Is polygyny a 'harmful cultural practice'? Marriage, food insecurity and child health in northern Tanzania

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Polygyny is cross-culturally common and a topic of considerable academic and policy interest, often deemed a '*harmful cultural practice*' serving the interests of men contrary to those of women and children. Supporting this view, large-scale studies of national African demographic surveys consistently demonstrate that poor child health outcomes are concentrated in polygynous households. Several studies also report negative population-level associations between polygyny and well-being consistent with the hypothesis that group benefits account for cultural shifts to socially-imposed monogamy. We challenge the consensus view that polygyny is harmful drawing on multi-level data from 56 ethnically diverse Tanzanian villages. We first demonstrate the vulnerability of aggregated data to confounding between ecological and individual determinants of health; while *across villages* polygyny is associated with poor child health and low food security, such relationships are often reversed *within villages,* particularly when children and fathers are coresident. We then provide supporting data demonstrating that the costs of sharing a husband are offset by greater wealth (land and livestock) of polygynous households. These results are consistent with models of polygyny based on female choice. Finally, we show that village-level negative associations between polygyny prevalence, food security and child health are fully accounted for by underlying differences in ecological vulnerability (rainfall) and socioeconomic marginalization (access to education). We highlight the need for improved, culturally sensitive measurement tools and appropriate scales of analysis in studies of polygyny and other purportedly harmful practices, and discuss the relevance of our results to theoretical accounts of marriage and contemporary population policy.

Evolutionary Anthropology | Public Health | Family Structure | Child Health | Food Security

Recent years have witnessed an increased recognition of the importance of gender in all aspects of international development (1). This includes domestic and international efforts to abolish so-called *'harmful cultural practices'*, a term used to describe practices of, typically non-western, cultures deemed detrimental to individual well-being, most often with regard to women and children. Most attention has focused on female genital cutting and on child and forced marriage (2, 3). In many policy-orientated texts this label is also given to polygynous marriage (hereafter 'polygyny'). For example, the United Nations Convention on the Elimination of Discrimination Against Women states that polygyny "*contravene[s] a woman's right to equality with men and can have such serious emotional and financial consequences for her and her dependents that such marriages ought to be discouraged and prohibited*" (2). Such statements are frequently presented as stylized facts, made without explicit reference to, or discussion of, supporting evidence. However, a recent spate of articles, mostly based on large-scale, multi-national analyses of African Demographic and Health Surveys (DHS), have concluded that polygyny is indeed harmful, reporting for example that children in polygynous households are consistently more likely to be of ill health or die in early childhood than children in monogamous households (4–8). Reviews of the literature have also informed policy in developed countries, including via the presentation of expert evidence in a recent retrial of the legal prohibition of polygyny in Canada (9).

Historically, over 80% of preindustrial societies are estimated to have permitted polygyny (10), and today it is most prevalent in rural regions of sub-Saharan Africa (11). If women and children do not benefit from polygyny then why is it so common? Evolutionary anthropologists have long puzzled the costs and benefits of polygyny versus monogamy (12). This literature, drawing on small-scale field studies of specific cultural contexts, reaches a broad consensus on the benefits of polygyny to men; polygynous men generally have higher reproductive success than their monogamous counterparts (e.g. 13–16). The potential benefits of, and motivation for, polygyny for women are less clear. One account, the 'polygyny-threshold model', posits that polygyny will occur when the costs of sharing a husband are offset by equal or greater resource access than could otherwise be obtained via monogamy (17, see also 18). Supporting this model, polygynous men are typically wealthier than monogamous men (19, 20), and several studies show no apparent deficit in reproductive success or child health for polygynously married women (e.g. 19, 21). However, in other cases polygyny is associated with relatively poor child health (20, 22–24). While poor outcomes for polygynous women and/or their children do not necessarily imply a rejection

Significance

Polygynous marriage is commonly regarded a 'harmful cultural practice', detrimental to female and child health at both the individual and group-level. We present counterevidence that polygyny is often positively associated with food security and child health *within communities*, and that while polygyny and health are negatively associated at the group-level, such differences are accounted for by alternative socioecological factors. These results support theoretical models of polygyny based on female-choice, and suggest that, in some contexts, prohibiting polygyny could have negative consequences for women and children by restricting marital options. Our study highlights the dangers of naive analyses of aggregated population data, and the importance of considering locally realizable alternatives and context-dependency when studying the public health implications of cultural practices.

