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Geography of underweight and overweight among women in India: A multilevel analysis of 3204 neighborhoods in 26 states

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Abstract

We investigated the geographic distribution and the relationship with neighborhood wealth of underweight and overweight in India. Using multilevel modeling techniques, we calculated state-specific smoothed shrunken state residuals of overweight and underweight, neighborhood and state variation of nutritional status, and the relationships between neighborhood wealth and nutritional status of 76,681 women living in 3204 neighborhoods in 26 Indian states. We found a substantial variation in overweight and underweight at the neighborhood and state levels, net of what could be attributed to individual-level factors. Neighborhood wealth was associated with increased levels of overweight and decreased levels of underweight, and was found to modify the relationship between personal living standard and nutritional status. These findings suggest that interventions to address the double burden of undernutrition and overnutrition in India must take into account state and neighborhood characteristics in order to be successful.

Keywords

Overweight; Underweight; Context; Neighborhood; Socioeconomic status; India

1. Introduction

Nutritional status is an important influence on health, with poor nutrition accounting for 12% of all deaths and 16% of all disability-adjusted life years lost globally (Murray and Lopez, 1997). While malnutrition encompasses a number of maladies, including micronutrient deficiencies, the most prevalent nutrition-related outcomes are those related to total energy intake, namely undernutrition, defined as having a body mass index (BMI) of less than 18.5 kg/m^2, and overnutrition, defined as having a BMI greater than or equal to 25 kg/m^2 (Shetty and James, 1994; WHO, 2003, 2000). Nutritional status, however, is unevenly distributed both within and between countries (Mendez et al., 2005; Monteiro et al., 2004). In developed countries, for instance in the United States, overweight and obesity disproportionately impact those having low incomes, having low education levels, and belonging to minority race/ethnicity (Drewnowski and Specter, 2004; USDHHS, 2001; Mokdad et al., 2003). In developing countries, such as India, nutritional status is related to levels of education, standard of living, and social status such that undernutrition is associated with low individual socioeconomic status (SES) and overnutrition is associated with high SES (Shukla et al.,

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2002; Subramanian and Davey Smith, 2006; Griffiths and Bentley, 2005; Osmani and Sen, 2003).

Although the social distribution of nutritional status is relatively well-described, the geographic distribution of nutritional status has received less empirical attention. In developed nations, the role of macro residential context, in recent years, has been implicated as a potential determinant of individual health status (Kawachi and Berkman, 2003; Kawachi and Subramanian, 2007), including nutritional status. For instance in the United States, southeastern and north-central regions of the country exhibit higher levels of obesity than the northeast or west even after accounting for individual-level socioeconomic and demographic characteristics (Mokdad et al., 2003, 1999). At the neighborhood level, obesity in the United States is associated with living in neighborhoods that have a high prevalence of residents living in poverty, even after accounting for one's own SES (Mobley et al., 2006; van Lenthe and Mackenbach, 2002; Do et al., 2007). While this line of research is relatively new, initial investigations suggest that this relationship may be due in part to the lack of healthy food options in these neighborhoods that promote "obesogenic" eating patterns (Cummins and Macintyre, 2006; Ulijaszek, 2007) or to urban design characteristics that discourage physical activity (Booth et al., 2005).

The distinction between "contextual" and "individual" influences is complex. Underweight, overweight, and BMI are conceptualized as a function of individual characteristics since contextual characteristics cannot affect health unless the individual interacts with the environment in some way. To that extent any place variation is seen to be an artifact of the distribution of these individual factors (Subramanian, 2004; Subramanian et al., 2007a, 2003). Moreover, the individual influences that explain a contextual effect are simply mediators of the true effect of the environment on health (Subramanian, 2004; Subramanian et al., 2007a, 2003). Adding to this complexity is the fact that individual characteristics may interact with contextual characteristics such that a particular environment may be detrimental to the health of some individuals but benign or even beneficial to others. In this study, we test the extent to which neighborhoods and states influence nutritional status independent of individual factors.

While investigations pertaining to the role of neighborhood environment are emerging in the context of developed countries, we are not aware of any corresponding research in the context of developing countries that has systematically investigated the extent to which there are independent influences of neighborhood environments on nutritional status. To address this shortcoming in the existing literature we use a large, nationally representative dataset of women in India to investigate the geographic distribution of nutritional status, as measured by BMI (WHO, 2004, 1995), at the levels of neighborhoods and states, after accounting for individual-level factors associated with nutritional status. Additionally, to directly assess the role of states and neighborhoods in influencing the twin burden of over-and undernutrition in India, we also analyze the geographic patterning of the risk of being overweight and underweight.

2. Methods

2.1. Data

We utilized the 1998–1999 Indian National Family Health Survey (NFHS; available at http://www.nfhsindia.org), a nationally representative cross-sectional study of 92,447 households administered to investigate maternal and child health outcomes (IIPS and ORC-Macro, 2000).[1] Trained data-collectors interviewed an adult member in each selected household to obtain socioeconomic and demographic information about the household and its

[1]IIPS is the International Institute for Population Sciences.

family members, obtaining a household response rate of 98%. From these households, the data-collectors interviewed 90,303 ever-married women aged 15–49 in face-to-face interviews obtaining a response rate of 96%. We excluded 6508 women who were pregnant during the survey and 6200 women for whom plausible anthropometric measurements were not obtained. An additional 914 women who were missing information for covariates considered in this analysis were excluded, yielding a final analytic sample of 76,681 women. These women were located in 3204 primary sampling units in the 26 Indian states. In rural areas, these primary sampling units were villages or village clusters which are autonomous self-governing political units. In urban areas the primary sampling units were census enumeration districts which were created to be as demographically homogenous as possible. As political autonomy and demographic homogeneity provide a theoretical foundation for investigating the effect of these areas above and beyond that provided by geographic proximity, for the purposes of this study we operationalized the primary sampling unit as one realization of an individual's neighborhood context.[2]

2.2. Outcome

Women were weighed using a solar-powered scale accurate to within 100 g, and height was measured using an adjustable measuring board designed to provide measurements in a field situation accurate to within 1 mm (IIPS and ORC-Macro, 2000). Body mass index was calculated in terms of kilograms per meter squared. Clinically relevant categories for underweight, normal weight, and overweight were created with the following respective cut-off points: <18.5, 18.5–24.9, and ≥25 kg/m^2. While the World Health Organization (WHO) suggests that these cut-off points for nutritional status may have different clinical implications among Asian populations than they do among Caucasian populations, the organization asserts that the recommended cut-off points still provide important guidelines in these populations (WHO, 2004). Additionally, the results presented in this study do not substantially change if we adopt a more detailed classification of BMI as used in recent empirical studies on India (Subramanian and Davey Smith, 2006).

2.3. Individual-level covariates

For the multivariable analysis, we included several demographic, socioeconomic, and behavioral variables that included urban-rural status, age, religion, marital status, social caste, standard of living, employment status, education, number of children birthed, affliction by a major illness, use of oral contraceptives, tobacco chewing, tobacco smoking, and alcohol drinking (Table 1). Information from the 1991 Indian National Census was used to create categories defining whether each neighborhood was in an urban area of over one million people (large city), an urban area of between 100,000 and one million people (small city), an urban area of less than 100,000 people (town), or a rural area (village). Rural areas are defined as having at least 1 of 3 characteristics: (1) fewer than 5000 residents, (2) population density less than 1000 per square mile, or (3) at least 25% of the adult male population being employed in agriculture. Age ranged from 15 to 49 and was specified in five year categories. Religion was grouped into the categories of Hindu, Muslim, Christian, Sikh, or other. Marital status was classified as married, widowed, or divorced/separated. Caste was based on the identification of the head of the household as belonging to a scheduled caste, scheduled tribe, other backward class, or the general class, classifications which have been discussed elsewhere (Subramanian et al., 2006). Briefly, scheduled castes are those consisting of members in the lowest level of the caste system that have suffered the greatest burden of social and economic deprivation. Scheduled tribes consist of approximately 700 officially recognized social groups that are historically characterized by their geographic isolation and limited social and economic

[2]Details of this study were approved by the Harvard School of Public Health Institutional Review Board Human Subjects Committee.

interaction with the rest of India. Other backward class is a legislatively defined group representing those who have historically suffered significant social deprivation, but not as severe as that endured by scheduled castes and tribes. The general class is thus a default group encompassing those who are not members of historically marginalized castes. Standard of living was defined in terms of living environment, and material possessions is a reliable and valid measure of household material well-being or wealth (Filmer and Pritchett, 2001). Each person was assigned a standard of living score that was based on a linear combination of the scores for 78 different household characteristics, such as the quality of the home, the type of fuel used for cooking, and the ownership of a bicycle or television, that were weighted according to a factor analysis procedure and standardized with a mean of 0 and a standard deviation of 1 (Rutstein and Johnson, 2004;Gwatkin et al., 2000). The analytic models used quintiles of these weighted scores. Employment was classified according to whether the women was not working, performing unpaid work, or working for pay in a manual, non-manual, or agricultural profession. Educational attainment of the women was specified as a categorical variable with each category representing significant milestones in the formal education system: 0 years, 1–5 years, 6–8 years, 9–10 years, 11–12 years, or 13 or more years. Number of children born included all live births, regardless of whether or not the children were alive at the time of the survey, and was categorized as 0, 1, 2, 3, or 4 or more births. A person was considered to be suffering from a major illness if they reported suffering from tuberculosis at the time of the survey, from malaria in the previous 3 months, or from jaundice in the previous 12 months. A woman was considered to be using oral contraceptives, chewing tobacco, smoked tobacco, or alcohol if she reported engaging in these activities at the time of the survey.

