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Sustainable aquatic food systems: Multisectoral analysis of determinants of child nutrition in coastal Kenya

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Marine foods produced by small-scale fishers can make vital contributions to sustainable, healthy food systems with multisectoral considerations of public health nutrition, gender equity, economics, and marine ecology. This pilot study aimed to map the multidimensional determinants of fish food security and young child nutrition in four coastal communities of Kenya with a view toward designing a large intervention trial. We compared anthropometric and dietary diversity indicators of children under 5 years in fishing vs. non-fishing households. Mixed methods included household surveys, 24-h recalls for dietary intake, and anthropometric measures of children. Child dietary diversity score (CDDS) and height-for-age Z (HAZ) were primary outcomes tested in ordinary least square regression modeling. Stunting was widely prevalent (20.2%), as were morbidities for acute diarrhea (29.0%) and fever (46.5%), with no statistically significant differences in fishing compared to non-fishing households. High proportions of children showed nutrient intake inadequacies for vitamins A, C, and E, iron and zinc; <50% met requirements for all nutrients except protein, which was derived primarily from plant-based foods. Regression modeling showed children living in fishing households were associated with lower CDDS. Maternal education, maternal body mass index (BMI), and household livelihood diversity were positively associated with both CDDS and HAZ, while child morbidities and north coast (of Mombasa) residence showed negative associations. Our findings highlight nutritional vulnerabilities within a coastal food system of Kenya and the need to involve multiple sectors—education, environment, health, finance, communications, and governance and policy—in deriving solutions.

KEYWORDS

child nutrition, anthropometry, child feeding, food and nutrient intake, food consumption, growth, Kenyan fisheries

Introduction

Small-holder producers are vital to food systems and nutrition security globally, yet paradoxically, these households are disproportionately undernourished (Dioula et al., 2013). It is estimated that small- and medium-scale farms produce an estimated 51–77% of calories and nutrients (protein, vitamin A, vitamin B12, folate, iron, and zinc) globally

(Herrero et al., 2017). Less is known about the situation of the 36 million small-scale fishers, and investments have been minimal for increasing production and food security (Mills et al., 2011). Fishing as a livelihood provides income that can be used by families to meet nutritional needs of the vulnerable household members such as young children. However, for economic reasons and likely lack of awareness, the catch is often sold to support other household needs (Fiorella et al., 2014). This study aimed to characterize the nutrition of young children within a coastal food system of Kenya, where evidence has been minimal.

Consensus exists around the potential for fish foods to contribute to nutrition security (Béné et al., 2016; Thilsted et al., 2016). Small pelagic fish, in particular, are notable for their high nutritional value, affordability, and minimal impact on the environment (they are generally caught with little to no impact on marine habitats and relatively little bycatch) compared to other animal source foods (Roos et al., 2007; Kawarazuka and Béné, 2011; Hilborn et al., 2018). Fish foods contain high concentrations of bioavailable nutrients commonly found deficient in young children such as proteins, long-chain fatty acids, iron, zinc, choline, and vitamin B12 (Iannotti, 2018). In Kenya, stunting affects 30% of young children in the coastal region, and only one in five children nationally were reported to have received any fish, meat, or poultry as complementary food (Kenya National Bureau of Statistics., 2019). Commonly caught marine fish in the Kenyan coastal communities studied here include: Tafi (*Siganidae,* white spotted rabbitfish), Pono (*Scaridae,* parrotfish), Changu (*Lethrinidae,* spotcheek emperor), Una (*Scombridae,* Indian mackerel), and Pweza (*Octopodidae,* octopus) (FAO FishFinder., 2010). This study examined the presence of any fish (inclusive of these species, reported elsewhere) and complementary foods in the diets of young children living at four sites (Shimoni and Tiwi in South Coast and Vipingo and Uyombo in North Coast) along the Kenyan coast between June and September 2019.

Water, sanitation and hygiene (WASH) are important components of Public Health and play a major role in disease prevention for populations. Globally and also in Kenya, millions of people are exposed to poor WASH conditions and consequently suffer from preventable diseases. Lack of safe WASH conditions affects nutrition and health status of communities (KNBS and ICF Macro, 2015; Baker et al., 2016).

Our study aimed to characterize determinants of young child nutrition from small-scale fishing households within the context of a coastal food system. We formed a team comprised of experts across multiple disciplines including public health nutrition, anthropology, gender, economics, and marine ecology. Several processes were initiated to engage local stakeholders from governmental, non-governmental, and research institutions with a view toward developing future sustainable interventions. To examine multiple factors influencing child nutrition in this coastal food system, we compared fisher- and non-fisher households taking advantage of a coastal highway separating the two groups. The highway provided a distinction between communities close to the ocean and were more likely to have fishing as a livelihood while other communities were far from the ocean and engaged in farming activities.

Methods

Study area and population

The study was conducted in fishing and non-fishing communities and families along the coast in Kenya: Kilifi and **Kwale** counties. In Kilifi County, which is in the North Coast, two communities (Vipingo and Uyombo) and in Kwale County, which is in the South Coast, two communities (Shimoni, and Tiwi) were studied where fishing and non-fishing households were interviewed (Supplemental Figure 1). Access to marine foods and thus connection to the coastal marine food system was the main criteria used for selecting the study sites. Kwale County in South coast was a predominantly Muslim community and polygamy was a normal occurrence. Kilifi County in North Coast had a mixture of Muslim and Christian communities with less polygamy in Christian households. Kilifi County covers an area of 12,370 km^2 with a population of 1.45 million and average household size of 4.8 persons (Kenya National Bureau of Statistics., 2019). Kilifi county has very high stunting levels at 52% compared to the national average of 26%, while the poverty rate is 46.4%. The national average poverty levels in 2019 in Kenya was 34.4%, much lower than Kilifi and Kwale Counties. Kilifi County has five Agro-Ecological Zones (AEZ) suitable for different agricultural and livestock uses ranging from ranching to farming activities like tree-cropping and food-crop production (County Government of Kilifi, 2018). Kwale county is located about 40 km south of Mombasa and covers an area of 8,267 km^2, with a total population just under 867,000 and an average household size of 5.0 (Kenya National Bureau of Statistics., 2019). Kwale county also has five AEZs. Kwale has lower rates of stunting in children under five years of age at 46.4% compared to Kilifi County, however it is still much higher than the national average of 26%. Kwale has a comparable poverty rate to Kilifi at 47.4% (KNBS and ICF Macro, 2015; Kenya Institute for Public Policy Research Analysis., 2020).

