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The relationship of household assets and amenities with child health outcomes: An exploratory cross-sectional study in India 2015–2016

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ABSTRACT

Healthy development of children in India is far from ensured. Proximate determinants of poor child health outcomes are infectious diseases and undernutrition, which are linked to socioeconomic status. In low- and middle-income countries, researchers rely on wealth indices, constructed from information on households' asset ownership and amenities, to study socioeconomic disparities in child health. Some of these wealth index items can, however, directly affect the proximate determinants of child health. This paper explores the independent association of each item used to construct the Demographic and Health Surveys' wealth index with diverse child health outcomes. This cross-sectional study used nationally representative sample of 245,866 children, age 0–59 months, from the Indian National Family Health Surveys conducted in 2015–16. The study used conditional Poisson regression models as well as a range of sensitivity specifications. After controlling for socioeconomic status, health care use, maternal factors, community-level factors, and all wealth index items, the following wealth index items were the most consistently associated with child health; type of toilet facilities, water source, refrigerator, pressure cooker, type of cooking fuel, land usable for agriculture, household building material, mobile phone, and motorcycle/scooter. The association with type of toilet facilities and water source was particularly strong for mortality, showing a 16–35% and 14–28% lower mortality, respectively. Most items used to construct the Demographic and Health Surveys' wealth index only indicate household socioeconomic status, while a few items may affect child health directly, and can be useful targets for policy intervention.

1. Introduction

Infectious diseases and undernutrition have negative consequences for child health and development and remain an enormous problem in low- and middle-income countries (LMICs) (Hoddinott, Alderman, Behrman, Haddad, & Horton, 2013; World Bank, 2018). For example, in India, 38% of children are stunted, indicating poor health and nutrition (International Institute for Population, 2018). An underlying cause is poverty (Victora et al., 2003). In poor households, parents lack the resources to invest in their children's health, such as being able to provide sufficient nutrition and clean and safe living quarters. These poor households are further more likely to be embedded in an environment that does not provide the infrastructure and services necessary to ensure

a child's health, such as improved water and sanitation facilities, disease control, healthcare, and food security (Mosley & Chen, 1984; Victora et al., 2003).

A correlation between various measures of socioeconomic status (SES) and health is well known (Galobardes, Lynch, & Smith, 2007). SES is a latent construct that can be measured using different proxy variables, such as education, income, wealth, and occupation. Mosley and Chen (1984) proposed an analytical framework for linking SES and child health in low-resource settings. All socioeconomic determinants of child health operate through biological mechanisms – proximate determinants – which directly affect child health. Mosley and Chen suggested five broad categories of proximate determinants; environmental contaminants (exposure to pathogens) and nutrient deficiencies – which

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were the primary exposures considered in this study – as well as maternal factors (age, parity, and birth interval), injuries, and personal illness control (curative and preventative treatments). They grouped socioeconomic determinants into three broad categories; individual-level variables (e.g., productivity and norms), household-level variables (e.g., income and wealth), and community-level variables (e.g., ecological setting, political economy, and health systems).

Income and consumption are preferred measures of SES, which also indicate specific ‘exposures’ that can be targeted by interventions, such as conditional cash transfers and social security. In many LMICs, however, a large portion of the population lives on subsistence agriculture or works in the informal sector. Therefore, estimating income or consumption can be time-consuming and unreliable (Filmer & Pritchett, 2001; Sahn & Stifel, 2004). Consequently, research in LMICs has relied on ‘wealth indices’ constructed from a household’s ownership of various durable consumer goods, productive assets, housing quality, water and sanitation facilities, and other amenities (hereafter called ‘wealth index items’) (Corsi, Neuman, Finlay, & Subramanian, 2012; Filmer & Pritchett, 2001). For example, the Demographic and Health Surveys (DHS), household surveys conducted in numerous LMICs, provide a wealth index that is widely used to study socioeconomic determinants and disparities in population health. Principal component analysis (PCA) is used to derive weights for each wealth index item, and the first factor is assumed to represent wealth (DHS, 2019). The DHS wealth index and other similar indices have shown socioeconomic differences in various health outcomes in numerous LMICs (Gwatkin, Rutstein, Johnson, Suliman, & Wagstaff, 2007; Kamal, 2011; Urke, Bull, & Mittelmark, 2011; Van Malderen, Van Oyen, & Speybroeck, 2013). Some researchers have claimed that wealth indices are not only more convenient but also superior to measures of expenditure, for identifying poverty and as a determinant of child health, due to the problems associated with transitory shocks and measurement error in expenditure data (Filmer & Pritchett, 2001; Sahn & Stifel, 2004). Further, measures of consumption and wealth indices have yielded similar results when estimating socioeconomic differences in child health (Wagstaff & Watanabe, 2003).