2.4. Neighborhood-level predictor

We included a neighborhood wealth variable to capture the level of socioeconomic status of people's residential context. Neighborhood wealth was calculated by averaging the weighted continuous household wealth scores by neighborhood and operationalized in tertiles.

2.5. Statistical analysis

Multilevel models (Goldstein, 2003; Raudenbush and Bryk, 2002), were estimated to distinguish the individual-, neighborhood-, and state-level sources of variation in nutritional status. The substantive and technical relevance of multilevel models to partitioning such variation is well described (Blakely and Subramanian, 2006; Subramanian, 2004; Subramanian et al., 2003). We estimated both linear models using BMI as a continuous measure as well as multinomial logistic models to model the risk of being underweight and overweight.

Three-level models were estimated, with a continuous response, BMI (y), for individual i living in neighborhood j in state k. The outcome y_{ijk} was related to a set of individual predictors, X, and a random effect for each level as $y_{ijk} = \beta_0 + \beta X + v_{0k} + u_{0jk} + e_{0ijk}$. The predictor on the right-hand side of the equation consisted of a fixed part ($\beta_0 + \beta X$) estimating the conditional coefficients for the individual compositional variables, and three random effects attributable to individuals (e_{0ijk}), neighborhoods (u_{0jk}), and states (v_{0k}), with each assumed to have an independent and identical distribution and variances (σ^2_{e0}, σ^2_{u0}, and σ^2_{v0}, respectively) estimated at each level. We also estimated the smoothed shrunken state residuals[3] which represent the difference between the state mean and the national mean after accounting for the variance and

[3]"Smoothed" or "shrunken" residuals are different from raw residuals in that account is taken of the reliability factor (i.e., the number of lower level units within each higher unit). At the state level, these residuals were calculated as:
$V'_{0k}=\{\sigma^2/(\sigma^2+[\sigma^2_{u0}/n_k]+[\sigma^2_{e0}/n_{jk}])\} \times V_k$, where V'_{0k} is the shrunken residual, σ^2_{v0} is the state level variance, σ^2_{u0} is the neighborhood level variance, σ^2_{e0} is the variance between individuals, n_k is the number of neighborhoods in state k, n_{jk} is the number of individuals in neighborhood j in state k, and V_k is the raw residual for state k. For more details see Goldstein (2003) and Subramanian et al. (2007a).

the number of individuals in each state (Goldstein, 2003). These residuals were estimated from two models: a null variance component model (with no individual predictor variables in the fixed part), and a variance component model with individual compositional variables specified in the fixed part of the model, as indicated above. The standard errors of these state residuals estimates were used to determine whether the estimates were significantly different from the national mean (Goldstein, 2003). Estimates reported from the linear models are maximum likelihood based using the Iterative Generalized Least Squares algorithm as implemented within MLwiN (Rasbash et al., 2005).

Categorical BMI data was analyzed using multinomial multilevel modeling procedures (Goldstein, 2003). Three-level models were estimated with a multinomial response (*y*, underweight, normal weight, overweight) for individual *i* living in neighborhood *j* in state *k*. The probability π_{ijk} of being in response level *s* (overweight or underweight) given reference category *t* (normal weight) was related to a set of categorical predictors, *X*, and a random effect for each level, by a logit-link function as log $(\pi_{ijk}^{(s)}/\pi_{ijk}^{(t)}=\beta_0^{(s)}+\beta X^{(s)}+v_{0k}^{(s)}+u_{0jk}^{(s)}$. The linear predictor on the right-hand side of the equation consisted of a fixed part $(\beta_0^{(s)}+\beta X^{(s)})$ estimating the conditional coefficients for the individual variables, and two random intercepts attributable to neighborhoods $(u_{0jk}^{(s)})$ and states $(v_{0k}^{(s)})$, with each assumed to have an independent and identical distribution and variance $(\sigma_{u0}^{(s)2}$ and $\sigma_{v0}^{(s)2})$ estimated for each non-normal weight outcome response level (underweight and overweight) at each higher contextual level (neighborhoods and states). The strength of these variance estimates was compared to their standard errors to determine whether each outcome response category varied at each higher contextual level. Besides the variance estimates for overweight and underweight, each higher contextual level also contained a covariance estimate in the random part which described the relationship between overweight and underweight at the respective contextual level, neighborhoods or states. We also estimated the smoothed shrunken state-level residuals for the log odds of both underweight and overweight from a null variance component model, and from a variance component model with the individual compositional variables specified in the fixed part of the model (Goldstein, 2003). The multilevel logistic multinomial models estimates were based on penalized quasi-likelihood approximation with 2nd order Taylor linearization, as implemented within MLwiN (Goldstein and Rasbash, 1996; Rasbash et al., 2005).

3. Results

3.1. Patterning of BMI, overweight, and underweight

The mean BMI for the sample was 20.6. Approximately, 32% of the women in the sample were underweight and 12.3% were overweight. The variation between states was evident in the wide range of state mean BMI with low BMI in Orissa (19.3) and Bihar (19.4) and high BMI in Punjab (23.1) and New Delhi (23.6). The variation within states was apparent in the substantial standard deviation of BMI within each state, which ranged from a low of 2.3 in Arunachal Pradesh to a high of 4.9 in Punjab. The distribution of neighborhood mean BMI also showed substantial variation within and between states with the standard deviation in neighborhood mean BMI ranging from 0.96 in Bihar to 2.5 in Maharashtra (Fig. 1). The mean neighborhood BMI ranged from 19.4 in Orissa to 23.8 in New Delhi (Fig. 2).

In models that did not adjust for the individual variables, state and neighborhood effects accounted for significant proportions of the variation in BMI, underweight, and overweight, respectively (Table 2). In the unadjusted models, states accounted for 7.1%, 7.3% and 11.3% of the total variation, and neighborhoods accounted for 15.7%, 8.6%, and 17.3% of the total variation in BMI, underweight, and overweight, respectively. Although the proportion of total variation attributed to context declined after adjusting for all the individual variables, variation at the state and neighborhood levels for all three outcomes remained highly statistically significant ($p < 0.001$), suggesting a high degree of clustering within neighborhoods based on individual-level covariates. In the models adjusted by individual variables, states accounted for 2.1%, 5.7% and 4.0% of the total variation, and neighborhoods accounted for 4.9%, 5.3%, and 3.8% of the total variation in BMI, underweight, and overweight, respectively. Thus, this adjustment by all individual variables reduced the variability in underweight by 26% and 40%, and reduced the variability in overweight by 73% and 83% at the state and neighborhood levels, respectively. The inclusion of the household standard of living alone to the null model explained 94% of the between-state variation and 89% of the between-neighborhood variation in BMI.

3.2. Geography of BMI

Fig. 3 shows the state-specific residuals in BMI before and after accounting for individual compositional factors. States with the highest BMI in unadjusted models (e.g., Punjab, New Delhi), as well as those states with the lowest BMI in the unadjusted models (e.g., Orissa, Bihar), had the most substantial attenuation toward the national mean. Adjusting for sociodemographic characteristics changed the signs of the residuals in several states, such as Goa, whose mean BMI was significantly above the national average before adjusting, but was below the national average after accounting for individual characteristics. Additionally, the adjusted models revealed significant contextual effects in a few states that had been hidden in the unadjusted models, such as Arunachal Pradesh and Tamil Nadu which had adjusted mean BMI significantly higher than the national average, and Mizoram and Gujarat which had adjusted mean BMI significantly lower than the national average.

3.3. Geography of underweight and overweight

Fig. 4 presents the state-specific residuals for the risk of being underweight. Orissa and Karnataka had the highest unadjusted underweight residuals, while Gujarat and Maharashtra had the highest underweight residuals after adjusting for individual covariates. Arunachal Pradesh and Sikkim had the lowest underweight residuals in both the unadjusted and adjusted models. For most states the effects in the adjusted models were attenuated toward the national mean. For example, while underweight residuals in New Delhi and Punjab were significantly lower than the national mean, and those in Goa and Himachal Pradesh were significantly higher than the mean, none of these states were different from the national mean in the adjusted model. There were, nonetheless, several exceptions, such as Assam and Meghalaya which had significantly lower underweight residuals than the national average in adjusted models, and Himachal Pradesh and Goa which had overweight residuals significantly higher than that of the national average in adjusted models, none of which were significant in unadjusted models.

There was also a wide variation in state overweight residuals (Fig. 5). While New Delhi and Punjab had the highest unadjusted overweight residuals in the sample, Punjab and Andhra Pradesh had the highest underweight residuals in the adjusted model. Arunachal Pradesh and Bihar had the lowest overweight residuals in the unadjusted model while Mizoram and Assam had the lowest adjusted residuals. For most states, the effects in the adjusted models attenuated the overweight residuals towards the national mean, notably New Delhi and Goa for whom adjustment greatly reduced the observed residuals and Arunachal Pradesh and Bihar for whom adjustment strongly increased the observed residuals. Notable exceptions were Andhra Pradesh and Karnataka, which were similar to the state mean in unadjusted models but significantly higher than the mean in adjusted models.

