

1 **Title: Associations between Maternal Participation in Agricultural Decision-Making and**
2 **Child Nutrition in Semi-arid Kenya**

1 Introduction

Undernutrition is one of the most important factors that contributes to lasting physical and cognitive morbidity and child mortality in developing countries each year.¹⁻³ Despite tremendous international and national efforts, household undernutrition presents significant and enduring challenges in many agrarian societies.⁴⁻⁸ In Kenya, although there has been reductions in food insecurity^{9,10} and childhood undernutrition since early 2000,¹¹ in the arid and semi-arid lands (ASAL) more than one in four children under five exhibit measures of stunted growth.¹¹ In Kenya's ASAL, increasing population pressure on land and productive resources, low adoption of agricultural innovations, high vulnerability to rising food prices and extreme climatic stresses all contribute to low agricultural yields, poverty and undernutrition.^{9,10} As a result, significant policy, research, and development attention has been directed towards addressing household food and nutritional security in the region.

Policy and capacity building efforts that aim to increase the quality, quantity, and diversity of smallholder agricultural production and household food consumption in the region have shown relatively limited impact.^{4-6,12} Recognizing women's substantial participation in subsistence and smallholder agriculture in many sub-Saharan African countries,¹³ previous research has identified gender dynamics in resource allocation as an important factor in household food and nutritional security.^{8,12-15} Such research has explored the relationships between childhood nutrition and social determinants of health, such as mother's education, household socio-economic status, and autonomy.^{2,12-20} Women's autonomy has also been defined in various ways in the literature²¹,

generally referring to “a woman’s ability to have control or influence over choices that affect herself and her family within her own particular context” (p. 452).¹⁹ Notably, women’s empowerment is a “complex construct ... [with] no universally accepted definition of the term or agreement regarding which domains and sub-domains comprise one’s empowerment... [It] refers to notions of power, agency, control and decision making” (p. 6).²⁰ In this study, we adopt Kabeer’s²² definition of empowerment as “the processes by which those who have been denied the ability to make choices acquire such an ability” (p.437). Previous systematic reviews have found that, in general, maternal autonomy and empowerment have positive associations with childhood nutritional outcomes.^{19,20} However, the relationship might vary depending on the domains of women’s empowerment, child’s age and other contextual factors.²⁰

Inconsistencies across studies in the conceptualization of women’s empowerment and the different domains used to assess empowerment have contributed to mixed conclusions. Context-specific differences related to cultural feeding behaviours and demographic characteristics such as household structures make cross-study comparisons and regional conclusions problematic.¹⁹⁻²⁰ Most existing studies have measured women’s autonomy around decisions of food consumption, household expenditure, access to health services, mobility, contraceptive use, attitudes towards domestic violence, and financial resources, such as household income, individual credit, and employment.¹⁸⁻²¹ However, Carlson et al. noted that as women are generally expected to be responsible in the domains of domestic expenditure, food preparation, and child-feeding, high levels of autonomy in these domains may not strongly indicate women’s empowerment.¹⁹ Moreover, common measurements of livelihood outputs, such as household income, have often been used with minimal consideration of gender²²⁻²⁵.

Until recently, there has been little empirical evidence concerning women's decision-making in the spheres of agricultural production and livelihoods.^{26,27} Similarly, although there have been calls for multi-sectoral approaches in designing nutrition-sensitive policies and interventions,^{17,28,29} there remains relatively little evidence on how intra-household decision-making dynamics relate to household nutrition security in the context of smallholder agriculture.^{30,31} Understanding women's autonomy, not only in making domestic decisions, but also in making agricultural decisions, is considered critical when undernutrition alleviation is a priority.¹⁴ This paper examines the relationships between childhood nutritional growth measures and maternal participation in agricultural decision-making in smallholder and subsistence agricultural production systems in the ASAL region of Kenya.