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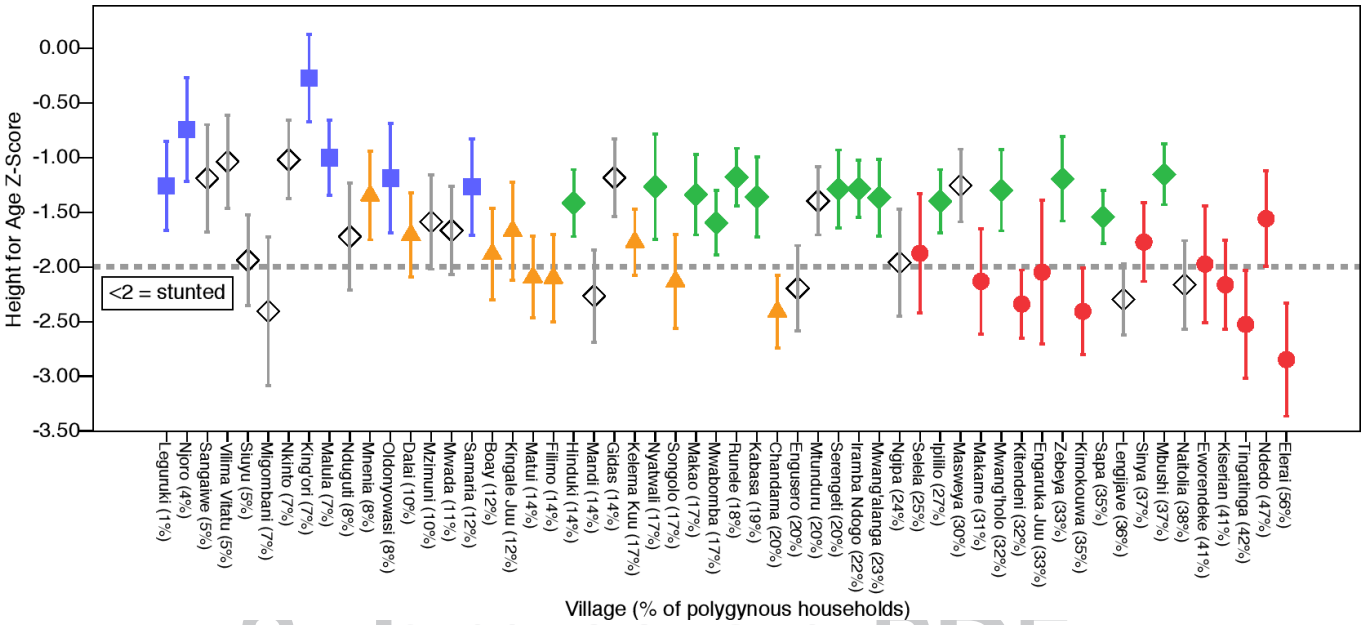

Fig. 1. – Child Height-for-age by Village Sorted by Polygyny Prevalence There is strong ethnic and village-level variation in child health. Relatively monogamous Meru villages tend to have relatively good child health, while relatively polygynous Maasai villages tend to have relatively poor child health. Dashed line represents the WHO cut-off for chronic malnutrition. Ethnicity is coded as the majority ethnic group residing in each village (**Table S1**), error bars represent 95% confidence intervals. Key: red circle: Maasai; green diamond: Sukuma; orange triangle: Rangi; blue square: Meru; white diamond: other ethnicity.