Study design

The researchers worked with different stakeholders within the marine food system that would contribute to improved child nutrition and sustainable fisheries in the coastal region. At the county and sub-county levels, the fisheries officers were introduced to the importance of fisheries in child health and nutrition. This created an entry point to the community through the Beach Management Units (BMU), local organizations that host all the fishermen in each location and ensured buy-in for the project objectives. In the health sector, the project worked with with the overall Medical Officer of Health, County and Sub-County nutritionists, Public Health Officers, Community Health Extension Workers and the Community Health Workers. This effort increased awareness around the project objectives and provided an entry point into working with the community. This allowed our team to work with caregivers of children under 5 years of age. Introductory meetings were also organized between the Fisheries and Nutrition sectors to enhance the complementarity of the sectors working together for a common goal, which had not been tried before.

Fishing and non-fishing households were identified within comparable communities in terms of standard of living drawing from prior research experience in the region (e.g., McClanahan and Humphries, 2012; Cinner et al., 2013). The two communities were of comparable household income levels and were from the same geographical region. Socio-economic and demographic characteristics were later measured as part of the research to adjust for any confounding effects in modeling child nutritional status and diets. The first step of sampling was purposive based on whether a household was fishing or non-fishing. The next step was identifying fishermen with children under 5 years. This was done by doing household listing with the community health workers. These households were then randomly selected from the list.

Study methods

To achieve the study objectives, we used mixed methods including quantitative surveys with primary caregivers of children 5 years of age or younger. We also conducted key informant interviews with caregivers of young children and individuals participating in the marine fishery. In selecting communities, we identified a representative sample based on income, geography, and access to markets. Our sample consisted of fishing ($n = 100$) and non-fishing households ($n = 100$) with children <5 years of age. Inclusion criteria were the following: children ages 6 mo-5 yr; fishing household HH (fish comprise more than 50% of income); non-fishing HH (fish comprise <50% of income). Surveys were conducted with primary caregivers to assess socio-economic and demographic factors, livelihood activities, education, access to healthcare, child diet and health, and gender dynamics. Other components of the study including the qualitative research findings and a market value chain survey conducted with fishers and traders are presented elsewhere (Cartmill et al., 2022).

Dietary intake was estimated using a 24-h dietary recall, an established method for assessing dietary intakes (Gibson and Ferguson, 2008). This was a semi-quantitative recall administered to mothers inquiring about what children consumed in the previous 24 h. Commonly used utensils (different cup sizes, plates, tablespoons and teaspoons) in the homes were used for estimating the quantities of foods and drinks fed to the child. The household measure quantities were then converted into grams through previously used estimations done in the Department of Human Nutrition at Egerton University or by directly weighing foods. These data were then entered into the Nutrisurvey program (www.nutrisurvey.de) to calculate estimated quantities of nutrients in the foods consumed. If foods were not available in the Kenyan food database, the FAO food minilist was used (www.fao.org/infoods). Actual intakes were compared to the reference recommended intakes from FAO (FAO/WHO., 2001) and the Kenyan National Clinical Nutrition and Dietetics reference manual (Ministry of Medical Services., 2010). References were age specific for all the nutrients. Dietary diversity score was calculated from the foods listed in the 24-h dietary recall.

We collected anthropometry data from 200 children-—50% from fishing households and 50% from non-fishing households—in order to calculate height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ), and weight-for-height Z-scores (WHZ). Weights were taken using SECA mother-infant scales (SECA, Hamburg, Germany) to the nearest 0.1 g. Children who could stand on their own were weighed directly with minimal clothing on, while those younger children who could not stand alone were weighed with their mothers and their weight obtained by the taring function of the scales. Heights were measured using SECA stadiometers (SECA, Hamburg, Germany) to the nearest 0.1 cm. Heights were obtained while standing for older children with minimal clothes and no head coverings or shoes, while those who could not stand were measured while the stadiometer was laid on a flat area of the ground. The weight and height data were converted into Z-scores based on the WHO growth standards (2006).

Statistics

Descriptive statistics were first applied to examine measures of central tendencies and distributions across characteristics. Kernel density estimation plots and the Shapiro-Wilks test assessed the normality of distributions on outcome variables of anthropometric and dietary diversity indicators. Univariate analyses with chi-squared and student's t-test were then applied to evaluate significant associations between fishing and non-fishing households on key variables at different levels—individual (child age; sex; nutrition and dietary intakes; morbidities), mother (education levels achieved; livelihood activities; BMI), household (livelihood activities, water, sanitation, and hygiene conditions; polygyny), and community locations (north vs. south coast residence).

Multivariate linear regression models were then applied to examine the effects of living in a fishing household (primary independent variable) on child nutrition outcomes (primary dependent or outcome variables of HAZ and CDDS). Other covariates were added to models in a stepwise manner based on the strength of the evidence-base for known associations with anthropometry and diet. Those strengthening the model fit (based on adjusted R^2 estimates) and trending significant (β coefficient p-value < 0.10) were included in final models. We tested for collinearity using variance inflation factor estimations and applied regression model diagnostics to achieve the greatest fit with parsimony (Bayesian Information Criterion, adjusted R^2). Significance of associations was reported at 0.05 significance level. All data analyses were performed using STATA software (version 16.0; StataCorp, College Station, TX).

Results

Differences were apparent in the characteristics of fishing vs. non-fishing households (Table 1). Fishing households had older children, more people living in the household, and a greater number of livelihood activities compared to non-fishing households. Non-fishing households were more likely to source drinking water from taps (inside house or public), treat drinking water, use flush toilets or pit latrines and have iron roofing materials compared to the fishing households. On average, 8.51 ± 8.20 people shared toilets in this population, with non-significant differences between fishing and non-fishing households. There were no differences between fishing and non-fishing households for the proportion of children found to be stunted, underweight, and wasted (Table 2). Similarly, height-for-age Z-scores (HAZ), weight-for-age Z scores (WAZ) and weight-for-height Z-scores (WHZ) were not different between fishing and non-fishing households. Acute diarrhea and fever were both highly

TABLE 1 Respondents' characteristics, by fishing and non-fishing households.