2 Conceptual framework

Figure 1 presents a causal loop diagram that depicts the theoretical pathways through which child growth is hypothesized to associate with a parent's participation in agricultural decision-making. The figure shows that there are two main reinforcing feedback loops. The initial pathway of the first feedback loop (R1) expects that proper child growth reduces a child's susceptibility to infectious diseases.³² In turn, it reduces his or her parent's time and expenditure in seeking health care services potentially enabling the parent more time to cultivate, and accumulate experience and knowledge in agriculture. This gained experience increases the parent's credibility in the household in terms of agriculture and child-rearing, which is expected to increase the parent's participation in agricultural decision-making³³. The second reinforcing feedback loop (R2) expects that a child's nutritional growth reinforces his or her parent's confidence in child care, increasing the parent's credibility in the household overall. The parent's credibility, in turn, increases his or

her participation in productive decision-making. In turn, there is greater likelihood for parents to consider and plan for nutritious food crops grown on the farm. In households where women's voice and agency are often secondary to the household head or senior household members, new knowledge through agricultural and nutritional training can be refuted or ignored. However, when women participate in decision-making, they are more likely to apply any new agricultural and nutritional knowledge that they have gained through training on the farm. In turn, knowledge generated through training may translate to increases in the availability of diverse crops grown on the homestead containing macro and micronutrients that promote healthy growth (Figure 1).

Building on this logic, we hypothesize that mothers' participation in agricultural decision-making is positively associated with their children's growth. By describing the various mechanisms with a causal loop diagram, the hypothesized relationships, including the intermediary and mediating factors, can be more clearly rationalized and explored (Figure 1). Such mediating factors include: household's wealth, mother's body mass index (BMI), mother's age and education attainment, child's age, child's illness history, and gender hierarchy measured via gender of the household head and gender of the child. The diagram depicts "parent" instead of "mother" to indicate the primary care-giver of the child, which suggests that the amount of time the parent spends with the child, regardless of gender, increases the likelihood that nutritional food crops are considered in the seasonal planning on the farm. We therefore test whether these relationships are empirically observed among Kamba households in the ASAL.

[Insert Fig. 1]

3 Participants and methods

3.1 Study population

The research was undertaken in Machakos and Makueni Counties, located in eastern Kenya. In the 2014 national health survey, these two counties exhibited high levels of undernutrition and food insecurity, with over 25% of children under age five exhibiting chronic undernutrition and 6.3 and 10.6 % of women at reproductive age being underweight ($<18.5\text{kg/m}^2$) in the two counties, respectively.¹¹ Total fertility rates were 3.3 (Machakos) and 3.9 (Makueni) children per woman, respectively, with under five mortality rates of 45 deaths per 1,000 live births reported in the broader Eastern province¹¹, typically linked to seasonal and acute infectious diseases. The residents in the two counties are predominantly Kamba people. Kamba households generally rely on semi-subsistence agro-pastoral livelihoods, supplemented with casual labor, beekeeping, and small-scale trading of artisanal crafts for additional income.^{9,34,35} Kamba livelihood activities are often supported by the collection of forest products for firewood, charcoal, herbal medicine, and wild-edible food,³⁶ which demonstrates a high reliance on the surrounding natural resources.

The Kamba community observes polygamous and monogamous marital unions within a patrilineal society.³⁷ In the Kamba culture, women are commonly given farm plots at marriage to cultivate together with their husband, which are delineated from plots cultivated by other household members (e.g. mother-in-law, brothers-in-law).³⁸ Multi-generational and skipped generational structures in households are common, in part due to the HIV/AIDS pandemic in the 1990s and 2000s, teenage pregnancies, as well as more women entering the labor market.^{39,40,41}

3.2 Data source

In 2012, the Kenya Medical Research Institute (KEMRI) administered a household survey in Machakos and Makueni Counties that collected anthropometric growth measures of children and women, as well as socio-demographic and biological variables, detailed in Section 3.3. A flow-chart representation of the sampling design is presented in the supplementary material (Suppl. Figure 1). Seventy-two farmer groups were listed and obtained from Machakos and Makueni Counties' Ministry of Agriculture and Extension Offices. From 1,500 members listed within the farmers' groups, 328 households met the inclusion criteria of having a non-pregnant woman aged 15 to 46 years old with her biological child between six to 36 months old. Two hundred and seventy-seven households were randomly selected with one mother-child pair per household recruited and assessed with a response rate of 85 %. The survey was carried out during the "long rain" season in May and June, 2012. The household survey was approved by the KEMRI ethics review board.