Although wealth indices are intended to serve as ‘markers’ of household SES in relation to child health, the individual wealth index items can also be seen as ‘exposures’ and determinants of child health. The conflation of ‘markers’ and ‘exposures’ is not helpful in terms of designing interventions and understanding of underlying etiology. In this paper, we explore the independent association of each item used to construct the widely used DHS wealth index with several child health outcomes, using the fourth Indian National Family Health Survey (NFHS) conducted in 2015 and 2016. It will further discuss which items are likely markers for household SES and which items can be directly linked to improved child health.

Household goods used for food storage, food preparation, sanitation, hygiene, and water supply can directly improve child health through improved nutrition and reduced infections. For example, refrigerators allow families to introduce more high-protein foods into their diets, such as meat and dairy, rather than relying exclusively on foods that do not require refrigeration, such as grains and vegetables (Meckel, 1990; Nickles, 2002; *The Economist*, 2014). Electric cooking stoves provide a cleaner way of preparing food than coal and wood-burning, which lead to indoor air pollution – a significant cause of pneumonia in LMICs (WHO, 2014, p. 292). Cooking with electricity is also quicker which reduces nutrient-value loss (Borchers & Ilne-Mari, 1997).

Further, since cooking food is time-consuming without modern cooking stoves, in many LMICs, food is commonly stored at ambient temperature for multiple feeding events, which increases the risk of contamination (Doza et al., 2018; Islam et al., 2012). Majority of diarrheal episodes are food-borne, and both refrigerators and electric cooking stoves can reduce food contamination (Meckel, 1990; Nickles, 2002; *The Economist*, 2014). Simple items, such as tables for preparing food can also reduce food contamination, since food is commonly

prepared on the floor in many countries (Takanashi et al., 2009). Proper water and sanitation facilities have been demonstrated to be of enormous importance in reducing water-borne infections and exposures to harmful fecal germs (Kjellstrom et al., 2007).

Durable goods and amenities can also indirectly improve child health by reducing the time needed for many household tasks and thereby increasing the time available for improving the quality of household work (e.g., improved hygiene), economic activities outside the home, and direct care of children (Greenwood, Seshadri, & Yorukoglu, 2005; Lewis, 2018; Mokyr, 2000). Time is a valuable input into child health in LMICs: for example, visits to public health care facilities are often free but require travel and waiting, good household hygiene is inexpensive while time-consuming, and oral rehydration therapy to treat diarrhea is effective and cheap but time-consuming (Desai, 2000; Miller & Urdinola, 2010).

Changing SES is a long and complicated process. However, small changes aimed at improving living standards and child health are more easily conceivable from a financing and implementation perspective. To do so, it is important to understand which specific assets and amenities can directly improve child health and be recommended for policy action.

2. Study population and sample

The data comes from the fourth NFHS, implemented by the International Institute for Population Sciences between January 20, 2015, and December 2, 2016 (International Institute for Population, 2018). The NFHS provides nationally representative household survey data using a two-stage stratified sampling design. Stratification was done by district, separated into rural and urban areas. Primary Sampling Units (PSUs) were selected from a sampling frame based on the 2011 census and consisted of villages in rural areas and Census Enumeration Blocks (CEBs) in urban areas. PSUs were selected with a probability proportional to size with independent selection in each stratum. Data collection was completed in 28,522 out of 28,586 selected PSUs.