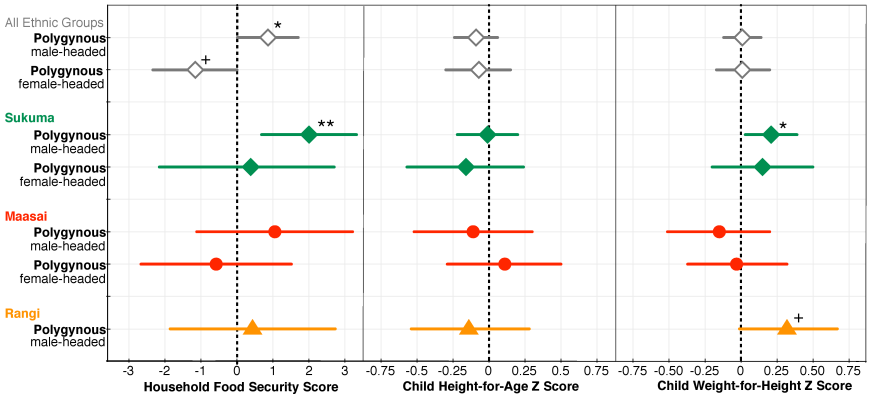

Fig. 2. – Food Security and Child Health by Household Type *Within villages* polygyny is associated with relatively high food security when households are headed by a male and relatively low food security when headed by a female (typically later wife households). Stratified analysis confirms higher food security in the Sukuma, and relatively improved child weight-for-height in both the Sukuma and Rangi, for male-headed polygynous households. The reference category (dashed line) is male-headed monogamous households (**Table S7** for full model output). + p<0.1 * p<0.05, ** p<0.01, *** p<0.001

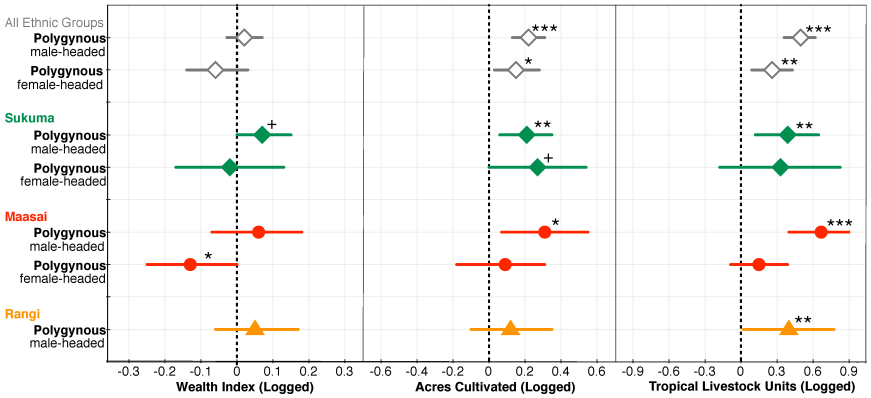

Fig. 3. – Wealth Index, Land Cultivated and Livestock Owned by Household Type *Within villages* polygynous households, particularly when headed by males, cultivate more land and own more livestock than monogamous households. The reference category (dashed line) is male-headed monogamous households (**Table S10** for full model output).+ p<0.1 * p<0.05, ** p<0.01, *** p<0.001

of the polygyny threshold model (12, 19), these findings have often been interpreted as evidence of sexual conflict, with polygyny placing women and their children in suboptimal situations relative to men (25). Drawing firm generalizable conclusions regarding the costs of polygyny to women and their children from the anthropological literature alone is difficult (25, 26). Findings are mixed, specific study sites are rarely representative of wider regions and nations, and, sample sizes often so small as to raise issues of statistical power (**SI for further discussion**). In this light, the consistency of findings presented in recent large-

