched Bakiga Local Councils during April of 2014 (n = 1,167). Individuals were classified as MAM and SAM based on middle upper-arm circumference (MUAC) for their age-sex strata. Mixed-effects regression models quantified the variation in malnutrition occurrence, considering individual, household, and community-ethnicity level effects. Models controlled for age, sex, number of dependents, education, and relative wealth.

Results. Malnutrition is high among Batwa children and adults, with nearly half of Batwa adults (45.34%, 95% CI 34.82 to 55.86 for males; 45.86%, 95% CI 37.39 to 54.33 for females) and nearly a quarter of Batwa children (20.31%, 95% CI 13.07 to 26.93 for males; 25.81%, 95% CI 17.56 to 32.84 for females) meeting MAM criteria. SAM prevalence is lower than MAM prevalence, with SAM highest among adult Batwa males (11.60%, 95% CI 4.83 to 18.37) and adult Batwa females (3.00%, 95% CI 0.10 to 5.90). SAM prevalence among children was higher for Batwa males (7.03%, 95% CI 1.36 to 12.70) compared to Bakiga males (0.57%, 95% CI 0 to 1.69). Models that incorporated community ethnicity explained the greatest variance (>60%) in MUAC values.

Conclusion. This research demonstrates a malnutrition inequality between the Indigenous Batwa and non-Indigenous Bakiga of Kanungu District, Uganda, with model results suggesting further investigation into the role of ethnicity as an upstream social determinant of health.

Keywords. Indigenous health; Malnutrition; Health inequalities; Uganda; Batwa

INTRODUCTION

Securing adequate adult nutrition and reducing infant and childhood malnutrition is a global health concern and international goal (1). High rates of global childhood malnutrition have proven especially persistent, with observed increases in some low- and middle-income countries, the majority of which are in Africa and Asia (2). There has been an increase in the number of undernourished individuals and wasting in children in Sub-Saharan Africa (2). Regional inequities have been by observed within countries, with nutritional outcomes patterned by social determinants of health, including but not restricted to education, gender, environment, and wealth (3, 4, 5).

Since 2005, the African Commission on Human and Peoples' Rights (ACHPR) has articulated that Indigenous peoples are among the most vulnerable groups on the African continent. While there are numerous understandings of what is reflected in the term 'Indigeneity' and Indigenous identity, there is a common focus on shared community, historic, and social experiences at the population-level (6, 7, 8). The ACHPR defines Indigenous groups in Africa as those whose: 1) cultures and ways of life differ considerably from the national majority, 2) cultures and ways of life that are, or historically have been, under threat (in some cases to the point of extinction), 3) survival depends on access and rights to traditional land and resources, 4) population suffers from discrimination due to being regarded as less developed and less advanced from the national majority, 5) the population typically lives in inaccessible regions (which also serves as a form of political and social marginalization), and 6) individuals are subject to domination and exploitation within structures suited to the interests and activities of the national majority (6). Despite variation between the estimated 250 million Indigenous peoples living in Africa, they similarly experience some of the poorest health indicators in the world (9, 10).

Globally, wide gradients in health have been observed between Indigenous and non-Indigenous populations living in the same region (11). Past studies of Indigenous populations in Africa and abroad consistently demonstrate higher rates of infectious and chronic disease, higher occurrence of mental illness, as well as higher rates of mortality and shorter life expectancy when compared to non-Indigenous populations (10, 12, 13). However, much of the research examining Indigenous health occurs in countries with developed health tracking capabilities, such as Australia, Canada, New Zealand, and the United States (12, 13, 14). Many factors may contribute to the lack of information around Indigenous health outside of these areas, and others have speculated that the lack of recognition of Indigenous peoples likely exacerbates this low availability of information (10). Little existing research addresses Indigenous health in areas like Sub-Saharan Africa where malnutrition rates are highest.

We contribute to this research gap by estimating and comparing the malnutrition prevalence between neighbouring Indigenous Batwa and non-Indigenous Bakiga populations in of Kanungu District in Southwestern Uganda and explore differences in their contexts that result in a notable health gradient. We first estimate and compare the prevalence of malnutrition using middle upper-arm circumference (MUAC) measures. We then explore the contribution of individual, household, community, and majority community ethnicity to variation in malnutrition estimates using multilevel analysis; this analysis seeks to unpack the aspects of living in an Indigenous community in affecting individual-level malnutrition. In doing so, we suggest possible mechanisms for disparities in malnutrition, and discuss the contexts in which Indigenous inequities have emerged.

METHODS

Study Population

The Batwa are an Indigenous people located in Kanungu District of Southwestern Uganda (15, 16). The Batwa self-identify as Indigenous and are recognized as ethnically distinct by the local populations; they are recognized by the pejorative ‘pygmy’, reflecting their traditionally short stature (hereafter we use short stature rather than ‘pygmy’). Currently, the Ugandan government does not recognize the Indigenous status or associated Indigenous rights of the Batwa as all ethnic groups in Uganda are considered Indigenous, therefore applying equal rights to all (16, 17, 18).

The Batwa are subject to ongoing and persistent racial and socioeconomic discrimination, both culturally and geographically (19). The Batwa of Kanungu District in Uganda were evicted from their traditional forest homelands in 1991 when Uganda demarcated protected areas. In doing so, the Batwa were forced into a sedentary living, contrasting with their traditional forest-based hunter-gatherer livelihoods (20, 21). This move paralleled the formal gazetting of forest areas in the region. With the establishment of Bwindi Impenetrable National Park (BINP) in 1991, the Batwa lost access rights to their former forest homelands. Integration of the Batwa into non-forest, sedentary, and agrarian livelihoods has been mixed. The Batwa experience a range of poorer health outcomes and lower socioeconomic indicators compared to non-Indigenous and populations living in the same region (22, 23, 24). Employment opportunities are limited for the Batwa as forest livelihoods are restricted by negligible forest access, and many Batwa communities are highly reliant on external aid and missionary support (25, 26).