	Fishing households ($n = 100$)	Non-fishing households ($n = 100$)	Total households ($n = 200$)	P-value[†]
Child				
Age, m	27.6 ± 13.4	23.0 ± 11.3	25.3 ± 12.6	0.010**
Female sex, %	55	56	55.5	0.887
Maternal				
Maternal age, yr	28 ± 7.1	27 ± 7.2	27 ± 6.7	0.412
BMI	22.27 ± 5.1	23.02 ± 5.6	22.79 ± 5.3	0.94
Education attained, total yrs	5.72 ± 3.64	6.66 ± 3.67	6.20 ± 3.68	0.077
Polygamous marriage, %	5	6	5.5	0.756
Household				
Total people living household	6.71 ± 2.94	5.83 ± 2.20	6.27 ± 2.63	0.002**
Water source (drinking), %				0.037*
Tap inside the house	0	6	3	
Public pump/tap	54	60	57	
Well/covered well	44	33	38.5	
Other	2	1	1.5	
Water source (washing, bathing), %				0.558
Public pump/tap	29	30	29.5	
Well/covered well	66	62	64	
Other	5	8	6.5	
Treat drinking water, %				0.010*
Yes	18	34	26	
No	82	66	74	
Toilet type, %				0.035*
Flush	18	29	23.5	
Pit latrine	44	49	46.5	
Bush	38	22	30	
Total people who share toilet	7.83 ± 8.59	9.20 ± 7.77	8.51 ± 8.20	0.238
Total number of livelihood activities	5.26 ± 3.17	3.89 ± 2.26	4.58 ± 2.83	<0.001***
Home ownership, %				0.215
Own	73	69	71	
Rent	9	17	13	
Other	18	14	16	
Roof material, %				0.002**
Iron	34	57	45.5	
Palm leaf	63	41	52	
Other	3	2	2.5	
Floor material, %				0.052
Cement	23	34	28.5	
Soil/dirt	67	60	63.5	
Other	10	6	8	
Energy type, %				0.766

(Continued)

TABLE 1 (Continued)

	Fishing households ($n = 100$)	Non-fishing households ($n = 100$)	Total households ($n = 200$)	P-value[†]
Electricity	26	32	29	
Solar	33	26	29.5	
Car battery	1	1	1	
None	37	36	36.5	
Other	3	5	4	

[†]Data presented as mean ± standard deviation or percentage. Chi squared for frequency outcome; t-tests for continuous variables normally distributed; and Wilcoxon rank sum (Mann-Whitney) test for continuous non-parametric variables: maternal age; maternal height; maternal body mass index.
BMI, total number of people sharing toilet; and fortnightly income.
*significant at $p < 0.05$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 2 Child health and nutrition status, by fishing and non-fishing households.

	Fishing households ($n = 100$)	Non-fishing households ($n = 98$)	Total households ($n = 198$)	P-value
Anthropometry				
Height-for-age Z score	−1.24 ± 1.05	−1.11 ± 1.28	−1.18 ± 1.17	0.464
Weight-for-age Z score	−0.92 ± 0.95	−0.77 ± 1.15	−0.85 ± 1.05	0.326
Weight-for-height Z score	−0.36 ± 0.97	−0.20 ± 0.99	−0.28 ± 0.98	0.240
Stunted, %	22.0	18.4	20.2	0.524
Underweight, %	16.0	10.1	13.1	0.217
Wasted, %	4.0	1.0	2.5	0.178
Morbidities, 2-week recall				
Acute diarrhea, %	23.0	35.0	29.0	0.061
Fever, %	40.0	53.0	46.5	0.065
Malaria, %	4.0	2.0	3.0	0.407
Acute respiratory infection, %	12.0	6.0	9.0	0.138
Ear infection, %	6.0	5.0	5.5	0.756
Throat infection, %	1.0	2.0	1.5	0.561
Worm infection, %	0	2.0	1.0	0.155
Skin infection, %	27.0	18.0	22.5	0.128

[†]Data presented as mean ± standard deviation or percentage.

prevalent in young children across all households, again with no significant differences in fishing vs. non-fishing households ($p < 0.05$). Skin infections or conditions were common, affecting over one-fifth of the children in the sample, with non-significant differences by fishing vs. non-fishing category.

There were high percentages of children in the lowest quartile of dietary intake adequacy for vitamins A, C, and E (Figure 1). Unadjusted differences in nutrient intakes showed significantly higher mean intakes for energy, protein, and thiamine (vitamin B1) in non-fishing households (Supplemental Table 1). These were differences seen before confounders were adjusted for in the regression analysis. Across all nutrients studied, less than half of children met or exceeded requirements with the exception of protein for which 71.8% were at or above the 100% reference value (Supplemental Table 2). However, most of the protein was from plant sources (89%) for example maize, with very little from animal source foods. The calculated dietary fish intake was 5.5 g/day [Tafi (*Siganidae,* white spotted rabbitfish) and Pono (*Scaridae,* parrotfish)] for fishing households compared to 1.2 g/day [Pono (*Scaridae,* parrotfish)] in non-fishing households.