In 2014, we revisited the same sample of mother-child pairs for a separate survey concerning agricultural decision-making in the household to contextualize the nutritional findings. Our study assumed that patterns of decision-making involvement among men and mothers in the household did not change significantly across the two-year survey interval. This assumption is supported by two review studies on household resource allocation^{42,43} that indicated households that have large authority differences between the men and women, a highly differentiated division of labor, and household members who received below post-secondary education (similar to the majority of rural Kamba households sampled) are reported to have low variability in participation in household decision-making.⁴²

The attrition rate in 2014 due to a mother's death, migration, or end of marriage was less than nine percent. Two hundred and fifty-two mothers completed the follow-up survey. Female caregivers to non-biological children were excluded. The final dataset contained 221 mother-child pairs available for analysis. Surveys lasted approximately 50 minutes and took place in participants' homes and were administered in the local Kikamba dialect. All women provided written consent at the time of data collection. Up to three attempts were made to interview the mothers if they were previously not present. (Anonymous Research Ethics Board approved the follow-up survey.

3.3 Indicators

Variables of interest were childhood weight-for-height z-scores (WHZ), height-for-age z-scores (HAZ), and weight-for-age z-scores (WAZ). The WHZ score measures children's thinness, the HAZ score measures children's tallness, and the WAZ score is a composite score of the first two.⁴⁴ Standing height, or lying down length for children below the age of two years, was measured using a standardized UNICEF stadiometer. Measurements were recorded to the nearest 0.1 cm. Weight was measured using UNICEF's Seca 762 classic mechanical medical weighing scale. Participants were weighed without shoes and with minimal clothing to the nearest 0.1 kg. Children who needed to be held by their mother had the mother's weight tared prior to being measured together with the child.⁴⁵ Standardized z-scores were calculated by normalizing measures with the WHO reference population's childhood median growth measures. Children with z-scores at two standard deviations below the WHO reference median were considered wasted, stunted, or underweight.⁴⁴ Stunting reflects an inadequate nutritional intake over an extended period and may also be affected by chronic illness. Wasting reflects inadequate nutrition intake in the days immediately before the

measurement administered by the survey. Underweight reflects the effects of both acute and chronic undernutrition.⁴⁴

The dependent variable of interest is mother's participation in agricultural decisions. Mothers were asked, "In the past season, who decided to: "buy specific seeds", "prepare the lands", "start weeding", "spray chemicals", "apply manure", "plant trees", "build terraces"? and "can you alone decide to sell the harvest from this land?" The first seven questions were constructed based on preliminary qualitative results of seasonal or permanent agricultural decisions commonly reported by Kamba farmers. The eighth question was added to reflect the critical factors of timing and market prices that farmers have been reported to regularly consider in order to enhance their access to land resources. Some farm decisions reflect available crop diversity (e.g. decisions to buy specific seeds or to plant fruit trees). From a list of ten possible household members and an option to specify a member not on the list, one or more decision-makers were recorded in the response. A positive response was counted when mothers reported themselves as one of the household members who made the decision. (For example, if a respondent reported that the "husband", "father-in-law", "mother-in-law", and "respondent" decided to apply manure in the last season, the positive response, 1, denoted the mother participated in the decision regarding manure application. If the "respondent" was not among the members who made the decision, the response was 0. Responses were weighted and summed to create an index score on maternal participation in making agricultural decisions. We targeted mother's participation in agricultural decision making rather than any woman in the household in order to reflect the unique mother-child relationships in our conceptual feedback loops (Figure 1). The data are based solely on responses from the mothers.