The patterning of overweight and underweight reveals regional clustering of states by nutritional status (Fig. 6). Groups of states in the far north and far south of the country had high prevalence of overweight, while a band of states in the north central region had high prevalence of underweight. A group of states covering substantial portions of the eastern and western coasts had high prevalence of both overweight and underweight, and a group of states in the northeast region had lower than average prevalence of both overweight and underweight.

As women experiencing overweight and those experiencing underweight resided in every state and virtually every neighborhood studied, we investigated the extent to which these two aspects of nutritional status were correlated. A unique advantage of multinomial multilevel models is the ability to estimate the covariance in the random effects associated with underweight and overweight, which in turn allows an assessment of the extent of the double burden in nutritional status at the level of neighborhoods and states. In the adjusted model, we observed a very weak inverse relationship between the random effects associated with underweight and overweight at the neighborhood level ($r = -0.13$, $p = 0.04$). In other words, neighborhoods where individuals were at a greater risk of being underweight tended to be those where individuals were at a lower risk of being overweight. At the state level, however, we observed no significant association between high rates of underweight and overweight ($r = 0.31$, $p = 0.14$).

3.4. Neighborhood wealth and BMI, underweight, and overweight

Neighborhood wealth was independently associated with individual BMI, such that a change from the poorest tertile of neighborhood wealth to the richest tertile was associated with a 0.29 increase in BMI ($p = 0.0001$), even after adjusting for a range of individual-level demographic and socioeconomic factors, including household wealth. In adjusted multinomial models, while risk of being overweight increased in neighborhoods with moderate wealth (odds ratio [OR] = 1.19; 95% confidence interval [CI] = 1.06–1.34) and high wealth increased (OR = 1.39; 95% CI = 1.20–1.59) compared to low-wealth neighborhoods, no substantial association was observed between neighborhood wealth and the risk of being underweight.

We additionally conducted tests of interaction between neighborhood wealth and household standard of living index. The interaction parameters were not substantial for BMI. The risk of being overweight, however, increased more quickly among those in the richest quintile of household compared to the rest of the sample, as neighborhood wealth increased (Fig. 7). In addition, while risk of underweight was reduced among women from more affluent households living in wealthier neighborhoods, no similar reductions occurred among women in poorer households. There also appears to be an interactive effect whereby an increase in neighborhood wealth by one standard deviation is associated with a decreased odds of underweight in large cities (OR = 0.85; 95% CI = 0.74–0.99) compared to the same increase in wealth in a rural village.

4. Discussion

Our multilevel study, based on a large and nationally representative sample, identifies the following key findings that are relevant to understanding the role of geography in influencing nutritional status among women in India. First, even after accounting for a range of individual-level demographic and socioeconomic risk factors of nutritional status, we find a substantial contextual variation in nutritional status at the level of neighborhoods and states in India. Second, in terms of the relative importance of the two contextual levels, the level of neighborhoods was observed to be relatively more important as opposed to state in the determination of BMI, but the two levels were almost equally influential in determining the probability of experiencing underweight and overweight. Third, while both overweight and underweight are clearly prevalent in India, there appears to be no geographic patterning of this double burden at the state or neighborhood levels. Finally, neighborhood socioeconomic status, or more specifically wealth, was independently, and positively associated with BMI and the risk of being overweight. With increasing neighborhood wealth, the risk of being underweight decreases largely for women belonging to high SES groups, but not low SES groups.

The contextual variation of nutritional status between neighborhoods observed in this study is consistent with a number of proposed physical, social, and economic pathways between neighborhoods and impact health outcomes (Sampson et al., 2002). Research into urban/rural differences in BMI in India provides some insight into how neighborhoods in India may serve to pattern nutritional status (Singh et al., 1997; Venkatramana and Reddy, 2002). Compared to living in rural areas, urban residency has been found to be associated with higher consumption of refined sugars and dietary fat suggesting that there may be patterning in the ease of access to these calorie-dense foods (Shetty, 2002; Singh et al., 1995, 1996). Additionally, those living in rural areas report lower rates of sedentary behavior than urban dwellers, providing evidence that context may influence transportation, occupational, and recreational patterns in physical activity (Singh et al., 1995, 1996; Venkatramana and Reddy, 2002). Exposure to media has been found to be related to nutritional status among adults in developed countries, presumably through marketing of calorie-dense foods and the promotion of sedentary recreational behavior (Foster et al., 2006). As both media exposure and the strength of the relationship between media exposure and health behaviors have been found to be geographically patterned in India (Ghosh, 2006), this is another potential mechanism through which neighborhoods could affect nutritional status.

In addition to the variation between neighborhoods, there are several pathways through which state-specific characteristics could be responsible for variations in nutritional status. India is a country with a large, culturally diverse population (Dyson and Moore, 1983). These cultural differences may result in differences in eating patterns that serve to promote or suppress overeating. In addition, there is a wide variation in social policy between states (Peters et al., 2003). This difference in social policy may mean that while some state governments implement strong, well-funded policies to promote the distribution of food to those in need, other states may be less diligent in this regard (Subramanian et al., 2007b; Vijayaraghavan, 2002).

In regards to the distribution of nutritional status found in this study, several states merit specific mention. After adjusting for individual sociodemographic characteristics, Punjab was found to have the highest average BMI and the highest prevalence of overweight. This may be due, at least in part, to agricultural advances that have made the area a net food exporter (Tiwana et al., 2005), as well as cultural shifts in which sedentary behavior and a calorie-dense diet have gained wide appeal (Sidhu et al., 2006). Many states in India's northeast, namely Arunachal Pradesh, Manipur, Mizoram, and Assam, had prevalences of both overweight and underweight which were below the national mean. This may be related to the fact that these areas are marked by having a high proportion of tribal communities which have been described as among the most egalitarian in India, placing less emphasis on the hierarchy of the Hindu caste system (Bhengra et al., 1999). While the western coastal states of Gujarat, Maharashtra, and Karnataka were found to have the highest adjusted prevalence of underweight in the country, the prevalence of overweight there was well above the national average. This simultaneous burden of overweight and underweight may result from higher levels of inequality that could disproportionately influence the distribution of food according to economic status in these states (Subramanian et al., 2007b; Subramanian and Davey Smith, 2006).

The nutrition transition is marked by the rapid rise in rates of overweight and obesity and the consequent rise in non-infectious disease in nations that undergo economic development typically accompanied by commensurate economic globalization and demographic urbanization (Caballero and Popkin, 2002; Popkin, 1998). This transition is also marked by the inverse relationship between SES and overweight in developed countries, and the direct relationship between SES and overweight in developing countries (Monteiro et al., 2004). The results of this study indicate that in terms of the clinically relevant standards created by the World Health Organization for this population, the prevalence of overweight is much lower

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than that of underweight in India, and much lower than that of most developed countries. This fact, combined with the direct relationship between household wealth and overweight indicate that India is in the initial stages of the nutrition transition. Nevertheless, the prevalence of overweight in India is not inconsequential, and in some areas, namely in New Delhi and Punjab, does achieve levels similar to those of many developed countries (Prentice, 2006). While the mortality attributed to elevated body mass index is currently 2.0% in India, this figure is expected to climb dramatically in the coming years as the prevalence of overweight among adult women in India is projected to climb to 30% by the year 2015 (WHO, 2005).

The growing prevalence of overweight-related non-communicable disease in the developing world is impacting populations that are still afflicted by high rates of infectious and nutrient deficiency diseases, a condition termed the “double burden” (Prentice, 2006; WHO, 2003). Although previous studies have documented the existence of a double burden of underweight and overweight in India (Singh et al., 1999; Subramanian et al., 2007b; Subramanian and Davey Smith, 2006), little has been written about how this double burden is distributed within India. While our investigation did find substantial levels of both underweight and overweight in the nation as a whole, we did not find significant patterning of nutritional status indicating that overweight and underweight do not tend to cluster together in the same states or neighborhoods. We did, however, find some states with prevalence of both underweight and overweight that was higher than the national mean.

One reason for the simultaneous coexistence of under- and overnutrition in some states and in the nation as a whole may be the increased production of processed foods, particularly animal products. Those Indians who have become wealthy in the past decades have increased the demand for animal-derived foods (Kaur et al., 2005) which uses up a significant portion of the cheaper raw unprocessed food grains (Gopinath et al., 1996). Use of these unprocessed grains to grow food animals diminishes the supply of unprocessed foods and increases the price of these staples that make up the diet of the disadvantaged groups. As such, it is possible that when the wealthier classes eat large amounts of calorie-dense animal-derived food and become overweight, those in the poorer classes have difficulty purchasing enough calories to meet their minimum daily necessities.

Our investigation into contextual correlates found that, while personal standard of living was more strongly related to nutritional outcomes, neighborhood wealth was associated with these nutritional outcomes as well. Specifically, neighborhood wealth was associated with both BMI and overweight, but not with underweight. Further analyses investigating the interaction between household living standard and neighborhood wealth revealed interesting relationships with nutritional status, particularly regarding the modeling of underweight. These results revealed that neighborhood wealth is associated with lower rates of underweight in wealthy families but had no association among poorer families. This interaction apparently hid the association between the main effect of neighborhood wealth and risk of underweight. Increases in neighborhood wealth were also associated with especially large increases in overweight risk among people living in wealthy households compared with modest increases in overeweight risk among people in poorer households. This interaction between neighborhood wealth and household living standard mirrors similar findings where improvements in state-level GDP only reduced the risk of underweight for high SES women in India (Subramanian et al., 2007b). These findings suggest that the benefits of economic progress are translating rather selectively in terms of raising the level of nutrition (Subramanian et al., 2007b).