Maize products (ugali which is made from maize flour and water making a thick paste) and maize porridge which is liquid in consistency were the main sources of most nutrients, contributing at least 90% of the nutrients sources (Table 3). Fishing households obtained most of their protein from fish (11%) although quantities consumed were very minimal, while non-fishing households obtained most of their protein from maize flour ugali (11%). However, non-fishing households obtained more of their calcium from cow's milk (18%) and omena (small, dried silver fish) (15%) compared to the fishing households that obtained the same from maize porridge (13%) and mandazi (deep fried wheat bread) (12%). Omena fish are small fish dried and eaten whole with the bones while the fishing households consumed bigger fish like tafi (*Siganidae,* white spotted rabbitfish) or pono (*Scaridae,* parrotfish) where bones are not consumed. Omena are available for sale in local markets and many non-fishing households have access to them and purchase, partly

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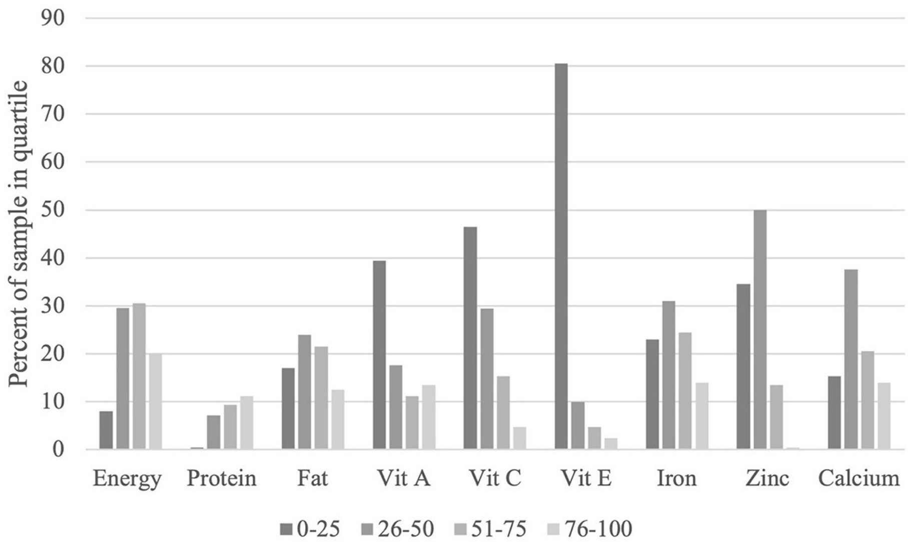

FIGURE 1
Percent of children in quartiles of nutrient adequacy. Percent of children falling into quartiles of nutrient adequacy cut-points. When percentages across quartiles of nutrient inadequacy do not sum to 100, the remaining children showed dietary intakes greater than required levels (Supplemental Table 2). Reference levels were taken from FAO (*Human and Vitamin and Mineral Requirements,* FAO/WHO., 2001) and the Kenyan National Clinical Nutrition and Dietetics reference manual (1st Ed, Feb, 2010). Based on a predominantly plant-based diets, we set iron bioavailability at 5%, and zinc considered "low bioavailability" (FAO/WHO., 2001).

because they are cheaper than big fish. For both groups, zinc and iron were obtained from maize flour and mandazi which are poor sources of these nutrients. Mean CDDS in this sample was 3.29, with fishing households having a score of 3.16 and non-fishing households having a score of 3.41. There was no significant difference in the mean scores of the two groups of children ($p = 0.114$).

Regression models for the two primary outcomes revealed explanatory factors at each level (Table 4). Our study showed that children from fishing households had significantly lower CDDS, though there was a non-significant association with HAZ after adjustment for other factors. Consumption of animal source foods was positively correlated with CDDS, and child fever morbidity negatively correlated with both CDDS and HAZ. Maternal BMI and years of education were positively associated with both outcomes, while polygyny (as indicated by higher wife numbers) showed a negative relationship with HAZ. Increasing household numbers of livelihood activities or occupations was associated with improved CDDS and HAZ, while the higher the number of people sharing a toilet only with HAZ. Finally, after adjusting for all covariates, north coast residence showed negative correlations with both outcomes.

Discussion

Our study sought to map the association of child malnutrition for small-scale fisher households living in coastal Kenya. Across both fishing and non-fishing communities in this food system, we found stunting and infectious disease morbidities to be highly prevalent. Dietary intake inadequacies were similarly evident for the limiting nutrients of vitamin A, C, E, iron, and zinc. Regression modeling enabled examination of various determinants across different sectors of the food system. Certain maternal characteristics including education level attained and BMI were drivers of child anthropometry, while second or subsequent wives in polygynous households showed a negative correlation with HAZ suggesting a negative impact of polygyny on child growth. Economic or livelihood factors also played a role. Specifically, having different types of employment within the household was associated with both increased dietary diversity and HAZ. This meant that households had higher income that could be used in procuring different types of foods. Finally, we found evidence that WASH conditions such as higher numbers of people sharing a toilet, negatively correlated with HAZ. This could be due to the fact that for shared toilets, children were more likely not use them if they were in a different compound and were more likely to defecate within or around their houses. This was then a risk for diarrhea disease that directly affects child growth.

Child stunting in this study was high, although slightly below the Kenyan average of 26% (KNBS and ICF Macro, 2015), for both fishing and non-fishing households. Stunting carries long-term consequences into adulthood affecting both productive and reproductive roles and therefore needs to be addressed early in life (Dewey and Begum, 2011). Underweight in children from fishing households was higher at 16% than the national average of 11% (KNBS and ICF Macro, 2015), while wasting in children from fishing households was at the same rate as the national average of 4%. In this study, the prevalence of stunting, underweight and wasting were lower than prevalence of the same in Ethiopia (Nigatu et al., 2018), however the prevalence was higher than what Amugsi et al. (2020) found in Ghana for the same age group, although they were not fishing communities (Bandoh et al., 2018).

Across both fishing and non-fishing households, there was evidence for highly prevalent infectious diseases with acute diarrhea prevalent in 29% and fever in 26.5% of children <5 years. WASH conditions are known drivers of infection, though in our study only number of individuals sharing a toilet correlated with HAZ in an unexpected direction. Previous studies have found that piped water

TABLE 3 Food sources with greatest contribution to key nutrients, by fishing and non-fishing households.