We included variables from the 2012 survey in the statistical analysis to adjust for potential confounding. We controlled for maternal characteristics: mother's age, maternal BMI, mother's marital status and mother's highest level of education. We used child's age, child's gender, whether the child had received deworming drugs to control for individual level health and demographic characteristics of the child. Household level variables were the gender of the household head, the household's access to electricity, and a household asset index. Male-headed households were households where the self-defined household head in relation to the mother was reported male from the KEMRI survey household member roster, most commonly a father-in-law, a father-by-birth, or a husband. The household asset index was calculated as a summation of consumer durables and housing stock from 13 types of assets^{i.46} Counties and agro-ecological zones were included to control for regional variation.

3.4 Statistical analysis

A cross-sectional dataset with 221 mother-child pairs was used for statistical analysis after households with missing data (n = 31) were excluded from the dataset. First, descriptive statistics of three sets of anthropometric z-scores were reported across socio-demographic variables of mothers and children. Second, Ordinal Least Square regression analyses were used to identify associations between continuous measures of child anthropometric z-scores and social-demographic determinants that could potentially confound with the associations between maternal participation of agricultural decision-making and child growth. The variables tested were: maternal BMI, marital status, mother's education, mother's age, child's age, child's gender, whether the child was dewormed, gender of household head, county, and agroecological zone. The dependent variable: 'maternal participation in decision-making', was not included in the regression model as

the data were collected two years after their child's anthropometric data. Instead, we stratified the continuous variables of anthropometric z-scores into four strata: (1) below -2; (2) -2 to below -1; (3) -1 to below 0; and (4) 0 and higher, for subsequent association analyses. We opted to use the Kruskal-Wallis H test to test whether there was a statistically significant difference in the participation of decision-making by women across the strata of WAZ, HAZ, and WHZ. The non-parametric Kruskal-Wallis H test is considered suitable to detect distributional differences of ordinal variables that do not meet the normality assumption between two or more groups.

We then selected the potential confounders identified from the Ordinary Least Squares regression analysis in addition to social determinants that have previously identified in public health literature^{47,48}, and employed two levels of stratification. These variables were gender of the household head, household asset index, maternal BMI, maternal age, child's age, child's gender, and whether the child received a deworming drug in the past six months. Each stratum contained a subset of the sample size and was tested separately using the Kruskal-Wallis H test for significant differences in maternal participation in decision-making across childhood WAZ, HAZ, and WHZ categories. By stratifying potential confounders into classes, we assumed that the variation of the confounder within each stratum was sufficiently minimized such that the associations observed were only between the two variables of interest. For example, stratifying children's ages into ten-month intervals assumed that children from age six to 16 months would possess similar characteristics, but different from children aged 17 to 26 months or 27 to 36 months. We used Dunn's Pairwise Comparison to test the directional distributions of the mean maternal participation that were statistically different across strata of potential confounders or across z-score categories.

The tests were conducted at a 95% confidence level, adjusted with a Bonferroni correction. Stata (version 14.0) was used in the statistical analyses.

3.5 Assumptions, limitations, and validity

The research was conducted based on several assumptions to address data and methodological limitations. The cross-sectional data had different variables collected from two different time periods. Childhood nutritional measures were collected in 2012 while responses of agricultural decision-making were collected in 2014. The investigation assumed that feedback mechanisms exist when children's nutritional measures can influence maternal participation in decision-making and in reverse, maternal participation in decision-making can influence children's nutritional measures. Evidence from the cross-sectional case study cannot be inferred as a generalizable causal relationship.

Research has previously shown that women tend to under-report their household decision-making power relative to reports given by their husbands.⁴⁹ Cognizant that there are traditional allocations of gender roles on various farm activities, our measure of maternal participation in agricultural decision-making does not unpack the dynamics of intra-household negotiation among household members that may be related to child growth. Future investigations with data collected from other males and females in the households would enable a more detailed examination of gender parity and cross-validate responses.

