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UNHEALTHY WEIGHT IN INDIAN FAMILIES: THE ROLE OF THE FAMILY ENVIRONMENT IN THE CONTEXT OF THE NUTRITION TRANSITION

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Abstract

India faces a dual burden of increasing obesity and persistent underweight as it experiences the nutrition transition—the dietary and lifestyle changes that accompany globalization, economic development, and technological change. Yet, the nutrition transition is not solely a top-down process; rather, global forces converge with local practices at multiple levels of the social ecology. The family environment, a key site for the transmission of local customs and norms, remains largely unexplored in India. We examined the extent to which opposite-gender siblings and mother-child pairs were concordant or discordant in body weight, and whether domains of the family environment, specifically, food practices, food-related gender norms, and household resources, were associated with patterns of unhealthy weight within and between families. Multilevel dyadic analysis and logistic regression were conducted using survey data from a representative sample of 400 families in a Southern Indian city. We identified substantial clustering of weight among opposite-gender sibling pairs ($ICC=0.43$) and mother-child pairs, as well as important patterns of discordance, including 11% of families experiencing a dual burden of underweight and overweight. Household resources, including mother's education and income, were salient in explaining the distribution of body weight within and between families. Importantly, less examined domains of the family environment were also relevant, including food practices (e.g. grocery shopping frequency), and food-related gender norms (e.g. mother's control of food served at home). Continued exploration of how global and local practices converge in households will be necessary to develop programming that effectively addresses India's dual burden of unhealthy weight.

Keywords

India; overweight; underweight; family environment; nutrition transition; gender

1. Introduction

India, like many low and middle-income countries (LMICs), appears to be facing a dual burden of increasing obesity and persistent underweight (Patel, Narayan, & Cunningham, 2015). In 2015–16, nearly 21% of women and 19% of men ages 15–49 were overweight or obese (BMI $\geq 25\text{kg/m}^2$), while 23% of women and 20% of men were underweight (BMI $<18.5\text{kg/m}^2$) (International Institute for Population Sciences & Macro International, 2016). At the same time, approximately 38% of children under five were stunted and 21% were wasted (International Institute for Population Sciences & Macro International, 2016). The consequences of unhealthy weight are vast, ranging from individual morbidity and mortality to onerous demands on the national health care system and reduced economic productivity (Tzioumis & Adair, 2014). Increases in obesity have been attributed to India's experience of the nutrition transition, or the changes in diet and lifestyle that accompany globalization, economic development, and technological change (Popkin, 2002; Shetty, 2002; Shrimpton & Rokx, 2012). Meanwhile, other types of malnutrition, including underweight, remain prevalent, particularly in rural areas where extreme poverty persists (Caballero, 2005; Chauhan et al., 2015).

Globally, the dual burden of malnutrition has been reported at the national, regional, household, and even individual levels, most commonly in countries experiencing sustained economic growth and development (Tzioumis & Adair, 2014). India's experience of the nutrition transition has been well-documented (Popkin, 2002; Shetty, 2002), with particular attention to altered food availability, accessibility, and preferences in globally connected urban centers. Recent research has also documented awareness and consumption of 'global' foods among rural adolescents (Shaikh et al., 2016). Yet, rather than conceptualizing the nutrition transition as a process that occurs solely from above, whereby local practices fall victim to the influence of Western culture, global forces can be understood as undergoing "imaginative reconstitution" in local settings as they mingle with existing practices and norms (Ray & Srinivas, 2012). The family environment, a key site for the transmission of culture and tradition (Bengtson & Allen, 1993), is one such setting where the global and local meet.

Despite India's increasing integration into the global economy, local customs and norms continue to guide everyday life, making India an opportune setting in which to study how global and local forces may converge in the family environment to affect body weight. Obesogenic environments that accompany the nutrition transition—characterized by increased access to processed foods and beverages, and sedentary forms of labor, transportation, and leisure activities—have proliferated in India, particularly in urban areas (Misra, Singhal, et al., 2011). As a result, the distribution of unhealthy body weight within Indian families is typically understood to be a function of socio-economic position, often treated as a proxy for exposure to Western culture: obesity clusters among wealthier, more globally connected urban families, while underweight clusters among poorer, more remote rural families (Sengupta et al., 2015; Tzioumis & Adair, 2014). Yet, families exposed to similar macro-level changes may experience divergent weight-related outcomes depending on their practices, norms, and resources. In particular, family food practices have gained

increasing attention as an important correlate of weight (Rosenkranz & Dziewaltowski, 2008), and decades of research have highlighted the salience of gender norms to health in India (Fikree & Pasha, 2004; Roy & Chaudhuri, 2008; Sen, 2003). In this paper, we examine three domains of the family environment that may be relevant to body weight within families: food practices, food-related gender norms, and household resources.

In India, where undernutrition persists, research on family food practices has largely focused on factors related to malnutrition and diarrheal disease, such as breastfeeding, food safety practices, and intra-household allocation of food (Harris-Fry et al., 2017; Patel et al., 2010). In contrast, research in Western settings has focused on identifying features of the family food environment associated with obesity, such as the frequency of family dinners, the number of meals eaten outside of the home, grocery shopping patterns, and mealtime practices, such as watching television while eating (Kegler et al., 2014; Rosenkranz & Dziewaltowski, 2008). Given India's growing burden of overweight, more examination of the family food environment is warranted. One of the few studies on family food practices in India highlights the salience of widespread global influences and changing norms: among families from four urban centers, the majority of children expressed preferences for eating outside of the home, describing home meals as 'old-fashioned', and nearly half reported regularly eating evening meals in front of the television (Gulati et al., 2013).

