Social support, nutrition, and health among women in rural Bangladesh: complex tradeoffs in allocare, kin proximity, and support network size

Mary K. Shenk[1], Anne Morse[1], Siobhán M. Mattison[2,3], Rebecca Sear[4], Nurul Alam[5], Rubhana Raqib[5], Anjan Kumar[5], Farjana Haque[5], Tami Blumenfield[2,6], John Shaver[7], Richard Sosis[8], and Katherine Wander[9]

[1] Pennsylvania State University, [2] University of New Mexico, [3] U.S. National Science Foundation, [4] London School of Hygiene and Tropical Medicine, [5] the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), [6] Yunnan University, [7] University of Otago, [8] University of Connecticut, [9] Binghamton University (SUNY)

ABSTRACT

Malnutrition among women of reproductive age is a significant public health concern in low- and middle-income countries. Undernutrition from underweight and iron deficiency, and overweight and obesity, all which have different negative health consequences for mothers and children, are of particular concern. Accumulating evidence suggests that risk for poor nutritional outcomes may be mitigated by social support, yet how social support is measured varies tremendously and its effects likely vary by age, kinship, and reproductive status. We examine the effects of different measures of social support on weight and iron nutrition among 677 randomly-sampled women from rural Bangladesh. While we find that total support network size mitigates risk for underweight, other results point to a potential trade-off in the effects of kin proximity, with nearby adult children associated with both lower risk for underweight and obesity and higher risk for iron deficiency and anemia. Social support from kin may then enhance energy balance but not diet quality. Results also suggest that a woman's network of caregivers might reflect their greater need for help, as those who received more help with childcare and housework had worse iron nutrition. Overall, although some findings support the hypothesis that social support can be protective, others emphasize that social relationships often have neutral or negative effects, illustrating the kinds of tradeoffs expected from an evolutionary perspective. The complexities of these effects deserve attention in future work, particularly within public health where what is defined as "social support" is often assumed to be positive.

INTRODUCTION

Undernutrition among women of reproductive age is a leading public health concern in many low- and middle-income countries (LMIC), particularly undernutrition from underweight (BMI<18.5) and iron deficiency anemia[1], both of which increase the risk that infants will be born preterm and small for gestational age (Alten 2000, Figueiredo et al. 2018, Han et al. 2011, Rahman et al. 2015). Iron deficiency anemia during pregnancy also increases risk for perinatal death of both the mother and infant (Daru et al. 2018, Marchant et al. 2004, Rahman et al. 2016). Undernutrition in adult caregivers, such as mothers, grandmothers, and others who care for children, may also adversely affect responsiveness to infants (Milman 2011) and work capacity (Haas and Brownlie 2001). Iron nutrition, including both anemia and iron deficiency, may also serve as markers of general health, as both are affected by inflammation as well as diets, and thus tend to occur in the presence of chronic or infectious disease (Weiss and Goodnough 2005).

Under conditions of market integration (increasing economic development and local integration with the market economy; following Lu (2007)) in LMIC, risk for undernutrition may co-exist with rising rates of overweight and obesity, leading to increased risks for chronic disease outcomes including type 2 diabetes (T2D) and cardiovascular disease (CVD) (Min et al. 2018). Obesity and T2D entail several risks for mothers, including gestational diabetes, pre-eclampsia, preterm birth, stillbirth, complications during labor and delivery, postpartum hemorrhage, and birth defects (Mahomed et al. 1998, Mandal et al. 2011, Poston et al. 2016, Ramachenderen et al. 2008, Siega-Riz and Laraia 2006, Waller et al. 2007). Obesity and chronic diseases may pose even greater risks to older caregivers, especially grandmothers, whose health may be compromised at a time of life when the need for care for young relatives is high.

Thus, in the context of rapid market integration, women of reproductive and post-reproductive age face dual threats to their health from undernutrition and overweight/obesity. It is critical to evaluate factors that may buffer women against these multiple facets of nutritional stress. Social support, which has been shown in many contexts to benefit both general health (e.g. Cohen 2004, and Christakis 2008) and maternal health, may be one such factor.

Social support likely buffers women against nutritional shortfalls (e.g. Jaeggi and Gurven 2013, Gurven et al. 2000). This could arise via direct sharing of food to increase food security, or via indirect investments in activities such as childcare that contribute to positive energy balance in mothers (e.g. Gibson and Mace 2005, Meehan et al. 2013, Page et al this issue; Vázquez-Vázquez et al this issue). Social support may also lower psychosocial stress (Gettler et al. this issue), which has been shown to be

[1] *Iron deficiency* refers to inadequate dietary iron to meet the body's iron needs, which include cellular metabolism and erythropoiesis (red blood cell production). *Anemia* refers to oxygen delivery to tissues due to low hemoglobin; anemia can result from dietary iron deficiency and/or other factors. Iron deficiency that is not severe enough to cause anemia is considered mild-to-moderate, and is understudied compared to iron deficiency anemia (WHO 2011, 2014).

an important risk factor for obesity across multiple settings (Siervo et al. 2009, Scott et al. 2012). However, there is limited empirical investigation of the impact of social support on undernutrition or obesity in LMIC. Here, we investigate whether several measures of social support protect reproductive and post-reproductive aged women against underweight, overweight, obesity, and iron deficiency anemia in rural Bangladesh.

How social support is characterized varies tremendously in the literature. Measures that elucidate actual sources of support, such as nearby kin or social network members, have benefits over measures that rely on ratings of, for example, community engagement or trust, since they are less likely to reflect differences in perception. However, the assumption that kin and other network members are a *de facto* source of social support (e.g., proximity of kin as a proxy for kin support) is inconsistent with evolutionary perspectives which highlight the cooperative and conflictual nature of social networks particularly among those in close residential proximity (e.g. Borgerhoff Mulder 2007, Page et al. 2017, Shenk 2005, Scelza 2011). Because kin often share resources, larger groups of locally resident kin may increase competition for family resources (Sear this issue). If there are more people to feed, for instance, some may need to go without or sacrifice diet quality. Resource competition may also result over money to pay school fees or medical bills if expenses are higher than the number of earners can easily contribute (e.g. Hedges et al. 2019). Or, more generally, a central position in social networks may come with both benefits and costs across different domains (Page et al. 2017). It is thus important to differentiate the effects of proximity from the direct effects of parenting or allocare [2] (e.g. Scelza 2011). Age is also an important consideration: Younger kin may be particularly demanding of attention and resources (Weisner 2015), and thus, more likely to compete for resources compared to adult kin, including adult children, who can act as sources of support and resource competition. Consequently, we considered the impacts of young and adult kin separately.

The majority of research on social support and maternal health has focused on women of reproductive age, but there are good reasons to also consider the effects of social support on the health of post-reproductive aged women. Cross-culturally, a significant amount of allocare is done by post-reproductive women (e.g. Sear & Mace 2008, Coall & Hertwig 2010), including but not limited to grandmothers, whose allocare efforts likely affect child health (e.g. Leonetti et al. 2007, Aubel 2012) and whose own health is likely impacted by their investment in allocare. Older women may sacrifice their own nutrition to preserve food for younger relatives, and custodial childcare by grandparents and older

[2] Caretaking of children by people other than their parents.

adults has been found to increase their mortality risk (Bachman and Chase-Lansdale 2005, Chen and Liu 2012). However, other research—mostly in high income contexts—has found that there may be health benefits to allocare, including enhanced cognitive functioning (Arpino and Bordone 2014), improved psychosocial and overall health (Grundy et al. 2012; Chen and Liu 2012), reduced stress (Poulin et al. 2013), and lower mortality (Hilbrand et al. 2017, Poulin et al. 2013). Interestingly, some authors find that providing allocare has beneficial effects while receiving help does not (e.g. Brown et al. 2003 found this effect for longevity). Such health benefits may come via social support or through the act of helping itself. We thus included in our analysis women of both reproductive and post-reproductive age, and evaluate multiple measures of social support—including giving and receiving assistance in childcare—as predictors of malnutrition outcomes.

Based on the existing literature, we predict that social support will be broadly related to improvements in maternal nutrition, however different types of measures of 'support' may highlight different effects, and women of reproductive and post-reproductive age may experience different outcomes relevant to either age or kin dynamics.

SAMPLE AND METHODS

Study Population

Matlab, Bangladesh, is a rural area located around 60 km from the capital city Dhaka, though accessing the region can be challenging due to flooding and difficult road conditions. Women in the area are primarily housewives (94.2% of women interviewed in 2018), whose major work entails cooking, housework, and childcare; housewives may also engage in subsistence tasks including harvesting or processing of agricultural products, caring for chickens or ducks, or making handicrafts, though these tasks vary greatly across women

Families live in close proximity to each other in residential complexes called *bari*s which often include families related patrilocally but may also include unrelated individuals. Patrilocal postmarital residence norms mean that young women are much more likely to live close to their in-laws than their natal kin, but as they age and their children mature, they become increasingly socially integrated with, as well as related to, the other members of their residential area (Koster et al. 2019). Related households are often economically inter-reliant; loans of money and sharing of useful objects are common, and land is often jointly owned by men in the same family until the death of the father, at which point the land may be divided. Interactions are generally cooperative but may also be competitive, especially in context of poverty or resource stress (e.g. Shenk et al. 2016).

It is common for women to live with or near their in-laws and other relatives, and for paternal grandmothers and aunts to take on significant roles in childcare. Maternal grandmothers and aunts may also help with childcare, especially if they live nearby, and neighboring women frequently engage in reciprocal childcare regardless of whether they are related. While women generally feed and bathe and perform intensive care tasks primarily for their own children or the children of close relatives, women often share in the duties of watching children with older children and other women in the *bari*. Women in rural Bangladesh have only entered the labor market in small numbers, so most women stay home with their children. Women with higher SES may be able to pay others to help with children, or to trade with their neighbors for needed help.

Less market-integrated women often have a more traditional, healthier whole food diet but may face risks of undernutrition due to low calorie intake or a lack of high-quality, iron-rich foods. In contrast, more market-integrated women may have access to higher-quality, iron rich foods but are more likely to have higher caloric intake and also likely to eat larger quantities of processed foods with added sugars (Popkin and Gordon-Larsen 2004, Khan and Talukder 2013).

Anemia is common among women of reproductive age in Matlab and other rural areas of Bangladesh (El Arifeen et al. 2018, Hyder et al. 2004, Kamruzzaman et al. 2015). Although less frequently investigated, high rates of iron deficiency have also been observed among pregnant and non-pregnant women of reproductive age, particularly in areas with low ground water iron content (Ahmed et al. 2018). Underweight is common among women of reproductive age in Matlab (El Arifeen et al. 2018, Ferdous et al. 2012), as, increasingly, are overweight and obesity, although more so in urban than rural settings (Alam et al. 2016, Razzaque et al. 2016).