Although this research investigated nutritional status in women, there is evidence to support the notion that these results may be applicable to men as well. Previous research indicates that distribution of nutritional status of men in India follow similar patterns to those detected in women regarding socioeconomic status and urban rural residency (Chhabra and Chhabra, 2007). However, the overall burden of disease due to abnormal nutritional status among men in India is likely to be lower, since women tend to have higher rates of both underweight and overweight compared to men in India (Chhabra and Chhabra, 2007; Sadhukhan et al., 2007; Sauvaget et al., 2008).

An important limitation of this study is the use of BMI as a measure of nutritional status. First, it is necessary to note that BMI is more purely a measure of energy intake, and it is possible to be overnourished in terms of energy intake and yet undernourished in terms of important micronutrients (Asfaw, 2007). BMI also has shortcomings as a measure of energy intake. Due to variations in body shapes and muscle mass, BMI has an imperfect relationship with other important risk factors related to nutritional status, such as body fat and abdominal obesity (Gill, 2001). As a result, the use of BMI as a predictor for clinical outcomes, such as cardiovascular disease, cancer, and diabetes has been called into question (Deurenberg-Yap et al., 2002). Other anthropomorphic measures, such as waist-to-hip ratio have been offered as better predictors of non-communicable disease (Cox and Whichelow, 1996). The utility of BMI as a measure of overweight has been further challenged by research that indicate an elevated risk of clinical outcomes for Asians compared to Caucasians at comparable BMI levels (Deurenberg-Yap et al., 2002). One very thorough multilevel study of nutrition and social inequality in Nepal found that anthropometric measures in general were severely limited in their ability to describe the nutritional status of members across ethnically distinct groups, even in a relatively small geographical area, as a result of the long term cross-generational physical adaptation of the members of these groups to their environments (Strickland and Tuffrey, 1997). Despite these shortcomings, BMI has been found to be related to clinical outcomes among Indians, prompting the World Health Organization to reiterate its support for the use of BMI as an important health metric among this population (WHO, 2004).

5. Conclusion

The findings from this study illustrate the important relationship between context and nutritional status in India. While the individual-level characteristics are clearly influential, the contextual effects remained after accounting for these covariates. These results indicate that interventions to address the double burden of undernutrition and overnutrition in India must take into account the characteristics of states and neighborhoods in order to be successful, and that further research to investigate the salient contextual influences on nutritional status are merited.

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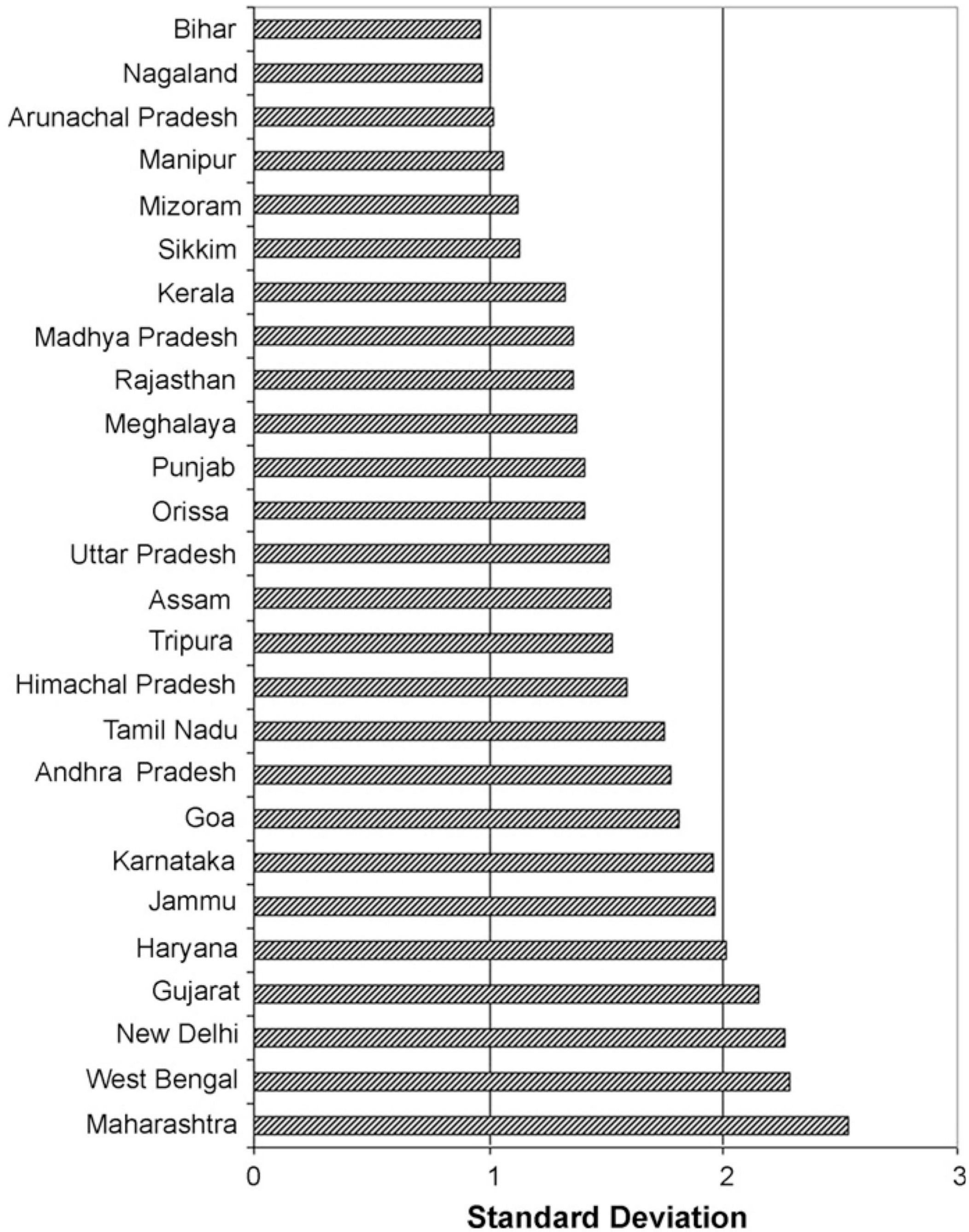

Fig. 1.
Standard deviation of unadjusted neighborhood BMI by state.

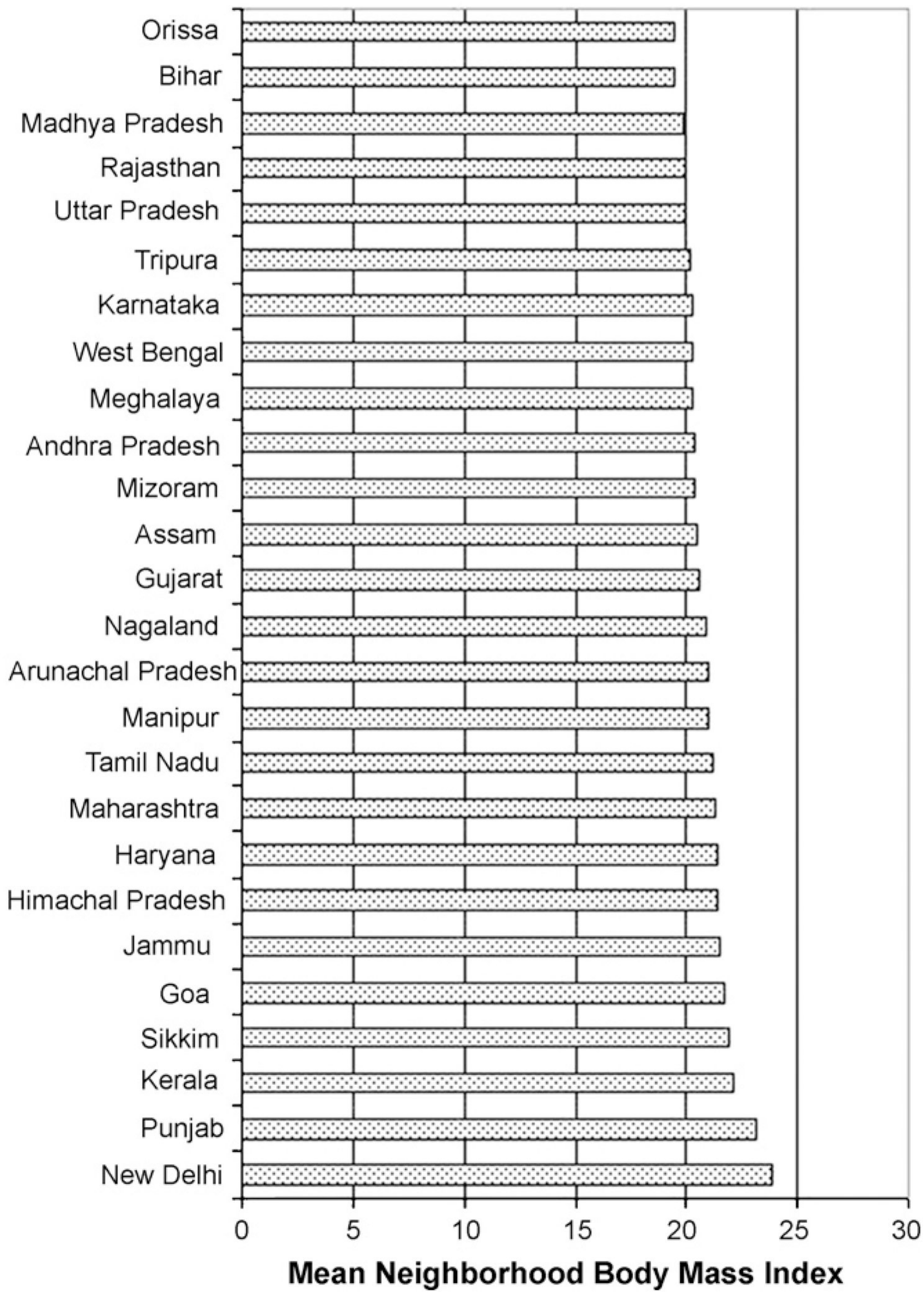

Fig. 2.
Mean unadjusted neighborhood BMI by state.