Food-related gender norms may also shape how the family environment affects weight status. In India, gender differences in health have been attributed, in part, to a cultural preference for sons (Mishra, Roy, & Retherford, 2004; Pande & Astone, 2007). A number of studies have pointed to gender biases in nutrition and related health outcomes, which generally disadvantage girls. For example, girls under five may be more likely to suffer from malnutrition (Bose, 2011), and less likely to receive diverse diets if they are born to illiterate mothers (Borooah, 2004). However, other studies have found no evidence of gender differences in solid food consumption, dietary diversity (Fledderjohann et al., 2014), or overall dietary patterns (Kehoe et al., 2014). Other research has highlighted that birth order and number of siblings may be relevant to the nutrition of all children in a household, with the poorest outcomes among girls who have more siblings and multiple older sisters (Biswas & Bose, 2010; Mishra et al., 2004; Pande, 2003; Raj, McDougal, & Silverman, 2015). While the majority of existing research has focused on children under five, Aurino (2017) found that disparities in dietary diversity among 5–15 year olds, which largely favored boys, became particularly pronounced during mid-adolescence. Further, several recent reviews have indicated that broader societal gender norms related to women's empowerment, particularly increased autonomy, decision-making power, and control over household resources, may improve maternal and child nutrition (Cunningham et al., 2015; Vir, 2016).

The process by which global trends become integrated in the local context may result in a variety of weight patterns within families. The clustering of similar, or *concordant*, weight status among family members is well established in the literature and generally attributed to the synergistic effects of genetic and environmental factors (Classen, 2010; Elks et al., 2012). Genetic factors have been estimated to account for between 24% and 81% of inter-individual variability in body weight (Arya et al., 2002; Elks et al., 2012), and the clustering of body weight appears to be highest among siblings, followed by parent-child dyads (Maes,

Neale, & Eaves, 1997). Few studies in India have simultaneously assessed sibling and parent-child relationships. One notable example, conducted among families in New Delhi, found that adiposity was most strongly correlated among sibling pairs, and that the weight status of parents and daughters was more similar than the weight status of parents and sons (Gupta & Kapoor, 2011). In contrast, Dasgupta (1997) found that, among Mahisya families in West Bengal, weight was more strongly correlated in parent-child pairs than sibling pairs; when disaggregated by gender, correlation was highest in sister-sister pairs, followed by mother-daughter pairs.

Discordant weight status, particularly the “dual burden” of an underweight child and an overweight mother in a single household, has been studied in countries experiencing sustained economic growth (Caballero, 2005; Doak et al., 2004; Tzioumis & Adair, 2014). Dual burden households may be a transitional phenomenon that occurs as countries progress through the nutrition transition. Specifically, as income increases, lifestyles become more sedentary, and energy-dense and nutrient-poor foods are more frequently consumed; while these foods promote obesity in adults, they are nutritionally insufficient for healthy growth in children (Tzioumis & Adair, 2014). A dual burden of over- and under-nutrition can also be conceptualized over the life course. Individuals who are malnourished in utero may have a higher susceptibility to excessive weight gain due to the development of fat stores, short stature, and a preference for high-fat foods (Bateson, Gluckman, & Hanson, 2014; Shrimpton & Rokx, 2012; Yajnik, 2004).

In this study, we examined patterns of weight in families with school-going adolescents in a mid-sized city in Southern India. Through this approach, we contribute to understanding the distribution of weight within and between families and the salience of family food practices, food-related gender norms, and household resources in the context of the nutrition transition. We focus on school-age children and their primary caregivers as the determinants of diet- and weight-related health during this period have received considerably less attention compared to under five populations. Adolescence is a critical time period for the development of health behaviors and the acquisition of resources that lay the foundation for adult health, and the family remains a central structure during this period (Patton et al., 2016). This research is operationalized using a city-representative sample of co-residing mother-child pairs and opposite-gender sibling pairs to answer the following questions:

1. What is the prevalence of concordant and discordant weight within families?
2. To what extent is the weight of opposite-gender siblings similar *within* families, and what characteristics explain differences in siblings' weight *between* families?
3. Do family characteristics relate to the weight of sisters and brothers differently?
4. What are the individual and family characteristics associated with discordant weight in sister-brother pairs?
5. What are the individual and family characteristics associated with discordant and concordant weight in mother-child pairs?

2. Materials and methods

2.1. Data

Data were collected from January–April of 2012 in Vijayapura district, a largely rural district located in the State of Karnataka. Although categorized as economically underdeveloped, the district is witnessing substantial population growth (over 20% between 2001 and 2011) (Government of India, 2014) and development, in part due to the presence of several institutions of higher education and the establishment of a thermal power project. Farming and agriculture-related businesses are the district's primary source of employment. Vijayapura City, the district capital, has a population of 327,427 (Government of India, 2014), and is experiencing the growth of small-scale agricultural industries as well as large-scale industries, such as sugar and textiles (Government of India Ministry of MSME, 2011). Over the past decade, the retail food environment in Vijayapura has changed; small bakeries, roadside eateries, and grocery stores have become increasingly common. Still, in contrast to larger urban areas, traditional vegetable vendors and small kirana shops remain the primary sources of retail food availability, and multinational fast food chains and supermarkets are rare.

The Institutional Review Boards (IRB) at [institutions blinded for review] approved the study protocols.