Sample and Data

Data were collected in rural Matlab, Bangladesh, by Shenk in collaboration with Alam and the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) in 2017-2018. Icddr,b has run a large Health and Demographic Surveillance System (HDSS) site in Matlab since the late 1960s documenting demographic events (births, deaths, marriages, migrations) on an ongoing basis and collecting periodic socioeconomic survey data for a current population of ~200,000 people.

Subsample survey data focused on fertility, fertility transition, and marriage were first collected in 2010 by Shenk and Alam from an age-stratified random sample of 944 female HDSS participants aged 20-64. A second wave of data were collected from the same women in 2017-2018 focusing on market integration, wealth, social networks, and health. 765 of the original 944 women were re-interviewed in the second wave. Attrition was primarily due to families moving out of the area (N=154), with a limited number of cases attributable to death (N=4), disability (N=14), refusal (N=4, typically due to illness or pressing obligations), or prolonged travel outside of Matlab (N=3). Data in this paper are exclusively from the women followed up in 2018.

Specimen collection and laboratory analyses

Capillary whole blood was collected via finger stick using a sterile lancet. Using a point-of-care hemoglobinometer (HemoCue 201+), hemoglobin concentration (gram per deciliter, g/dl) was estimated in a single drop of whole blood. Up to five additional drops of whole blood were allowed to fall freely onto Whatman #903 filter paper cards for dried blood spot (DBS) specimens. DBS were allowed to dry for up to 24h and were then transferred to freezer storage (-20C) until analysis.

We selected soluble transferrin receptor (TfR) as a biomarker of iron deficiency because it is robust to inflammation and has been validated for measurement in DBS (McDade and Shell-Duncan 2002). In populations with a high infectious disease burden, biomarkers of iron deficiency that have a physiological role in iron sequestration and inflammation, such as ferritin, become difficult to interpret in a large number of participants; TfR is free of this limitation (McDade and Shell-Duncan 2002; Wander et al 2009). TfR was estimated using an enzyme immunoassay (Ramco Laboratories), adapted for use with DBS (McDade and Shell-Duncan, 2002). One 3.2 mm disc of DBS specimen, equivalent to 1.5 µl serum, was removed with a hole punch and eluted in assay buffer overnight. Eluent was assayed without further dilution. For the 35 plates of sTfR evaluated for this project, the intra-assay CV was 3.48%, and the inter-assay coefficient of variation (CV) was 14.8% at low concentration and 9.5% at high concentration.

Anthropometry

Height was measured with a stadiometer (Seca 213) and weight with a digital scale (Tanita BC-545) validated for similar work (Wang and Hui 2015). BMI was calculated as weight (kg)/height $(m)^2$.

Dependent variables

We used BMI to classify women as underweight (BMI < 18.5), lean (18.5 ≤ BMI < 25), overweight (25 ≤ BMI < 30), and obese (BMI ≥ 30) (WHO 2000).

There is currently a lack of consensus around precise TfR cutpoints for identification of iron deficiency (WHO 2014). In light of this, we considered two definitions of iron deficiency: TfR ≥ 8.3 mg/l (suggested by the assay manufacturer) and TfR > 5.0 mg/l (validated in DBS against the gold standard of zinc protoporphyrin:heme; Wander et al 2009). Anemia was defined as hemoglobin < 12 g/dl (WHO 2011). We classified women as *iron replete* if they were neither iron deficient nor anemic, having *mild-to-moderate iron deficiency* if they were iron deficient but not anemic, having *iron deficiency anemia* (sometimes also referred to as *severe iron deficiency*) if they were iron deficient and anemic, and having *non-iron deficiency anemia* if they were anemic but not iron deficient.

Underweight and both iron deficiency anemia and non-iron deficiency anemia co-occur more than predicted by chance (Pearson's chi-squared = 6.3058, p = 0.012), but not dramatically so, and otherwise there are no clear associations between weight and iron status. This suggests that the two sets of measures used in this study are capturing distinct aspects of nutrition and health, though a deficient diet is likely to be deficient in multiple ways.

Independent variables

We focused on two distinct, but potentially overlapping, measures of social support: social support network members and family members living nearby. Social support network members are people with whom a person reports regular and meaningful social interaction. Nearby family members have the potential to be sources of social support yet may also compete for resources. Considering both of these measures allows us to separate the effects of proximity of kin—who may be supportive, competitive (particularly when in need), or both—from actual reported support.

The social network items were collected using the "name generator" method, which explicitly asked participants to list people who either provided the participant with assistance in various domains or whom the participant provided assistance to. We considered three variables from these items: The total number of unique social support network members nominated in response to all 12 name generator questions asked in our 2018 survey was used as a measure of participants' *total support network size*. In addition, we considered participants' social support network members named in relation to childcare and housework: "Who helps you with childcare or housework when you need it?" and "Who do you help with childcare or housework?" These provided the number of the *childcare/housework network helpers* and *help recipients*, respectively. See Supplemental Information for further details.

Nearby family members were considered as both potential sources (adult kin) and recipients (young kin) of social support. Separate survey items asked respondents about their family members, including their relationship, age, and current location. From these questions, we created the predictor variable *nearby young kin*, a count of the relatives, other than the respondent's own children, who were 1) in early childhood (age ≤ ~5 years at the time of the survey, born in the year 2012 or later), and 2) living in the respondent's household (*khana*) or neighborhood (*bari*). We also created the predictor variable *nearby adult children*, a count of the relatives who were 1) adult (age ≥ ~18 years at the time of the survey, born in 1999 or earlier), 2) the respondent's child, and 3) living in the respondent's khana or bari. Adult children were the focus here as we had clear data on their location and because their status as close kin is unambiguous, whereas cooperation with other kin may be more variable across families or contexts.

Respondent age at the time of the survey was considered as a continuous variable, but was replaced by a dichotomous variable for reproductive (age 20-49 years) and post-reproductive (age ≥ 50 years). Reproductive/post-reproductive status was considered as both a predictor and an interaction effect with other predictors of interest.

Several additional variables were considered to control for aspects of socioeconomic status (education, income, MacArthur Ladder, marital status) and exposures likely to be associated with nutritional outcomes and predictors of interest (food insecurity, smoking, betelnut use). These variables are described in detail in the Supplemental Information, where relevant results and discussion for these variables is also included.

Modeling

We used multinomial logistic regression analysis. The reference category for BMI was lean and for iron deficiency was iron replete. We estimated both relative risk ratios (RRR) and average marginal effects (AME) to describe effect sizes, as RRR or odds ratios can overstate the magnitude of an effect for outcomes that are not rare. Although we present p-values for both RRR and AME estimates, p-values for RRR were emphasized in interpreting results. All data analyses were conducted with Stata 16.

Network variables (*total support network size*, *childcare/housework network helpers, childcare/housework network help recipients*) and nearby kin variables (*nearby young kin* and *nearby adult children*) were examined with respect to each outcome variable. Interactions between reproductive/post-reproductive age and predictors of interest were assessed. We considered F statistics, deviance, and Bayesian information criterion to compare nested models and to select the SES control variables included in final models.

RESULTS

Descriptives

While a total of 765 women participated in the study, complete information on the variables of interest was available for 677 women (the final sample; Table S1A); these women were similar to the full sample (Table S1B). These women's *childcare/housework networks* included on average, 1.98 (SD = 1.17) *helpers* and 1.49 (SD = 1.09) *help recipients*. Participants *total support network size* ranged from 0-25, with an average of 8.86 (SD=3.16) individuals. Participants had, on average 0.85 (SD = 1.09) *nearby adult children* and 0.16 (SD = 0.41) *nearby young kin*.

The prevalence of underweight was 10.19%, overweight was 29.84%, and obesity was 7.24%. Anemia was identified among 48.01% of participants. The sTfR cutpoint of 8.3 mg/l identified iron deficiency among 4.73% of participants (Table S1B); this is an implausibly low rate of iron deficiency for the rate of anemia we identified (e.g. Ahmed et al. 2018, Islam et al. 2001). The sTfR cutpoint 5.0 mg/l (Wander et al. 2009) identified iron deficiency among 52.73% of participants, which better matches our understanding of women's health in this region; thus, we used the 5.0 mg/l cutpoint to identify iron deficiency in all subsequent analyses. 24.96% of participating women were iron replete, 27.03% had mild-to-moderate iron deficiency, 25.70% had iron deficiency anemia, and 22.30% had non-iron deficiency anemia.

BMI: Underweight, overweight and obesity

Total support network size was inversely associated with underweight (RRR: 0.91; 95% CI: 0.82, 1.01): each additional person in a woman's network was associated with an average marginal effect (AME) of -0.01 (95% CI: -0.02, 0.00), or a 1% lower probability of underweight (Table S2). Total support network size was positively associated with overweight (RRR: 1.05; 95% CI: 0.99, 1.12), but not obesity. Neither *childcare/housework network helpers* nor *help recipients* significantly predicted BMI. The effects of *nearby adult children* differed substantially for women of reproductive and post-reproductive age. For those of reproductive age (20-49 years), each adult child living nearby was associated with lower probability of underweight (RRR: 0.26; 95% CI: 0.07, 1.02). For women of post-reproductive age (over 50 years), the number of nearby adult children was weakly positively associated with underweight (RRR: 1.08; 95% CI: 0.82, 1.41). Figure 1A shows these divergent associations as predicted probabilities of underweight among reproductive and post-reproductive age women. Similarly, divergent effects were apparent for obesity: reproductive aged women with more nearby adult children were less likely to be obese (RRR: 0.46: 95% CI: 0.19, 1.11), while no effect was apparent for post-reproductive women (Figure 1B). *Nearby young kin* (≤~5y) were unassociated with underweight, overweight, or obesity, regardless of age category. Unmarried women (primarily widows) were not more likely to be underweight (RRR: 1.08; 95% CI: 0.56, 2.09), overweight (RRR: 1.02; 95% CI: 0.60, 1.73), or obese (RRR: 0.42; 95% CI: 0.14, 1.28) when marital status was included in the model in Table S2. See SI for effects of socioeconomic and other control variables.

Iron nutrition: iron deficiency and anemia

Iron deficiency anemia was associated with *childcare/housework network* size, and the direction of the association differed by type of help (Table S3). *Childcare/housework network helpers* were positively associated with iron deficiency anemia (RRR: 1.27; 95% CI: 1.01, 1.60), such that each additional helper was associated with a 3% increase in a woman's probability of iron deficiency anemia (Figure 2). In contrast, in the same model, *childcare/housework network help recipients* were inversely associated with iron deficiency anemia (RRR: 0.71; 95% CI: 0.60, 0.90), such that each additional help recipient was associated with a 7% decrease in a woman's probability of iron deficiency anemia. *Total support network size* was unassociated with iron deficiency.