Comparatively, members of the Bakiga ethnic group make up the majority of the non-Batwa population (22, 24). The Bakiga rely on subsistence farming of cash and food crops, although there are some employment opportunities via the gorilla tourism industry for BINP. Bakiga households – and the region at large – tend to have larger household sizes that have resulted in overpopulation issues and outward migration to surrounding areas of Uganda (27).

Data Structure

We explored the construct of Indigeneity as a social- and community-based health determinant in our empirical analyses. Individuals were classified as Batwa or Bakiga based on their residence in a Batwa or Bakiga community, regardless of their individual ethnic background. Individual ethnicity within Batwa and Bakiga communities is relatively homogenous, with negligible inter-marriage and infrequent Batwa or Bakiga living outside of communities aligned with their ethnicity. It is not uncommon for Bakiga men to father children with Batwa women, though children are typically raised by their mother within a Batwa community. Thus, the resulting 'Ethnicity' variable represents a hierarchical social construct rather than serving as only community ethnic categorization. It is meant to reflect the substantive and meaningful social divisions that mediate gradients in health in addition to determinants at the individual, household, and community levels. The following figure illustrates the hierarchy used to describe the structure of the data and subsequent models (Figure 1).

We did not attempt to measure ethnic or Indigenous status at the individual level —which would have been both difficult and culturally inappropriate to achieve with any reasonable analytic precision— instead focusing on the majority ethnic alignment of communities. While Batwa and Bakiga communities are dispersed within the same area and are not geographically separated, there is clear self-identification of community-level ethnicity.

Study Design

Retrospective cross-sectional face-to-face surveys were administered to 10 Batwa communities, reflecting an attempted census of all Batwa in Kanungu District, as well as 10 matched Bakiga Local Councils (LCs, the smallest unit of government administration). For the Bakiga, a two-step proportional systematic random-sample of households was carried out. The result of the random sample represents approximately 40% of the Bakiga adults in each LC and a randomly chosen child from each household. Due to frequent travel for employment, household membership was verified by an LC chairperson. A locally hired field assistant administered two surveys in the local language of Rukiga (spoken by both Batwa and Bakiga): (1) an individual-level health questionnaire for all ages, and (2) a household-level food security questionnaire for the head of the household (or a household representative above the age of 18). The survey was informed by, and validated with, local research assistants, local partners, and the communities themselves during pilot testing in Batwa communities during July and October 2012. In April 2014, 1250 individuals were surveyed: 471 Batwa, 696 Bakiga, and 83 (69 Batwa, 14 Bakiga) respondents later deemed unusable due to inaccurate or incomplete information (usable respondents totaling 1,167). The response rate was 94.9% (540/569) among Batwa and 95.4% (710/743). Female adults were overrepresented in both surveys, with more overrepresentation among Bakiga women than among Batwa women. This overrepresentation is likely due to the migratory employment of both Batwa and Bakiga adult men.

Measuring and defining malnutrition cases

We used MUAC to detect the presence of malnutrition in Batwa and Bakiga individuals. MUAC is advantageous in community-based programs due to ease of administration (i.e. low technology, ease of use) and is currently considered valid across many populations (high ROC curve, known constant increase with age) (28). MUAC was chosen as the most robust measure for malnutrition since it is likely to be the least subject to the anthropometric difficulties of comparing height or weight between short stature and non-short stature populations. While MUAC can be adjusted for age or height, the diversity of population contexts makes international adjustment guidelines difficult to prescribe. MUAC aligns with many established protein-energy malnutrition cutoffs and has been used in anthropometric assessment of short stature populations (29, 30, 31); however, there exists little guidance on the methodological implications of using a non-short-stature-derived diagnostic in short stature populations.

We calculated two binary classifications of acute protein-energy malnutrition: moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). We established locally appropriate MAM and SAM cutoffs using the World Health Organization (WHO) and Republic of Uganda's Ministry of Health Integrated Management of Acute Malnutrition Guidelines (IMAMG) (Table 1). In addition to binary classifications of MAM and SAM, we also calculated MUAC percentiles based on a given individual's sex, age group, and ethnicity.

The WHO provides global MUAC cutoff guidelines, whereas the IMAMG provides locally-situated assessment and diagnostic criteria (as well as medical classification and action plans) for MAM and SAM in the following age ranges: 6-59 months, 5-9 years, 10-14 years, 15-18 years, and >18 years. While the IMAMG are specific to the context of Uganda, there are no specific instructions within the IMAMG regarding Indigenous populations within the country. Ongoing debates continue about the broad-scale implications of prescribing global cutoffs, especially in vulnerable populations experiencing violence, famine, or chronic undernourishment (32 - 36). We used unadjusted MUAC measurements to classify individuals into MAM and SAM following the IMAMG age- and sex-specific categories. When considering continuous MUAC measurements in models, values were centered on the mean MUAC for their age-sex class (36). MUAC percentiles were then obtained by subtracting the mean age-sex class MUAC value from a given individual's MUAC value, calculating a z-score from the resulting value, and then comparing that z-score to the normal distribution for a percentile estimate. The same process was also used with age-sex smoothed MUAC values using a standard robust nonlinear moving-window smoother to reduce random noise in data of interest (38).

Statistical analysis

We calculated the prevalence of MAM and SAM by age group and sex. Differences between groups were assessed through formal t-tests and confidence intervals were used to assess level of variability around estimates.

An asset-based wealth index was calculated as a proxy for wealth; this approach has been validated in rural and resource poor settings in other health studies (23, 39). We used a principle component analysis to create this index. Asset variables included ownership of a radio, ownership of animals, ownership of soap, ownership of a cellphone, ownership of a bicycle, receiving remittances, and owning land.

For multivariable models, we considered two primary outcome variables: MAM status (binary outcome where 1 = MAM status and 0 = no MAM status) and age-sex class MUAC percentile (continuous numeric value between 0 and 100). SAM was not included as an outcome because there were an insufficient number of cases for statistical power in multivariable testing; modeling on the few observed cases risked overfitting.