2.1.1. Sample—The study sample is representative of school-going adolescents in Vijayapura City. Three government and three private schools were randomly selected from a list of secondary schools in the city. An equal number of boys and girls ages 13–16 years were randomly selected from each school's roster ($n = 408$). There were approximately 100 adolescents selected from one government school, 100 selected from one private school, and 50 selected from each of the four remaining schools; adolescents were interviewed at school. As one of the aims of the project was to understand whether there are systematic differences in food and physical activity access between boys and girls living in the same household, we also sampled, during subsequent home visits, the co-residing opposite-gender sibling of school-eligible age (5–19 years) who was closest in age to the primary respondent. For a multidimensional understanding of the family environment, we also interviewed the primary caregiver of the respondent during the home visit. Of the 408 adolescents initially sampled, one adolescent and three caregivers did not participate. There were 366 households in which the primary caregiver was the mother, which was of primary interest for the current study; there was an opposite-gender, school-eligible sibling residing in 201 of these households. The final analytic sample consisted of 201 sibling pairs and 567 mother-child pairs.

2.1.2. Outcome Measures—Weight was measured in kilograms to the nearest 0.1 kg using the average of two measures from a digital scale. For adolescents interviewed at school, height was measured in meters to the nearest 0.1 cm, using the average of two measures from a portable adult stadiometer. The height of mothers and siblings was measured at home using non-stretch Seca tape and the same measurement protocol.

For analyses, we calculated age- (in months) and sex-specific *BMI z-scores* ($\text{kg}/\text{meters}^2$) for children and adolescents, and *BMI* ($\text{kg}/\text{meters}^2$) for mothers. We created *weight categories*

using World Health Organization (WHO) guidelines. For children aged 5–19 years, we used the WHO growth reference for school-aged children (de Onis et al., 2007). For mothers, weight categories were created using WHO BMI cut-points (World Health Organization, 2006). Given the small number of children who were obese, we collapsed overweight and obese into one category for both children and mothers, hereafter referred to as overweight.

Using these weight categories, we created two dyad-level variables. First, a binary variable, *discordant sibling weight*, was created to indicate whether or not siblings were in one of three discordant weight pairings: overweight and normal weight; overweight and underweight (i.e. dual burden); and normal weight and underweight. Second, a multinomial variable was created to represent the most common discordant and concordant *mother-child pairings*. Concordant pairs were those where both mother and child were normal weight, underweight, or overweight. Discordant pairs were those where the mother was normal weight and the child was underweight; the mother was underweight and the child was normal weight; the mother was overweight and the child was normal weight; or the mother was overweight and the child was underweight (i.e. dual burden).

2.1.3 Covariates—Covariates covered five domains: characteristics of the child; characteristics of the mother; household resources; family food practices; and food-related gender norms. All children were asked about their gender, age, and whether they attended a government or private school. Three variables were created to describe the *sibling pairs*: whether they went to the same type (private or government) of school (yes/no), their age difference (continuous), and whether the sister or the brother was the older child in the pair (sister older vs. brother older). Characteristics of the mother were age (continuous) and education completed (lower primary school or below vs. high primary school or above). Mothers reported household social and economic characteristics: religion (Hindu vs. non-Hindu), caste (General Caste, Other Backward Castes, and Scheduled Caste/Scheduled Tribe), number of household members (continuous), and household income (<10,000 vs. 10,000 Indian rupees (INR) per month).

Several family food practices were considered. Children were asked whether they needed to ask permission from a family member before eating something at home (always or sometimes vs. never) and whether they were forced to eat more by family members during meals (yes/no). Mothers were asked whether they promised their child sweets for doing chores (yes/no); whether family meals were typically eaten in front of the television (yes/no); whether meals or snacks from outside the home were eaten at least once per week (yes/no); whether groceries were purchased at least once per week (yes/no); and whether the household was vegetarian (yes/no).

The survey included exploratory questions on gendered norms and food practices. Mothers indicated whether girls should eat less food because putting on weight will make it difficult for them to marry (completely or somewhat agree vs. disagree or strongly disagree); whether foods were prepared specifically for boys or girls according to the child's preferences (for boys only vs. for girls only, both, or neither); whether boys or girls were restricted from eating dairy, sweets, oily foods, salty foods, non-vegetarian foods, or fruits (restrictions were the same for both genders vs. restrictions differed by gender); whether there was a gendered

order to eating meals (men first vs. women first, children first, or everyone together); and whether the mother most often decided the household menu (yes/no).

2.2. Analysis

All analyses included sampling weights to account for the school-going adolescents' probability of selection. Maximum likelihood estimation with robust standard errors was used for all models to account for the clustering of children and mothers in households. Standard errors were computed using a Huber-White Sandwich Estimator with the cluster option. Missing data on covariates were handled through multiple imputations. Mplus was used to impute missing data from Bayesian estimation of the default unrestricted variance covariance model. Twenty imputed datasets were generated and analyzed using maximum likelihood estimation with robust standard errors. Parameter estimates and standard errors were then averaged across all datasets to produce final estimates; the preceding steps are automated in Mplus (Asparouhov & Muthén, 2010). All variables were missing less than 6% of observations. Variance inflation factors (VIF) were calculated to assess multi-collinearity for each model; using a cut-point of <10, we did not identify any issues (Kleinbaum et al., 1998). Descriptive statistics were calculated using SAS 9.4 (SAS Institute Inc., Cary, NC); multiple imputations, binary logistic, multinomial logistic, and multilevel dyadic models were run using Mplus 7 (Muthén & Muthén, Los Angeles, CA).

We conducted univariate analyses of each variable, assessed normality of distributions for continuous variables, and checked for outliers and influential observations. Bivariate analyses of outcomes and covariates were performed for children and mothers to assess unadjusted significance and linearity of each association. To assess the prevalence of concordant and discordant weight within families, weight status was cross-tabulated between sibling pairs and mother-child pairs, and Pearson correlation coefficients were estimated for siblings' BMI z-scores and mother's BMI-child's BMI z-score.