The stratification method assumes that within each stratum, the relationships between the confounders and the variables of interests are sufficiently eliminated, leaving the associations observed to be the associations between childhood nutritional growth measures and the participation in decision-making. However, to ensure sufficient sample size within each stratum,

we limited the stratification of confounders to a maximum of three classes. Similarly, a small sample size limited our analysis to two levels of stratification. We were therefore unable to control for more than one confounder at a time. We used equally weighted components to construct the participation in agricultural decision-making indices, while being cognizant that customarily, certain agricultural responsibilities may be gender-specific. However, we do not believe that these limitations detract from the key findings and their policy implications. Triangulations with multiple indicators were used to minimize measurement errors and systematic recall bias inherent in observational studies.

4 Results

Table 1 presents the descriptive statistical results WAZ, HAZ, and WHZ from the 221 mother-child pairs across socio-demographic variables. Sixty-five percent of mothers reported having a below-mean level of participation in agricultural decisions, with the mean index score being 2.8 decisions. Maternal BMI, child's age, child's deworming history in the past 6 months, and household asset wealth were significantly associated with child WAZ, HAZ, or WHZ (Table 2). We stratified the sample by these variables, in addition to maternal age, child's gender, and household head's gender in subsequent testing of the relationship between maternal participation in agricultural decision-making and child anthropometric measures. Table 3 shows that 33 percent of children suffered from stunting, three percent from wasting, and nine percent from being underweight, which is corroborated in a study by Bukania et al.⁵⁰

The statistical results were organized into four main findings. In general, we found significant positive associations between childhood WAZ, HAZ, and WHZ measures and maternal participation in agricultural decision-making, when adjusted for biological (maternal and child

age, BMI, or deworming) or socio-demographic (child's gender, mother's education, household asset tertile, or gender of household head) confounders. We found that there were significant differences in mothers' participation in agricultural decision-making across childhood WAZ categories [Kruskal-Wallis $X^2(3, N = 221) = 7.28, p = 0.06$, Table 3]. Mothers with children in the lowest WAZ category ($WAZ < -2$) reported lower participation levels than mothers with children that had higher WAZ scores ($-2 \leq WAZ < -1$) [Dunn's Pairwise Comparison Bonferroni-adjusted $p=0.02$, Table 4].

Second, after stratifying by household characteristics, we found a significant positive association between mothers' reported participation in decision-making and childhood WAZ within male-headed households [Kruskal-Wallis $X^2(3, n = 173) = 9.36, p = 0.02$, Table 3] but not in female-headed households [Kruskal-Wallis $X^2(3, n = 48) = 0.71, p = 0.87$, Table 3]. In male-headed households, we also found a positive association between WHZ child growth measures and maternal participation in agricultural decision-making [Table 4]. Significant positive association between WAZ and maternal participation in decision making was found among households in the lowest asset tertile [Kruskal-Wallis $X^2(3, n = 62) = 8.22, p = 0.04$, Table 3]. Relevance of food crop decision-making may be more saliently associated with child growth in resource-poor households than in wealthier households.

Third, our results revealed that mothers' participation in decision-making can have critical implications for the undernutrition cycle between mothers and daughters. We adjusted for maternal BMI by stratifying respondents into three categories: those who had normal BMI ($18.5 \text{ kg/m}^2 \leq \text{BMI} < 25 \text{ kg/m}^2$), those who were underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$), and those who were overweight ($\text{BMI} \geq 25 \text{ kg/m}^2$). Although we lacked a sufficient sample size of underweight

mothers to test for statistical significance, our data revealed that among mothers who were underweight, 13 percent had underweight children ($WAZ < -2$), compared to eight percent among mothers with a normal BMI and nine percent among mothers who were overweight. We found a significant association between children's WAZ and mothers' participation among those with a normal BMI [Kruskal-Wallis $X^2(3, n = 146) = 8.34, p = 0.04$, Table 3] and among overweight respondents [Kruskal-Wallis $X^2(3, n = 43) = 9.37, p = 0.03$, Table 3]. However, a negative association was observed among overweight mothers and their child's WAZ measures (Table 4).