Nutrient	Food source	
	Fishing household (% of total nutrient intake made by food†)	Non-fishing household (% of total nutrient intake made by food†)
Energy, kcal	Whole maize flour ugali (14.0)	Whole maize flour ugali (12.0)
	Mahamri (12.0)	Maize porridge (11.0)
	Basic mandazi (10.0)	Potato chips (10.0)
	Maize porridge (9.0)	Basic mandazi (9.0)
Protein, g	Tilapia (11.0)	Whole maize flour ugali (11.0)
	Whole maize flour ugali (11.0)	Maize porridge (11.0)
	Maize porridge (9.0)	Stewed Nile perch (6.0)
	Stewed Nile perch (9.0)	Basic mandazi (6.0)
Calcium, g	Maize porridge (13.0)	Cow's milk (18.0)
	Basic mandazi (12.0)	Fried omena (silver sardine fish) (15.0)
	Tilapia (10.0)	Maize porridge (12.0)
	Amaranthus (9.0)	Amaranthus (8.0)
Zinc, mg	whole maize flour ugali (20.0)	Whole maize flour ugali (16.0)
	Maize porridge (15.0)	Maize porridge (15.0)
	Fried omena (silver sardine fish) (5.0)	Fried omena (silver sardine fish) (9.0)
	Boiled rice (4.0)	Ready to use supplemental food (7.0)
Iron, mg	Whole maize flour ugali (14.0)	Whole maize flour ugali (12.0)
	Basic mandazi (11.0)	Basic mandazi (11.0)
	Maize porridge (10.0)	Amaranthus (10.0)
	Tilapia (7.0)	Potato chips (10.0)

†Represents the % contribution of a food to the total nutrient intake, indicated by unit in first column.

in rural areas reduces the risk of diarrhea in young children (Baker et al., 2016; Komarulzaman et al., 2017). In our study, non-fishing households were more likely to access tap water and treat their drinking water compared to fishing households. However, almost three quarters of all households in our study—regardless of whether they were fishing or non-fishing households—did not treat their water compared to slightly over half of Kenyan households nationally (KNBS and ICF Macro, 2015). Additionally, approximately one-third of the fishing households had no toilets compared to three quarters of non-fishing households who had access to some form of toilet. In the Global Enteric Multicenter Study (GEMS) sites of Africa and South Asia, sharing of toilets increased the risk of diarrhea in children and sharing was common in rural Kenya similar to our study (Baker et al., 2016). A systematic review and meta-analysis of WASH activities and nutrition interventions also concluded that use of latrines among other WASH activities are predictors of child stunting (Ngure et al., 2014; Bekele et al., 2020).

A study in Ethiopia by Tosheno et al. (2017) that assessed child morbidities found lower prevalence of this than in our study. In the present study, almost one in three children experienced acute diarrhea in the two weeks prior, which is double what was found in the Kenya Demographic and Health Survey (DHS) at 15% (KNBS and ICF Macro, 2015). Almost half the children had experienced fever in the last 2 weeks compared to 24% reported for the same period in the DHS (KNBS and ICF Macro, 2015) and 20% of the children experienced a skin infection. The relationship between poor nutrition and infection in young children is well documented, where poor nutrition leads to increased susceptibility to infection while at the same time infections worsen nutrition status (Olofin et al., 2013; De Onis and Branca, 2016; Tosheno et al., 2017).

The results of this study agree with results of a study in India in a comparable sample population in terms of environmental conditions, and socio-economic and nutritional status of the sample (Sinha et al., 2018). This study found maternal BMI, child age and use of toilets were important predictors of child stunting. Children of mothers with lower BMI were more likely to be stunted and underweight while older children were more likely to be underweight or stunted. This was also corroborated in a comparative study of countries in Sub-Saharan Africa that found child age, maternal weight and maternal BMI were correlates of linear growth in children (Amugsi et al., 2017, 2020). However, in the Indian study by Sinha et al. (2018), child morbidities and maternal education also predicted child stunting while in our study child morbidities and maternal education were not significant in the regression model.

The low CDDS in the study, 3.29 food groups, is evidenced by the source of the different nutrients which came primarily from four starch-based foods with hardly any animal source foods, typical of diets in Kenya and other developing countries (Neumann et al., 2007; Ijarotimi, 2013). Animal source foods have been demonstrated to benefit child growth and cognitive development (Neumann et al.,

TABLE 4 Regression models for child dietary diversity score and height-for-age Z score.

	Child dietary Diversity score ($n = 180$)			Height-for-age Z score ($n = 178$)		
	β-coeff	SE	*P*-value	β-coeff	SE	*P*-value
Primary determinant						
Fishing household	−0.408	0.169	**0.017***	−0.149	0.176	0.402
Child-level determinants						
Child age, mo‡	0.013	0.007	0.065	–	–	–
Child gender, female	–	–	–	–	–	–
Child diet, animal source foods	0.334	0.177	0.061	–	–	–
Child morbidity, fever	−0.191	0.164	0.246	−0.233	0.173	0.179
Mother-level determinants						
Mother BMI†	0.026	0.015	0.095	0.046	0.016	**0.005****
Mother education, total years	0.041	0.023	0.069	0.047	0.024	0.056
Wife number (polygynous households)	–	–	–	−0.532	0.199	**0.008****
Household-level determinants						
Number of occupations in household	0.048	0.030	0.101	0.086	0.031	**0.006****
Number of people sharing toilet	–	–	–	0.023	0.011	**0.034***
Community-level determinant						
North Coast residence	−0.277	0.165	0.095	−0.305	0.185	0.102
Adjusted R^2	0.10			0.11		
F (7, 172)	3.52			3.64		
Prob > F	0.0009			0.0006		

† body mass index, BMI.
*significant at $p < 0.05$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.
‡Child age (β-coeff = 0.002 SE = 0.007, $P = 0.783$) and sex (age (β-coeff = −0.150 SE = 0.175, $P = 0.392$) in the height-for-age Z score model but these covariates were not retained due to diminished model fit (adjusted $R^2 = 0.10$).
Bold values are explained in the legend as signficant *P*-values.

2007; Dror and Allen, 2011; Iannotti et al., 2017; Iannotti, 2018). Here we found that fishing households negatively correlated with CDD, similar to other studies where involvement in fishing activities was not associated with improved household fish consumption (Garaway, 2005; Fiorella et al., 2014; Rusdiana and Mulyawan, 2020). As evidenced from our qualitative research findings, fishing households tend to sell fish in order to purchase the less expensive starch-based foods (Cartmill et al., 2022). However, other studies have found that fishing households are likely to consume more fish than non-fishing households (Gomna and Rana, 2007: Moreau and Garaway, 2018) contrary to our study findings. Other studies in sub-Saharan Africa have diverged somewhat in terms of dietary diversity findings in part due to study design, but generally, have comparable findings for low CDDS and those meeting MDD, now adjusted to five or more food groups (Tosheno et al., 2017; Byrd et al., 2019). In their recommendations for improving MDD, Ahoya et al. (2019) showed that Kenyan government actions for improving complementary feeding included increasing dietary diversity well-articulated in the national nutrition action plans.