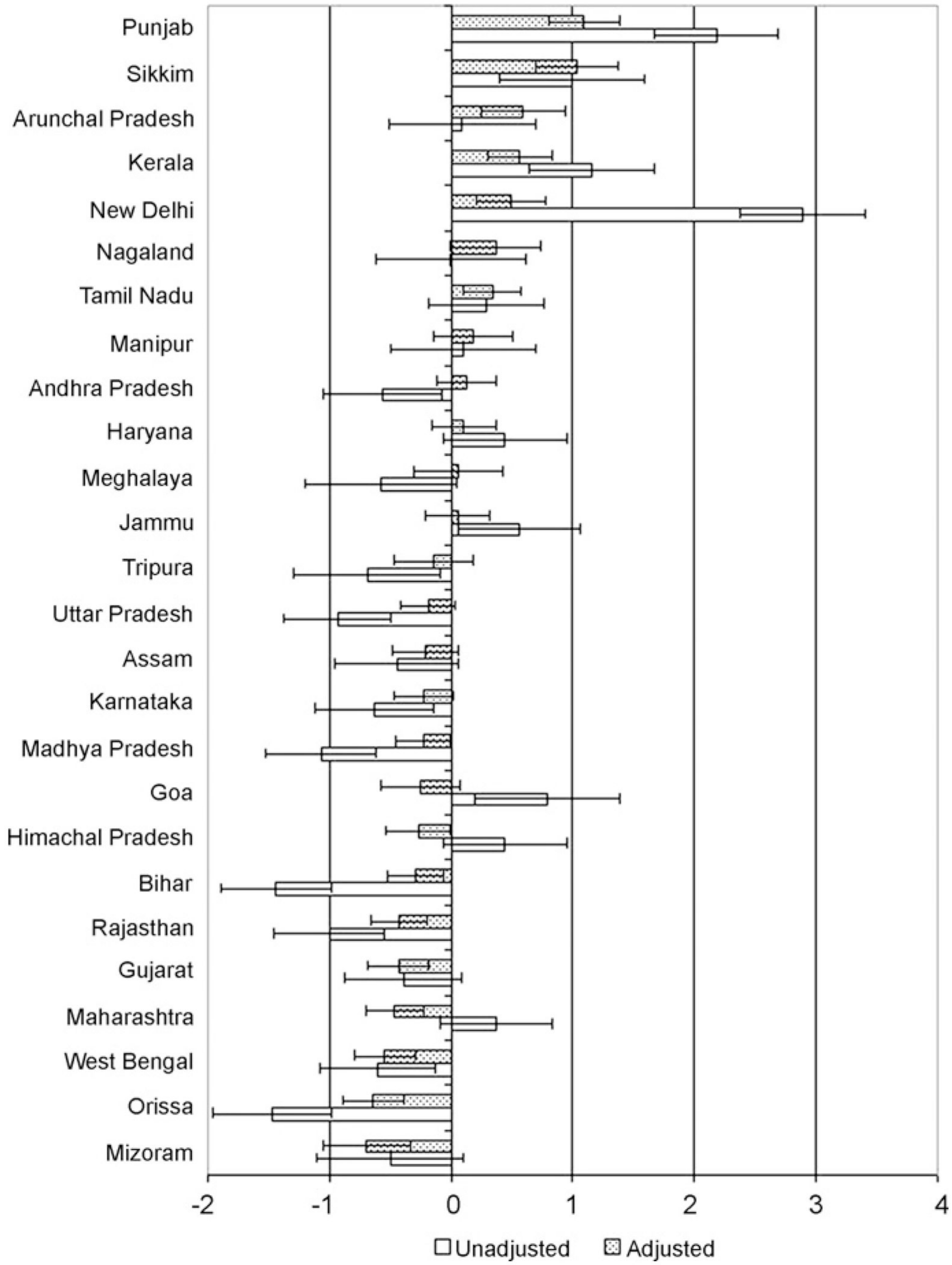

Fig. 3.
Unadjusted and adjusted state BMI residuals and 95% confidence intervals.

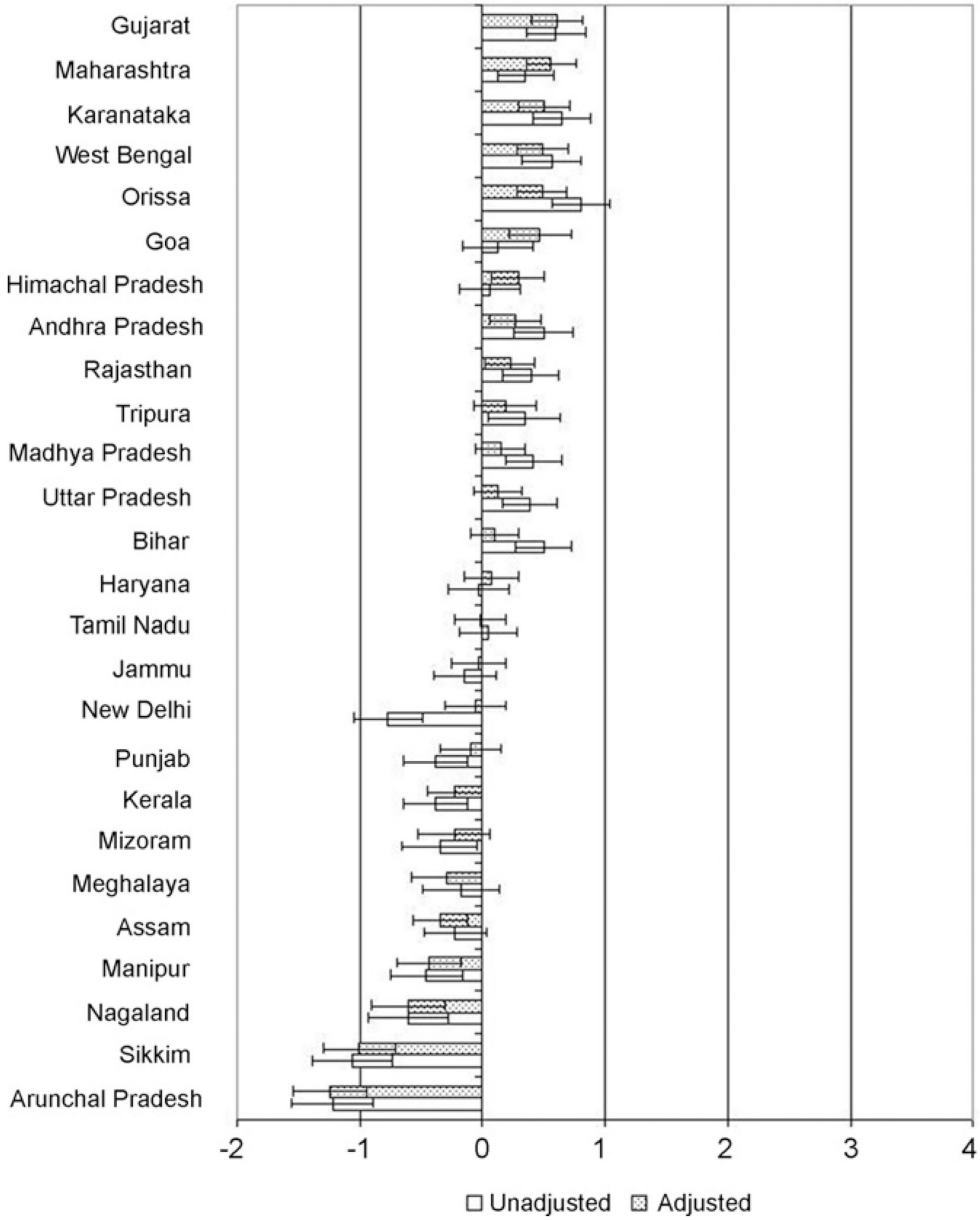

Fig. 4.
Unadjusted and adjusted state underweight residuals and 95% confidence intervals. Note: residuals indicate log odds of underweight compared to the national mean.