We conducted multilevel dyadic analysis (Kenny, Kashy, & Cook, 2006) to assess the extent to which sibling weight is similar *within* families, identify individual and family-level characteristics that explain differences in child weight *between* families, and determine whether family-level characteristics differently relate to the weight of brothers and sisters. The data have a hierarchical structure with sibling dyads nested within families, and were analyzed using multilevel modeling strategies described below. Children were the level-one unit of analysis and families were the level-two unit of analysis. Because each dyad in our analysis is comprised of one boy and one girl, we were able to create cross-level interaction terms between child's gender and family-level variables to assess whether family characteristics were differently associated with the weight of brothers and sisters.

Six sequential random intercept models were estimated to isolate the child-level effects from the family-level effects on the outcome of BMI z-score (Raudenbush & Bryk, 2002). The first, null or empty model, was used to calculate the intra-class correlation coefficient (ICC) estimating how much of the variation in child's BMI z-score was attributable to differences between households. After the null model, five consecutive models were expanded by adding groups of conceptually related variables as described above. The second model added level-one variables to identify characteristics of the child that explain between-family

variation in child's BMI z-score. The remaining models, 3–6, each added level-two variables to identify characteristics of the family that explain between-family variation in child's BMI z-score. Finally, cross-level interaction terms were added and tested for significance. Cross-level interaction terms were created between child's gender and family-level variables significantly associated with child's weight in bivariate analyses.

Model fit was assessed by proportional reduction in variance statistics for each model in comparison to the null model (Raudenbush & Bryk, 2002), which indicates how much of the variation in child weight between families is explained by the addition of a conceptual group of variables. Two proportional reduction in variance statistics were calculated to explain variance at level one (child-level) and level two (family-level); we expect to see an increasing amount of variance explained with the addition of theoretically meaningful predictors, and the deviance is expected to decrease as theoretically meaningful variables are added and model fit improves (McCoach, 2010).

Binary logistic regression was used to assess the individual and family-level characteristics associated with discordant weight status among opposite-gender siblings; multinomial logistic regression was used to assess the individual and family-level characteristics associated with discordant and concordant weight status among mother-child pairs. Less than 5% of mother-child pairs were excluded from the multinomial models because they comprised very small outcome categories which could not be collapsed with other categories on theoretical grounds: mother and child underweight; and mother underweight and child normal weight.

3. Results

3.1. Characteristics of Children and Mothers

Children were 14 years old on average, with a mean age difference between siblings of 3 years (Table 1). Approximately 45% of children were girls. The majority of children attended government schools (59%), and, among sibling pairs, the majority (70%) went to the same type of school (i.e. government or private). Mothers were 37 years old on average; less than half (45%) had completed upper primary school or above. Households consisted, on average, of 5.5 people. The majority of households were Hindu (72%). Approximately half of the population belonged to a Backward caste (55%), 26% belonged to a scheduled caste or tribe, and 19% to a General caste; 58% of households had an income of less than 10,000 INR per month (~150 USD).

The majority of children were normal weight. Boys were more often in an unhealthy weight category than girls (Figure 1): approximately 17% of girls and 29% of boys were underweight; 7% of girls and 8% of boys were overweight; and 76% of girls and 64% of boys were normal weight. In contrast to their children, the majority of mothers were overweight (26% overweight and 40% obese), 29% were normal weight, and 5% were underweight.

Table 2 shows the prevalence of discordant and concordant weight status within families. The most common patterns among siblings were concordant pairs comprised of a normal

weight sister and a normal weight brother (50%) and discordant pairs comprised of a normal weight sister and an underweight brother (23%). The next most frequent pairings were discordant pairs comprised of a normal weight brother and an underweight sister (9%), and concordant pairs where both the sister and brother were underweight (8%). There was a moderate positive correlation between the BMI z-scores of brothers and sisters ($\rho=.37$; $p<.0001$).

Among mother-child pairs, approximately half were discordant pairs comprised of an overweight mother and a normal weight child, and 17% were concordant pairs where both the mother and child were normal weight. The next most frequent pairings were discordant pairs comprised of a normal weight mother and an underweight child (11%), and dual burden pairs (11%). Every overweight child had an overweight mother. There was a moderate positive correlation between mother's BMI and child's BMI z-score ($\rho=.40$; $p<.0001$), with a stronger correlation between mothers and daughters ($\rho=.43$; $p<.0001$ daughters; $\rho=.39$; $p<.0001$ sons).

3.2. Clustering of Sibling Weight Within Households

Table 3 shows results from six sequential dyadic multilevel models with random intercepts, estimated to characterize weight patterns within and between families. The intercept of the null model was -0.9 , indicating that, on average, children were nearly one SD below the WHO-defined mean BMI z-score for children of their age and sex. The ICC indicated that a substantial portion (43%) of the variation in child BMI z-score was attributable to differences between households.

Model 2 added child-level characteristics. The BMI z-scores of girls were over a quarter of a standard deviation (SD) higher than boys, and the BMI z-scores of children who attended private school were one-third of a SD higher than children who attended government schools. Models 3–6 sequentially added the level two, or family-level characteristics. When characteristics of the mother were taken into account (Model 3), girls continued to have higher BMI z-scores than boys, but differences between children who attended private and government schools were no longer significant. For every one-point increase in mother's BMI, child's BMI z-score was 0.12 of a SD higher; this association remained consistent across all subsequent models. When accounting for family resources and socio-demographic characteristics (Model 4), children in poorer households had BMI z-scores that were nearly a quarter of a SD lower than those with an income of 10,000 INR per month or more ($p<.10$). Model 5 added family food practices. Children who reported that they were forced to eat more during meals had BMI z-scores nearly one-third of a SD lower, and children who were promised sweets for doing chores had BMI z-scores nearly one quarter of a SD higher ($p<.10$). Model 6 added food-related gender norms. In families where the mother's choices most often decided the menu for the household, child's BMI z-score was nearly a quarter of a SD higher ($p<.10$). In additional models, cross-level interaction terms between child's gender and family-level variables indicated that family-level variables were not differently associated with boys' and girls' BMI z-scores (available upon request).