Nearby adult children were associated with iron deficiency anemia; as above, these associations differed for women of reproductive and post-reproductive age, though in the opposite direction. Among women of reproductive age, each additional nearby adult child was associated with higher probability of iron deficiency anemia (RRR: 1.88; 95% CI: 1.09, 3.24); no association was apparent for women over age 50 years (Figure 1C). *Nearby adult children* were also positively associated with mild-to-moderate iron deficiency (RRR: 1.70; 95% CI: 1.01, 2.88) and non-iron deficiency anemia (RRR: 1.64; 95% CI: 0.92, 2.94) among women under age 50 years. *Nearby young kin* were associated with higher risk for mild-to-moderate iron deficiency (RRR: 1.54; 95% CI: 0.90, 2.67), but not iron deficiency anemia.

DISCUSSION

Whether characterized as social network members or nearby kin, our findings point to complex relationships between social support and nutrition (summarized in Table 1) that suggest the importance of tradeoffs in social relationships.

Table 1. Summary of results

	Underweight	Overweight	Obese	Mild/ moderate iron deficiency	Iron deficiency anemia	Non-iron deficiency anemia
Social support network members						
# childcare/housework network helpers					+	
# childcare/housework network help recipients					-	
total support network size	-	+				
Nearby family members						
# nearby young kin ≤ ~5 y				+		
# nearby adult children (women<50)	-		-	+	+	+
#nearby adult children (women 50+)	+					

BMI

As predicted, and as others have observed in LMIC settings (), women with larger social networks were less likely to be underweight, consistent with the hypothesis that social support protects women against undernutrition. These findings are consistent with findings from rural Tanzania that social support protects households against food insecurity (Hadley et al. 2007) and from rural western Uganda that maternal social support improves young children's diet quality (Ickes et al. 2018). Social network members may reduce women's risk for underweight by buffering them against hunger, through, for example, sharing meals or reducing workloads (and thus improving energy balance). Women with larger social networks were also marginally more likely to be overweight, though not obese, consistent with greater access to food or reduced workloads. Such benefits of cooperation are central to theories that see food sharing and cooperative childrearing as key to human evolution (e.g. Hawkes et al. 1998, Hrdy 2009, Kramer 2010, 2011, Jaeggi and Gurven 2013). Yet, we considered multiple measures that should have captured cooperative childrearing—childcare/housework network helpers and help recipients, nearby young kin (other than the respondent's own children), who could potentially represent needed allocare—and these were all unassociated with underweight or obesity. In contrast to the overall effects of total support network size, these findings suggest either that help with childcare is not that helpful, or—perhaps more ethnographically plausible—that mothers who have help with childcare are likely to invest the saved energy back into their children and thus experience no net positive outcome from help with childcare alone (Page this issue). This interpretation is especially plausible as some of our findings suggest that help with childcare may be in part need-based (see below).

By contrast, nearby adult children, who could be sources of either social support *or* kin competition, were associated with reduced risks of both underweight and obesity among women of reproductive age, suggesting a social support effect for this outcome. Nearby adult children likely protect women against underweight through kin support, including the provision of food, but potentially also help with childcare/eldercare or other work, leading to positive energy balance (Page et al. this issue). Protection against obesity may similarly be related to reduced workloads, reduction of psychosocial stress (Geiker et al. 2018), and/or food sharing (particularly of higher quality foods, such as fish or vegetables, if these replace more obesogenic, processed foods (Pagliai et al. 2021)).

For post-reproductive age women, however, we found a modest positive association between the nearby adult children and underweight, signaling the potential for kin competition over resources, consistent with effects that have been found in other land-limited agricultural or market-oriented populations in the region and elsewhere (e.g. Borgerhoff Mulder 2007, Shenk 2005). These effects could also be driven by an increased motivation for parental investment in which women forgo their own nutritional needs to ensure that their children's and grandchildren's needs are met—a practice commonly reported by our participants. In summary, our findings suggest that women's energy balance benefits from social support through both their total social networks and their nearby adult children.

Iron Nutrition

In contrast to results for BMI, iron nutrition does not show a relationship with total support network size, but it does show clear patterns related to allocare—though these were more complex than we had predicted. Receiving childcare/housework help from more social network contacts was associated with higher risk for iron deficiency anemia, while providing childcare/housework help to more contacts was associated with lower risk of iron deficiency anemia.

A health-protective effect for allocare providers has been described in other populations (e.g. Brown et al. 2003, Chen and Liu 2012, Hilbrand et al. 2017, Poulin et al. 2013). For iron deficiency anemia, a protective effect of *providing* allocare support to others could manifest through a direct pathway, such as provisioning of iron-rich foods. A further possible explanation is that women with better iron nutrition may be more willing to engage in allocare. For instance, women with iron deficiency anemia are likely to be fatigued and experience a reduced ability to work, potentially reducing their ability to provide allocare. This pattern is also in keeping with functional explanations of cooperation based on reciprocity, in which individuals with ample resources may share those additional resources with others now to ensure they receive future, more beneficial, support (Axelrod and Hamilton 1981;

Gurven 2006).

Women who received support from more social network contacts had a higher rate of iron deficiency anemia, suggesting social competition for resources which could result in a poorer diet or greater exposure to infectious disease. Reverse causation or selection effects may also be at work here, however; if a mother's need for help inspires people to help her, a pattern consistent with research on need-based sharing (e.g. Cronk et al. 2019, Smith et al. 2019) and kin selection, in which relatives gain increased fitness returns when assistance is directed at the most needy (Page et al 2019, Koster 2011, Snopkowski & Sear 2015, Hames 1987, Thomas et al 2018). In either case, our results suggest that the support women receive from their childcare/housework networks is often not enough to protect them from iron deficiency—though it is possible that their health would be worse without that help. Need-based helping of resource-stressed women could reduce energy deficits without necessarily improving micronutrient status, consistent with a lack of effect on BMI alongside increased risk of iron deficiency anemia for the same predictors.

Nearby young kin were associated with increased risk for mild-to-moderate iron deficiency, consistent with kin competition or women sacrificing the quality of their own diet to benefit young children. In contrast to the effects for underweight, however, the nearby adult children showed negative effects on participants' iron nutrition for reproductive aged women. (While post-reproductive age women had higher rates of iron deficiency anemia in both the presence and absence of nearby adult children.) Effects of kin competition on iron nutrition may be more apparent among reproductive aged women due to the iron stressors such women face through menstruation, childbirth, and the work burdens of caring for both children and elders; however, the higher risk among post-reproductive women suggest this vulnerability to iron deficiency persists throughout adulthood, and may increase with aging, as well as with chronic and infectious disease, which are more common among older women (Friedman et al. 2012, Kassebaum et al. 2014). It is only in reproductive aged women that we see a contrast in the effects of nearby adult children, who protect against underweight, but elevate risk for iron deficiency and anemia. Among older women, effects of kin proximity are generally small and unimportant, begging the question of whether this should be termed support.

Complex Trade-offs: improved BMI *and* worsening iron deficiency?

The relationship between nearby adult children differed for BMI and iron deficiency in reproductive aged women. These divergent findings may relate to the dual burden of malnutrition with rapid market integration. Adult children, particularly in populations with short generation times, will have younger children who require support while the mother is still of reproductive age (i.e. not all grandmothers are post-reproductive, Page et al. this issue). Therefore, these women may be caught in a bind between caring for younger children and helping to support adult children and their families. Such women may voluntarily share food, and especially high-quality food, with younger relatives, at the expense of their own iron intake. At the same time, food may flow to these women from their adult children, but be of lower quality, particularly in the context of rapid market integration and the high availability of calorically dense but nutrient poor foods. This is especially likely in the context of dual burden malnutrition in Bangladesh (Kamal et al. 2015) where overweight/obesity are commonly found alongside poor iron nutrition.

Finally, our results highlight contrasting effects of different types of measures of social support. Direct support with allocare, as measured by childcare/housework network helpers, was generally associated with poor nutrition, reflecting need. In contrast, childcare/housework network help recipients and total support network size were protective against poor nutrition, consistent with general expectations in the literature. Finally, nearby kin appear to demonstrate dual effects of reductions in undernutrition/obesity and increases in iron deficiency and anemia. This may be indicative of competitive effects or obligations to kin, demonstrating the complex and interdependent nature of social relationships among close kin.

Conclusions

Although some of our findings support the hypothesis that social support can protect women in rural Bangladesh against undernutrition and improve their health, others emphasize that social relationships are not always supportive, but may often have neutral or negative effects. Our results additionally suggest that the effects of social relationships are dynamic and may shift over time from reproductive to post-reproductive periods of life. Overall, our results illustrate the kinds of tradeoffs we often see when viewing human social relationships from an evolutionary perspective: the benefits of cooperation are clearly visible alongside the costs of resource limitations and competition. Our results indicate that social support, as measured by adult kin proximity, may serve to enhance energy balance but not dietary quality, indicating that social relationships have costs to reproductively aged women. Further, social support is a cooperative behavior and as a result may be dependent on both the mother's need for support, and the cost of providing support to the supporters. Such dynamics produce complex results in which support is not necessarily associated with positive nutritional outcomes.

Regardless of the mechanism involved, our results make it clear that variables chosen as proxies of “social support”, including kin proximity, are not necessarily straightforward measures of help but instead may reflect complex social interactions with both positive and negative outcomes, either exacting costs or—perhaps more likely—ameliorating what could have been even worse states of health (Emmott, Myers and Page this issue).

The complexities of these effects require careful attention in future work, particularly in the literature of public health, where “social support” is often taken in a positive light with less attention to challenging dynamics. Building social support through social networks is an appealing target for public health interventions aimed at promoting maternal health (e.g., de la Haye et al. 2019, Kim et al. 2015) among other outcomes. Our findings suggest that this may indeed be an avenue to reduce rates of some forms of malnutrition. However, our findings also suggest that social support has complex effects on women’s nutrition, potentially due to the obligations, as well as benefits, that social and kin relationships bring. Nuanced and context-specific information is thus needed to understand how interventions seeking to enhance social support are likely to impact women’s nutrition and health.

REFERENCES

Ahmed F, Khan MR, Shaheen N, Ahmed KM, Hasan A, Chowdhury IA, Chowdhury R. Anemia and iron deficiency in rural Bangladeshi pregnant women living in areas of high and low iron in groundwater. Nutrition. 2018 Jul 1;51:46-52.

Alam, Dewan S., Shamim H. Talukder, Muhammad Ashique Haider Chowdhury, Ali Tanweer Siddiquee, Shyfuddin Ahmed, Sonia Pervin, Sushmita Khan, Khaled Hasan, Tracey LP Koehlmoos, and Louis W. Niessen. "Overweight and abdominal obesity as determinants of undiagnosed diabetes and pre-diabetes in Bangladesh." *BMC obesity* 3, no. 1 (2016): 19.

Allen LH. Anemia and iron deficiency: effects on pregnancy outcome. The American journal of clinical nutrition. 2000 May 1;71(5):1280S-4S.

Arpino, B., & Bordone, V. (2014). Does grandparenting pay off? The effect of child care on grandparents' cognitive functioning. Journal of Marriage and Family, 76(2), 337–351.