Multilevel multivariable regression models with random intercepts at the household, community, and ethnicity levels were built for both dependent variables of interest. To reach these final models, univariate linear and logistic models were generated with variables of interest and the two primary dependent variables (Table 1 and Table 2 of supplementary materials). Collinearity was assessed through graphical analysis of the Pearson residuals as well as an examination of relative variance inflation factors (VIF). To check for confounding, variables were added and removed to detect if their presence shifted coefficient values by more than 25%. Age group- and sex-stratified models were specified in a sensitivity analysis to see how results would change when stratified (Table 1 and Table 2 of sup Materials). Final models were compared using the Akaike Information Criterion (AIC) for model parameters. In post-estimation, Pearson's residuals were graphically assessed to test assumptions of normality and homogeneity (BLUPs).

To assess the extent to which different levels could explain differences in malnutrition among the Batwa and Bakiga, the variance partitioning coefficient (VPC) was used to calculate the percentage of the variance explained by the highest level of clustering in each model (40). Four models were constructed in total, each positing a hypothesized social hierarchy of empirical interest thought to shape the outcome of malnutrition in the Batwa and Bakiga (these models correspond to the column headers of Table 3): (Model 1) Individual, Household, and Community Levels (excluding covariates), (Model 2) Individual, Household, and Community Levels (including covariates), (Model 3) Individual, Household, Community, and Ethnicity Levels (excluding covariates), and (Model 4) Individual, Household, Community, and Ethnicity Levels (including covariates). Models 1 and 2 demonstrate the multilevel mixed regression results if we were to only model Individual, Household, and Community characteristics. Models 3 and 4 include Community and Ethnicity levels, which we explicitly modeled to account for differences in malnutrition clustering at different social levels between Batwa and Bakiga populations. For the Individual and Household levels, control parameters were selected based on AIC, wherein the model with the lowest AIC values to minimize the estimated effect of missing data in the model (41).

RESULTS

Prevalence of malnutrition among Batwa and Bakiga

Malnutrition is high in among both Batwa children and adults. Nearly half of all Batwa adults and nearly a quarter of all Batwa children experienced moderate acute malnutrition (MAM)

(Table 2, Figure 2). SAM was highest among male Batwa adults at 11.60% (95% CI: 4.83-18.37%), followed by male Batwa children (prevalence: 8%; 95% CI: 1.36-12.7%). MAM and SAM prevalence were significantly higher ─ across all age- and sex-strata ─ among Indigenous Batwa compared to the non-Indigenous Bakiga (Table 2, Figure 2), with the exception of female children (whose prevalence of SAM was similar at 3.36%, 95% CI 0.19-6.53, and 3.40%, 95% CI 0.72 – 6.08, respectively). The highest rates of malnutrition among Bakiga were male children, with 2.30% (95% CI: 0.03–4.37%) of the population classified as MAM.

Multivariable model

Clustering of malnutrition (MUAC) between individuals within the same household and community (Model 1) indicated substantial clustering of MUAC within households; household-level clustering explained 57% of variation in the distribution of smoothed MUAC percentiles. An additional 4% of variation in MUAC was explained by clustering between households in the same community location, with 39% left unexplained. The addition of covariates at the household level demonstrated strong associations with number of dependents and relative wealth as factors that contribute to the clustering of malnutrition among individuals within the same household (Model 2).

The addition of community ethnicity as a higher-level variable resulted in a noteworthy shift in model results (Models 3 and 4), with community ethnicity explaining 64-66% of variation in MUAC. The inclusion of community ethnicity led to a drop in the explanatory power of household-level clustering, with community-level variance remaining minimal. There was minimal change in results when covariates were included in the model (Model 4). The greatest portion of variance in malnutrition was explained by community ethnicity (>60%), both with and without controls (Table 3, Figure 3). When community ethnicity was included in the model, household level predictors dramatically lowered their explanation of variance. Community level variance changed only incrementally between models (changing between 2-3%). These results point to a significant and strong clustering effect of malnutrition between Batwa and Bakiga that are not solely explained by compositional (i.e. individual and household) risk factors for malnutrition or unmeasured characteristics of individuals, households, or community location.

DISCUSSION

This research highlights high occurrence of MAM in all Batwa age- and sex-strata in Kanungu District, Uganda. The prevalence of MAM and SAM was high among all age- and sex-strata of Batwa - all Batwa age-sex strata met the WHO major emergencies criteria for a 'Critical health situation crisis' in regard to malnutrition prevalence (Table 2) (42). In contrast, none of the Bakiga sex-age strata presented MAM or SAM rates that meet WHO criteria for a malnutrition crisis based on presence of wasting (i.e. MAM or worse) in a given population (Table 2) (42). Because of the great variety of nutrition indicators used by different international reporting agencies, it is difficult to directly compare the Batwa's malnutrition prevalence to that of other populations. The Batwa's population prevalence of malnutrition is high compared to reported wasting prevalence by UNICEF in Uganda (43, 44). The FAO measurement of undernourishment prevalence reports that Sub-Saharan Africa is estimated to be 23.2% from 2014-2016 (45). The malnutrition prevalence of the Batwa who reside in Kanungu demonstrates a substantial health inequity that may persist across multiple scales. This gradient in malnutrition is paralleled by other health inequalities faced by the Batwa, cumulatively resulting in a broad trend of health and social disadvantage as highlighted in other research (see Table 4 of supplementary materials).

The health inequality faced by the Batwa is in alignment with inequalities documented to be occurring in other Indigenous populations around the world, especially amongst Indigenous children (46, 47). Across Latin America, rates of malnutrition among Indigenous children are double that of the general population (48). Among Aboriginal peoples living in Australia's Northern Territory, Indigenous children under five years old had a higher prevalence of underweight (14.5%), stunting (11.3%), and wasting (9.0%) compared to the healthy population profile for the area where the underweight prevalence was expected to be 2.3% (49). The Orang Asli of Peninsular Malaysia demonstrated high proportions of underweight (49%) and stunted (64%) children compared to Malaysian national averages (11%) (44, 50). Despite differences in the magnitude of the malnutrition inequality from one Indigenous context to another, there is persistent evidence of an Indigenous gradient in health associated with malnutrition in diverse contexts.