In each household, women age 15–49 were interviewed. The response rate was 97.6% for households and 96.7% for women. Information regarding birth histories, health of children under the age of 5, and information on wealth index items were collected. We only included children born 0–59 months before the survey was administered to reduce recall bias and since detailed health information was only collected for that age group. We further only included children born to respondents who were residents of the interviewed household (94.7% of remaining births). Table 1 shows further deductions from the full sample to our final samples.

3. Outcome variables

3.1. Stunting

Stunting, height-for-age below -2 z-scores (standard deviations) from the WHO, 2006 reference median (WHO, 2006), indicates chronic exposure to undernutrition and infections (de Onis & Blössner, 1997) and reflects health and cognitive development (Hoddinott et al., 2013).

3.2. Underweight

Underweight, weight-for-age below -2 z-scores from the WHO, 2006 growth standards (WHO, 2006), is a composite indicator of chronic and acute undernutrition (de Onis & Blössner, 1997).

3.3. Wasting

Wasting, weight-for-height below -2 z-scores from the WHO, 2006 growth standards (WHO, 2006), indicates acute starvation and severe infections but may also be caused by chronic unfavorable environment (de Onis & Blössner, 1997).

Table 1
Sample deductions for each child health outcome.

	Stunting	Underweight	Wasting	Anemia	Diarrhea	Low birth weight	Mortality
Full sample	245,866	245,866	245,866	245,866	245,866	245,866	245,866
Dead	11,237	11,237	11,237	11,237	11,237	NA	NA
Not present	0	0	0	86	NA	NA	NA
Refused (don't know ¹)	2234	2234	2234	5392	NA	8205	NA
No measure (not weighted ¹)	2487	2487	2487	2487	NA	54,988	NA
Implausible outcome	1125	1125	1125	NA	NA	NA	NA
Implausible age	18	18	18	NA	NA	NA	NA
Flagged measure	9732	9732	9732	NA	NA	NA	NA
Unknown reason	5405	5405	5405	26,594	525	181	0
Missing covariates	9390	9390	9390	8746	12,551	9661	13,296
Single obs. in PSU ²	1131	1131	1131	1299	897	1532	852
No outcome in PSU ²	17,578	23,766	45,643	8048	110,272	53,036	145,546
Final sample	185,529	179,341	157,464	181,977	110,384	118,263	86,172

Notes: ¹For low birth weight. ²PSUs that only had a single observation or had no observations that experience the outcome were excluded from conditional Poisson models using PSU fixed-effects.

3.4. Anemia

Severe, moderate, or mild anemia, indicated by hemoglobin level of less than 11.0 g/dl, is caused by insufficient micronutrients, particularly iron, but also folic acid, and vitamin B₁₂ (WHO, 2001). Other causes are infections such as diarrhea or intestinal parasites (Howard, de Pee, Sari, Bloem, & Semba, 2007; Kotecha, 2011).

3.5. Low birth weight

Low birth weight, birth weight below 2500 g, differs from our other outcomes since it is determined by in utero factors, such as maternal nutrition and infections during pregnancy (Almond, Chay, & Lee, 2002). Birth weight is obtained from a written card or mother's recall.

3.6. Diarrhea

Diarrhea, defined as occurrence of diarrhea in the two weeks preceding the survey as reported by mothers, is the second leading cause of death in children and the leading cause of undernutrition. Primary causes are unsafe drinking water and inadequate hygiene and sanitation. Underlying malnutrition is also a significant cause (WHO, 2017a).

3.7. Mortality

An indicator for whether a child born less than 60 months before the survey had died was used to indicate under-5 mortality. Major causes of mortality in the neonatal period in India are prematurity and low birth weight, neonatal infections, and birth asphyxia and trauma. After the neonatal period, pneumonia and diarrhea are the most common causes of mortality in children under five (Million Death Study Collaborators, 2010).