Aubel, J. (2012). The role and influence of grandmothers on child nutrition: culturally designated advisors and caregivers. *Maternal & child nutrition*, *8*(1), 19-35.

Axelrod R, Hamilton WD. The evolution of cooperation. science. 1981 Mar 27;211(4489):1390-6.

Bachman, H. J., & Chase-Lansdale, P. L. (2005). Custodial grandmothers' physical, mental, and economic well-being: Comparisons of primary caregivers from low-income neighborhoods. Family Relations, 54(4), 475–487.

Borgerhoff Mulder, M. (2007). Hamilton's rule and kin competition: the Kipsigis case. *Evolution and Human Behavior*, *28*(5), 299-312.

Brown, S. L., Nesse, R. M., Vinokur, A. D., & Smith, D. M. (2003). Providing social support may be more beneficial than receiving it: Results from a prospective study of mortality. Psychological Science, 14(4), 320–327.

Chen, F., & Liu, G. (2012). The health implications of grandparents caring for grandchildren in China. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 67B(1), 99–112.

Cohen S. Social relationships and health. American psychologist. 2004 Nov;59(8):676.

Coker, A. L., Smith, P. H., Thompson, M. P., McKeown, R. E., Bethea, L., & Davis, K. E. (2002). Social support protects against the negative effects of partner violence on mental health. *Journal of women's health & gender-based medicine*, *11*(5), 465-476.

Cronk, Lee, Colette Berbesque, Thomas Conte, Matthew Gervais, Padmini Iyer, Brighid McCarthy, Dennis Sonkoi, Cathryn Townsend, and Athena Aktipis. "Managing risk through cooperation: Need-based transfers and risk pooling among the societies of the Human Generosity Project." In *Global Perspectives on Long Term Community Resource Management*, pp. 41-75. Springer, Cham, 2019.

Daru J, Zamora J, Fernández-Félix BM, Vogel J, Oladapo OT, Morisaki N, Tunçalp Ö, Torloni MR, Mittal S, Jayaratne K, Lumbiganon P. Risk of maternal mortality in women with severe anaemia during pregnancy and post partum: a multilevel analysis. The Lancet Global Health. 2018 May 1;6(5):e548-54.

de la Haye K, Bell BM, Salvy SJ. The role of maternal social networks on the outcomes of a home-based childhood obesity prevention pilot intervention. Journal of Social Structure. 2019 Aug 15;20(3).

El Arifeen S, Ekström EC, Frongillo EA, Hamadani J, Khan AI, Naved RT, Rahman A, Raqib R, Rasmussen KM, Selling KE, Wagatsuma Y. Cohort Profile: the maternal and infant nutrition interventions in Matlab (MINIMat) cohort in Bangladesh. International journal of epidemiology. 2018 Dec;47(6):1737.

Ferdous J, Ahmed A, Dasgupta SK, Jahan M, Huda FA, Ronsmans C, Koblinsky M, Chowdhury ME. Occurrence and determinants of postpartum maternal morbidities and disabilities among women in Matlab, Bangladesh. Journal of health, population, and nutrition. 2012 Jun;30(2):143.

Figueiredo AC, Gomes-Filho IS, Silva RB, Pereira PP, Da Mata FA, Lyrio AO, Souza ES, Cruz SS, Pereira MG. Maternal anemia and low birth weight: a systematic review and meta-analysis. Nutrients. 2018 May;10(5):601.

Friedman, Arnold J., et al. "Iron deficiency anemia in women across the life span." *Journal of women's health* 21.12 (2012): 1282-1289.

Geiker, N. R. W., et al. "Does stress influence sleep patterns, food intake, weight gain, abdominal obesity and weight loss interventions and vice versa?." *Obesity Reviews* 19.1 (2018): 81-97.

Gibson MA, Mace R. Helpful grandmothers in rural Ethiopia: A study of the effect of kin on child survival and growth. Evolution and Human Behavior. 2005 Nov 1;26(6):469-82.

Grundy, E. M., Albala, C., Allen, E., Dangour, A. D., Elbourne, D., & Uauy, R. (2012). Grandparenting and psychosocial health among older Chileans: A longitudinal analysis. Aging & Mental Health, 16(8), 1047–1057.

Gurven M. The evolution of contingent cooperation. Current Anthropology. 2006 Feb;47(1):185-92.

Gurven, M., Allen-Arave, W., Hill, K. & Hurtado, M. 'It's a Wonderful Life': signaling generosity among the Ache of Paraguay. *Evol. Hum. Behav.* **21**, 263–282 (2000).

Haas JD, Brownlie IV T. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal. The Journal of nutrition. 2001 Feb 1;131(2):676S-90S.

Hadley, Craig, Monique Borgerhoff Mulder, and Emily Fitzherbert. "Seasonal food insecurity and perceived social support in rural Tanzania." *Public health nutrition* 10.6 (2007): 544-551.

Hames R. Garden labor exchange among the Ye'kwana. Ethology and Sociobiology. 1987 Jan 1;8(4):259-84.

Han Z, Mulla S, Beyene J, Liao G, McDonald SD. Maternal underweight and the risk of preterm birth and low birth weight: a systematic review and meta-analyses. International journal of epidemiology. 2011 Feb 1;40(1):65-101.

Hawkes K, O'Connell JF, Jones NB, Alvarez H, Charnov EL. Grandmothering, menopause, and the evolution of human life histories. Proceedings of the National Academy of Sciences. 1998 Feb 3;95(3):1336-9.

Heck JE, Marcotte EL, Argos M, Parvez F, Ahmed A, Islam T, Sarwar G, Hasan R, Ahsan H, Chen Y. Betel quid chewing in rural Bangladesh: prevalence, predictors and relationship to blood pressure. International journal of epidemiology. 2012 Apr 1;41(2):462-71.

Hedges S, Lawson DW, Todd J, Urassa M, Sear R. Sharing the Load: How Do Coresident Children Influence the Allocation of Work and Schooling in Northwestern Tanzania?. Demography. 2019 Oct 1;56(5):1931-56.

Hilbrand, S., Coall, D. A., Gerstorf, D., & Hertwig, R. (2017). Caregiving within and beyond the family is associated with lower mortality for the caregiver: A prospective study. *Evolution and Human Behavior*, *38*(3), 397-403.

Hrdy SB. Mothers and others. Harvard University Press; 2011 Apr 15.

Hyder SZ, Persson LÅ, Chowdhury M, Lönnerdal BO, Ekström EC. Anaemia and iron deficiency during pregnancy in rural Bangladesh. Public health nutrition. 2004 Dec;7(8):1065-70.

Kim DA, Hwong AR, Stafford D, Hughes DA, O'Malley AJ, Fowler JH, Christakis NA. Social network targeting to maximise population behaviour change: a cluster randomised controlled trial. The Lancet. 2015 Jul 11;386(9989):145-53.

Koster J. Interhousehold meat sharing among Mayangna and Miskito horticulturalists in Nicaragua. Human Nature. 2011 Dec;22(4):394-415.

Kramer KL. Cooperative breeding and its significance to the demographic success of humans. Annual Review of Anthropology. 2010 Oct 21;39:417-36.

Kramer KL. The evolution of human parental care and recruitment of juvenile help. Trends in ecology & evolution. 2011 Oct 1;26(10):533-40.

Ickes, Scott B., et al. "Associations between social support, psychological well-being, decision making, empowerment, infant and young child feeding, and nutritional status in Ugandan children ages 0 to 24 months." *Maternal & child nutrition* 14.1 (2018): e12483.

Islam MZ, Lamberg-Allardt C, Bhuyan MA, Salamatullah Q. Iron status of premenopausal women in two regions of Bangladesh: prevalence of deficiency in high and low socio-economic groups. European journal of clinical nutrition. 2001 Jul;55(7):598-604.

Jaeggi, A. V. & Gurven, M. Natural cooperators: Food sharing in humans and other primates. *Evol. Anthropol.* **22**, 186–195, doi:10.1002/evan.v22.4 (2013).

Kamal SM, Hassan CH, Alam GM. Dual burden of underweight and overweight among women in Bangladesh: patterns, prevalence, and sociodemographic correlates. Journal of health, population, and nutrition. 2015 Mar;33(1):92.

Kamruzzaman M, Rabbani MG, Saw A, Sayem MA, Hossain MG. Differentials in the prevalence of anemia among non-pregnant, ever-married women in Bangladesh: multilevel logistic regression analysis of data from the 2011 Bangladesh Demographic and Health Survey. BMC women's health. 2015 Dec 1;15(1):54.

Kassebaum, Nicholas J., et al. "A systematic analysis of global anemia burden from 1990 to 2010." *Blood* 123.5 (2014): 615-624.

Khan SH, Talukder SH. Nutrition transition in B angladesh: is the country ready for this double burden. obesity reviews. 2013 Nov;14:126-33.

Koster J, Lukas D, Nolin D, Power E, Alvergne A, Mace R, Ross CT, Kramer K, Greaves R, Caudell M, MacFarlan S. Kinship ties across the lifespan in human communities. Philosophical Transactions of the Royal Society B. 2019 Sep 2;374(1780):20180069.

Mahomed K, Williams MA, Woelk GB, Jenkins-Woelk L, Mudzamiri S, Longstaff L, Sorensen TK. Risk factors for pre-eclampsia among Zimbabwean women: maternal arm circumference and other anthropometric measures of obesity. Paediatric and perinatal epidemiology. 1998 Jul;12(3):253-62.

Mandal D, Manda S, Rakshi A, Dey RP, Biswas SC, Banerjee A. Maternal obesity and pregnancy outcome: a prospective analysis. The Journal of the Association of Physicians of India. 2011 Aug;59:486.

McDade TW, Shell-Duncan B. Whole blood collected on filter paper provides a minimally invasive method for assessing human transferrin receptor level. The Journal of nutrition. 2002 Dec 1;132(12):3760-3.

Malenica M, Prnjavorac B, Bego T, Dujic T, Semiz S, Skrbo S, Gusic A, Hadzic A, Causevic A. Effect of cigarette smoking on haematological parameters in healthy population. Medical Archives. 2017 Apr;71(2):132.

McClintock TR, Parvez F, Wu F, Wang W, Islam T, Ahmed A, Shaheen I, Sarwar G, Demmer RT, Desvarieux M, Ahsan H. Association between betel quid chewing and carotid intima-media thickness in rural Bangladesh. International journal of epidemiology. 2014 Aug 1;43(4):1174-82.

Marchant T, Schellenberg JA, Nathan R, Abdulla S, Mukasa O, Mshinda H, Lengeler C. Anaemia in pregnancy and infant mortality in Tanzania. Tropical medicine & international health. 2004 Feb; 9(2):262-6.

Meehan CL, Quinlan R, Malcom CD. Cooperative breeding and maternal energy expenditure among Aka foragers. American Journal of Human Biology. 2013 Jan;25(1):42-57.

Milman N. Postpartum anemia I: definition, prevalence, causes, and consequences. Annals of hematology. 2011 Nov 1;90(11):1247.