Possible limitations: genetic considerations between short stature and non-short statured populations

Might our results, however, reflect the Batwa genetic heritage as a short stature population rather than an Indigenous health inequity? If this were so, the difference between Batwa and Bakiga presented here might be attributable to a genetic short stature —leading to underestimated and biased Batwa MUAC measures— rather than wider social determinants of Indigenous disadvantage. There is debate over the meaning and relevance of short stature status with respect to stature, and negligible literature validating anthropometric measures for short stature populations. Some theorize that short stature emerged due to persistent environmental stressors that lead to malnutrition across generations (51), potentially indicating that historical — rather than recent and current —conditions drive lower anthropometric measures found among short stature peoples. This theory is challenged by others, however, including Migliano, whose research on the Efe and Lese of the Philippines suggests that the effect of chronic malnutrition on stature trajectory is incompatible with the growth rate in short stature adolescence, thus suggesting a possible genetic component that drives short stature rather than malnutrition (51).

Genetic arguments for the emergence of short stature in a population point to environmental pressures that favored the short stature of pygmies (52 - 56). Theories purport that the emergence of the short stature phenotype would have been environmentally advantageous, such that a given population could adapt to environmentally harsh situations (such as a dense wooded environment) to increase thermoregulation, increase forest-environment mobility (i.e. scaling trees, avoiding continuous crouching), or to facilitate a relatively early age of reproduction (i.e.) (52 – 55, 57). Rather than attribute short stature to ever-present malnutrition driven by a deterministic environment (51), genetic theories suggest an adaptation by peoples living in a harsh environment that maximizes fitness under conditions of limited lifespan. Alternate explanations argue for the possibility that the short stature phenotype as a historic artefact rather than an advantageous evolutionary adaptation or environmentally-induced change (56, 58). Somewhat similarly, other authors have suggested that difference in stature may be attributable to a genetic split that drove height in opposite directions (56, 59). Although these are less frequent and poorly supported explanations — their explanation for the short stature phenotype is that it comes from random mutations in the reproductive cycle— they are recurring narratives in short stature literature.

In the context of the results presented here for Batwa and Bakiga, evolutionary theories could explain adult differences in malnutrition between the Batwa and Bakiga that reflect historic contexts and pressures. In this case, however, we might expect to observe a narrower gradient for malnutrition inequality among Batwa and Bakiga children, who have no experience with forest livelihoods, and in many cases whose parents lived outside of the forest much of their life as well.

Moreover, MUAC was the least likely nutritional assessment tool to be biased due to differences in stature (weight or height) between Batwa and Bakiga. Severe gradients in other health outcomes between the Batwa and Bakiga other than anthropometry (21, 22, 60), and consistency with other Indigenous inequality literature (46 - 50), point to a strong role for common social determinants of health that plausibly supersede genetic explanations for the results found here. However, appropriate and innovative methods are still needed to resolve long-standing issues faced when attempting to synthesize the available evidence on Indigenous health (61).

Conclusion

Our multilevel model results support the role of social mechanisms driving the Indigenous gradient in malnutrition we observed. In our models focusing on household-level factors, household-level variation explained over half of malnutrition differences and demonstrated a strong and significant household-level wealth gradient, indicating that household wealth plays a key role in determining—or represents an important proxy for— malnutrition. The inclusion of community-level ethnicity, however, emerged as a strong predictor of individual malnutrition; suggesting that household-level variation and household wealth are likely proxies for ethnicity. Controlling for community had little contribution to any of our models, suggesting that individual community location plays a negligible role in determining malnutrition among individuals. Notably, we matched Indigenous and non-Indigenous communities in our analysis, implying that our measure of community clustering did not reflect the Indigenous status of the communities (which was retained as a higher clustering level in our hierarchical models), and more likely represented pertinent differences in community-level characteristics such as landscape type, access to small markets, road proximity and quality, and soil quality (62).

The social gradients in health literature points to the potential role of social context in explaining community-level ethnic gradients in health. In this context, community ethnicity can be understood and interrogated as a determinant of health among the Batwa and Bakiga (4). There has been substantial literature theorizing such links between ethnicity and health, ranging in both approach and focus (63 – 68). As a social determinant of health, ethnicity has been posited as a proxy for socio-economic factors (such as employment, education, and income), environmental factors (such as the quality of the physical environment) and social power relations (both within communities and in regard to political empowerment, sometimes referred to as distal determinants of health) (63). When ethnicity stratifies available employment options, marginalized ethnicities are less likely to obtain similar levels of social support from their peers and are more likely to find means of employment with hazardous or insecure working conditions that negatively affect health (69 - 71). In Indigenous peoples, there is a unifying history of colonialism, racism, and social exclusion, within which many other determinants can be constructed (72 - 74). One important legacy of colonialism on Indigenous peoples was — and continues to be — the dispossession and displacement from traditional lands, wherein Indigenous peoples were restricted from continuing established social activities (such as hunting, trapping, and gathering) that are integral to survival and cultural continuity (75 - 78).

Our results point to — but cannot decisively establish — a likely role for socially- and historically-constructed community ethnicity as a health determinant among the Indigenous Batwa population of Kanungu District, Uganda. In our fully adjusted model (Model 4 of Table 3), community ethnicity accounted for the majority (66%) of variation in MUAC measures; the specific community (5%) and household (<1%) explained very little when community ethnicity was taken into account. To more decisively distinguish the contribution of individual genetic factors from community-level social gradients would require individual-level ethnicity data, which were not available or considered feasible to collect in this case. Ambiguity regarding the causes and contributions of historic short stature status to current anthropometric measurements may obscure meaningful discussion of the persistent social contexts contributing to severe inequity in malnutrition among the Batwa. These results contribute to the evidence base characterizing and unpacking health disparities between Indigenous and non-Indigenous populations, and in particular Indigenous inequities in developing nations.