We stratified the children by gender to adjust for potential confounding as national stunting and underweight prevalence in Kenyan girls had increased, while boys' decreased, especially from 2003 to 2008-09 after the global food price crisis occurred.⁵¹ Selective gender differences in allocation of nutrition and health resources to children have been reported in other rural settings.^{52,53} A general positive association between childhood WAZ measures and mothers' participation in decision-making was also found among female children [Kruskal-Wallis $X^2(3, n = 115) = 7.10, p = 0.07$, Table 3, Dunn's Pairwise Comparison Bonferroni-adjusted $p = 0.02$, Table 4] but not among male children [Kruskal-Wallis $X^2(3, n = 106) = 1.70, p = 0.64$, Table 3]. Taken together, these results have implications for the perpetuation of undernutrition in women's life cycles, which we discuss in Section 5.

Fourth, we found that the mother's age and child's age were related to the mothers' level of participation in agricultural decision-making. Older mothers (34 to 46 years old) reported significantly higher participation than younger mothers (15 to 28 years old and 29 to 33 years old) [Kruskal-Wallis $X^2(2, N = 221) = 18.43, p < 0.01$]. However, after stratifying for mother's age, we did not find a significant association between child anthropometric measures and mothers'

participation in decision-making (Table 3). We observed that mothers with older children (27 to 36 months old) reported a higher level of participation in agricultural decision-making than mothers with younger children (6 to 16 months old) [$X^2(2, N = 221) = 10.11, p < 0.01$].

After stratifying by child's age groups, significant positive associations remained between child's WAZ [Kruskal-Wallis $X^2(3, n = 64) = 10.83, p = 0.01$, Table 3] and WHZ [Kruskal-Wallis $X^2(3, n = 64) = 12.44, p < 0.01$, Table 3] measures and mothers' participation in decision-making among children six to 16 months old and 17 to 26 months old [Kruskal-Wallis $X^2(3, n = 79) = 7.55, p = 0.06$, Table 3]. Specific pairwise differences can be found in Table 4. Study findings show salient associations between child growth and mother's participation in agricultural decision-making, especially at the stage when mothers are recommended to introduce weaning foods to complement breastfeeding when a child reaches six months old. Mother's participation in deciding which food crops are grown on the farm may influence the types of weaning food available to young children.

When stratified by mother's education attainment, a positive association was found between maternal participation in decision-making and children's HAZ scores [Kruskal-Wallis $X^2(3, n = 42) = 7.50, p = 0.06$, Table 3, Dunn's Pairwise Comparison Bonferroni-adjusted $p = 0.02$, Table 4]. However, mixed results were found when we adjusted for a child's deworming history in the past six months. In what follows, we discuss the above findings to better understand the relationship between mothers' household decision-making concerning agriculture and child growth.

5 Discussion

This study contributes to our understanding of the social determinants of child undernutrition. First, our conceptual framework (Figure 1) proposes potential pathways through which a child's growth performance may be both the determinant and the result of maternal participation in agricultural decision-making. Here, it is possible that child nutritional performance provides affirmation to mothers who are participating in agricultural decision-making to gain further confidence in voicing their concerns regarding food crops that will become available for domestic use. Poor child nutritional performance, to the degree that the child is underweight, may delegitimize a mother's ability to provide nourishment.^{54,55} Children who are undernourished are also more prone to illnesses that might occupy a mother's time and attention, potentially lowering their participation in agricultural decision-making.⁵⁶ The negative relationship can also be understood in cases where mothers who are more involved in farm management have less time and attention to care for sick children, exacerbating their nutritional growth, as we observed in female-headed households. A reverse mechanism is possible where mothers incorporate their knowledge and experience as care-givers, food providers, and agricultural producers as they make agricultural decisions. Mothers who engage in agricultural decision-making may consider crop and dietary diversity within the home. We argue that both mechanisms are likely present in a reinforcing feedback loop. Here, the feedback mechanism enables the well-nourished children to enhance mothers' participation in decision-making on the farm, which influences dietary and nutritional food intake. Having poorly-nourished and sick children reduces mothers' participation in farm decision-making, constraining the inclusion of their knowledge and preferences on farm management.