Min J, Zhao Y, Slivka L, Wang Y. Double burden of diseases worldwide: Coexistence of undernutrition and overnutrition-related non-communicable chronic diseases. Obesity reviews. 2018 Jan;19(1):49-61.

Page AE, Chaudhary N, Viguier S, Dyble M, Thompson J, Smith D, Salali GD, Mace R, Migliano AB. Hunter-gatherer social networks and reproductive success. Scientific reports. 2017 Apr 25;7(1):1-0.

Page AE, Thomas MG, Smith D, Dyble M, Viguier S, Chaudhary N, Salali GD, Thompson J, Mace R, Migliano AB. Testing adaptive hypotheses of alloparenting in Agta foragers. Nature human behaviour. 2019 Nov;3(11):1154-63.

Pagliai, G., et al. "Consumption of ultra-processed foods and health status: a systematic review and meta-analysis." *British Journal of Nutrition* 125.3 (2021): 308-318.

Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. International journal of obesity. 2004 Nov;28(3):S2-9.

Poston L, Caleyachetty R, Cnattingius S, Corvalán C, Uauy R, Herring S, Gillman MW. Preconceptional and maternal obesity: epidemiology and health consequences. The lancet Diabetes & endocrinology. 2016 Dec 1;4(12):1025-36.

Poulin, M. J., Brown, S. L., Dillard, A. J., & Smith, D. M. (2013). Giving to others and the association between stress and mortality. American Journal of Public Health, 103(9), 1649–1655.

Rahman MM, Abe SK, Kanda M, Narita S, Rahman MS, Bilano V, Ota E, Gilmour S, Shibuya K. Maternal body mass index and risk of birth and maternal health outcomes in low-and middle-income countries: a systematic review and meta-analysis. Obesity reviews. 2015 Sep;16(9):758-70.

Rahman MM, Abe SK, Rahman MS, Kanda M, Narita S, Bilano V, Ota E, Gilmour S, Shibuya K. Maternal anemia and risk of adverse birth and health outcomes in low-and middle-income countries: systematic review and meta-analysis, 2. The American journal of clinical nutrition. 2016 Feb 1;103(2):495-504.

Ramachenderan J, Bradford J, Mclean M. Maternal obesity and pregnancy complications: a review. Australian and New Zealand Journal of Obstetrics and Gynaecology. 2008 Jun;48(3):228-35.

Razzaque A, Nahar L, Mustafa AH, Ahsan KZ, Islam MS, Yunus M. Sociodemographic differentials of selected noncommunicable diseases risk factors among adults in Matlab, Bangladesh: findings from a WHO STEPS survey. Asia Pacific Journal of Public Health. 2011 Mar;23(2):183-91.

Reynolds AZ, Wander K, Sum CY, Su M, Thompson ME, Hooper PL, Li H, Shenk MK, Starkweather KE, Blumenfield T, Mattison SM. Matriliny reverses gender disparities in inflammation and hypertension among the Mosuo of China. Proceedings of the National Academy of Sciences. 2020 Nov 11.

Scelza BA. The place of proximity. Human Nature. 2011 Jul 1;22(1-2):108-27.

Scott KA, Melhorn SJ, Sakai RR. Effects of chronic social stress on obesity. Current obesity reports. 2012 Mar 1;1(1):16-25.

Shenk, M. K. (2005). Kin investment in wage-labor economies. *Human Nature*, *16*(1), 81-113.

Siega-Riz AM, Laraia B. The implications of maternal overweight and obesity on the course of pregnancy and birth outcomes. Maternal and Child Health Journal. 2006 Sep 1;10(1):153-6.

Siervo M, Wells JC, Cizza G. The contribution of psychosocial stress to the obesity epidemic: an evolutionary approach. Hormone and metabolic research= Hormon-und Stoffwechselforschung= Hormones et metabolisme. 2009 Apr;41(4):261.

Smith KP, Christakis NA. Social networks and health. Annu. Rev. Sociol. 2008 Aug 11;34:405-29.

Snopkowski K, Sear R. Grandparental help in Indonesia is directed preferentially towards needier descendants: A potential confounder when exploring grandparental influences on child health. Social Science & Medicine. 2015 Mar 1;128:105-14.

Thomas MG, Ji T, Wu J, He Q, Tao Y, Mace R. Kinship underlies costly cooperation in Mosuo villages. Royal Society open science. 2018 Feb 21;5(2):171535.

Waller DK, Shaw GM, Rasmussen SA, Hobbs CA, Canfield MA, Siega-Riz AM, Gallaway MS, Correa A. Prepregnancy obesity as a risk factor for structural birth defects. Archives of pediatrics & adolescent medicine. 2007 Aug 1;161(8):745-50.

Wander K, Shell-Duncan B, McDade TW. Evaluation of iron deficiency as a nutritional adaptation to infectious disease: an evolutionary medicine perspective. American Journal of Human Biology: The Official Journal of the Human Biology Association. 2009 Mar;21(2):172-9.

Wang L, Hui SS. Validity of four commercial bioelectrical impedance scales in measuring body fat among Chinese children and adolescents. BioMed Research International. 2015 Jun 8;2015.

Weisner TS. Childhood: anthropological aspects. International encyclopedia of the social & behavioral sciences. 2015 Jan 1:451-8.

Weiss G, Goodnough LT. Anemia of chronic disease. New England Journal of Medicine. 2005 Mar 10;352(10):1011-23.

World Health Organization. Obesity: preventing and managing the global epidemic. World Health Organization; 2000.

World Health Organization. Serum transferrin receptor levels for the assessment of iron status and iron deficiency in populations. World Health Organization; 2014.

World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. World Health Organization; 2011.

Acknowledgments

The authors would like to thank our study participants, and acknowledge Fayeza Sultana, Sufia Sultana, Tanima Rashid, Shamsun Nahar, Lutfa Begum, Ummehani Akter, Fatema Khatun, Borhan Uddin, and Reyad Hassan for invaluable assistance with data collection. We would like to thank Abigail Page and an anonymous reviewer for useful comments on the manuscript.

Funding

The US National Science Foundation (BCS-1461522, BCS-1839269), the John S. Templeton Foundation (Grant ID 61426), and The Pennsylvania State University funded this research. For one contributor, this material is based upon work supported by (while serving at) the National Science Foundation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Ethics Statement

The data analyzed in this article were collected under research protocols approved by icddr,b (PR-17062) in Bangladesh and The Pennsylvania State University (STUDY00007821) in the United States.

Data Accessibility Statement

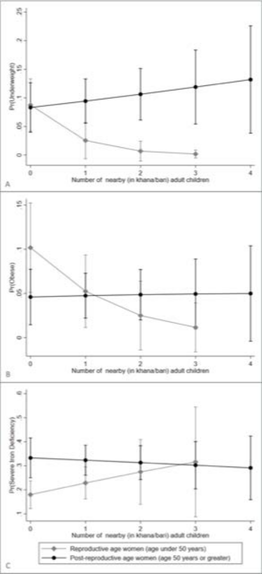
Data are available upon request to the first author subject to ethics restrictions on identifiable human subjects data.

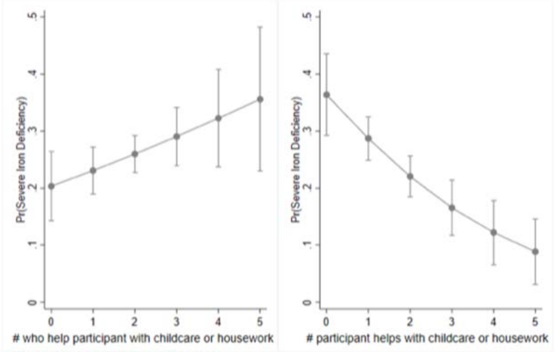
Author Contributions

MKS, SMM, TBK, JHS, RS, and RS obtained funding; MKS, SMM, NA, and KW designed the study; MKS, NA, and KW trained field staff and oversaw data collection; AK and FM performed laboratory analyses; AM and KW performed statistical analyses; MKS, SMM, TBK, JHS, RS, RS, and KW contributed to theoretical framing, MKS, AM, and KW drafted the paper; all authors edited the paper.

100 Word Media Summary/Lay Abstract

Malnutrition from underweight and iron deficiency, alongside rising rates of overweight and obesity, are of significant public health concern in low- and middle-income countries. We examine the effects of different measures of social support on weight and iron nutrition among 677 randomly-sampled women from rural Bangladesh. Our results suggest that social support from kin serves to enhance energy balance but not diet quality, consistent with increased access to low quality foods with economic development and nutrition transition. We further find that women who received help were in greater need of it, and thus had worse iron nutrition outcomes. Such complex effects deserve attention within public health where “social support” is often assumed to be positive.


Pr(Underweight)
0
.05
.1
.15
.2
.25
0
1
2
3
4
Number of nearby (in khana/bari) adult children
A
Pr(Obese)
0
.05
.1
.15
0
1
2
3
4
Number of nearby (in khana/bari) adult children
B
Pr(Severe Iron Deficiency)
.1
.2
.3
.4
.5
.6
0
1
2
3
4
Number of nearby (in khana/bari) adult children
Reproductive age women (age under 50 years)
Post-reproductive age women (age 50 years or greater)
C



Note: holding other variables at the mean

Figure 1. Predicted probabilities of underweight, obesity, and anemia among reproductive and post-reproductive aged women.

Figure 2. Predicted probabilities of iron deficiency anemia from individuals who help (left) or are helped by (right) the respondent.

Supplemental Information for "Social support, nutrition, and health among women in rural Bangladesh: complex tradeoffs in allocare, kin proximity, and support network size"

by Mary K. Shenk, Anne Morse, Siobhán M. Mattison, Rebecca Sear, Nurul Alam, Rubhana Raqib, Anjan Kumar, Farjana Haque, Tami Blumenfield, John Shaver, Richard Sosis, and Katherine Wander

Supplemental Information (SI) for this paper consists of eight documents, this Word document containing text and Table S1 and six additional Word documents containing oversized tables. Following is a list of the tables included in the SI as additional documents.

Table S1: Descriptive statistics of the study sample and full sample

Table S2. Multinomial logistic regression with lean as the reference category (N=677)

Table S3. Multinomial logistic regression with iron replete as the reference category (N=677)

Table S4. Multinomial logistic regression with iron replete as the reference category (N=677) using the iron deficiency cutpoint of TfR > 8.3 mg/l

Table S5. Full multinomial logistic regression with lean as the base outcome (N=677)

Table S6. Full multinomial logistic regression with iron replete as the base outcome (N=677); Iron deficiency defined as soluble transferrin receptor > 5.0 mg/L

Table S7. Full multinomial logistic regression with iron replete as the base outcome (N=677); Iron deficiency defined as soluble transferrin receptor > 8.3 mg/L

Additional Predictors: Methods, Results, Discussion

Variable Descriptions

Our name generator questions asked about several social network domains—giving and receiving help with childcare and housework, giving and receiving small and large loans, giving and receiving advice and discussion of important matters, who participants spend time with, and who might come to their aid if they need help. Yet while we asked about many domains, we only analyze the total network size and the questions related to help with childcare and housework. We are strictly limited in this paper in terms of space, thus we limit ourselves here to only the most relevant data. Analyses of other ego network questions will be included in future papers.