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Table 1. IMAMG MAM and SAM MUAC Cutoff Guidelines

IMAMG Age Ranges	Expected (i.e. healthy) MUAC Measurement	MAM MUAC Cutoff+	SAM MUAC Cutoff+
6-59 Months	>13.5 cm	11.5 cm to < 12.5 cm	<11.5 cm
5-9 Years	>14.5 cm	13.5 cm to < 14.5 cm	<13.5 cm
10-14 Years	>18.0 cm	16.0 cm to < 18.5 cm	<16.0 cm
15-18 Years	>22.0 cm	18.5 cm to < 21.0 cm	<18.5 cm
>18 Years	>23.0 cm	19.0 cm to < 22.0 cm	<19.0 cm

+ Adapted from the Integrated Management of Acute Malnutrition Guidelines, made publicly available by the Republic of Uganda's Ministry of Health (78)

Abbreviations: IMAMG (Integrated Management of Acute Malnutrition Guidelines), MAM (Moderate Acute Malnutrition), SAM (Severe Acute Malnutrition), MUAC (Middle Upper Arm Circumference)

Table 2. Age- and sex- specific prevalence of MAM and SAM for the Bakiga and Batwa of SW Uganda, April 2014

Gender and ethnicity grouping	Total	Mean MUAC (CI)	MAM % (CI)*	SAM % (CI)*	WHO Crisis Cutoffs (-- for acceptable, - for poor, + for serious, ++ for Critical)
Children (<18 years of age)					
Male Bakiga	175	19.65 (19.08-20.22)	2.30% (0.03-4.37)	0.57% (0-1.69)	--
Male Batwa	128	16.04 (15.58-16.50)	20.31% (13.07-26.93)	7.03% (1.36-12.70)	++
Female Bakiga	176	19.83 (19.25-20.40)	1.71% 0-3.61)	3.40% (0.72-6.08)	--
Female Batwa	124	16.47 (15.96-16.99)	25.81% (17.56-32.84)	3.36% (0.19-6.53)	++
Adults (>=18 years of age)					
Male Bakiga	106	27.47 (26.99-27.94)	0.90% (0-2.70)	0% (NA)	--
Male Batwa	86	22.21 (21.57-22.85)	45.34% (34.82-55.86)	11.60% (4.83-18.37)	++
Female Bakiga	239	28.55 (28.16-28.94)	0.42% (0-1.24)	0% (NA)	--
Female Batwa	133	22.68 (22.24-23.11)	45.86% (37.39-54.33)	3.00% (0.10-5.90)	++

Abbreviations: MUAC (Middle Upper Arm Circumference), MAM (Moderate Acute Malnutrition), SAM (Serious Acute Malnutrition).
*Lower 95% CI bound restricted to 0 to keep in line with the interpretation of prevalence (i.e. as between 0 and 100%).

Table 3. Multilevel mixed regression results for Batwa and Bakiga malnutrition

Model name (description)	All models control for household and community level clustering, and control for individual age and sex			
	Model 1 Baseline with household and community clustering, controlling for age and sex	**Model 2** Model 1 and household-level predictors	**Model 3** Model 1 and clustering by ethnicity	**Model 4** Model 1 and household-level predictors and clustering by ethnicity
Variance partitioning (explanatory ability of clustering by household, community, and ethnicity)				
Total variation (%)	373.94 (100)	325.45 (100)	438.74 (100)	445.03 (100)
Explained by Household (%)	215.67 (57)	183.10 (56)	4.34e^-14 (<1)	5.7e^-14 (<1)
Explained by Community (%)	14.25 (4)	6.13 (2)	21.53 (4.9)	21.76 (5)
Explained by Ethnicity (%)	-	-	280.92 (64)	296.26 (66)
Random effects/ Unexplained (%)	144.02 (39)	126.22 (42)	136.29 (31)	127.01 (28)
Intercept/Constant	57.78	45.098	49.97	46.152
Individual Predictors (95% CI)				
Age category				
<5	Ref.	Ref.	Ref.	Ref.
5-18	-2.38 (-4.76 - -0.008)	**-3.186 (-6.27 – 0.093)***	-1.36 (-3.24 – 0.524)	-2.00 (-4.44 – 0.44)
18-45	7.08 (4.83 – 9.32)	**6.235 (3.43 – 9.03)***	6.76 (4.83 – 8.70)	**6.202 (3.88 – 8.52)***
>45	3.94 (1.24 – 6.65)	**5.047 (2.04 – 8.05)***	4.13 (1.94 – 6.32)	**4.622 (2.22 – 7.02)***
Sex				
Female	Ref.	Ref.	Ref.	Ref.
Male	-2.87 (-4.56 - -1.18)	**-1.912 (-3.65 - -0.165)***	-2.45 (-3.81 - -1.09)	**-1.88 (-3.27 - -0.49)***
Household-level Predictors (95% CI)				
Number of dependents	-	**1.027 (0.260 – 1.795)***	-	**0.686 (0.30 – 1.06)***
Max education category				
No formal schooling Primary incomplete	-	Ref.	-	Ref.
Primary complete or Above	-	1.28 (-1.09 – 3.66)	-	1.42 (-0.442 – 3.29)
	-	2.45 (-2.37 – 6.86)	-	0.498 (-3.07 – 4.07)
Wealth category				
Least wealthy	-	Ref.	-	Ref.
Middle wealthy	-	**8.17 (4.67 – 11.67)***	-	-1.19 (-2.93 – 0.542)
Most wealthy	-	**14.36 (10.81 – 17.91)***	-	0.571 (-1.32 – 2.46)
AIC of model	10255.77	9210.81	9484.77	8517.34

*Denote significance using a 95% confidence level.