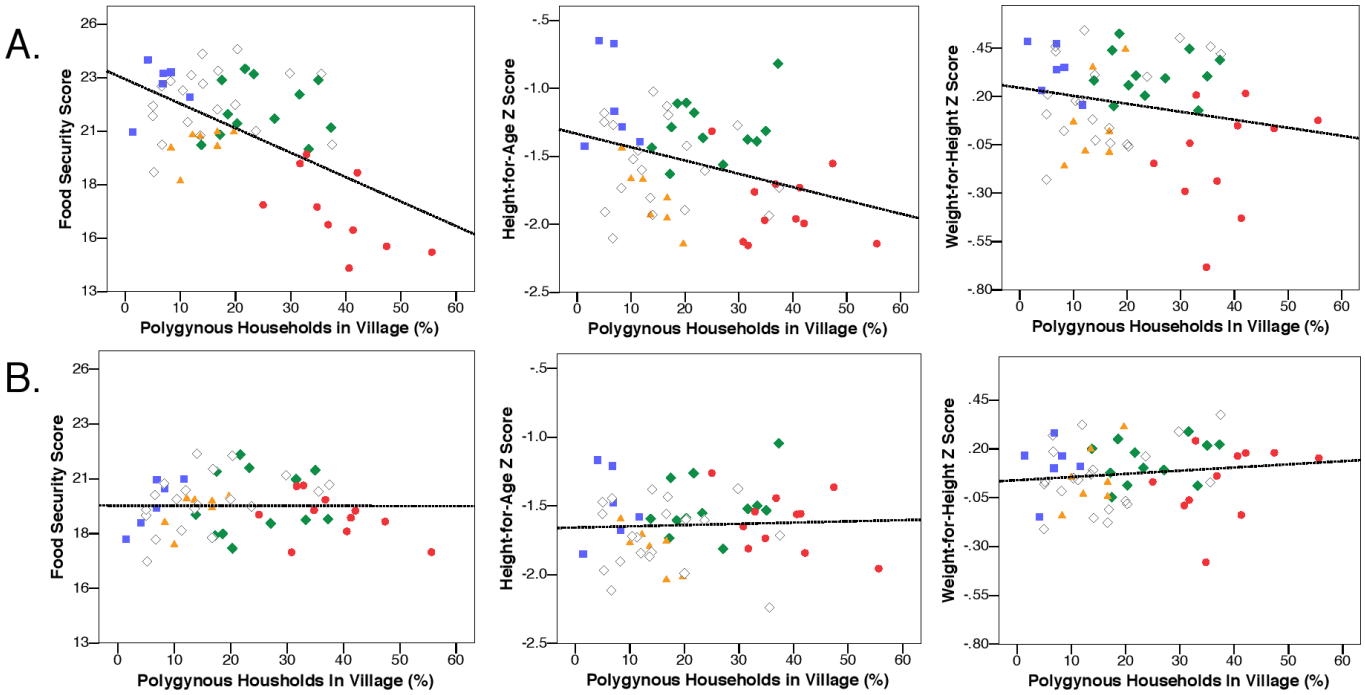

Fig. 4. –Food Security and Child Health by Polygyny Prevalence Predicted village intercepts before (A) and after (B) adjustment for village-level differences in ecological vulnerability (annual rainfall) and socioeconomic marginalisation (distance to district capital and proportion of household head's with non-zero education). After adjustment, polygyny prevalence is unrelated to food security and HAZ and positively predicts WHZ. Intercepts are mean/mode centred for household characteristics. See text for estimated coefficients and **Table S12** for corresponding model output. Key: red circle: Maasai village; green diamond: Sukuma village; orange triangle: Rangi village; blue square: Meru village; white diamond: other ethnicity village.

scale, representatively sampled demographic studies of polygyny and child health is seductive (4–8). As we will argue however, studies relying on highly aggregated data bring their own, often overlooked, methodological problems (27), problems that are particularly acute when contrasting polygynous and monogamous households, in part because the tendency of the former to be most common in remote and/or marginalized groups facing numerous socioecological barriers to health.

Not only policy, but also grand theory is built on the common view that polygyny is harmful to women and children. More specifically, it has been argued that cultural shifts to 'socially-imposed monogamy' in modern stratified societies can be accounted for by detrimental effects of normative polygyny at the group-level, including costs to child health (28, 29). Most recently, Henrich et al. (28) assert that transitions to monogamy evolve by cultural group selection, with normative polygyny (i) incentivising strategies of reduced paternal investment, so that male effort is diverted into accumulating wives rather than raising offspring, and (ii) increasing the propensity for social unrest driven by a larger pool of unmarried men. To support the specific claim that polygyny has negative group-wide consequences for children, Henrich et al. (28) rely on both the national comparative data discussed above, as well as on selected population-specific contrasts where children of polygynous women experience poorer well-being than children of monogamous women. Consistent with the claim of greater social unrest in polygynous, the authors review evidence that the proportion of unmarried men positively predicts national rates of rape, murder, assault, theft and fraud. However, such crude comparisons have limited inferential value in the face of many potential confounding factors. A recent review reveals no clear association between adult sex ratio, a likely correlate of the proportion of unmarried men, and violent crime (30).