Dietary intake inadequacy across multiple micronutrients was found for both fishing and non-fishing households. Despite the highly cereal-based diets, slightly more than two thirds of the children met at least three quarters of their energy needs, while only 12% met more than 100% of their needs. Paul et al. (2012) in their study on complementary feeding in Zimbabwe and Byrd et al. (2019) in a similar study in Kenya also found poor energy intake during complementary feeding. Protein intake was better than all other nutrient intakes in the present study with over two thirds of the children receiving all recommended intakes for their age. However, most of the protein was obtained from plants except for a few cases where it came from fish. This agrees with findings from the DHS (KNBS and ICF Macro, 2015) that most children were not given animal source foods. Other studies in Kenya (Byrd et al., 2019) and other African countries (Gegios et al., 2010; Harika et al., 2017) have also found low micronutrient intakes in children in the complementary feeding age group. The results of our study on micronutrient intake are also in agreement with the most current Kenya National Micronutrient Survey (2011) where grains were the most important source of all micronutrients.

Our study compared fishing and non-fishing households living on either side of a coastal highway. The highway provided a distinction between communities close to the ocean and were more likely to have fishing as a livelihood while the other communities were far from the ocean and engaged in farming activities. However, it was ultimately an observational study with risks of biases and potential confounding variables. We matched fishing and non-fishing households across the coastal highway on some characteristics, drawing from prior research in the region, such as income, geography, and access to markets, but others were part of the hypothesized differences including nutritional status and dietary intakes. Age was found to be higher in children of fishing households and thus, controlled for in regression modeling. Another related limitation was that our study was collected primarily during *kaskazi* (north-east monsoon) season when fishers are more likely to have greater catches, potentially increasing both income and fish available in families for consumption. Ideally, we would have conducted another round of surveys during *kusi* (the southeast monsoon), to have representative diet and household conditions. Nonetheless, one could speculate that non-fishing households also had greater access to fish in the markets during the *kaskazi* season allowing for some comparison.

Another potential limitation was use of the CDDS in older children as this indicator was developed for young children ages 6–23 mo. However, recent analyses have validated its use for children ages 24–59 mo (Diop et al., 2021). Finally, we were only able to perform a single 24-h dietary recall to assess dietary intakes in the children. While we were careful to choose representative days of the week, some aspects of usual diet may have been missed. In our view, it showed the commonly eaten foods in the population and thus the study was able to estimate mean nutrient intakes and identify likely nutrient deficiencies.

Conclusion

This study examined multiple factors playing a role in child nutrition in the context of a coastal marine food system. Together with the proximal determinants of child diet and disease morbidities, we assessed household and community-level drivers related to social and gender dynamics, WASH, livelihoods, fish market value chain, and the marine coastal ecology. Stunting and infectious disease prevalence were high in this study for both fishing and non-fishing households. There was dietary inadequacy for both groups which was evidenced by the low CDDS and also the source of most nutrients which was the cereal-based foods. There was also low intake of animal source foods. Maternal characteristics like BMI and years of education were found to be important in predicting CDDS and HAZ. The number of income generating activities in a household also predicted increased CDDS as well as improved HAZ. This study has been able to demonstrate the predictors of child nutrition within the fishing system and thus provide a basis for future interventions.

From the outset, we engaged stakeholders from these different sectors with a view toward designing and implementing a trial examining a large-scale multidisciplinary intervention, informed by this research. Ultimately, this formative research was used to design a multifaceted intervention involving several sectors and targeting the domains of education, livelihoods, sustainable fisheries, and public health nutrition communication (Blackmore et al., 2022). The results of this study were used to plan health promotion messages through social marketing in order to improve child nutrition and health outcomes through Samaki Salama Project.

The resulting Samaki Salama ("secure or safe fish" in Kiswahili) project is a cluster randomized controlled trial with three arms: (1) control group; (2) social marketing for behavior change; and (3) social marketing plus modified fish traps. The social marketing component uses different platforms (household dialogue, fisher workshops, cooking demonstrations, and community health workers) to convey messages about healthy sustainable diets and the importance of keeping some fish for child nutrition. The modified traps, a sustainable fish production gear type, enables fishers to increase their fish catch or biomass while allowing juvenile fish to escape thereby protecting the marine ecosystem. Such integrated strategies, drawing on multidisciplinary formative research and working across sectors will improve the wellbeing of small-fisher households and allow for their larger contributions to sustainable healthy food systems.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The Ethical approval for this study was obtained from the Human Resource Protection Office of Washington University in St. Louis, the Pwani University Ethics Review Committee and the Office of Research Compliance at Mississippi State University. The project also received a research permit license from the National Commission for Science, Technology and Innovation (NACOSTI), Kenya.

Author contributions

EK-M, LI, AW, CL, and AH designed the initial study. CS, RM, CC, and JC were involved in data collection. EK-M, LI, AN-G, and CS conducted data analyses, while EK-M, LI, AN-G, AW, AH, CL, and IB contributed to in writing of this manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1091339/full#supplementary-material

References

Ahoya, B., Kavle, J. A., Straubinger, S., and Gathi, C. M. (2019). Accelerating progress for complementary feeding in Kenya: Key government actions and the way forward. *Maternal Child Nutr.* 15, 1–18. doi: 10.1111/mcn.12723

Amugsi, D. A., Dimbuene, Z. T., and Kimani-Murage, E. W. (2020). Socio-demographic factors associated with normal linear growth among pre-school children living in better-off households: a multi-country analysis of nationally representative data. *PLoS ONE* 15, e0224118. doi: 10.1371/journal.pone.0224118