We considered three variables to control for socioeconomic status: education, reported income from multiple sources (wage labor, sale of crops, remittances, etc.), and the MacArthur Ladder measure of relative status (which asks the respondent to place themselves on one rung of a 10-rung ladder relative to "the people who have the highest standing in their community" and "the people who have the lowest standing"). We created a categorical variable for education, based on respondent's self-report: no education/illiterate, some primary school (5 years' education)/literate, and any secondary or higher education (8+ years of education). This categorization was based on substantive knowledge of education in the study area, and was verified with post-estimation tests for significant differences between coefficients of the educational categories. MacArthur Ladder and income estimates were modeled as continuous variables. Finally, we considered whether the respondent was married (compared to those who were widowed, divorced, or abandoned).

Additional exposures that were likely to be associated with both nutritional outcomes and predictors of interest, without lying on the hypothesized causal path of social support, were controlled in modeling. These included participant's religion (Islam, Hindu), household exposure to cigarette smoke (any, none) due to the effect of tobacco smoke on hemoglobin production (Malencia et al. 2017), use of betel nut (any, none; a commonly-chewed plant product which can affect appetite and multiple aspects of nutrition (Heck et al. 2012, McClintock et al. 2014)), and food insecurity, all as self-reported in response to survey items. Any reported food insecurity (ranging from "always have enough but sometimes quality is poor" to "never or almost never have enough") was considered in creation of a binary variable (compared to "always have enough").

Because the health of women with more children might be compromised (compared to that of women with fewer adults children) due to maternal depletion (i.e., the physiological burden of repeated pregnancy and lactation), confounding associations reflected social support received from (or given to) these children as adults, we considered participants' total number of living children, regardless of age, as an additional predictor of interest. This variable overlaps with predictor variables in the model and thus could not be considered at the same time as them (i.e., as a control variable). We instead ran separate models to capture this effect and compare it to the effects of nearby adult and young children.

Results

Tests of model fit (F statistics, deviance, and BIC) suggested education and the MacArthur ladder provided the most parsimonious measures of socioeconomic status; inclusion of additional socioeconomic variables, such as reported monthly income, did not improve model fit once MacArthur ladder and education were controlled.

As shown in Table S2, MacArthur ladder was inversely associated with underweight (RRR: 0.84, 95% CI: 0.70, 1.00): each one-unit increase in the MacArthur ladder was associated with a 2% decrease in probability of underweight. The MacArthur ladder was unassociated with overweight, but positively associated with obesity (RRR: 1.17; 95% CI: 0.98, 1.39), such that each one-unit increase in the MacArthur ladder was associated with a 1% increase in the probability of being obese. Women with primary education were 8% more likely to be overweight (RRR: 1.52; 95% CI: 0.96, 2.43); those with secondary education were 9% more likely to be overweight (RRR: 1.74; 95% CI: 0.99, 3.05) and 4% more likely to be obese (RRR: 2.33; 95% CI: 0.87, 6.21). Food insecure women were 6% more likely to be underweight (RRR: 1.81; 95% CI: 1.01, 3.24). Associations of interest were robust to control for age as a continuous variable, and age was unassociated with underweight once the dichotomous age variable was controlled. Being widowed (or divorced/abandoned) was unassociated with underweight (RRR: 1.07; 95% CI: 0.56, 2.09), overweight (RRR: 1.02; 95% CI: 0.60, 1.73), or obesity (RRR: 0.42; 95% CI: 0.14, 1.28). Total fertility (number of living children) was inversely associated with underweight in a similar manner to nearby number of adult children: each additional child decreased risk for underweight among women under age 50 years (RRR: 0.52; 95% CI: 0.31, 0.88) but not among those aged 50 years or older; number of living children was unassociated with overweight or obesity. When number of living children was included in the model in Table S2, the associations between underweight and nearby adult children were largely unchanged, and the effect of fertility was minimal (RRR: 1.05; 95% CI: 0.86, 1.29). Thus, it seems likely that total fertility and nearby adult children overlap in capturing the effects of children on the health of women of reproductive age.

As shown in Table S3, relative affluence was inversely associated with non-iron-deficiency anemia: each unit increase in the MacArthur ladder was associated with a 3% decrease in probability of non-iron-deficiency anemia (RRR: 0.81; 95% CI: 0.71, 0.93). Primary education was similarly inversely associated with non-iron-deficiency anemia (RRR: 0.60; 95% CI: 0.34, 1.06). Secondary education was associated with a 14% higher probability of severe iron deficiency (RRR: 2.49; 95% CI: 1.23, 5.04). Being widowed (or divorced/abandoned) was unassociated with mild-to-moderate iron deficiency (RRR: 0.80; 95% CI: 0.42, 1.53), iron deficiency anemia (RRR: 1.15; 95% CI: 0.62, 2.12), or non-iron deficiency anemia (RRR: 0.77; 95% CI: 0.41, 1.45) when included in the model shown in Table S3. Passive exposure to tobacco smoke was inversely associated with mild-to-moderate iron deficiency (RRR: 0.68; 95% CI: 0.44, 1.06), iron deficiency anemia (RRR: 0.57; 95% CI: 0.36, 0.91), and non-iron deficiency anemia (RRR: 0.49; 95% CI: 0.30, 0.79), likely reflecting enhanced erythropoiesis due to hypoxic stress among those with household exposure to tobacco smoke. Inclusion of fertility in the model in Table S3 did not appreciably alter any of the reported associations, nor was fertility independently associated with iron deficiency outcomes, alone or in interaction with reproductive/post-reproductive age. Age (continuous) was unassociated with iron deficiency outcomes and associations of interest in Table S3 remained after controlling for age category (reproductive/post-reproductive).

Discussion

Economic variables had predicted effects: underweight was less common and obesity more common among those with higher socioeconomic status, and underweight was more common among those who were food insecure. Primary and secondary education increased risk for overweight, while secondary education also increased risk for obesity. In this context education may serve as a proxy for latent aspects of socioeconomic status not well measured in other variables, and more highly educated women not only have access to more food (including less-healthy store-bought foods) but are also more sedentary as they are less likely to work in the fields and are more likely to have domestic help for heavy household tasks.

Wealthier women were unsurprisingly less likely to have non-iron-deficiency anemia. Women with primary education were more likely to have mild-to-moderate iron deficiency, and those with secondary education were more likely to have iron deficiency anemia. As with obesity, these patterns may be related to the increased purchase and consumption of processed foods associated with wealth and education, both of which are likely to index greater market integration at the level of the household.

Table S1: Descriptive statistics of the study sample and full sample										
	Study sample					Full sample				
	N	Mean or %	SD	Min	Max	N	Mean or %	SD	Min	Max
Dependent variables										
Weight	677	23.60	4.31	12	40	724	23.57	4.31	12	40
Underweight	69	10.19				78	10.77			
Lean	357	52.73				377	52.07			
Overweight	202	29.84				219	30.25			
Obese	49	7.24				50	6.91			
Iron nutrition	677					691				
Iron replete	344	50.81				348	50.36			
Mild-to-moderate iron deficiency	8	1.18				8	1.16			
Severe iron deficiency	24	3.55				24	3.47			
Non-iron deficiency anemia	301	44.46				311	45.01			
Independent variables										
Age	677	49.77	12.08	20	73	708	50.04	12.20	20	76
Religion	677					726				
Hindu	71	10.49				71	9.78			
Islam	606	89.51				606	83.47			
Passive smoke	677					757				
Yes	240	35.45				259	34.21			
No	437	64.55				498	65.79			
Chews betel nut	677					757				
Yes	364	53.77				398	52.58			
No	313	46.23				359	47.42			
Education	677					757				
No education	229	33.83				254	33.55			
Literate & Primary	243	35.89				263	34.74			
Any secondary	205	30.28				240	31.70			
MacArthur Ladder	677	4.57	1.83	0	10	727	4.56	1.85	0	10
Food Insecurity	677					726				
Yes	218	32.20				241	33.20			
No	459	67.80				485	66.80			
Social support network members										
# childcare/housework network helpers	677	1.98	1.17	0	8	710	1.96	1.17	0	8
# childcare/housework network help recipients	677	1.49	1.09	0	6	710	1.47	1.09	0	6
Total support network size	677	8.86	3.16	0	25	757	8.79	3.19	0	25
Kin support variables										
# of nearby adult children	677	0.85	1.09	0	7	757	0.84	1.08	0	7
# of nearby young kin (≤5y)	677	0.16	0.41	0	2	757	0.15	0.40	0	2

Table S2. Multinomial logistic regression with lean as the reference category (N=677).