The proportional reduction in variance statistics indicated that more complex models explained a greater degree of within- and between-household variance in BMI z-scores. The

between-household variance was reduced by nearly 50% from the null to the fully adjusted model. The greatest reductions were observed when characteristics of the mother (Model 3) and family food practices (Model 4) were added. The reductions appear to be explained by mother's BMI and whether children were forced to eat more during meals, both of which remained significant across all models. Deviance decreased across models, indicating improved fit.

3.3 Discordant Weight Among Sibling Pairs

While multilevel models provided evidence of significant clustering of weight among siblings, patterns of discordant weight were also present (Table 2). Binary logistic regression models were estimated where sibling discordant weight status was defined as a brother and sister in different weight categories (Table 4). Siblings whose mother had a lower primary school education or less had 47% higher odds of discordant weight status than those whose mother had more schooling ($p < .10$). Larger households were more likely to contain sibling pairs with discordant weight, with 18% higher odds of discordance for each additional household member.

3.4 Discordant and Concordant Weight Among Mothers and Children

Multinomial logistic regression models compared the odds of being in the most common mother-child weight pairings with the "ideal" category of normal-weight mother and child (Table 5). Discordant pairs in which the child was underweight and the mother was normal weight had 60% lower odds of containing girl.

The odds of a household containing a normal weight child and an overweight mother were 12% higher for each one-year increase in mother's age. Households where groceries were purchased at least once per week had 58% lower odds of containing this pairing.

Concordant pairs in which both mother and child were overweight were more likely to contain older mothers, with 11% higher odds for each one-year increase in mother's age. These pairs had 80% lower odds of belonging to a general caste, compared to a scheduled caste or tribe, and 86% lower odds of earning below 10,000 INR per month. Households in which children reported being forced to eat more by family members during meals had 76% lower odds of containing this type of pairing.

Dual burden pairs comprised of an underweight child and overweight mother had 61% lower odds of containing girls, and were more likely to contain older mothers, with 13% higher odds for each one-year increase in mother's age.

4. Discussion

We examined patterns of body weight concordance and discordance among brother-sister and mother-child pairs in a developing Southern Indian city to understand how local features of the family environment may affect body weight in the context of more recently arrived global forces that accompany the nutrition transition. Underweight and overweight were prevalent both within and between families. The distribution of body weight differed greatly between families, as evidenced by the high degree of clustering within households and the

salience of family-level characteristics in explaining these differences. Important patterns of discordance were also present within families, although we did not find evidence that features of the family environment were differently related to the body weight of brothers and sisters. Each domain of the family environment examined—food practices, food-related gender norms, and household resources—was salient in explaining patterns of body weight within and between families.

We first examined the distribution of weight categories and patterns of discordant and concordant weight within families. Among children, underweight was the primary unhealthy weight issue. Almost one third of boys and one fifth of girls were underweight, and the majority of discordant sibling pairs were comprised of an underweight brother and a normal weight sister (23%). The higher prevalence of underweight among boys is consistent with national estimates (Patel et al., 2015), yet the factors underlying this difference require research. One study, conducted in Northeast India, suggested that boys experience higher chronic energy deficiency than girls due to a combination of greater energy expenditure and higher susceptibility to infection and food scarcity (Khongsdier, Varte, & Mukherjee, 2005). Similar to national estimates, we did not find gender differences in the prevalence of overweight (Patel et al., 2015).

The strikingly high prevalence of overweight and obesity among mothers (66%) is consistent with evidence for the emergence of overweight in less developed Indian states (Sengupta et al., 2015). Our estimates were much higher than India's most recent National Family Health Survey, which reported that 31.8% of urban women ages 15–49 in the State of Karnataka were overweight or obese (International Institute for Population Sciences & Macro International, 2016). This may be due, in part, to the fact that the women in our study, as mothers of adolescents, are at the point in the lifespan when weight tends to peak due to factors such as parity-related weight gain (Jehn & Brewis, 2009).

Notably, every overweight child had an overweight mother, consistent with research indicating that intergenerational correlation of weight is particularly strong at high levels of BMI (Classen, 2010). At the same time, the 11% prevalence of the dual burden is on the higher end of regional estimates, which range from approximately 4% in rural Bangladesh to 11% in rural Indonesia (Oddo et al., 2012). These findings underscore that the dual burden is no longer solely an urban phenomenon and may be shifting to more interior regions of society. Despite discordance between mothers and children, BMI was still moderately correlated ($\rho = .40$), similar to results found among children and their parents in Karnataka and Andhra Pradesh ($\rho = .35$) (Swaminathan et al., 2013). In contrast to previous research, the correlation between siblings was slightly weaker ($\rho = .37$) than between mothers and children (Gupta & Kapoor, 2011).

Secondly, we assessed the degree to which children's weight was clustered *within* households and the individual- and family-level characteristics that explained differences in children's weight *between* households. Nearly half of the variation in BMI z-score was attributable to differences between households (ICC = 0.43). This is comparable to, but higher than, findings on the clustering of weight among siblings in Maharashtra, Tamil Nadu, and Uttar Pradesh (ICC = .33, .29, .33, respectively) (Griffiths, Matthews, & Hinde,

2002). We did not find evidence that features of the shared family environment were differently related to brothers and sisters, indicating that gender differences in weight observed in the full population of school-going adolescents are likely due to differences between families, rather than differential treatment of boys and girls within families. Indeed, *between*-household variation in child's BMI z-score was reduced by nearly 50% when family-level characteristics were added to the models.