Table 4. Table comparing socioeconomic and health indicators of the Batwa and Bakiga (adapted from the doctoral thesis of Blanaid Donnlley, 2016)

Indicator	Batwa	Bakiga	SW Uganda	Uganda
Health				
Life Expectancy at birth (years)	28[a]	n/a	n/a	59[b]
Child mortality (% under 5 years)	38[b]	n/a	12.8[g]	9[g]
HIV/AIDS (%)	2.3[c]	9[j]	3.8[c]	7.4[h]
Malaria Prevalence Among Adults (proportion of population in July 2013 and April 2014 – all adults Batwa, sample adults Bakiga)	29 (6.45)[d]	20 (4.46)[d]	n/a	19%[k]
Mean birth weight in grams	2797.0g[n]	3090.0g[n]	n/a	Measured differently at national level – see 58 section 'Child Health'
Education				
Adult literacy (% 15-49 years)	<10[e]	n/a	Women: 75.5, Men: 77.4[g]	Women: 64.2, Men: 77.5[g]
Livelihoods and Income				
GDP per capita (Constant 2000 USD)	160[f]		n/a	696[f]
Household mosquito net use (did not have nets, proportion of population)	93 (70.99)[d]	218 (53.56)[d]	n/a	71.6%[k]
Assets (did not have any assets, proportion of population)	82 (62.12)[d]	77 (19.01)[d]	0.30 Gini Coefficient[l]	0.29 Gini Coefficient[l]
Access to handwashing facilities (did not have access to handwashing facilities, proportion of population)	96 (73.85)[d]	229 (56.40)[d]	86.8%[m]	86.0%[m]
Access to soap (did not have access to soap, proportion of population)	98 (75.38)[d]	252 (62.06)[d]	8.3% of people had access to handwashing facilities with both water and soap[m]	Average of 7.2% of people had access to handwashing facilities with both water and soap[m]

a As of 2000 (52)
b As of 2011 (53)
c As of 2009 for Mpungu and Kayonza subcountines in Kanungu District (54)
d As of 2013 and 2014 (16)
e As of 2012 (55)
f As of 2013 and 2014 (56)
g As of 2011 (57)
h As of 2014 (58)
i As of 2014 (53)
j As of 2011 (59)
k As of 2015 (60)
l As of 2015 – Gini coefficient based on composite wealth index (60)
m As of 2012 and 2013 (61)
n From a sample of births spanning 2012 to 2015 (92)

Supplementary Table 1. Results for univariate OLS regressions between smoothed MUAC percentile and different variables of interest (Odds Ratio, CI, p-value in stars, ** = 90% and * at 95%)

Variable Name	Entire population	Children (<18)	Adult Males	Adult females
Ethnicity (Ref. = Bakiga)	27.17 (14.15 – 52.14)*	13.20 (5.92 – 29.41)*	42.29 (5.63 – 317.50)*	84.48 (20.22 – 352.91)*
AVPS	1.01 (0.973 – 1.048)	1.00 (0.945 – 1.060)	1.028 (0.936 – 1.129)	1.024 (0.966 – 1.085)
Dependents	1.07 (0.980 – 1.17)	0.943 (0.816 – 1.090)	1.035 (0.859 – 1.247)	1.244 (1.070 – 1.445)*
Education category				
No schooling	Ref.	Ref.	Ref.	Ref.
Primary incomplete	0.817 (0.568 – 1.175)	1.96 (1.04 – 3.72)*	0.462 (0.189 – 1.126)**	0.464 (0.256 – 0.843)
Primary complete or higher	0.229 (0.054 – 0.970)*	0.791 (0.097 – 6.427)	0.206 (0.024 – 1.754)	Omitted.
Wealth				
Least wealthy	Ref.	Ref.	Ref.	Ref.
Middle wealthy	0.796 (0.551 – 1.15)	0.968 (0.557 – 1.683)	0.461 (0.191 – 1.110)**	0.783 (0.424 – 1.446)
Most wealthy	0.258 (0.156 – 0.428)*	0.237 (0.1016 – 0.5527)*	0.165 (0.051 – 0.526)*	0.324 (0.151 – 0.695)*
Alcohol	3.62 (1.87 – 7.01)*	-	1.99 (0.533 – 6.31)	5.58 (2.42 – 12.87)*
Land ownership	0.993 (0.701 – 1.406)	1.00 (0.591 – 1.713)	0.932 (0.416 – 2.085)	0.967 (0.544 – 1.718)
Bednet use	0.193 (0.026 – 1.427)	0.357 (0.468 – 2.727)	Omitted.	Omitted.
Land Quality				
Flat	Ref.	Ref.	Ref.	Ref.
Mixed	0.675 (0.452 – 1.010)**	0.626 (0.343 – 1.143)	0.542 (0.237 – 1.736)	0.754 (0.388 – 1.468)
Hilly	0.905 (0.560 – 1.462)	0.749 (0.359 – 1.562)	1.389 (0.477 – 4.049)	0.986 (0.433 – 2.244)

Supplementary Table 2. Results for univariate logit regressions between MAM status and different variables of interest (coefficient, CI, p-value in stars, ** = 90% and * at 95%)

Variable Name	Entire population	Children (<18)	Adult Males	Adult females
Ethnicity (Ref. = Bakiga)	-33.06 (-34.56 - -31.56)*	-27.33 (-28.81 - -25.85)*	-32.21 (-36.42 - -28.00)**	-50.67 (-55.71 - -45.63)*
AVPS	-0.183 (-0.44 – 0.077)	0.036 (-0.255 – 0.328)	-0.047 (-0.750 – 0.656)	-0.421 (-1.16 – 0.321)
Dependents	-0.151 (-0.789 – 0.486)	0.274 (-0.442 – 0.991)	-0.622 (-2.10 – 0.863)	-1.26 (-3.20 – 0.67)
Education category				
No schooling	Ref.	Ref.	Ref.	Ref.
Primary incomplete	2.05 (-0.55 – 4.66)	-3.56 (-6.44 - -0.677)*	6.79 (-0.88 – 14.48)**	13.82 (6.52 – 21.12)*
Primary complete or higher	11.3 (5.37 – 17.39)*	4.23 (-3.79 – 12.25)	14.10 (1.69 – 26.51)*	21.52 (5.52 – 37.52)*
Wealth				
Least wealthy	Ref.	Ref.	Ref.	Ref.
Middle wealthy	9.24 (6.54 – 11.96)*	7.30 (4.40 – 10.20)**	10.73 (3.54 – 17.93)*	13.51 (5.38 – 21.63)*
Most wealthy	17.41 (14.68 – 20.15)*	14.98 (12.02 – 17.94)**	18.42 (11.24 – 25.59)**	27.05 (19.04 – 35.07)*
Alcohol	-10.04 (-15.24 - -4.83)*	-	-3.76 (-11.15 – 3.63)	-20.95 (-31.68 - -10.21)*
Land ownership	1.90 (-0.56 – 4.36)	2.377 (-0.293 – 5.049)**	2.71 (-3.66 – 9.10)	2.34 (-5.02 – 9.71)
Bednet use	14.59 (8.05 – 21.13)*	13.56 (6.76 – 20.36)*	16.23 (-2.96 – 35.42)**	28.43 (5.64 – 51.22)*
Land Quality				
Flat	Ref.	Ref.	Ref.	Ref.
Mixed	3.21 (0.240 – 6.18)**	3.94 (0.732 – 7.155)*	0.679 (-7.18 – 8.54)	7.74 (-1.06 – 16.55)**
Hilly	2.70 (-0.926 – 6.34)	2.88 (-1.02 – 6.80)	1.332 (-7.97 – 10.63)	10.55 (-0.684 – 21.79)**