Amugsi, D. A., Dimbuene, Z. T., Kimani-Murage, E. W., Mberu, B., and Ezeh, A. C. (2017). Differential effects of dietary diversity and maternal characteristics on linear growth of children aged 6–59 months in sub-Saharan Africa: a multi-country analysis. *Public Health Nutr.* 20, 1029–1045. doi: 10.1017/S1368980016003426

Baker, K. K., O'Reilly, C. E., Levine, M. M., Kotloff, K. L., Nataro, J. P., Ayers, T. L., et al. (2016). Sanitation and hygiene-specific risk factors for moderate-to-severe diarrhea in young children in the global enteric multicenter study, 2007–2011: case-control study. *PLoS Med.* 13, e1002010. doi: 10.1371/journal.pmed.1002010

Bandoh, D.,Manu, A., Kenu, E. (2018). Lacking in abundance: undernutrition in a Peri-urban fishing community in Coastal Ghana. *BMC Nutr.* 4, 20. doi: 10.1186/s40795-018-0229-8

Bekele, T., Rawstorne, P., and Rahman, B. (2020). Effect of water, sanitation and hygiene interventions alone and combined with nutrition on child growth in low and middle income countries: a systematic review and meta-analysis. *BMJ Open* 10, e034812. doi: 10.1136/bmjopen-2019-034812

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., et al. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World Develop*, 79, 177–196. doi: 10.1016/j.worlddev.2015.11.007

Blackmore, I., Wamukota, A., Kamau-Mbuthia, E., Humphries, A., Lesorogol, C., Cohn, R., et al. (2022). Samaki Salama—Promoting healthy child growth and sustainable fisheries in coastal Kenya: a study protocol. *Front. Public Health* 10, 934806. doi: 10.3389/fpubh.2022.934806

Byrd, K., Dentz, H. N., Williams, A., Kiprotich, M., Pickering, A. J., Omondi, R., et al. (2019). A behaviour change intervention with lipid-based nutrient supplements had little impact on young child feeding indicators in rural Kenya. *Maternal Child Nutr.* 15, e12660. doi: 10.1111/mcn.12660

Cartmill, M. K., Blackmore, I., Sarange, C., Mbeyu, R., Cheupe, C., Cheupe, J., et al. (2022). Fish and complementary feeding practices for young children: qualitative research findings from coastal Kenya. *PLoS ONE* 17, e0265310. doi: 10.1371/journal.pone.0265310

Cinner, J. E., Huchery, C., Darling, E. S., Humphries, A. T., Graham, N. A., Hicks, C. C., et al. (2013). Evaluating social and ecological vulnerability of coral reef fisheries to climate change. *PloS ONE* 8, e74321. doi: 10.1371/journal.pone.0074321

County Government of Kilifi. (2018). *Integrated Development Plan 2018–2022: Towards Realizing Peoplefocused Transformation for Wealth Creation.* Available online at: http://www.devolution.go.ke/wp-content/uploads/2020/02/Kilifi-CIDP-2018-2022.pdf

De Onis, M., and Branca, F. (2016). Childhood stunting: a global perspective. *Maternal Child Nutr.* 12, 12–26. doi: 10.1111/mcn.12231

Dewey, K. G., and Begum, K. (2011). Long-term consequences of stunting in early life. *Maternal Child Nutr.* 7, 5–18. doi: 10.1111/j.1740-8709.2011.00349.x

Diop, L., Becquey, E., Turowska, Z., Huybregts, L., Ruel, M. T., Gelli, A., et al. (2021). Standard minimum dietary diversity indicators for women or infants and young children are good predictors of adequate micronutrient intakes in 24–59-month-old children and their non-pregnant non-breastfeeding mothers in rural Burkina Faso. *J. Nutr.* 1, 412–22. doi: 10.1093/jn/nxaa360

Dioula, B., Deret, H., and Morel, J. Etienne du Vachat, E., and Kiaya, V. (2013). *Enhancing the Role of Smallholder Farmers in Achieving Sustainable Food and Nutrition Security.* FAO/WHO. (www.fao.org/publications)

Dror, D. K., and Allen, L. H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food Nutr. Bull.* 32, 3. doi: 10.1177/156482651103200307

FAO FishFinder. (2010). *Commercially Important Coastal Fishes of Kenya. A Pocket Guide.* http://www.fao.org/fishery/species/2468/en

FAO/WHO. (2001). *Human Vitamin and Mineral Requirements, Report of a joint FAO/WHO expert consultation.* Bangkok, Thailand.

Fiorella, K. J., Hickey, M. D., Salmen, C. R., Nagata, J. M., Mattah, B., Magerenge, R., et al. (2014). Fishing for food? Analyzing links between fishing livelihoods and food security around Lake Victoria, Kenya. *Food Security* 6, 851–860. doi: 10.1007/s12571-014-0393-x

Garaway, C. (2005). *Fish, fishing and the rural poor.* A case study of the household importance of small-scale fisheries in the Lao PDR. Aquatic Resources, Culture and Development.

Gegios, A., Amthor, R., Maziya-Dixon, B., Egesi, C., Mallowa, S., Nungo, R., et al. (2010). Children consuming cassava as a staple food are at risk for inadequate zinc, iron, and vitamin A intake. *Plant Foods Hum Nutr.* 65, 64–70. doi: 10.1007/s11130-010-0157-5

Gibson, R., and Ferguson, E. (2008). "An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries," in *HarvestPlus Technical Monograph 8.* Washington, DC and Cali: International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT).