4. Exposure variables

The exposure variables of interest, shown in Table 2, were all wealth index items (assets and amenities) used to construct the DHS wealth index for the 2015–2016 NFHS dataset. Some wealth index items were binary variables indicating household's ownership of specific items, such as refrigerator, car, radio, and water pump. There were also categorical variables, which were dummy coded in our analysis with the most prevalent category, in terms of our samples of children, for each variable as an omitted reference category (RC). Categorical variables in our analysis were the type of toilet facilities, type of water access, type of cooking fuel, and type of materials used to build the floor, wall, and roof. The only continuous wealth index item was the number of residents per bedroom in the household. Exposures were grouped into five broad categories; a) water and toilet facilities, b) food storage and preparation,

Table 2
Five groups of assets and amenities.

a) Water and toilet facilities	b) Food storage and preparation	c) Other consumer goods	d) Housing quality	e) Other items
Ownership of a water pump	Ownership of a refrigerator	Ownership of a radio	Number of residents per bedroom	Household has staff
Type of toilet facility	Ownership of a pressure cooker	Ownership of a bicycle	Main material of the floor	Household member has a bank account
Type of water access	Type of cooking fuel	Ownership of a motorcycle/scooter	Main material of the roof	Household has access to electricity
		Ownership of a car/truck	Main material of the walls	Ownership of an animal-drawn cart
		Ownership of a telephone (land-line)		Ownership of land usable for agriculture
		Ownership of a mobile telephone		Household has access to internet
		Ownership of a watch		Ownership of a thresher
		Ownership of a mattress		Ownership of a tractor
		Ownership of a chair		Household member owns a house
		Ownership of a cot/bed		
		Ownership of a table		
		Ownership of an electric fan		
		Ownership of a black and white television		
		Ownership of a color television		
		Ownership of a sewing machine		
		Ownership of a computer		
		Ownership of an air conditioner/cooler		
		Ownership of a washing machine		

c) other consumer goods, d) quality of living quarters, e) and other items, mostly producer durables such as farm equipment which determine SES (Montgomery & Hewett, 2005), but also amenities, such as access to electricity and internet.

5. Covariates

Ownership of items included in the wealth index is likely associated with a host of other attributes, such as income and living standards in general, as well as the availability of services and other community-level and ecological factors, demographic behaviors (e.g., fertility), and even the past living standards of the parents. Therefore, this study used numerous control variables to estimate the independent association of each wealth index item with child health, guided by Mosley and Chen's (1984) analytical framework.

Firstly, maternal age at birth, birth order, and birth interval were controlled for. The birth interval was adjusted for firstborns and twins (or triplets) using a dummy variable adjustment. Maternal age at birth was controlled for using a linear and a squared term because children of young mothers may have worse outcomes due to less developed child-rearing skills, physiological immaturity, and SES disadvantages (Fraser, Brockert, & Ward, 1995), while biological factors may also cause worse outcomes for children born to older mothers (Schmidt, Sobotka, Bentzen, & Nyboe Andersen, 2012). We controlled for two indicators of health care use; whether the child had not received any vaccines and whether the child was born at home and not in a health facility. Vaccination status was only collected for surviving children and was therefore excluded when analyzing mortality, as well as low birth weight, to increase sample size, as birth weight was also collected for non-survivors.

We controlled for SES measures; maternal education, membership of a scheduled caste, scheduled tribe, or other backward classes, and wealth index quintiles. We also controlled for maternal height, which indicates the mother's past living standards and accumulated health and nutrition (Subramanian, Ackerson, Smith, & John, 2009). We controlled for unobserved community-level factors indicated by PSUs, which represent a rural village or an urban neighborhood (and therefore also implicitly controlling for urban-rural differences).

We avoided controlling for determinants of child health that may be directly affected by the wealth index items, such as mother's body mass index and anemia. All models controlled for months since the birth and sex of the child.