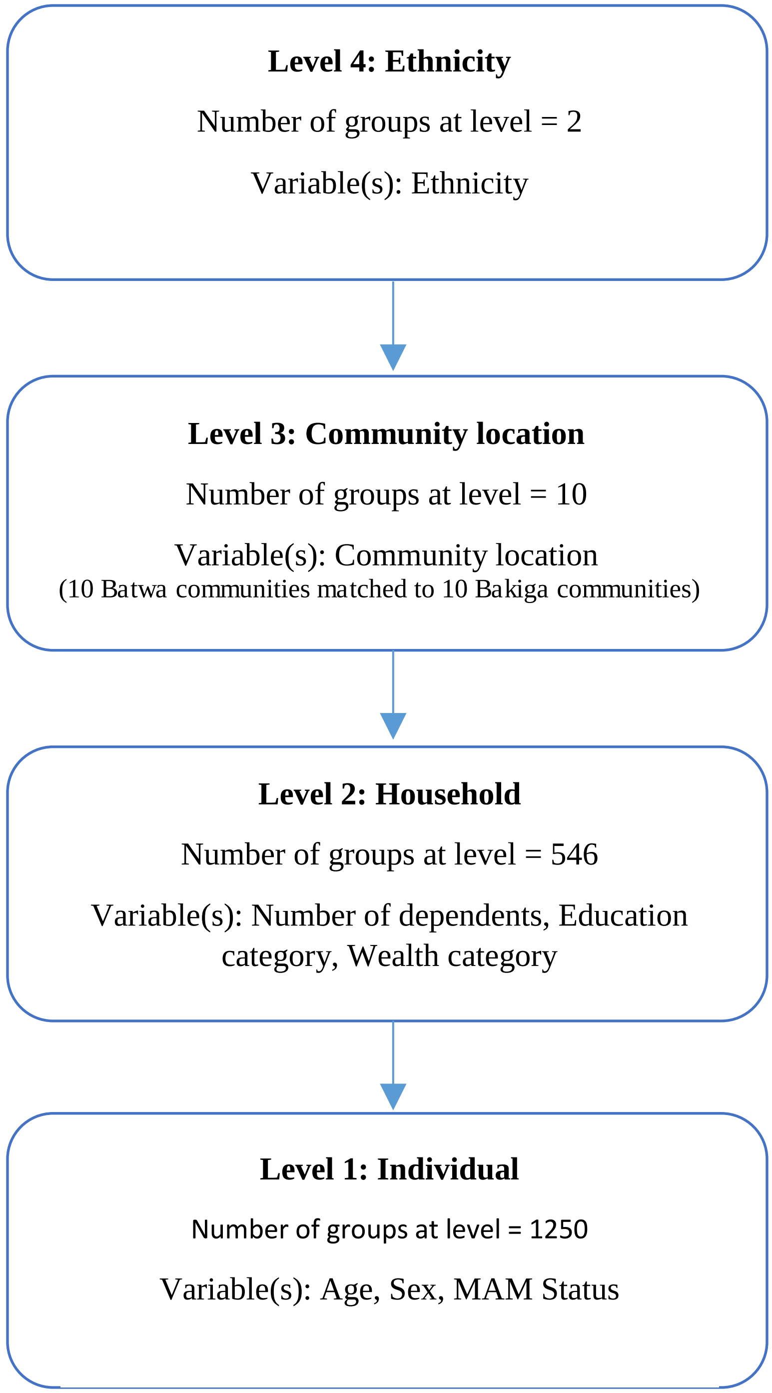

Figure 1. Visualization of hierarchical data structure that is also used in multilevel model. There are 1250 observations in total, so at Level 1 the number of groups is the number of distinct individuals. For Level 2 through Level 4, the number of groups is the number of distinct variable categories to which an individual belongs (i.e. 546 different households, 10 different communities, 2 different ethnicities). Abbreviations: MAM (Moderate Acute Malnutrition).