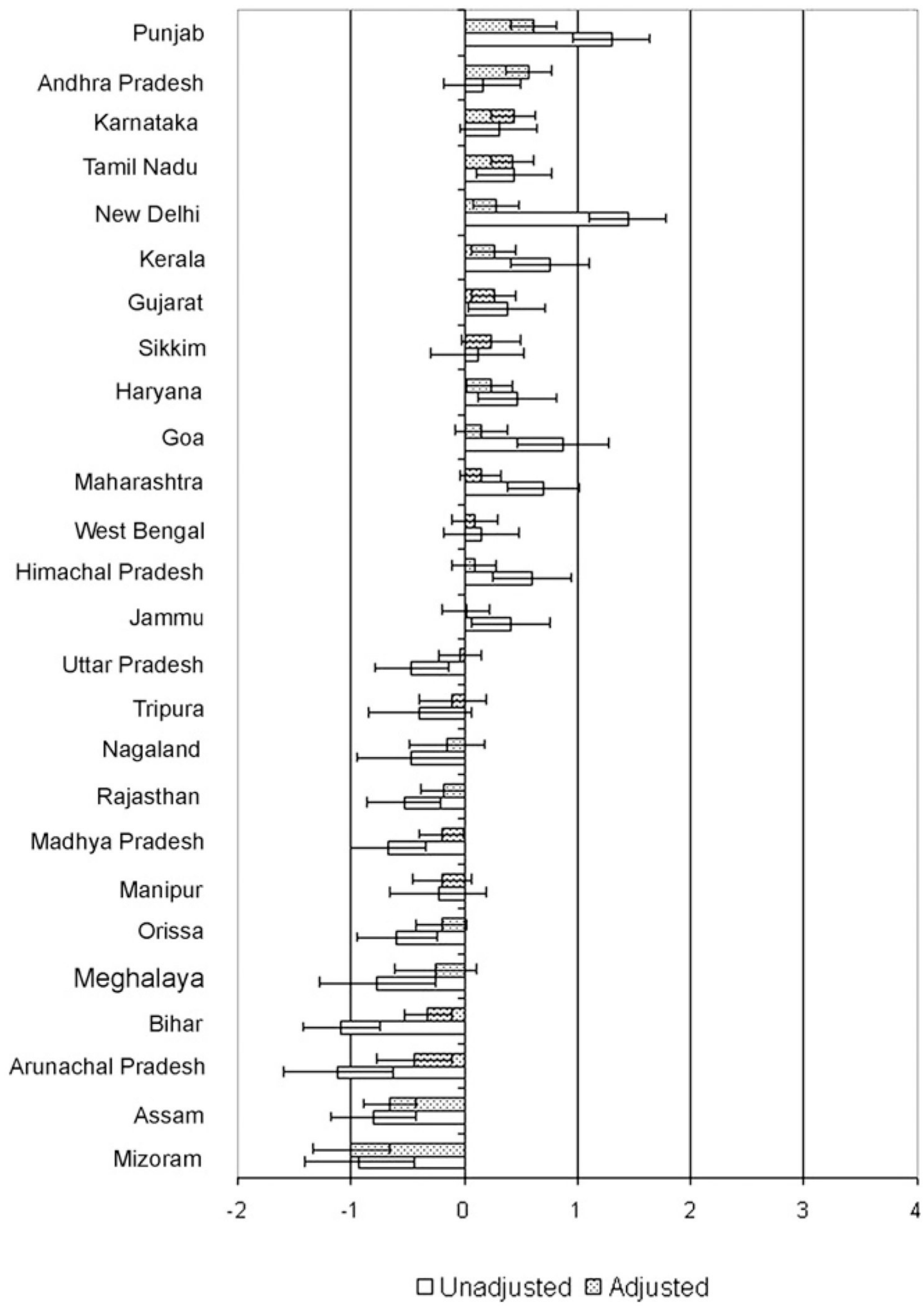

Fig. 5.
Unadjusted and adjusted state overweight residuals and 95% confidence intervals. Note: residuals indicate log odds of overweight compared to the national mean.

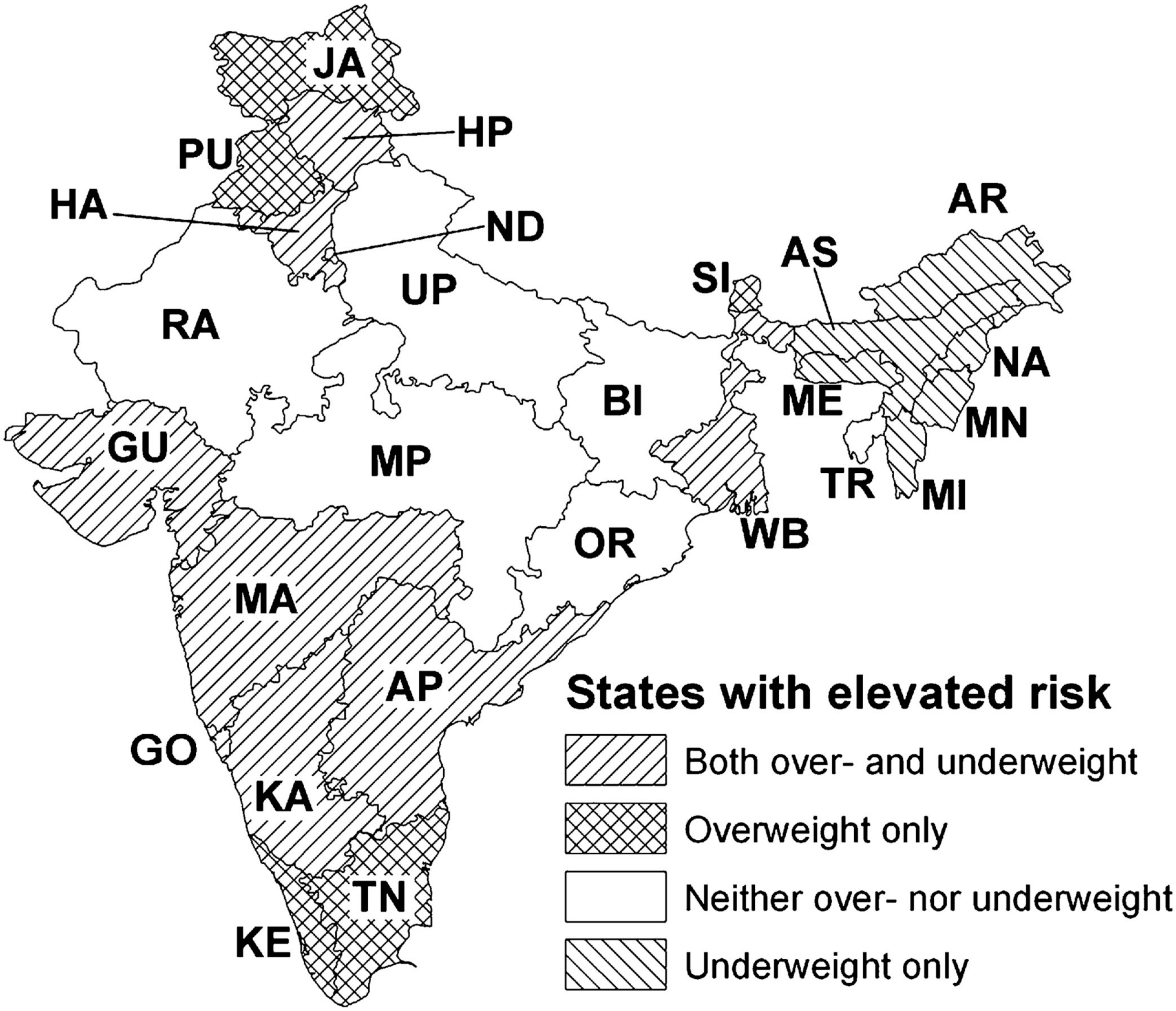

Fig. 6.

Map of state levels of overweight and underweight in adjusted models compared to national means. State name abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BI, Bihar; GO, Goa; GU, Gujarat; HA, Haryana; HP, Himachal Pradesh; JA, Jammu; KA, Karnataka; KE, Kerala; MA, Maharashtra; ME, Meghalaya; MI, Mizoram; MN, Manipur; MP, Madhya Pradesh; NA, Nagaland; ND, New Delhi; OR, Orissa; PU, Punjab; RA, Rajasthan; SI, Sikkim; TN, Tamil Nadu; TR, Tripura; UP, Uttar Pradesh; WB, West Bengal.