Second, our study found a significant positive association between childhood WAZ measures and maternal participation in agricultural decision-making. The significant positive association between WHZ and maternal participation in decision-making among children 6 to 16 months old aligns with previous research suggesting that the WHZ score is more closely associated with women's autonomy in child-feeding behavior.¹⁹ Similarly, significant associations found between HAZ and maternal participation in decision-making among children who were dewormed and not dewormed in the last six months support a previous review that suggested the HAZ score is more closely associated with mother's autonomy in maternal and child health access and the child's exposure to diseases.¹⁹ Deworming status is, however, an insufficient proxy to determine a child's digestive condition. Children could have received deworming through routine school programs or after being diagnosed with helminths parasites. Yet, children who were not dewormed could be healthy or undiagnosed. As WAZ is a composite indicator of WHZ and HAZ, it is an overall measure of childhood growth affected by short- and long-term changes. It reflects both the daily fluctuation of body weight and chronic growth conditions associated with poor long-term nutritional intake. We therefore discuss the implications of the associations found between WAZ and maternal participation in decision-making when we controlled for other social-demographic indicators.

Although higher household income and resource availability contributes to food and nutritional security, resource distribution may play a more important role in young children's nutritional intake and growth, particularly in households with low financial capital. This view is supported by the positive association identified between WAZ and maternal participation in agricultural decision-making among the poorest households in our study. For example, households

may try to increase income by investing in cash crop cultivation in larger portions of their fields, or intensifying the use of agricultural inputs and labour for weeding to increase crop yields.^{57,58} However, a higher household income may not 'trickle down' to improving their children's dietary intake and nutrition. Rather, increased income is often associated with increased caloric consumption and access to health care services.^{58,59,60} This also corroborates observations that women are more likely spending a higher proportion of additional income, whether from harvest or non-farm activities, on domestic consumption and inputs into their children's health and nutrition.⁵⁸

The significant positive association found in male-headed households but not in female-headed households indicated that two mechanisms are likely at play. First, mothers' observation of children in childcare informs their preferences in agricultural decision-making. Second, maternal empowerment through participation in decision-making within male-headed household is positively associated to child growth. In female-headed households, findings showed that mothers' participation in agricultural decision-making did not significantly differ across child growth measures. Although mothers' preferences can also be reflected in their agricultural decision-making within female-headed households, the potential benefits are offset by constraints in their access to capital and labour that female-headed households in Kenya often face.^{13,14,61}

The feedback mechanism proposed in our conceptual framework (Figure 1), where women's decision-making is informed by children's nutritional growth conditions, may be secondary to the economic constraints often experienced in female-headed households. Poorer access to livelihood capitals, such as smaller and less fertile land parcels, credit, information, off-farm household income, and shortage in farm and child-rearing labour, likely contribute to lower agricultural

productivity, lower nutritional food intake, and a higher prevalence of child stunting.⁴⁵ In contrast, the process of planning and joint decision-making with other household members can reduce trial and error in livelihood activities.²⁵

In male-headed households, our findings align with previous literature on child health care seeking,⁶¹ and rural credits and savings,⁶² indicating improvements in childhood and household wellbeing when mothers are more actively involved in decision-making. Higher levels of participation in decision-making observed in female-headed households may be driven by need, such as in households with widows or single mothers. Our results suggest that gender differentiation in preferences related to agricultural production can have a direct association with children's nutritional growth, one of which is possibly through dietary diversity arising from nutrition-sensitive agricultural practices.^{14,55} Policy and programmatic efforts that encourage women to participate more and men to engage with women in decision-making have the potential to contribute to more equitable gender power hierarchies and resource distribution within Kamba households.⁶³

Interestingly, we found that sons' growth measures did not vary significantly with maternal participation in agricultural decision-making. This finding also aligns with previously reported systematic gender-bias in intra-household food allocation for boys in the Kamba region of Mwingi and Makueni districts in eastern Kenya,⁶⁴ where daughters were reported to consistently have lower food intake than sons. Furthermore, parents with a gender preference towards sons have been reported to be more likely to have more children until their preferred daughter to son ratio is met.⁵⁸ Averaging across households with this gender preference, girls will more likely have more siblings than boys, possibly resulting in lower expenditure per child in these households.