Gomna, A., and Rana, K. (2007). Inter-household and intra-household patterns of fish and meat consumption in fishing communities in two states in Nigeria. *Br. J. Nutr.* 97, 145–152. doi: 10.1017/S0007114507201734

Harika, R., Faber, M., Samuel, F., Mulugeta, A., Kimiywe, J., Eilander, A., et al. (2017). "Are low intakes and deficiencies in iron, Vitamin A, Zinc, and Iodine of Public Health Concern in Ethiopian, Kenyan, Nigerian, and South African Children and Adolescents?," In *Food and Nutrition Bulletin,* Vol. 38, Issue 3 (SAGE Publications Inc.). p. 405–427. doi: 10.1177/0379572117715818

Herrero, M., Thornton, P. K., Power, B., Bogard, J. R., Remans, R., Fritz, S., et al. (2017). Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *Lancet Planetary Health.* 1, e33–e42. doi: 10.1016/S2542-5196(17)30007-4

Hilborn, R., Banobi, J., Hall, S. J., Pucylowski, T., and Walsworth, T. E. (2018). The environmental cost of animal source foods. *Front. Ecol. Environ.* 16, 329–335. doi: 10.1002/fee.1822

Iannotti, L. L. (2018). The benefits of animal products for child nutrition in developing countries. *Revue Scientifique et Technique* 37, 37–46. doi: 10.20506/rst.37.1.2738

Iannotti, L. L., Lutter, C. K., Stewart, C. P., Andres Gallegos Riofrío, C., Malo, C., Reinhart, G., et al. (2017). Eggs in early complementary feeding and child growth: a randomized controlled trial. *Pediatrics* 1, 140. doi: 10.1542/peds.2016-3459

Ijarotimi, O. S. (2013). Determinants of childhood malnutrition and consequences in developing countries. *Current Nutr. Rep.* 2, 129–133. doi: 10.1007/s13668-013-0051-5

Kawarazuka, N., and Béné, C. (2011). The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. *Public Health Nutr.* 14, 1927–1938. doi: 10.1017/S1368980011000814

Kenya Institute for Public Policy Research and Analysis. (2020). *Kenya Economic Report 2020.* Available online at: https://kippra.or.ke/index.php/publications?task=download.sendandid=226andcatid=4andm=0

Kenya National Bureau of Statistics (KNBS) and ICF Macro. (2015). *Kenya Demographic and Health Survey 2014. Calverton, Maryland: KNBS and ICF Macro.* Available online at: www.DHSprogram.com

Kenya National Bureau of Statistics. (2019). *Kenya Population and Housing Census.* Available online at: https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

Komarulzaman, A., Smits, J., and de Jong, E. (2017). Clean water, sanitation and diarrhoea in Indonesia: effects of household and community factors. *Global Public Health* 12, 1141–1155. doi: 10.1080/17441692.2015.1127985

McClanahan, T. R., and Humphries, A. T. (2012). Differential and slow life-history responses of fishes to coral reef closures. *Marine Ecol. Progress Ser.* 469, 121–131. doi: 10.3354/meps10009

Mills, D. J., Westlund, L., De Graaf, G., Kura, Y., Willman, R., and Kelleher, K. (2011). "Under-reported and undervalued: Small-scale fisheries in the developing world," in *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World.* doi: 10.1079/9781845936075.0001

Ministry of Medical Services. (2010). *Kenya National Clinical Nutrition and Dietetics Reference Manual.* Available online at: http://nak.or.ke/wp-content/uploads/2017/12/KENYA-NATIONAL-CLINICAL-NUTRITION-AND-DIETETICS-REFERENCE-MANUAL.pdf

Moreau, M. A., and Garaway, C. J. (2018). "Fish rescue us from hunger": the contribution of aquatic resources to household food security on the Rufiji River floodplain, Tanzania. *Hum Ecol.* 46, 831–848. doi: 10.1007/s10745-018-0030-y

Neumann, C. G., Murphy, S. P., Gewa, C., Grillenberger, M., and Bwibo, N. O. (2007). Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *J. Nutr.* 137, 1119–1123. doi: 10.1093/jn/137.4.1119

Ngure, F. M., Reid, B. M., Humphrey, J. H., Mbuya, M. N., Pelto, G., Stoltzfus, R. J., et al. (2014). *Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: Making the links.* Annals of the New York Academy of Sciences. doi: 10.1111/nyas.12330

Nigatu, G., Assefa Woreta, S., Akalu, T. Y., and Yenit, M. K. (2018). Prevalence and associated factors of underweight among children 6–59 months of age in Takusa district, Northwest Ethiopia. *Int. J. Equity Health* 17, 329–35. doi: 10.1186/s12939-018-0816-y

Olofin, I., McDonald, C. M., Ezzati, M., Flaxman, S., Black, R. E., Fawzi, W. W., et al. (2013). Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: a pooled analysis of ten prospective studies. *PLoS ONE* 8, e64636. doi: 10.1371/journal.pone.0064636

Paul, K. H., Muti, M., Chasekwa, B., Mbuya, M. N. N., Madzima, R. C., Humphrey, J. H., et al. (2012). Complementary feeding messages that target cultural barriers enhance both the use of lipid-based nutrient supplements and underlying feeding practices to improve infant diets in rural Zimbabwe. *Maternal Child Nutr.* 8, 225–238. doi: 10.1111/j.1740-8709.2010.00265.x

Roos, N., Wahab, M. A., Chamnan, C., and Thilsted, S. H. (2007). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *J. Nutr.* 137, 1106–9. doi: 10.1093/jn/137.4.1106

Rusdiana, A. Sanuri, Subandi, M., and Mulyawan, S. (2020). The relationship between socioeconomic status and consumption pattern of fishermen household in Indonesia. *Asian J. Agric. Rural Develop.* 10, 141–148. doi: 10.18488/journal.1005/2020.10.1/1005.1.141.148

Sinha, R., Dua, R., Bijalwan, V., Rohatgi, S., and Kumar, P. (2018). Determinants of stunting, wasting, and underweight in five high-burden pockets of four Indian states. *Indian J. Commun. Med.* 43, 279–283. doi: 10.4103/ijcm.IJCM_151_18

Thilsted, S. H., Thorne-Lyman, A., Webb, P., Bogard, J. R., Subasinghe, R., Phillips, M. J., et al. (2016). Sustaining healthy diets: the role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. *Food Policy* 61, 126–131. doi: 10.1016/j.foodpol.2016.02.005

Tosheno, D., Mehretie Adinew, Y., Thangavel, T., and Bitew Workie, S. (2017). Risk factors of underweight in children aged 6–59 months in Ethiopia. *J. Nutr. Metabol.* 137, 1106–9. doi: 10.1155/2017/6368746

WHO growth standards (2006). Available onlinea at: https://www.who.int/tools/child-growth-standards