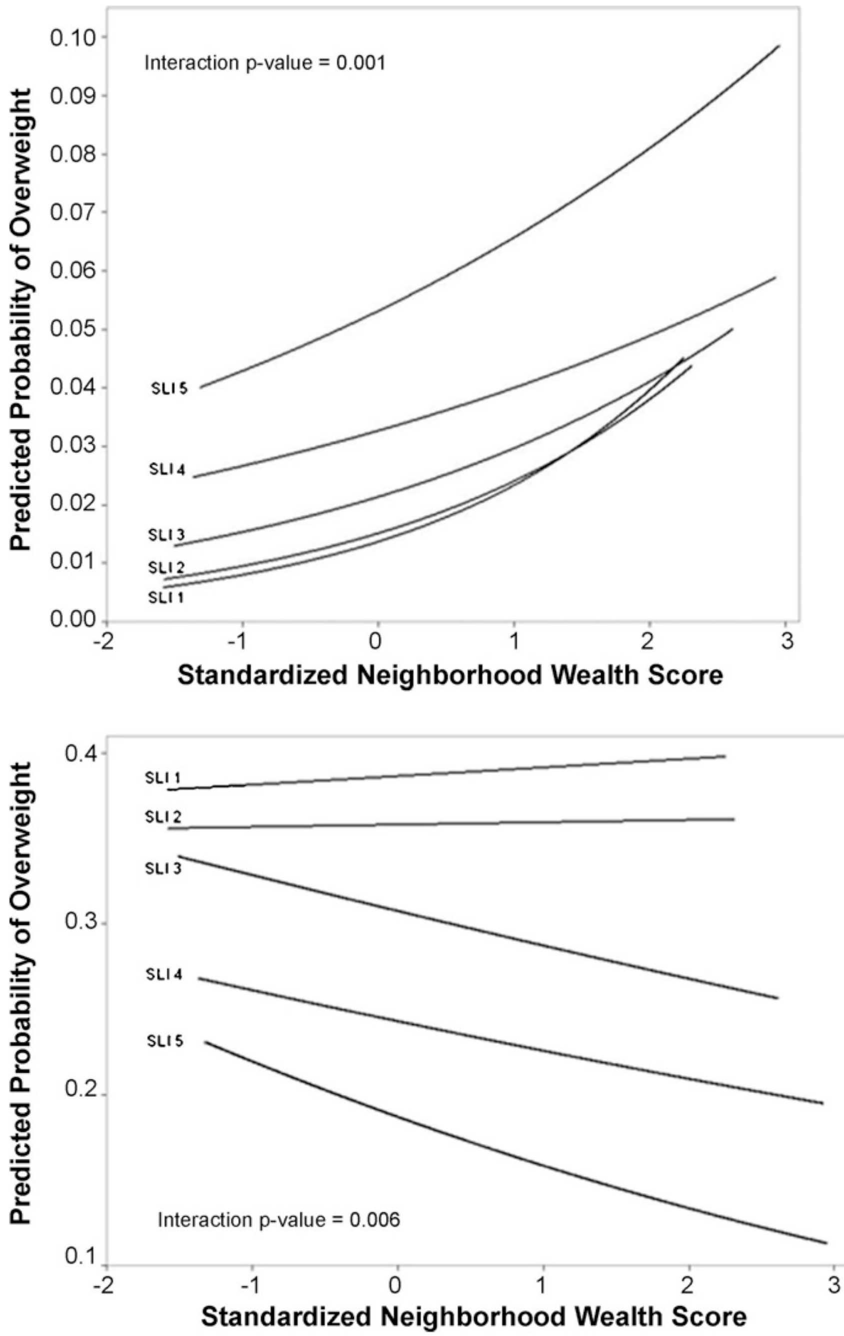

Fig. 7.

Predicted probability of overweight and underweight by the interaction of household standard of living index and neighborhood wealth.

Table 1

Descriptive statistics of the sample

Variable	Subjects	%[a]	Underweight	%[b]	Overweight	%[c]	Mean BMI	S.D.
Location								
Village	52415	68.4	19560	37.3	3457	6.6	19.8	3.2
Town	10737	14.0	2557	23.8	2157	20.1	21.7	4.2
Small city	4964	6.5	1080	21.8	1209	24.4	22.2	4.6
Large city	8565	11.2	1393	16.3	2584	30.2	23.0	4.7
Age								
15–19	4919	6.4	1938	39.4	80	1.6	19.3	2.3
20–24	12200	15.9	4755	39.0	442	3.6	19.5	2.7
25–29	15230	19.9	5363	35.2	1229	8.1	20.1	3.3
30–34	14037	18.3	4296	30.6	1876	13.4	20.8	3.9
35–39	12441	16.2	3414	27.4	2141	17.2	21.3	4.2
40–44	10035	13.1	2766	27.6	1978	19.7	21.5	4.4
45–49	7819	10.2	2058	26.3	1661	21.2	21.7	4.5
Religion								
Hindu	59840	78.0	20393	34.1	6731	11.2	20.4	3.7
Muslim	8750	11.4	2663	30.4	1230	14.1	20.8	4.0
Christian	4280	5.6	860	20.1	576	13.5	21.3	3.6
Sikh	1875	2.5	316	16.9	578	30.8	23.0	4.8
Other/missing religion	1936	2.5	358	18.5	292	15.1	21.5	3.7
Caste								
General	31866	41.6	8476	26.6	5765	18.1	21.4	4.2
Scheduled caste	22572	29.4	7744	34.3	2265	7.2	20.3	3.6
Scheduled tribe	9220	12.0	3158	34.3	444	4.8	19.8	2.9
Other backward class	13023	17.0	5212	40.0	933	10.0	19.8	3.3
Marital status								
Married	71770	93.6	22890	31.9	8853	12.3	20.6	3.8
Widowed	3294	4.3	1119	34.0	407	12.4	20.5	3.9
Divorced/separated	1617	2.1	581	35.9	147	9.1	20.2	3.5
Education								

Variable	Subjects	%[a]	Underweight	%[b]	Overweight	%[c]	Mean BMI	S.D.
No formal schooling	38149	49.8	15117	39.6	2231	5.8	19.7	3.1
1–5 years	12910	16.8	4154	32.2	1515	11.7	20.6	3.8
6–8 years	9621	12.6	2522	26.2	1545	16.1	21.3	4.0
9–10 years	8951	11.7	1847	20.6	1938	21.7	22.0	4.3
11–12 years	3269	4.3	539	16.5	827	25.3	22.6	4.4
13 or more years	3781	4.9	411	10.9	1351	35.7	23.7	4.5
Employment								
Not working	47753	62.3	13890	29.1	7021	14.7	21.0	4.0
Unpaid	7817	10.2	2933	37.5	429	5.5	19.8	3.0
Paid non-manual	3773	4.9	616	16.3	977	25.9	22.6	4.3
Paid agricultural	10502	13.7	4714	44.9	288	2.7	19.1	2.7
Paid manual	6836	8.9	2437	35.7	692	10.1	20.3	3.6
Living standard								
1st (lowest) quintile	14113	18.4	6734	47.7	226	1.6	18.9	2.4
2nd quintile	15080	19.7	6414	42.5	421	2.8	19.3	2.7
3rd quintile	15685	20.5	5539	35.3	1016	6.5	19.9	3.1
4th quintile	16024	20.9	3978	24.8	2355	14.7	21.2	3.8
5th (highest) quintile	15779	20.6	1925	12.2	5389	34.2	23.6	4.6
Oral contraceptive use								
No	74730	97.5	24074	32.2	9198	12.3	20.6	3.8
Yes	1951	2.5	516	26.5	209	10.7	20.8	3.4
Children								
0	6554	8.6	2131	32.5	424	6.5	20.1	3.1
1	10516	13.7	3347	31.8	1079	10.3	20.4	3.5
2	16821	21.9	4918	29.2	2732	16.2	21.1	4.1
3	15614	20.4	4877	31.2	2243	14.4	20.9	4.1
4+	27176	35.4	9317	34.3	2929	10.8	20.4	3.8
Illness								
No	72313	94.3	22788	31.5	9153	12.7	20.7	3.8
Yes	4368	5.7	1802	41.3	254	5.8	19.6	3.3
Tobacco chewing								

Variable	Subjects	%[a]	Underweight	%[b]	Overweight	%[c]	Mean BMI	S.D.
No	67481	88.0	20998	31.1	8784	13.0	20.7	3.9
Yes	9200	12.0	3592	39.0	623	6.8	19.7	3.3
Tobacco smoking								
No	74615	97.3	23759	31.8	9312	12.5	20.6	3.8
Yes	2066	2.7	831	40.2	95	4.6	19.5	3.0
Alcohol use								
No	74487	97.1	23911	32.1	9307	12.5	20.6	3.8
Yes	2194	2.9	679	31.0	100	4.6	20.1	2.9
Total	76681	100.0	24590	32.1	9407	12.3	20.6	3.8

[a]Indicates the percentage of women in the sample who have that characteristic.

[b]Indicates the percentage of women with that characteristic who are underweight.

[c]Indicates the percentage of women with that characteristic who are overweight.

Table 2

Variance in BMI, underweight, and overweight present at higher contextual levels

	Body mass index[a]		Underweight[b]		Overweight[b]	
	Variance (S.E.)	Percentage of variance	Variance (S.E.)	Percentage of variance	Variance (S.E.)	Percentage of variance
Unadjusted[c]						
State	1.059 (0.303)	7.1	0.287 (0.082)	7.3	0.523 (0.150)	11.3
Neighborhood	2.325 (0.072)	15.7	0.336 (0.014)	8.6	0.795 (0.035)	17.3
Adjusted[d]						
State	0.231 (0.067)	2.1	0.211 (0.060)	5.7	0.141 (0.041)	4.0
Neighborhood	0.550 (0.025)	4.9	0.199 (0.011)	5.3	0.134 (0.015)	3.8

Note: All variances are significantly different from 0 at $p < .001$.

[a] Modeling the variation in linear body mass index in units of kg/m^2.

[b] Modeling the variation of log odds of under/overweight status in relation to the reference normal weight group.

[c] Unadjusted models are null models with no predictors.

[d] Models are adjusted for age, religion, marital status, education, occupation, caste, oral contraceptive use, number of children, recent major illness, use of chewing tobacco, smoking, and alcohol use.