6. Models

We used conditional Poisson regression models to estimate the prevalence ratio of each wealth index item:

$$\text{Poisson}(y_{ihp} = 1) = \sum_{j=1}^J \beta_j w_{jh} + \gamma' \mathbf{x}_{ih} + \mu_p$$

where y indicates whether child i in household h and PSU p has experienced the outcome, and w_{jh} is wealth index item j in household h . μ_p is a PSU fixed effect that controls for unobserved ecological and community-level factors. \mathbf{x}_{ih} is a vector of control variables at the household- or individual-level. $\exp(\beta_j)$ is presented and shows the prevalence ratio for wealth index item j .

It has been suggested that prevalence ratios are more desirable than odds ratio from logit models when outcomes are common (greater than 10%) since the differences between odds ratios and prevalence ratios can be substantial. Poisson regressions with robust standard errors have been suggested as a good alternative to estimate prevalence ratios consistently and efficiently (Barros & Hiraakata, 2003; Zou, 2004).

We conducted sensitivity checks to assess the robustness of our results. First, we present models using different adjustments. Controlling for all wealth index items simultaneously may cause problems for

interpretations in some cases. For example, part of the protective association of electricity may be related to having electronic household appliances, and entering all wealth index items simultaneously may control away some of the impact of electricity on child health. Therefore, we show models where each wealth index item was entered separately into statistical models, both without (Table A1 in the supplementary appendix) and with (Table A2 in the supplementary appendix) covariates for maternal factors, SES, and health care use. The conditional Poisson models with PSU fixed-effects exclude PSUs with single observations and PSUs with no observations experiencing the outcomes, which reduces the analytical sample (see Table 1). We addressed this using alternative models using district fixed-effects in our sensitivity analysis (Table A3 in the supplementary appendix). We also show models excluding fixed-effects (Table A4 in the supplementary appendix).

Second, to test for sensitivity to the choice of statistical models we used conditional logit models and present odds ratios which is a common approach to modeling binary outcomes (Table A5 in the supplementary appendix). We also show results from PSU fixed-effects linear regression models using height-for-age, weight-for-age, weight-for-height, hemoglobin level, and birth weight as continuous measures (Table A6 in the supplementary appendix).

Finally, we impute missing outcomes and covariates using multiple imputation chained equations. We used all independent variables and outcomes for the imputation as well as number of auxiliary variables (listed under tables). We show imputed results for conditional Poisson regressions using district fixed-effects (Table A7 in the supplementary appendix) in order to obtain results for the whole sample.

Since multicollinearity was a concern when including many independent variables, we also show the variance inflation factor (VIF) for each wealth index item (Table A8 in the supplementary appendix). The VIF quantifies how much the variance of an estimate increases due to multicollinearity. Multicollinearity does not influence the estimates but causes problems for significance testing and, in extreme cases, the interpretation of coefficients. No firm cut-off point indicates when multicollinearity becomes a problem, but a VIF of 5 or 10 is commonly suggested as a rule of thumb (James, Witten, Hastie, & Tibshirani, 2013, pp. 99–101). Multicollinearity was not a big concern in this analysis. Some items show a VIF of up to 18 while most items had a VIF below 5. Wealth indices have generally been found to explain very little of the total variance in the wealth index items (7% in our case), which explains the low multicollinearity (Howe et al., 2012; Rutstein & Johnson, 2004).

We use robust standard errors adjusted for clustering at the PSU-level. We included all items in our statistical models, but only present results for common wealth index items that had a prevalence of at least 5% for households, in our main table (full outputs are shown in Table A9 in the supplementary appendix). We interpret estimates that are statistically significant at the 5% level. It should, however, be kept in mind that due to the large number of relationships being estimated, several estimates are likely to be statistically significant due to random sampling error. We, therefore, focus our discussion of results on items that are most consistently associated with different child health outcomes.

7. Results

Table 3 shows descriptive statistics for outcomes and covariates. The means were 0.387 (95% confidence interval [CI] 0.383, 0.391) for stunting, 0.359 (95% CI 0.356, 0.363) for being underweight, 0.21 (95% CI 0.207, 0.213) for wasting, 0.585 (95% CI 0.581, 0.589) for anemia, 0.091 (95% CI 0.089, 0.093) for occurrence of diarrhea in the two weeks preceding the interview, 0.182 (95% CI 0.178, 0.185) for low birth weight, and 0.044 (95% CI 0.043, 0.045) for mortality.