Given the significance of the purported harmful effects of polygyny for both policy development and our understanding of human variation in marriage systems, we conducted a novel study addressing both individual and group-level relationships between polygyny, food security and child health. Our study draws on multi-level data from an ethnically diverse sample of 56 villages in northern Tanzania (**Figure S1**). Polygyny is widespread in Tanzania, particularly in rural areas, where an estimated quarter of currently married women have at least one co-wife (31). The status of women is poor; internationally Tanzania scores 124/152 on the Gender Inequality Index (32). The nation also has a high burden of child malnutrition; 45% of children are physically stunted (32). In many respects, our data combine the relative strengths of prior large-scale demographic and small-scale anthropological studies. Our sample is large (n=3584), including more households than the Tanzanian DHS for the same regions (33; **Table S1**). Yet unlike the DHS, we collected data on ethnicity and livelihood-specific measures of household wealth (i.e. land cultivated and livestock owned), and crucially sufficient village-level data to enable a statistically robust consideration of within and between-village variation (**SI**). Four main ethnic groups reside in the area, including the highly polygynous Maasai and Sukuma, moderately polygynous and predominantly Muslim Rangi and the predominantly monogamous and Protestant Meru (33). This provides a unique opportunity to consider relationships between polygyny and health in a context of varied and transitioning marital norms.

Results

Contrasting monogamous and polygynous households

We first estimate relationships between polygyny, food security and child health using linear regression aggregating data across all villages. This method is analytically equivalent to DHS studies, which routinely ignore both ethnic variation and village-level spatial clustering of health (**SI**). Consistent with such studies, polygynous households have lower food security than monogamous households (B=-1.56, 95% confidence intervals (95%CI)=-2.31;-0.81, p<0.001) and lower child height-for-age (HAZ, B=-0.21, 95%CI=-0.34;-0.08, p<0.01). Child weight-for-

height (WHZ) did not differ between polygynous and monogamous households (B=-0.05, 95%CI=-0.16;0.05, p>0.1). However, individual scores are strongly clustered by village, with a clear tendency for relatively polygynous villages and ethnic groups to have relatively poor child health (**Figure 1**). This same pattern of clustering is also true for differences in household food insecurity (33). Accounting for this village-level variance using multilevel regression demonstrates that neither food security nor child health are significantly associated with polygyny when contrasted *within villages* (Food security: B=0.26, 95%CI=-0.47;0.98, p>0.01; HAZ: B=-0.07, 95%CI=-0.20;0.06, p>0.01; WHZ: B=0.00, 95%CI=-0.12;0.11, p>0.01 **Table S5**). As such multilevel analysis reveals a 'Simpson's paradox' (27) i.e. village-level differences obscure underlying relationships between polygyny, food security and child health within villages.

Polygynous men generally resided with their first wife (**SI**); with only 10% co-residing with multiple wives (most commonly in the Sukuma where 17% of polygynous men where coresident with multiple spouses). Second or later co-wives and their children typically lived in separate, but often adjacent, dwellings to their husbands. Distinguishing between these household types reveals that male-headed polygynous households have significantly higher food security than monogamous households within villages (B=0.86, 95%CI=0.01;1.70; p<0.05). Stratified analysis confirms a trend towards higher food security for male-headed polygynous households is present in all three ethnic groups with a substantial prevalence of polygyny (**Figure 2**), although only statistically significant in the Sukuma (B =2.00 95%CI=0.68;3.32, p<0.01). Furthermore, in both the Sukuma and Rangi, children in male-headed polygynous households also had higher WHZ (Sukuma: B=0.21 95%CI=0.03;0.39, p<0.05, Rangi: B= 0.32 95%CI=-0.01 – 0.67, p=0.06). Overall female-headed polygynous households had lower food security than monogamous households within the same village (B=-1.16, 95%CI=-2.34;0.01, p=0.05), although this pattern did not approach statistical significance in stratified analyses (**Figure 2, Table S6-7**).

Polygyny and wealth

Wealth was measured by an asset-based household wealth index (**SI**), a generic measure favoured by large-scale national surveys since it can be employed across rural and urban contexts and subsistence types (34). This measure indicates minimal differences in wealth between monogamous and polygynous households. However, livelihood-specific measures of wealth reveal that polygynous households, particularly when male-headed, both cultivate more land (B=0.22, 95%CI=-0.14;0.31, p<0.001) and own more livestock (B=0.49, 95%CI=-0.36;0.62, p<0.001) than monogamous households (**Figure 3**). These differences are apparent in all major ethnic groups in stratified analyses and are robust to statistical adjustment for the number of adults and young dependents in the household (**Table S8-S11**). Thus, consistent with the polygyny threshold model, higher wealth presents a strong candidate mechanism for improved food security and child nutrition in male-headed polygynous households.