All domains of the family environment were associated with children's weight in dyadic multilevel models. As the mean weight for boys and girls across households was nearly one SD below the WHO-defined mean BMI z-score, the higher weight of girls underscores their generally healthier weight and supports the need for additional research on gender and body weight during adolescence. Mother's BMI was also positively associated with child's weight across all models. Previous research from regional Indian samples has identified significant positive associations between the weight of mothers and children, pointing to genetic and environmental factors such as shared diets and eating habits (Gulati et al., 2013; Gupta & Kapoor, 2011). Accordingly, the greatest reduction in *between*-household variation in child's BMI z-score occurred when characteristics of the mother were added to the model.

With regard to household resources, boys and girls who attended private school weighed more than children who attended government schools, and children living in lower income households weighed less than children living in higher income households. This socio-economic patterning of body weight has been identified in previous studies in India; higher prevalence of overweight among private school students has been attributed to greater access to packaged snacks and fast foods, inactive commuting to school (e.g. by car or bus), and limited chores, which are instead performed by servants (Misra, Shah, et al., 2011).

Food practices and gender norms were also salient to children's weight status. Children who were forced to eat more during meals had significantly lower BMI z-scores than those who were not. Children who are perceived to be thin may be pushed to eat more as a result of the belief that "a fat child is a healthy child" (Raychaudhuri & Sanyal, 2012). Pressure to eat and its association with weight has primarily been studied in developed countries; while some studies have shown positive associations between pressure to eat and child weight gain, others have identified inverse associations (Clark et al., 2007). Children who were promised sweets for doing chores had significantly higher BMI z-scores. The use of food as a reward may be associated with obesogenic eating behaviors, including higher preference for the reward foods and the promotion of emotional eating in the absence of hunger (Rodgers et al., 2013). Additional research on these practices, including their motivations and health consequences, is needed in lower- and middle-income countries where child underweight remains prevalent and child overweight is increasing. Regarding family gender norms, children had significantly higher BMI z-scores when their mothers decided the menu. Previous research from India and other South Asian countries has reported less underweight in households where mothers have more control over household resources and decision-making, as mothers tend to allocate more resources toward food and ensure its equitable distribution (Cunningham et al., 2015).

Despite evidence of substantial clustering of weight among brothers and sisters, weight discordance was present. Consistent with previous literature, we found that larger families and mothers with lower educational attainment were more likely to have opposite-gender siblings in different weight categories. Larger and poorer households may have insufficient resources to feed all household members, resulting in unequal distribution of resources between siblings (Kumar & Ram, 2013; Pande, 2003). Further, mother's education, a marker of socio-economic status, is related to knowledge of and access to practices and programs that improve child nutrition (Smith & Haddad, 2015).

Our final research question examined predictors of weight patterns among mother-child pairs, the majority of which were discordant in weight. Overall, characteristics were more predictive of the individual weight of each pair member than of the pair as a whole. For example, older maternal age was associated with pairs in which the mother was overweight, regardless of child's weight. Similarly, girls were less likely to be in pair types where the child was underweight, regardless of mother's weight. Consistent with previous research on the dual burden, we did not observe any characteristics that were uniquely associated with dual burden pairs, underscoring that the phenomenon is largely driven by its component parts (Dieffenbach & Stein, 2012). In addition to the socio-economic patterning of weight pairings, family food practices were salient. Compared to households in which both mother and child were normal weight, households where the child was normal weight and the mother was overweight were less likely to shop for groceries weekly. Less healthy dietary patterns have been associated with less frequent grocery shopping in Western settings, as healthier foods, such as fruits and vegetables, are typically more perishable and thus require more frequent purchase (Gustat et al., 2015). In this setting, it is likely that poorer families shop more frequently because they are only able to afford small amounts of food during each shopping trip. Further research is needed to explore how shopping frequency is associated with diet and weight in poorer settings.

This study is subject to several limitations. First, we were unable to compare different types of concordance and discordance among sibling pairs due to sample size limitations. Future research should consider different types of unhealthy weight pairings among siblings, as well as include same-gender sibling and father-child pairs. Second, while the measures used to assess gender norms were developed using formative research in this population, they were exploratory and may not capture the full range of relevant practices. It is also possible that gender differences in food practices may be relevant to dietary diversity or micronutrient adequacy but not body weight. Marcoux (2002) suggested that nutrition-related disadvantages among girls may not be consistently identified due to their occurrence in specific circumstances; for example boys and girls born after multiple siblings of their gender experience poorer nutrition during the first 5 years of life, while boys born after multiple girls experience the best nutritional outcomes (Pande, 2003). We cannot explore this possibility in the present study, as we did not collect birth histories from mothers. Another consideration is that different types of equipment were used to measure height in participants measured at school versus at home due to the different types of flooring in each setting and the need to have portable field equipment. Our results are only generalizable to Vijayapura's population of school-going adolescents. Finally, the study was cross-sectional

and causal inference between features of the family environment and patterns of unhealthy weight is not possible.

4.1. Conclusions

Programs and policies designed to address unhealthy weight should consider the coexistence of underweight and overweight at the household and community levels. This will require moving beyond the notion that overweight is a wealthy, urban problem while underweight is a poor, rural problem, toward greater consideration of influences on body weight at multiple levels of the social ecology. Features of the family environment, including family food practices, food-related gender norms, and household resources were salient in explaining the distribution of body weight within and between families. Over the past decade, the development of obesity prevention programs targeting the family food environment in Western settings has increased, and research to identify effective and sustainable intervention strategies continues. As India progresses through the nutrition transition, the adaptation of such interventions, with particular attention to the ways in which global and local forces converge in households, may prove beneficial.

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Figure 1.