Appendix A

Adjusted estimates and standard errors for body mass index, and odds ratios and 95% confidence intervals for overwieght and underweight for ever-married women age 15–49 in the 1998–1999 National Family Health Survey in India

Fixed effect	Body mass index		Underweight		Overweight	
	Estimate	S.E.	OR	95% CI	OR	95% CI
Intercept	18.99	0.12				
Location						
Village (reference)	0.00		1.00		1.00	
Town	0.45	0.06	1.41	1.26–1.57	1.31	1.21–1.43
Small city	0.67	0.08	0.94	0.87–1.01	1.64	1.49–1.81
Large city	1.19	0.07	0.75	0.68–0.83	0.91	0.82–1.02
Age (years)						
15–19 (reference)	0.00		1.00		1.00	
20–24	−0.30	0.06	1.11	1.03–1.20	1.02	0.94–1.10
25–29	0.15	0.06	0.85	0.78–0.93	0.75	0.69–0.82
30–34	0.83	0.06	0.77	0.70–0.84	0.74	0.67–0.82
35–39	1.26	0.07	1.36	1.06–1.74	2.79	2.20–3.55
40–44	1.48	0.07	4.80	3.77–6.10	6.48	5.08–8.25
45–49	1.65	0.07	7.86	6.16–10.04	8.62	6.73–11.03
Religion						
Hindu (reference)	0.00		1.00		1.00	
Muslim	0.26	0.05	1.02	0.95–1.09	0.79	0.70–0.89
Christian	0.28	0.08	0.96	0.80–1.15	0.76	0.66–0.88
Sikh	0.29	0.11	1.40	1.28–1.53	1.14	1.00–1.30
Other/missing religion	0.46	0.09	1.25	1.07–1.45	1.31	1.11–1.53
Caste						
General (reference)	0.00		1.00		1.00	
Scheduled caste	−0.36	0.04	1.18	1.11–1.24	1.00	0.93–1.08
Scheduled tribe	−0.05	0.06	1.06	1.01–1.11	0.83	0.76–0.91
Other backward caste	−0.20	0.03	0.84	0.73–0.97	0.89	0.83–0.95
Marital status						
Married (reference)	0.00		1.00		1.00	

Fixed effect	Body mass index		Underweight		Overweight	
	Estimate	S.E.	OR	95% CI	OR	95% CI
Widowed	−0.19	0.06	1.05	0.97–1.14	1.14	1.02–1.28
Divorced	−0.05	0.08	0.93	0.82–1.05	1.03	0.85–1.25
Education (years)						
0 (reference)	0.00		1.00		1.00	
1–5	0.19	0.04	0.98	0.93–1.03	0.91	0.86–0.97
6–8	0.35	0.04	0.87	0.81–0.94	0.83	0.74–0.93
9–10	0.38	0.05	0.78	0.69–0.89	1.21	1.11–1.31
11–12	0.42	0.07	1.33	1.22–1.45	1.40	1.28–1.53
Over 12	0.59	0.07	1.40	1.25–1.57	1.57	1.40–1.76
Employment						
Not working (reference)	0.00		1.00		1.00	
Unpaid	−0.16	0.05	0.99	0.93–1.05	0.83	0.75–0.92
Paid non-manual	0.15	0.06	1.11	1.05–1.18	1.07	1.01–1.14
Paid agricultural	−0.41	0.04	0.73	0.65–0.82	0.92	0.83–1.01
Paid manual	−0.33	0.05	0.57	0.50–0.65	0.79	0.72–0.87
Standard of living						
First (lowest) quintile (reference)	0.00		1.00		1.00	
Second quintile	0.13	0.04	0.91	0.86–0.95	0.75	0.71–0.80
Third quintile	0.44	0.04	0.54	0.50–0.58	0.34	0.31–0.38
Fourth quintile	1.26	0.05	1.30	1.10–1.54	2.13	1.82–2.49
Fifth (highest) quintile	2.78	0.06	3.38	2.89–3.95	5.97	5.06–7.04
Oral contraceptive use						
No (reference)	0.00		1.00		1.00	
Yes	−0.01	0.08	0.87	0.78–0.97	0.87	0.74–1.02
Number of children						
0 (reference)	0.00		1.00		1.00	
1	−0.14	0.05	1.19	1.11–1.28	1.21	1.12–1.30
2	0.03	0.05	1.21	1.12–1.31	1.26	1.17–1.36
3	0.02	0.05	1.05	0.92–1.19	1.15	1.02–1.30
4 or more	−0.18	0.06	1.10	0.97–1.25	1.06	0.93–1.21

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Fixed effect	Body mass index		Underweight		Overweight	
	Estimate	S.E.	OR	95% CI	OR	95% CI
Illness						
No (reference)	0.00		1.00		1.00	
Yes	−0.39	0.05	1.23	1.15–1.32	0.79	0.69–0.92
Tobacco chewing						
No (reference)	0.00		1.00		1.00	
Yes	−0.37	0.04	1.20	1.13–1.26	0.94	0.85–1.04
Tobacco smoking						
No (reference)	0.00		1.00		1.00	
Yes	−0.64	0.08	1.41	1.27–1.56	0.73	0.58–0.91
Alcohol drinking						
No (reference)	0.00		1.00		1.00	
Yes	0.28	0.08	0.84	0.74–0.94	0.91	0.71–1.15

Appendix B

Mean and standard deviation (SD) of the household characteristics used to calculate the standard of living score in the 1998–1999 Indian National Family Health Survey

Characteristic	Mean	SD
Has electricity	0.66530	0.47189
Has a radio	0.41640	0.49296
Has a television	0.38955	0.48765
Has a refrigerator	0.14346	0.35054
Has a bicycle	0.43583	0.49587
Has a motorcycle	0.12632	0.33221
Has a car	0.02432	0.15403
Has a telephone	0.10082	0.30109
Uses a separate room as a kitchen	0.54776	0.49772
Household owns agricultural land	0.49206	0.49994
Acres of land under cultivation	119.4	589.4
Acres of irrigated land under cultivation	4068.3	3413.1
Household owns livestock	0.46785	0.49897
Has a mattress	0.57765	0.49394
Has a pressure cooker	0.38259	0.48602
Has a chair	0.52696	0.49928
Has a cot or bed	0.83841	0.36808
Has a table	0.48950	0.49989
Has a clock or watch	0.71219	0.45274
Has a fan	0.48738	0.49984
Has a bicycle	0.43583	0.49587
Has a sewing machine	0.24008	0.42713
Has a telephone	0.10082	0.30109
Has a refrigerator	0.14346	0.35054
Has a television (black and white)	0.27052	0.44423
Has a television (color)	0.13270	0.33925
Has a water pump	0.08141	0.27346
Has a bullock cart	0.06047	0.23836
Has a thresher	0.01707	0.12954
Has a tractor	0.01634	0.12677
Household has a domestic worker not related to head	0.00043	0.02079
Household works the family’s agricultural land	0.19366	0.39517
Number of members per sleeping room	2.28628	1.88105
Has piped drinking water in residence	0.26282	0.44017
Has piped drinking water in public tap	0.17843	0.38287
Has a well in residence	0.01236	0.11048
Gets water from a public well	0.05867	0.23500
Uses a spring for drinking water	0.01941	0.13796
Uses a river, a canal, or surface water for drinking	0.03066	0.17241

Characteristic	Mean	SD
Uses rainwater for drinking	0.00118	0.03431
Uses a tanker truck for drinking water	0.00219	0.04680
Gets water from a covered public well	0.01041	0.10151
Gets water from a public open well	0.09959	0.29946
Uses a residential handpump	0.13024	0.33656
Uses a public handpump	0.18927	0.39173
Uses another source of drinking water	0.00467	0.06819
Has a private flush toilet	0.22489	0.41751
Has a public flush toilet	0.02964	0.16958
Uses a private pit latrine	0.13684	0.34368
Uses a public pit latrine	0.00660	0.08095
Uses a shared pit latrine	0.02032	0.14108
Uses a shared flush toilet	0.03696	0.18866
Uses the bush or a field as latrine	0.54355	0.49810
Uses another type of latrine	0.00112	0.03351
Uses clay kitchenware	0.01023	0.10062
Uses aluminum kitchenware	0.36287	0.48083
Uses kitchenware made of cast iron	0.00271	0.05202
Uses brass or copper kitchenware	0.01379	0.11660
Uses stainless steel kitchenware	0.60984	0.48779
Uses another kind of kitchenware	0.00003	0.00570
Uses electricity for lighting	0.66530	0.47189
Uses kerosene for lighting	0.33061	0.47044
Uses gas for lighting	0.00055	0.02348
Uses oil for lighting	0.00130	0.03600
Uses other lighting	0.00158	0.03970
Uses wood cooking fuel	0.57660	0.49410
Uses dung cooking fuel	0.05214	0.22231
Uses coal cooking fuel	0.01582	0.12477
Uses charcoal cooking fuel	0.00302	0.05484
Uses kerosene cooking fuel	0.08719	0.28212
Uses LPG cooking fuel	0.21486	0.41073
Uses biogas cooking fuel	0.00434	0.06570
Uses crop residual for cooking fuel	0.03629	0.18700
Uses electricity for cooking	0.00790	0.08855
Uses other cooking fuel	0.00158	0.03970
House is made from high quality materials	0.35097	0.47728
House is made from low quality materials	0.29623	0.45660
House is made from mixed quality materials	0.35079	0.47722