Contrasting monogamous and polygynous villages

Independently of individual marital status, each 10% increase in the proportion of polygynous households sampled per village is associated with an estimated -1.52 unit decrease in food security (B=-1.52, 95%CI=-2.09;-0.95, p<0.001), a -0.15 reduction in child HAZ (B=-0.15, 95%CI=-0.25;-0.05, p<0.001) and a -0.07 reduction in child WHZ (B=-0.07, 95%CI=-0.15;0.01, p<0.1). However, once we adjust analyses for village-level proxies for ecological vulnerability (annual village rainfall) and socioeconomic marginalisation (distance to district capital and the proportion of household heads with non-zero education) these associations dramatically attenuate and become statistically non-significant in the case of food security and child HAZ, while the proportion of polygynous households in a village becomes positively associated with child WHZ (B=0.08, 95%CI=-0.01;0.18, p<0.1) (**Figure 4, Table S12**). As such our analyses do not support the idea that polygyny has negative group-level consequences on wellbeing.

Discussion

We challenge the widespread notion that polygyny is harmful to children. Consistent with prior studies (4–8) polygyny is indeed predictive of relatively low food security and poor child health in aggregated data. However, such associations are driven entirely by the tendency of polygyny to be more common in marginalised and ecologically vulnerable villages and ethnic groups. Within villages, polygynous households, at least those headed by males, often had higher food security and better child outcomes than monogamous households. Polygynous households were also wealthier in terms of livelihood-specific forms of wealth (land and livestock), though not in asset ownership, the foundation of wealth indices favoured by national demographic surveys (34). These findings are consistent with classic evolutionary and economic models that suggest that sharing a husband may be in a women's strategic interest when it enables access to equal or greater wealth than could be achieved via monogamy (17, 18). They also highlight the inherent weaknesses of highly aggregated samples such as the DHS, the primary data source for population health scientists studying family structure and child health outcomes in sub-Saharan Africa (35).

That polygyny is associated with better outcomes for specifically male-headed households, indicates that cowives resident with their husband are most likely to benefit from polygyny. Female-headed polygynous households on the other hand may be more likely to loose cowife conflicts over shared resources in times of scarcity. We found that female-headed polygynous households had lower food security than monogamous households when considering the sample as a whole, although child health did not differ (**Figure 2**). In this context, first wives are most often coresident with their husband. Advantages to first wives in terms of child health outcomes have been shown in other populations (13, 24, but see 22). For example, Gibson and Mace (13) found among rural Ethiopian families, first wives were in better physical health and had more surviving offspring than monogamous women, and that relatively poor child nutritional status was only associated with polygyny for second or later co-wives. This may reflect selection effects, i.e. that women of relatively good health and social standing are more likely to enter polygynous marriages as first wives than later wives, such that differences in child outcomes, or indeed food security, cannot be seen as consequences of polygyny itself (13, 16). Alternatively first wives may benefit from exclusivity prior to sharing their husband with other women, and subsequent seniority over later wives. Thus, to the extent which deficits in child health or food security are unequally portioned among wives, we note that polygyny may, in some instances, be considered harmful.

We also demonstrate ethnic variation in the relationship between polygyny and health. Mixed findings from prior small-scale studies suggest such variation, but comparing results across studies is hampered by differences in sampling and statistical methodology (25). Specifically, we detect an advantage of being raised in male-headed polygynous households for the Sukuma (the largest ethnic group in Tanzania) and the Rangi, but not for the Maasai. At least two factors may account for these differences – the low status of Maasai women and the relative poverty of this ethnic group. Previous studies have emphasized low female status in the Maasai (36), restricting women's control over their own marital arrangements (including divorce and the addition of cowives), and/or preventing women from effectively investing household resources into child health (37). The Maasai also suffered the greatest burden of low food security and poor child health in our study (33). Borgerhoff Mulder (38, 39) found that polygyny

was negatively associated with child survival *only* in the poorest households in Kenyan Kipsigis. While, Strassmann (22) observed negative associations between polygyny and child health in the Dogon of Mali in all but one "exceptionally large and wealthy village" (p.10897). Thus, it might be that polygyny fails to provide better circumstances in conditions of relative resource scarcity where children are most vulnerable, and that this accounts for the differences between the Maasai and neighbouring ethnic groups.