Weight status of mothers and children in Vijayapura, India

Note. All results are survey adjusted. For siblings 19 years of age, weight status calculated from age and gender-specific BMI (kg/meters²) z-scores.

Table 1

Characteristics of mothers and children in Vijayapura, India

	% or Mean	SE
<i>Child characteristics (n=567)</i>		
Child's age	13.94	0.16
Age difference between sibling (years) ^a	2.92	0.14
School type		
Private	40.93	14.57
Public	59.07	14.57
Siblings go to different school type ^a	30.22	4.39
Siblings go to same school type ^a	69.78	4.39
Gender		
Girl	45.42	1.39
Boy	54.58	1.39
<i>Mother characteristics (n=366)</i>		
Mother's age	37.13	0.35
Mother's education		
Lower primary or below	54.85	4.68
High primary or above	45.15	4.68
<i>Household socio-demographic characteristics (n=366)</i>		
Size of family	5.46	0.34
Religion		
Hindu	72.29	6.81
Non-Hindu	27.71	6.81
Caste		
General caste	19.25	2.50
Backward caste	55.04	4.42
Scheduled caste/tribe	25.71	3.60
Income		
<10,000 INR	57.48	4.11
10,000 INR	42.52	4.11

Note. All results are survey adjusted.

^a n=201; restricted to sibling pairs

Table 2

Distribution of body weight within families

Boy sibling				
	Underweight	Normal weight	Overweight/obese	Total
Girl sibling				
Underweight	8.17	9.19	0.31	17.67
Normal weight	23.35	49.7	3.16	76.21
Overweight/obese	0.23	4.48	1.41	6.12
Total	31.74	63.37	4.89	100
$\rho=.37^{***}$				
Girl-boy sibling pairs n=201				
Mother				
	Underweight	Normal weight	Overweight/obese	Total
Child				
Underweight	2.38	10.63	10.53	23.55
Normal weight	2.03	17.47	49.8	69.31
Overweight/obese	0	0	7.14	7.14
Total	4.42	28.1	67.48	100
$\rho=.40^{***}$ (Mother-girl child $\rho=.43^{***}$; Mother-boy child $\rho=.39^{***}$)				
Mother-child pairs n=567				

Note. All results are survey adjusted. Table displays overall percentages ρ indicates correlation coefficient between the BMI (body mass index)/BMI z-score (for age 19 years) of the two family members

 $p < .0001$.

Table 3

Individual and family-level predictors of children's BMI z-score

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Fixed effects						
Intercept	-0.88 ***	-1.30 **	-4.13 ***	-3.63 ***	-3.30 ***	-3.24 ***
Level 1 (n_{child}=567)						
<i>Child characteristics</i>						
Child's Age		0.01	-0.01	-0.01	-0.01	-0.01
School type (reference = public)						
Private		0.33 **	0.09	0.05	0.05	0.07
Gender (reference = boy)						
Girl		0.27 **	0.28 **	0.29 **	0.28 **	0.27 **
Level 2 (n_{family}=366)						
<i>Mother characteristics</i>						
Mother's BMI			0.12 ***	0.11 ***	0.11 ***	0.11 ***
Mother's age			0.01	0.004	0.005	0.001
Mother's education (reference = high primary or above)						
Lower primary or below			-0.08	-0.07	-0.03	-0.03
<i>Household resources</i>						
Household size				-0.03	-0.02	-0.02
Religion (reference = Hindu)						
Non-Hindu				0.07	0.02	0.03
Caste (reference = scheduled caste/tribe)						
General						
Backward caste				-0.23	-0.19	-0.09
Income (reference = 10,000 INR)				0.03	0.04	0.06
<10,000 INR				-0.23 †	-0.20	-0.22 †
<i>Family food practices</i>						
Child needs to ask permission to eat (reference = never)						
Always/sometimes					0.06	0.06

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Child promised sweets					0.22 [†]	0.15
Child forced to eat more					-0.31 ^{**}	-0.33 ^{**}
Household is vegetarian					-0.07	-0.09
Household purchases groceries 1/week					-0.26	-0.24
Meals typically eaten in front of television					-0.07	-0.07
Family eats outside of home 1/week					-0.08	-0.05
<i>Family gender norms</i>						
Mother decides menu for household						0.24 [†]
Special food by gender (reference = girls or both)						
Boys get special food						0.03
Gendered order to eating (reference = women or no order)						
Men eat first						-0.18
Food restrictions do not differ by gender						-0.12
Belief that girls need to keep off weight for marriage						0.24
Random effects						
τ_{00} (intercept)	0.83 ^{***}	0.82 ^{***}	0.54 ^{***}	0.52 ^{***}	0.46 ^{***}	0.43 ^{***}
σ^2	1.11 ^{***}	1.08 ^{***}	1.07 ^{***}	1.06 ^{***}	1.07 ^{***}	1.08 ^{***}
Model fit						
Reduction in τ_{00}		2%	35%	37%	45%	49%
Reduction in σ^2		3%	4%	4%	2%	2%
Deviance	1946.23	1931.69	1852.83	1845.88	1832.65	1824.30

Note. All results are survey adjusted.