	Underweight						Overweight						Obese					
	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*
SOCIAL SUPPORT VARIABLES																		
# childcare/housework network helpers	1.14	0.85, 1.53	0.366	0.01	-0.01, 0.04	0.280	0.94	0.79, 1.13	0.539	-0.01	-0.05, 0.02	0.470	0.92	0.66, 1.27	0.612	-0.01	-0.03, 0.02	0.631
# childcare/housework network help recipients	0.80	0.60, 1.07	0.129	-0.02	-0.04, 0.01	0.156	0.97	0.81, 1.18	0.780	0.00	-0.03, 0.04	0.830	0.84	0.59, 1.19	0.320	-0.01	-0.03, 0.01	0.398
Total support network size	0.91	0.82, 1.01	0.083	-0.01	-0.02, 0.00	0.045	1.05	0.99, 1.12	0.096	0.01	0.00, 0.02	0.023	0.97	0.86, 1.08	0.548	0.00	-0.01, 0.00	0.438
Age category (under age 50 years as reference)																		
50 years or over	0.98	0.40, 2.39	0.964	0.05	0.01, 0.10	0.025	1.32	0.74, 2.35	0.353	0.01	-0.08, 0.11	0.769	0.47	0.17, 1.25	0.129	-0.02	-0.07, 0.02	0.310
Number of nearby adult children	0.26	0.07, 1.02	0.053	-0.03	-0.07, 0.01	0.163	1.04	0.71, 1.53	0.835	0.01	-0.03, 0.06	0.636	0.46	0.19, 1.11	0.084	-0.02	-0.06, 0.01	0.148
Age 50 or over x number of nearby adult children	4.17	1.03, 16.85	0.045				0.80	0.51, 1.25	0.334				2.13	0.82, 5.54	0.121			
Number of nearby young kin (age 0-5 years)	0.85	0.37, 1.97	0.703	-0.01	-0.08, 0.06	0.818	0.90	0.56, 1.43	0.654	-0.01	-0.09, 0.08	0.895	0.60	0.25, 1.43	0.247	-0.03	-0.08, 0.02	0.285
CONTROL VARIABLES																		
Religion (Hindu as reference)																		
Islam	1.24	0.51, 3.00	0.629	0.01	-0.06, 0.08	0.763	1.55	0.83, 2.90	0.165	0.08	-0.02, 0.19	0.112	0.76	0.31, 1.89	0.560	-0.03	-0.10, 0.04	0.403
Health passive smoke	1.01	0.58, 1.76	0.974	0.00	-0.02, 0.04	0.956	1.12	0.77, 1.62	0.569	0.02	-0.05, 0.09	0.519	0.91	0.46, 1.78	0.778	-0.01	-0.05, 0.03	0.688
Chews betel nut	1.29	0.64, 2.62	0.476	0.03	-0.02, 0.09	0.259	0.56	0.36, 0.88	0.11	-0.13	-0.21, -0.05	0.002	1.49	0.68, 3.28	0.318	0.04	-0.01, 0.09	0.143
MacArthur Ladder	0.84	0.70, 1.00	0.050	-0.02	-0.03, 0.00	0.033	1.00	0.90, 1.11	0.999	0.00	-0.02, 0.02	0.928	1.17	0.98, 1.39	0.087	0.01	0.00, 0.02	0.053
Food insecurity	1.81	1.01, 3.24	0.048	0.06	0.01, 0.10	0.023	0.89	0.59, 1.35	0.592	-0.03	-0.10, 0.05	0.527	0.60	0.26, 1.34	0.211	-0.03	-0.09, 0.02	0.189
Education (illiterate as reference)																		
Literate or primary	0.77	0.40, 1.49	0.443	-0.04	-0.09, 0.02	0.203	1.52	0.96, 2.43	0.077	0.08	-0.01, 0.16	0.080	1.92	0.82, 4.53	0.135	0.03	-0.01, 0.08	0.181
Any secondary	0.94	0.38, 2.32	0.886	-0.03	-0.10, 0.05	0.513	1.74	0.99, 3.05	0.054	0.09	-0.01, 0.20	0.082	2.33	0.87, 6.21	0.091	0.04	-0.02, 0.10	0.161
Constant	0.60	0.14, 2.67	0.504				0.26	0.09, 0.71	0.009				0.17	0.03, 0.83	0.029			

RRR: relative risk ratio (exp(coefficient)); AME: average marginal effect

Table S3. Multinomial logistic regression with iron replete as the reference category (N=677)

	Mild to moderate iron deficiency						Severe iron deficiency						Non-iron deficiency anemia					
	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*
SOCIAL SUPPORT VARIABLES																		
# childcare/housework network helpers	1.12	0.89, 1.40	0.347	0.00	-0.04, 0.03	0.909	1.27	1.01, 1.60	0.040	0.03	0.00, 0.06	0.077	1.13	0.89, 1.43	0.321	0.00	-0.03, 0.03	0.994
# childcare/housework network help recipients	1.02	0.81, 1.28	0.862	0.02	-0.01, 0.06	0.177	0.71	0.56, 0.90	0.005	-0.07	-0.10, -0.03	0.000	1.05	0.82, 1.34	0.716	0.03	-0.01, 0.06	0.124
Total support network size	0.94	0.88, 1.02	0.125	-0.01	-0.02, 0.01	0.331	0.95	0.88, 1.03	0.190	0.00	-0.01, 0.01	0.554	0.97	0.90, 1.04	0.384	0.00	-0.01, 0.01	0.914
Age category (under age 50 years as reference)																		
50 years or over	1.27	0.63, 2.55	0.508	-0.07	-0.16, 0.02	0.145	2.93	1.43, 5.98	0.003	0.10	0.01, 0.20	0.030	1.84	0.88, 3.86	0.105	0.02	-0.07, 0.11	0.669
Number of nearby adult children	1.70	1.01, 2.88	0.046	0.03	-0.01, 0.07	0.183	1.88	1.09, 3.24	0.023	0.02	-0.02, 0.06	0.319	1.64	0.92, 2.94	0.095	0.01	-0.03, 0.05	0.571
Age 50 or over x number of nearby adult children	0.68	0.38, 1.22	0.194				0.55	0.30, 1.01	0.053				0.67	0.35, 1.26	0.210			
Number of nearby young kin (age 0-5 years)	1.54	0.90, 2.67	0.118	0.09	0.00, 0.18	0.039	1.20	0.65, 2.21	0.554	0.02	-0.07, 0.12	0.621	0.71	0.33 1.52	0.375	-0.09	-0.20, 0.02	0.106
CONTROL VARIABLES																		
Religion (Hindu as reference)																		
Islam	1.28	0.65, 2.55	0.475	0.02	-0.09, 0.13	0.721	1.10	0.55, 2.19	0.787	-0.02	-0.13, 0.09	0.696	1.53	0.72, 3.26	0.270	0.05	-0.05, 0.14	0.315
Health passive smoke	0.68	0.44, 1.06	0.089	0.00	-0.07, 0.07	0.902	0.57	0.36, 0.91	0.018	-0.04	-0.10, 0.03	0.315	0.49	0.30, 0.79	0.003	-0.07	-0.13, 0.00	0.052
Chews betel nut	1.08	0.63, 1.84	0.782	-0.01	-0.10, 0.07	0.753	1.16	0.67, 2.00	0.604	0.00	-0.08, 0.08	0.941	1.39	0.78, 2.46	0.264	0.04	-0.04, 0.12	0.300
MacArthur Ladder	0.94	0.83, 1.06	0.315	0.01	-0.01, 0.03	0.546	0.91	0.80, 1.03	0.137	0.00	-0.02, 0.02	0.848	0.81	0.71, 0.93	0.004	-0.02	-0.04, -0.01	0.011
Food insecurity	1.01	0.62, 1.66	0.961	0.00	-0.07, 0.08	0.945	1.11	0.67, 1.85	0.676	0.03	-0.04, 0.10	0.488	0.87	0.52, 1.47	0.610	-0.03	-0.10, 0.04	0.420
Education (illiterate as reference)																		
Literate or primary	1.48	0.85, 2.58	0.171	0.09	0.01, 0.18	0.037	1.26	0.72, 2.22	0.423	0.04	-0.03, 0.12	0.285	0.60	0.34, 1.06	0.081	-0.12	-0.20, -0.04	0.003
Any secondary	1.57	0.78, 3.15	0.202	0.02	-0.08, 0.12	0.701	2.49	1.23, 5.04	0.011	0.14	0.03, 0.24	0.011	1.09	0.53, 2.25	0.822	-0.07	-0.17, 0.03	0.174
Constant	0.89	0.28, 2.83	0.838				0.89	0.27, 2.92	0.842				1.32	0.38, 4.63	0.664			

RRR: relative risk ratio (exp(coefficient)); AME: average marginal effect

Table S4. Multinomial logistic regression with iron replete as the reference category (N=677) using the iron deficiency cutpoint of TfR > 8.3 mg/l

	Mild to moderate iron deficiency						Severe iron deficiency						Non-iron deficiency anemia					
	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*	RRR	95% CI	*p*	AME	95% CI	*p*
SOCIAL SUPPORT VARIABLES																		
# childcare/housework network helpers	2.52	1.20, 5.29	0.015	0.01	0.00, 0.02	0.053	1.17	0.75, 1.81	0.488	0.00	-0.01, 0.02	0.724	1.16	0.98, 1.37	0.094	0.03	-0.01, 0.06	0.165
# childcare/housework network help recipients	0.54	0.24, 1.20	0.129	-0.01	-0.01, 0.00	0.217	0.66	0.41, 1.05	0.076	-0.01	-0.03, 0.00	0.156	0.85	0.71, 1.01	0.059	-0.03	-0.07, 0.01	0.137
Total support network size	0.71	0.51, 0.99	0.046	0.00	-0.01, 0.00	0.081	0.98	0.84, 1.15	0.833	0.00	-0.01, 0.00	0.949	0.99	0.93, 1.04	0.597	0.00	-0.01, 0.01	0.804
Age category (under age 50 years as reference)																		
50 years or over	3.44	0.30, 38.9	0.318	0.01	-0.02, 0.04	0.629	1.03	0.25, 4.25	0.972	-0.05	-0.11, 0.00	0.056	2.24	1.32, 3.79	0.003	0.17	0.06, 0.27	0.001
Number of nearby adult children	0.97	0.15, 6.13	0.972	0.00	-0.02, 0.01	0.553	1.91	0.97, 3.73	0.059	0.01	-0.01, 0.03	0.358	1.19	0.81, 1.76	0.365	0.02	-0.03, 0.06	0.477
Age 50 or over x number of nearby adult children	0.44	0.04, 5.11	0.509				0.32	0.11, 0.95	0.041				0.83	0.54, 1.26	0.385			
Number of nearby young kin (age 0-5 years)	0.78	0.14, 4.40	0.780	0.00	-0.02, 0.02	0.899	1.43	0.53, 3.86	0.483	0.02	-0.02, 0.05	0.306	0.71	0.44, 1.14	0.157	-0.08	-0.19, 0.02	0.127
CONTROL VARIABLES																		
Religion (Hindu as reference)																		
Islam	211,712	--	0.977	0.01	0.00, 0.02	0.003	2.80	0.36, 22.0	0.327	0.02	-0.01, 0.06	0.177	1.10	0.65, 1.86	0.712	0.01	-0.11, 0.13	0.921
Health passive smoke	7.19	1.27, 40.7	0.026	0.02	0.00, 0.05	0.041	0.48	0.17, 1.31	0.150	-0.02	-0.05, 0.01	0.240	0.69	0.49, 0.97	0.031	-0.09	-0.16, -0.01	0.029
Chews betel nut	0.87	0.13, 5.96	0.888	0.00	-0.02, 0.02	0.812	3.22	1.12, 9.28	0.030	0.04	0.00, 0.07	0.043	1.10	0.74, 1.66	0.629	0.01	-0.08, 0.10	0.890
MacArthur Ladder	0.94	0.59, 1.49	0.787	0.00	-0.01, 0.00	0.971	0.89	0.69, 1.15	0.374	0.00	-0.01, 0.01	0.619	0.89	0.81, 0.98	0.020	-0.02	-0.05, 0.00	0.027
Food insecurity	0.29	0.03, 2.92	0.295	-0.01	-0.04, 0.01	0.317	0.78	0.27, 2.25	0.645	-0.01	-0.04, 0.03	0.664	1.00	0.69, 1.45	0.997	0.01	-0.07, 0.09	0.822
Education (illiterate as reference)																		
Literate or primary	1.26	0.09, 17.2	0.863	0.00	-0.01, 0.02	0.769	1.59	0.45, 5.68	0.472	0.02	-0.01, 0.05	0.293	0.68	0.46, 1.03	0.066	-0.09	-0.18, 0.00	0.048
Any secondary	4.51	0.31, 66.5	0.273	0.01	-0.01, 0.04	0.279	2.49	0.59, 10.5	0.215	0.02	-0.02, 0.06	0.280	1.31	0.78, 2.19	0.301	0.04	-0.07, 0.16	0.475
Constant	0.00	--	0.971				0.03	0.00, 0.47	0.013				1.14	0.47, 2.76	0.773			