Our analyses do not support the assertion that polygyny has group-wide costs on child health (28). Instead, it seems parsimonious that highly polygynous, predominantly Maasai, villages do poorly not because of polygyny, but because of vulnerability to drought, low service provision and broader socio-political disadvantages. Highly monogamous, predominantly Meru, villages on the other hand occupy the relatively high rainfall, fertile slopes of mount Meru in close proximity to Arusha city, benefiting from improved health care and education infrastructure (33). It remains possible that polygyny has negative group-level consequences on unmeasured aspects of well-being. However, we are sceptical of the theoretical foundation of such arguments. In particular, recent reformulations of sexual selection theory emphasize facultative responses to partner availability, predicting that the more common sex will cater to the preferences of the rarer sex in order to acquire and retain a mate. As such when polygyny leads unmarried women to be in relatively short supply we might expect higher not lower levels of paternal investment (30, 40). Consistent with this perspective, our fully adjusted analyses found that child WHZ was marginally higher in the most polygynous villages (**Table S12**).

If monogamy does not bestow group benefits, what accounts for widespread transitions to socially-imposed monogamy with economic development? In the Tanzanian context, the spread of both Islam and Christianity have clearly influenced marital norms. A long history of missionary influence may be partially responsible for the current ubiquity of monogamy among the Meru (41). However, explanations based solely on religion are unsatisfactory since religious prescriptions and marriage patterns ultimately coevolve, constrained by some extent by systems of production (42). Fortunato and Archetti (43) propose that monogamy evolves via the maximization of individual, not group benefits, and is best understood as an inheritance strategy favoured in contexts where intergenerational resource transfers are highly divisible and critical to descendent success. Monogamy may thus be beneficial to both men and women when returns to investment favour parental strategies focused on offspring 'quality' over quantity. In line with this account, the Meru were early adopters of relatively intensified agriculture (41). In our sample they also have the highest levels of educational attainment (33), which is associated with demographic transitions to 'modern' low fertility rates. Once individuals opt for smaller family sizes, a pattern best understood as motivated by economic rather than reproductive success (44), the reproductive advantages of polygyny for men become irrelevant.

While we make important methodological advancements, our study shares a number of limitations with prior studies of polygyny and health. In particular our use of the standard household concept [Materials and Methods] cleaves polygynous families into distinct survey units. This prevents contrasts of children of first and later wives sharing the same husband. Cross-sectional data also prevents a direct consideration of the impact of additional wives on previously monogamous women and their children. A recent retrospective study among the Tsimane of Bolivia, reports that, while polygynous women overall had lower fertility than monogamous women, the addition of a second wife did not impact on the fertility of the first wife in intra-individual analyses (16) This suggests that self-selection rather than polygyny itself may be responsible for reported negative effects of polygyny in some cross-sectional studies (see also 13). We also caution that relatively small number of female-headed polygynous households (at least for the Sukuma and Rangi (Table S2)) in our study may have resulted from disagreement between village registers used as the sampling frame and the household definition used by enumerators on the ground. If unsampled households systematically differ from sampled households this may bias our estimates. We emphasize that the common use of rigid household definitions is coming under increasing criticism for their potential to obscure the measurement of demographic phenomena and the estimation of wealth (which may be shared between households). In this light we strongly support Randall et al.'s (45) call for population scientists to experiment with alternative, culturally sensitive survey methodologies that more accurately cater to the reality of African family structure.

Our study concerns food insecurity and child health and cannot tell us about the wider potential of polygyny to cause harm. Other aspects of physical and mental wellbeing, including sexual transmitted infections (STIs) have also been proposed to be influenced by polygyny (46). Recent studies counter simple intuition. For example, polygyny is associated with *lower* HIV prevalence at both the national and sub-national regional level across Africa. Reniers and colleagues (47) suggest while polygyny may increase individual exposure to STIs, a selective recruitment of HIV-positive women into polygynous marriages where coital frequency is lower acts to isolate transmission risks to the wider population. Whatever the outcome, we do not anticipate universal relationships between polygyny and wellbeing. We have demonstrated variation in the estimated consequences of polygyny both between women (by co-residence with husband) and between ethnic groups. Moreover, the vital insight of both economic and anthropological theory is that cultural diversity in marriage practices stems in large part from context-dependency in the pay-offs to alternative behavioural strategies (48).