[†] p<.10;
^{*} p<.05;
^{**} p<.01;
^{***} p<.0001

Table 4

Odds of discordant weight status among opposite gender siblings (n=201)

	OR	95% CI	
<i>Child characteristics</i>			
Age difference	0.96	0.85	1.09
School type (reference = siblings go to same school type)			
Siblings go to different school type	1.10	0.47	2.58
Sibling pair type (reference = brother is older)			
Sister is older	0.93	0.64	1.34
<i>Mother characteristics</i>			
Mother's age	1.05	0.94	1.18
Mother's education (reference = high primary or above)			
Primary or below	1.47 [†]	0.94	2.28
<i>Household resources</i>			
Size of family	1.18 ^{**}	1.07	1.30
Religion (reference = Hindu)			
Non-Hindu	0.62	0.27	1.44
Caste (reference = scheduled caste/tribe)			
General caste	1.26	0.51	3.14
Backward caste	0.79	0.25	2.53
Income (reference = 10,000 INR)			
<10,000 INR	1.37	0.79	2.38
<i>Family food practices</i>			
Child promised sweets	0.72	0.30	1.73
Household is vegetarian	0.59	0.24	1.44
Household purchases groceries 1/week	1.24	0.52	2.97
Meals typically eaten in front of television	1.02	0.47	2.23
Family eats outside of home 1/week	1.08	0.82	1.42
<i>Family gender norms</i>			
Mother decides menu for household	1.28	0.67	2.43
Special food by gender (reference = girls or both)			
Boys get special food	1.06	0.55	2.06
Gendered order to eating (reference = women or no order)			
Men eat first	0.80	0.21	3.02
Food restrictions do not differ by gender	1.16	0.66	2.04
Belief that girls need to keep off weight for marriage	1.00	0.36	2.84

Note. All results are survey adjusted.

[†] p<.10

* p<.05;

** p<.01;

p<.0001

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Table 5

Odds of weight status pairings among mothers and their children (n=546)

	Child underweight/mother normal weight ^a		Child normal weight/mother overweight/obese ^a		Both mother/child overweight/obese ^a		Dual burden (mother overweight/obese, child underweight) ^a					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI				
<i>Child characteristics</i>												
Child's age	1.03	0.85	1.24	0.96	0.85	1.10	0.91	0.76	1.08	1.06	0.89	1.25
School type (reference = public)												
Private	0.88	0.35	2.22	1.68	0.79	3.54	2.23	0.77	6.46	1.03	0.38	2.82
Gender (reference = boy)												
Girl	0.40 *	0.19	0.82	0.81	0.55	1.20	0.72	0.36	1.46	0.39 **	0.21	0.74
<i>Mother characteristics</i>												
Mother's age	1.03	0.94	1.12	1.12 **	1.05	1.20	1.11 *	1.02	1.20	1.13 **	1.04	1.22
Mother's education (reference = high primary or above)												
Lower primary or below	1.42	0.65	3.15	1.58	0.76	3.30	1.25	0.45	3.47	1.68	0.67	4.22
<i>Household resources</i>												
Size of family	1.04	0.92	1.17	0.95	0.83	1.09	0.94	0.81	1.10	1.07	0.90	1.26
Religion (reference = Hindu)												
Non-Hindu	1.33	0.41	4.33	0.51	0.21	1.27	0.81	0.25	2.64	0.43	0.13	1.37
Caste (reference = scheduled caste/tribe)												
General caste	0.74	0.20	2.70	0.59	0.20	1.73	0.20 *	0.04	0.99	1.01	0.25	4.09
Backward caste	0.62	0.17	2.23	1.18	0.45	3.11	0.71	0.19	2.70	1.34	0.37	4.82
Income (reference = 10,000 INR)												
<10,000 INR	0.72	0.28	1.88	0.81	0.35	1.84	0.14 **	0.04	0.45	0.58	0.21	1.64
<i>Family food practices</i>												
Child needs to ask permission to eat (reference = never)												
Always/sometimes	0.83	0.35	1.97	1.19	0.66	2.14	1.07	0.44	2.59	0.93	0.41	2.11
Child promised sweets	1.12	0.45	2.78	1.77	0.83	3.76	1.76	0.59	5.27	0.87	0.31	2.46
Child forced to eat more	1.11	0.44	2.75	0.98	0.54	1.77	0.24 **	0.10	0.59	1.00	0.45	2.22
Household is vegetarian	0.69	0.27	1.76	0.67	0.32	1.38	0.56	0.21	1.54	0.72	0.28	1.81

	Child underweight/mother normal weight ^a		Child normal weight/mother overweight/obese ^a		Both mother/child overweight/obese ^a		Dual burden (mother overweight/obese, child underweight) ^a	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Household purchases groceries 1/week	1.01	0.45 2.24	0.42*	0.20 0.86	0.47	0.13 1.62	0.91	0.35 2.35
Meals typically eaten in front of television	1.30	0.56 3.03	1.33	0.69 2.58	0.76	0.30 1.95	1.54	0.61 3.87
Family eats outside of home 1/week	1.24	0.44 3.49	0.98	0.47 2.06	1.35	0.52 3.47	1.45	0.56 3.78
<i>Family gender norms</i>								
Mother decides menu for household	0.49	0.20 1.16	0.61	0.28 1.32	0.81	0.26 2.52	0.53	0.21 1.35
Special food by gender (reference = girls or both)								
Boys get special food	1.09	0.46 2.62	0.54	0.22 1.33	1.19	0.22 6.35	0.58	0.14 2.47
Gendered order to eating (reference = women or no order)								
Men eat first	1.31	0.56 3.10	0.88	0.40 1.90	0.57	0.18 1.85	0.67	0.23 1.93
Food restrictions do not differ by gender	0.87	0.30 2.53	1.37	0.54 3.53	1.12	0.34 3.67	1.55	0.42 5.74
Belief that girls need to keep off weight for marriage	0.47	0.10 2.25	1.34	0.47 3.83	2.41	0.68 8.60	1.89	0.54 6.63

Note. All results are survey adjusted and account for clustering of children within households. N does not equal full sample size due to exclusion of mother-child pairs that comprised small outcome categories (n=21).

^a Reference category = both mother/child normal weight

† p<.10;

* p<.05;

** p<.01;

*** p<.0001