Positive associations observed between maternal participation in decision-making and child growth was statistically significant among the most marginalized groups: among households in the lowest asset tertile, and among daughters. In our research sample, daughters with optimal nutritional growth measures were associated with mothers who reported having high participation in agricultural decision-making. However, this association may be overshadowed by biological factors such as mothers being underweight or overweight. Maternal undernutrition is known to contribute to fetal growth restriction and increases the risk of stunting in children.¹ Nevertheless, this evidence has implications for potentially breaking the undernutrition cycle prevalent among mothers and daughters in marginalized households with limited assets or agricultural resources.

Our analysis also identified that the mother's age and child's age were important confounders to the observed associations. While we adjusted the age variables by stratification, residual confounding might be present within each stratum. Nevertheless, there are policy implications from the two-level stratification analysis. We found that older respondents are associated with greater participation in decision-making. Studies have previously found that women's livelihood assets and intra-household bargaining power were associated with women's age and education in Ethiopia and in Bangladesh.^{65,66} Maternal age may be a proxy for experience and confidence in child rearing among mothers, as well as social positions within the household. A mother's agency may depend on her position within a multi-generational household. Birth order of the child, which is associated with mother's age, may also relate to child growth performance.⁶⁷ Hence variations in mother's age associate strongly with variations in child anthropometric measures and the social association between maternal participation in decision-making and child growth was not observed when adjusted for mother's age.

There is already a substantial body of literature linking social determinants, such as women's education, to improvements in women's status and bargaining power. However, our results did not find a significant association between children's growth measures and their mother's formal education. Evidence on the effects of mother's formal education on early childhood nutrition, mortality, and health service use has been inconsistent.⁶⁸⁻⁶⁹ Interestingly, Basu and Stephenson discussed how resource-constrained education systems often teach students to respect and obey authority figures, disproportionately suppressing women's opportunities to think critically and independently.⁷⁰ Correspondingly, observable child and maternal health benefits from delayed childbirth and increased income-generating opportunities may not be observed until women reach post-secondary education. Complementary to formal education, efforts in sharing applied knowledge on drought resistant crops, dietary diversity, and maternal and child health by non-governmental organizations, government extension services, or informally within community based farmers' groups may be more influential in enhancing household food and nutrition security. The result concerning maternal education raises questions that will require further examination in future research.

Women's involvement in agricultural decision-making is a pertinent measure of their empowerment within smallholder and subsistence farming households. Our results shed new light on some of the complexities and feedback mechanisms regarding maternal participation in agricultural decision-making and child growth in the Kamba communities of rural Kenya. Early childhood has a lasting impact on health in adulthood. The significant associations we identified between maternal participation in decision-making and child growth among children 6 to 16 months of age are important. Future food and nutrition security policies will likely benefit from a

greater consideration of the gender biases that can exist in food allocation within household. Further research and programmatic efforts are needed to sensitize smallholder farmers to household nutritional needs. Although there are improvements in national trends concerning food and nutritional security,¹¹ gender transformative approaches,^{71,72} such as educational programs that encourage collaborative and equitable decision-making processes between men and women remain critical to reduce the high prevalence of childhood undernutrition in the ASAL region of Kenya.^{29,63}

6 Compliance with ethical standards

Funding agencies has no role in the study design, data collection, data analysis, interpretation, or writing of findings. Participants provided informed written consent to surveys in 2012 and 2014. The authors had access to all of the data and had final responsibility in the decision to submit for publication. All authors approved the final submission. The authors declare no competing interests.

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ⁱ Assets used to construct the household asset index were: clock, radio, television, mobile phone, solar panel, bicycle, motorcycle, animal cart, vehicle, boat, corrugated iron material used for roof, cement or ceramic tiles used for floor, and latrine with a slab or ventilated improved pit latrine.