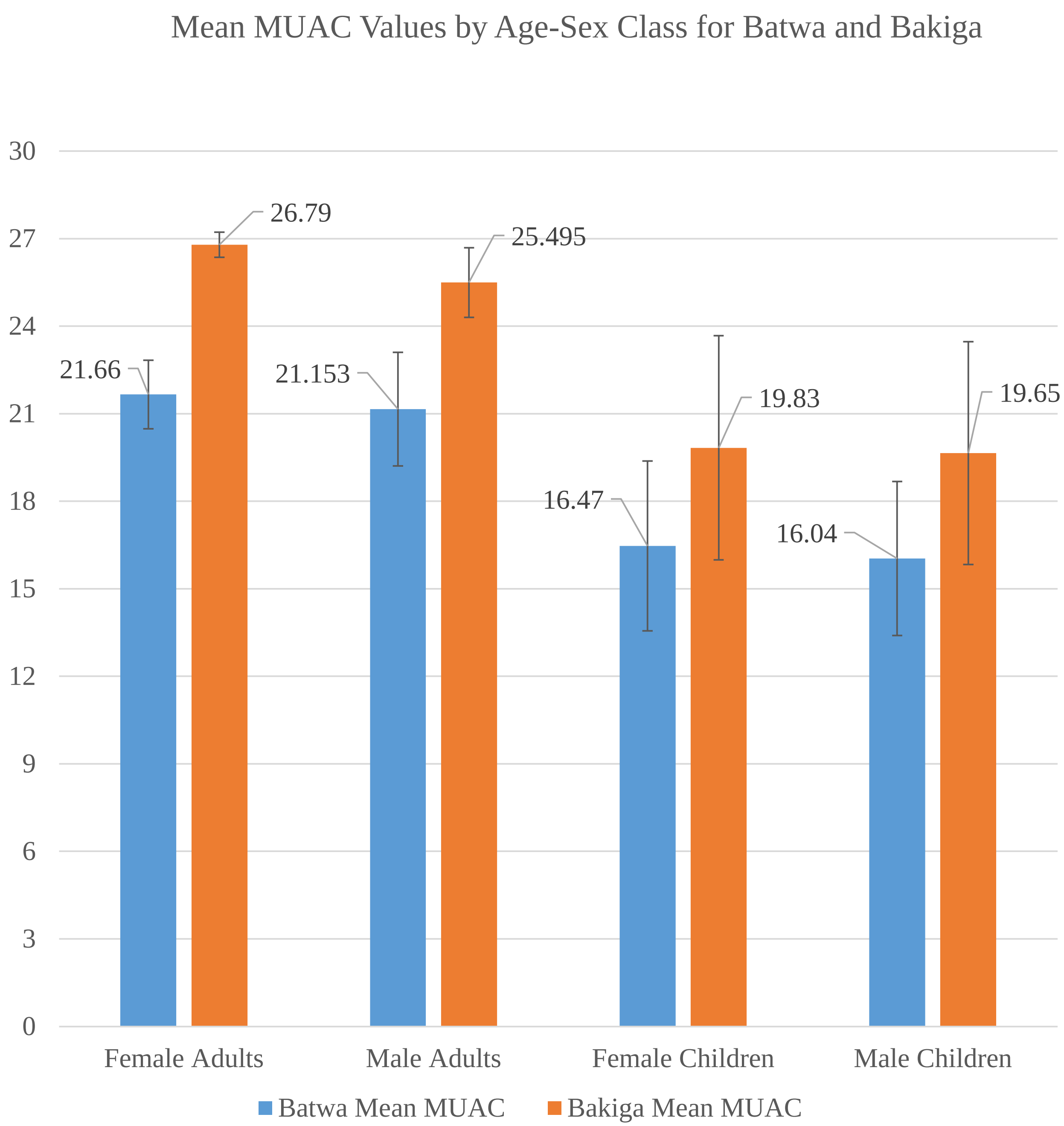

Figure 2. Comparison of Batwa and Bakiga MUAC means across population strata. Abbreviations: MUAC (Middle Upper Arm Circumference).

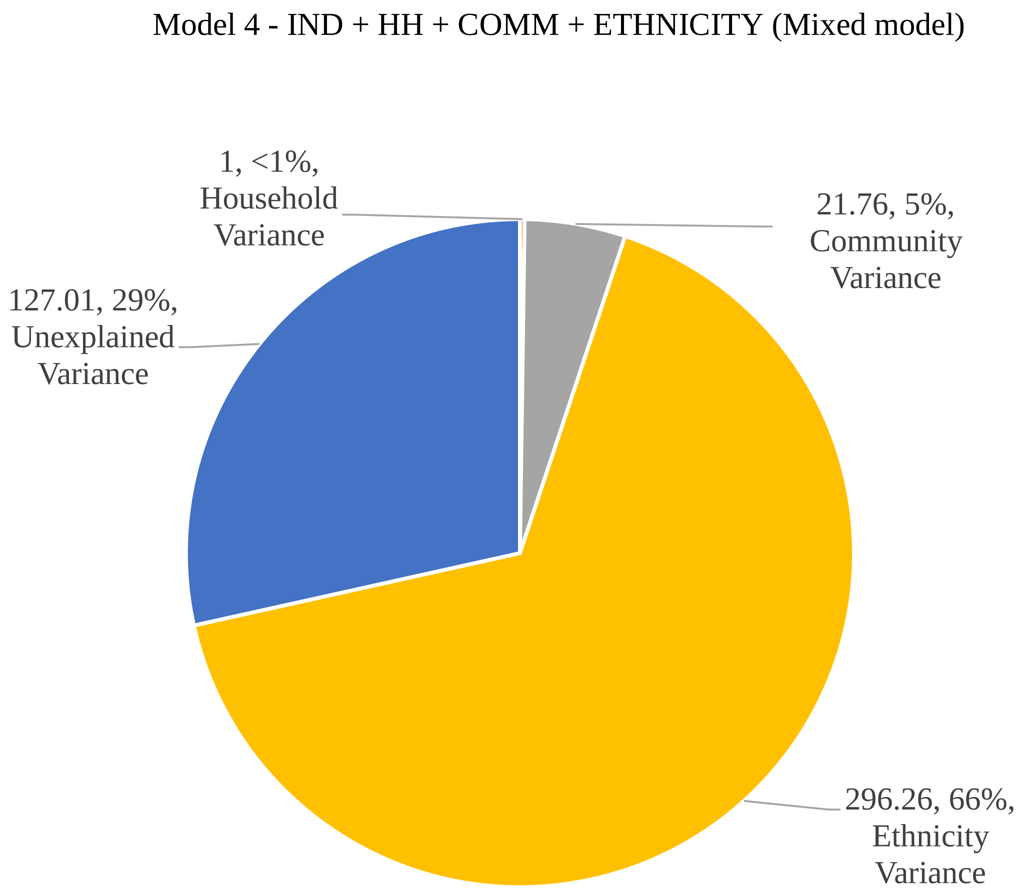

Figure 3. Variance partitioning from Model 4 (taken from Table 3, graphical representation). Abbreviations: IND (Individual), HH (Household), COMM (Community).