RRR: relative risk ratio (exp(coefficient)); AME: average marginal effect

Table S5. Full multinomial logistic regression with lean as the base outcome (N=677)

	Underweight				Overweight				Obese			
	Coefficient	**SE**	**95% CI**	***p***	**Coefficient**	**SE**	**95% CI**	***p***	**Coefficient**	**SE**	**95% CI**	***p***
Religion (Hindu as reference)												
Islam	0.22	0.45	(-0.66, 1.10)	0.629	0.44	0.32	(-0.18, 1.06)	0.165	-0.27	0.46	(-1.17, 0.64)	0.560
Health passive smoke	0.01	0.28	(-0.55, 0.57)	0.974	0.11	0.19	(-0.27, 0.48)	0.569	-0.10	0.34	(-0.77, 0.57)	0.778
Chews betel nut	0.26	0.36	(-0.45, 0.96)	0.476	-0.57	0.23	(-1.02, -0.13)	0.011	0.40	0.40	(-0.39, 1.19)	0.318
MacArthur Ladder	-0.18	0.09	(-0.35, -0.00)	0.050	0.00	0.05	(-0.10, 0.10)	0.999	0.15	0.09	(-0.02, 0.33)	0.087
Food insecurity	0.59	0.30	(0.01, 1.18)	0.048	-0.11	0.21	(-0.53, 0.30)	0.592	-0.52	0.41	(-1.33, 0.29)	0.211
Education (illiterate as reference)												
Literate or primary	-0.26	0.34	(-0.92, 0.40)	0.443	0.42	0.24	(-0.04, 0.89)	0.077	0.65	0.44	(-0.20, 1.51)	0.135
Any secondary	-0.07	0.47	(-0.98, 0.84)	0.886	0.55	0.29	(-0.01, 1.11)	0.054	0.85	0.50	(-0.14, 1.83)	0.091
# childcare/housework network helpers	0.14	0.15	(-0.16, 0.43)	0.366	-0.06	0.09	(-0.24, 0.12)	0.539	-0.08	0.17	(-0.41, 0.24)	0.612
# childcare/housework network help recipients	-0.22	0.15	(-0.51, 0.07)	0.129	-0.03	0.10	(-0.22, 0.16)	0.780	-0.18	0.18	(-0.52, 0.17)	0.320
Total support network size	-0.09	0.05	(-0.20, 0.01)	0.083	0.05	0.03	(-0.01, 0.11)	0.096	-0.04	0.06	(-0.15, 0.08)	0.548
Age category (under 50 as reference)												
50 or over	-0.02	0.46	(-0.91, 0.87)	0.964	0.28	0.30	(-0.30, 0.86)	0.353	-0.76	0.50	(-1.75, 0.22)	0.129
# of nearby adult children	-1.35	0.70	(-2.73, 0.02)	0.053	0.04	0.20	(-0.34, 0.42)	0.835	-0.78	0.45	(-1.66, 0.10)	0.084
Age 50 or over x # of nearby adult children	1.43	0.71	(0.03, 2.82)	0.045	-0.22	0.23	(-0.66, 0.23)	0.334	0.76	0.49	(-0.20, 1.71)	0.121
# of nearby young kin	-0.16	0.43	(-1.01, 0.68)	0.703	-0.11	0.24	(-0.58, 0.36)	0.654	-0.52	0.45	(-1.39, 0.36)	0.247
Constant	-0.51	0.76	(-2.00, 0.98)	0.504	-1.35	0.52	(-2.37, -0.34)	0.009	-1.8	0.82	(-3.41, -0.18)	0.029

Table S6. Full multinomial logistic regression with iron replete as the base outcome (N=677); Iron deficiency defined as soluble transferrin receptor > 5.0 mg/L

	Mild/moderate iron deficiency				Severe iron deficiency				Non-iron deficiency anemia			
	Coefficient	**SE**	**95% CI**	**P**	**Coefficient**	**SE**	**95% CI**	**P**	**Coefficient**	**SE**	**95% CI**	**P**
Religion (Hindu as reference)												
Islam	0.25	0.35	(-0.44, 0.94)	0.475	0.09	0.35	(-0.59, 0.78)	0.787	0.43	0.39	(-0.33, 1.18)	0.270
Health passive smoke	-0.38	0.23	(-0.83, 0.06)	0.089	-0.56	0.23	(-1.02, -0.10)	0.018	-0.72	0.25	(-1.21, -0.24)	0.003
Chews betel nut	0.08	0.27	(-0.46, 0.61)	0.782	0.14	0.28	(-0.40, 0.69)	0.604	0.33	0.29	(-0.25, 0.90)	0.264
MacArthur Ladder	-0.06	0.06	(-0.19, 0.06)	0.315	-0.10	0.07	(-0.23, 0.03)	0.137	-0.21	0.07	(-0.35, -0.07)	0.004
Food insecurity	0.01	0.25	(-0.48, 0.51)	0.961	0.11	0.26	(-0.40, 0.61)	0.676	-0.14	0.27	(-0.66, 0.39)	0.610
Education (illiterate as reference)												
Literate or primary	0.39	0.28	(-0.17, 0.95)	0.171	0.23	0.29	(-0.33, 0.80)	0.423	-0.51	0.29	(-1.09, 0.06)	0.081
Any secondary	0.45	0.36	(-0.24, 1.14)	0.202	0.91	0.36	(0.21, 1.62)	0.011	0.08	0.37	(-0.64, 0.81)	0.822
# childcare/housework network helpers	0.11	0.12	(-0.12, 0.34)	0.347	0.24	0.12	(0.01, 0.47)	0.04	0.12	0.12	(-0.12, 0.36)	0.321
# childcare/housework network help recipients	0.02	0.12	(-0.21, 0.25)	0.862	-0.34	0.12	(-0.58, -0.10)	0.005	0.05	0.12	(-0.20, 0.29)	0.716
Total support network size	-0.06	0.04	(-0.13, 0.02)	0.125	-0.05	0.04	(-0.13, 0.03)	0.190	-0.03	0.04	(-0.11, 0.04)	0.384
Age dichotomous (under 50 as reference)												
50 or over	0.24	0.36	(-0.46, 0.94)	0.508	1.07	0.36	(0.36, 1.79)	0.003	0.61	0.38	(-0.12, 1.35)	0.105
# of nearby adult children	0.53	0.27	(0.01, 1.06)	0.046	0.63	0.28	(0.09, 1.17)	0.023	0.50	0.30	(-0.09, 1.08)	0.095
Age 50 or over x # of nearby adult children	-0.39	0.30	(-0.97, 0.20)	0.194	-0.59	0.31	(-1.20, 0.01)	0.053	-0.41	0.32	(-1.04, 0.23)	0.210
# of nearby young kin	0.44	0.28	(-0.11, 0.98)	0.118	0.18	0.31	(-0.43, 0.79)	0.554	-0.35	0.39	(-1.11, 0.42)	0.375
Constant	-0.12	0.59	(-1.28, 1.04)	0.838	-0.12	0.61	(-1.31, 1.07)	0.842	0.28	0.64	(-0.98, 1.53)	0.664

Table S7. Full multinomial logistic regression with iron replete as the base outcome (N=677); Iron deficiency defined as soluble transferrin receptor > 8.3 mg/L

	Mild/moderate iron deficiency				Severe iron deficiency				Non-iron deficiency anemia			
	Coefficient	**SE**	**95% CI**	***p***	**Coefficient**	**SE**	**95% CI**	**P**	**Coefficient**	**SE**	**95% CI**	**P**
Religion (Hindu as reference)												
Islam	12.3	426.7	(-824.0, 848.5)	0.977	1.03	1.05	(-1.03, 3.09)	0.327	0.10	0.27	(-0.42, 0.62)	0.712
Health passive smoke	1.97	0.88	(0.24, 3.71)	0.026	-0.74	0.51	(-1.74, 0.27)	0.150	-0.38	0.17	(-0.72, -0.03)	0.031
Chews betel nut	-0.14	0.98	(-2.06, 1.78)	0.888	1.17	0.54	(0.11, 2.23)	0.030	0.10	0.21	(-0.31, 0.50)	0.629
MacArthur Ladder	-0.06	0.24	(-0.53, 0.40)	0.787	-0.12	0.13	(-0.38, 0.14)	0.374	-0.12	0.05	(-0.22, -0.02)	0.020
Food insecurity	-1.23	1.17	(-3.53, 1.07)	0.295	-0.25	0.54	(-1.31, 0.81)	0.645	0.00	0.19	(-0.37, 0.37)	0.997
Education (illiterate as reference)												
Literate or primary	0.23	1.33	(-2.39, 2.85)	0.863	0.47	0.65	(-0.80, 1.74)	0.472	-0.38	0.21	(-0.79, 0.03)	0.066
Any secondary	1.51	1.37	(-1.18, 4.20)	0.273	0.91	0.74	(-0.53, 2.35)	0.215	0.27	0.26	(-0.24, 0.79)	0.301
# childcare/housework network helpers	0.92	0.38	(0.18, 1.67)	0.015	0.16	0.22	(-0.28, 0.59)	0.488	0.14	0.09	(-0.02, 0.31)	0.094
# childcare/housework network help recipients	-0.62	0.41	(-1.41, 0.18)	0.129	-0.42	0.24	(-0.89, 0.04)	0.076	-0.17	0.09	(-0.34, 0.01)	0.059
Total support network size	-0.34	0.17	(-0.68, 0.01)	0.046	-0.02	0.08	(-0.17, 0.14)	0.833	-0.02	0.03	(-0.07, 0.04)	0.597
Age dichotomous (under 50 as reference)												
50 or over	1.23	1.24	(-1.19, 3.66)	0.318	0.03	0.72	(-1.39, 1.45)	0.972	0.80	0.27	(0.28, 1.33)	0.003
# of nearby adult children	-0.03	0.94	(-1.88, 1.81)	0.972	0.65	0.34	(-0.03, 1.32)	0.059	0.18	0.20	(-0.21, 0.56)	0.365
Age 50 or over x # of nearby adult children	-0.83	1.25	(-3.29, 1.63)	0.509	-1.14	0.56	(-2.23, -0.05)	0.041	-0.19	0.22	(-0.61, 0.24)	0.385
# of nearby young kin	-0.25	0.88	(-1.97, 1.48)	0.780	0.36	0.51	(-0.64, 1.35)	0.483	-0.35	0.24	(-0.83, 0.13)	0.157
Constant	-15.7	426.7	(-852.0, 820.5)	0.971	-3.61	1.46	(-6.47, -0.76)	0.013	0.13	0.45	(-0.76, 1.02)	0.773