We particularly advocate that policy makers take greater care to distinguish low female autonomy from polygyny rather than treat the later as a definitive indicator of the former. Where women have control over their marital placements we do not anticipate costs to polygyny. Indeed, if there are large differences in male wealth, prohibiting polygyny may be more likely to be disadvantageous to women by restricting marital options. Levirate marriages or 'widow inheritance', whereby a women marries the brother or close male relative of her deceased spouse as a polygynous bride is also likely to offer women and their children substantially better prospects than living as a single widow in many contexts (49). On the other hand when female autonomy is low, and/or when polygyny is not clearly associated with differences in male wealth, marital placements may logically be prone to negative impacts of male coercion. We also recommend future research prioritises the collection and analysis of data at the level of social groups (villages, neighbourhoods). Institutions for marriage and child-raising are rapidly changing across the globe, and are their gendered impacts are increasingly taking centre stage in discussions of international development (1). Policy analysts concerned with the consequences of these transformations need to consider appropriate comparison groups, selection effects and broader community confounds. Only by making meaningful contrasts, which capture alternatives readily available to individuals, and by fully taking into account the distribution of specific practices across different communities and ecologies, can we expect to achieve a true understanding of the public health implications of cultural practices.

Materials and Methods

Study Site and Sampling

56 villages were sampled between 2009 and 2011 as part of the Whole Village Project (WVP). The WVP is coordinated by the non-governmental organisation 'Savannas Forever Tanzania' in collaboration with the University of Minnesota (UM) and the Tanzanian National Institute of Medical Research

(NIMR). The WVP received ethical approval from the UM Institutional Review Board (code: 0905S65241) and NIMR. Village sampling was based partly on the priorities of development agency partners and government permission, although effort was made to randomize sampling where possible and to ensure a wide geographic spread (Figure S1). In each village, between 60-75 households were randomly selected, leading to a sample of 3584 households. Four ethnicities, the Maasai, Sukuma, Rangi and Meru, make up 60% of the households and 65% of the households contributing child health data. The Maasai are traditionally semi-nomadic pastoralists, but have recently diversified into cultivation and permanent settlement. The Sukuma, Rangi and Meru are all characterised as agro-pastoralists. Rangi and Meru almost exclusively identified as Muslims and Protestant respectively, while the Sukuma and Maasai identified with either Christian or indigenous religions (33). Anthropometric measurements were taken for all resident children under five years. 2268 households contributed child data, just under half of which provided data on more than one child (2 children 35%; 3+ children 10%). Our current analysis is limited to households with a married head of at least 16 years, bringing our working sample to 1764 housheolds, containing 2833 children (averaging 32 households and 51 children per village).

Child, Household and Village Data

We use two indicators of child nutritional status based on World Health Organisation growth standards (50). HAZ is indicative of chronic malnourishment, while WHZ is indicative of acute malnourishment, from inadequate food intake or illness. Relatedness data was available for 75% of children [villages 15-56]: 80% were biological children of the household head, 14% grandchildren and 6% other relatives. Household head marital status is used to contrast monogamous and polygynous family settings. Heads were identified as the person responsible for the upkeep of the household, and household membership defined on the basis of *de jure* residence. Households were defined as "*a group of persons who live together in the same house or compound, share the same house-keeping arrangments, and eat together as one unit*". This method, consistent with the majority of past studies of polygyny and child health, cleaves polygynous families into distinct survey units. A wealth index was calculated using principle component analysis applied to data on the ownership of 37 individual assets (33), not including the size of farmland or livestock ownership. Acres cultivated and tropical livestock units were recorded separately (SI). All wealth measures were transformed (Log x +1) to approximate normal distributions for analysis. The Household Food Insecurity Access Scale assesses food insecurity during the last month, leading to a continuous 27 point outcome variable (51). We reversed this measure for analysis so that a higher score indicates greater food security. Village mapping was used to compute distance to district capital (as a measure of remoteness), and estimated annual rainfall (33).

Statistical Analysis

All regressions were fit using maximum likelihood estimation and include controls for child age and sex, age of household head and whether or not the village was sampled during a hunger season. Multilevel models include a random intercept for village, but not household because when clusters (i.e. households) are unbalanced and sparsely populated (i.e. ≤2 cases per level) both fixed and random effects may be overestimated (52). Full model output is presented in **Tables S5-12**.

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