7.1. Water source and toilet facilities

Table 4 shows our main results. Panel a) shows results for items

Table 3
Descriptive statistics.

	Mean	95% CI	Missing values	Valid observations
Stunting	0.387	0.383, 0.391	21,001	2,13,628
Underweight	0.359	0.356, 0.363	21,001	2,13,628
Wasting	0.210	0.207, 0.213	21,001	2,13,628
Anemia	0.585	0.581, 0.589	34,559	2,00,070
Diarrhea	0.091	0.089, 0.093	525	2,34,104
Low birth weight	0.182	0.178, 0.185	63,374	1,82,492
Mortality	0.044	0.043, 0.045	0	2,45,866
Female	0.479	0.476, 0.482	0	2,34,629
Age (months)	30.180	30.08, 30.27	0	2,34,629
Siblings ever born	2.490	2.470, 2.500	0	2,34,629
Birth order	2.210	2.200, 2.220	0	2,34,629
Birth interval (months) ¹	38.000	37.76, 38.23	87,531	1,47,098
First born	0.376	0.373, 0.379	0	2,34,629
Mother's age at birth (years)	24.770	24.72, 24.81	0	2,34,629
Mother's education: none	0.302	0.297, 0.308	0	2,34,629
Mother's education: primary	0.139	0.136, 0.142	0	2,34,629
Mother's education: secondary	0.455	0.450, 0.460	0	2,34,629
Mother's education: higher	0.104	0.101, 0.107	0	2,34,629
Caste/tribe: schedule caste	0.223	0.218, 0.228	9,162	2,25,467
Caste/tribe: schedule tribe	0.110	0.106, 0.114	9,162	2,25,467
Caste/tribe: other backward class	0.456	0.449, 0.462	9,162	2,25,467
Caste/tribe: none of them	0.202	0.197, 0.207	9,162	2,25,467
Caste/tribe: don't know	0.009	0.008, 0.010	9,162	2,25,467
Wealth quintile: first	0.248	0.242, 0.253	0	2,34,629
Wealth quintile: second	0.222	0.218, 0.226	0	2,34,629
Wealth quintile: third	0.199	0.196, 0.203	0	2,34,629
Wealth quintile: fourth	0.181	0.177, 0.186	0	2,34,629
Wealth quintile: fifth	0.150	0.145, 0.154	0	2,34,629
Singleton birth	0.986	0.985, 0.987	0	2,34,629
First born twin/triplet etc.	0.007	0.007, 0.008	0	2,34,629
Later born twin/triplet etc.	0.007	0.006, 0.007	0	2,34,629
Delivered at home	0.208	0.203, 0.212	559	2,34,070
Received no vaccination	0.079	0.077, 0.082	0	2,34,629
Maternal height (z-score)	-2.020	-2.03, -2.01	3,030	2,31,599

Notes: Estimates were weighted and standard errors (SE) and 95% confidence intervals (CI) were adjusted for clustering at the PSU-level. ¹Excludes firstborns and twins in this table.

related to water source and toilet facilities. Compared to having no toilet, the most common type of toilet facilities (0.389 of households, 95% CI 0.383, 0.395), having a toilet which flushes to a septic tank has a statistically significant protective association with all outcomes except wasting and diarrhea. The prevalence ratio was 0.943 (95% CI 0.919, 0.968) for stunting, 0.946 (95% CI 0.920, 0.973) for being underweight, 0.969 (95% CI 0.953, 0.985) for anemia, 0.950 (95% CI 0.908, 0.995) for low birth weight, and 0.841 (95% CI 0.762, 0.928) for mortality. Having a toilet which flushes to a piped sewer system also shows a statistically significant protective association for stunting (0.931; 95% CI 0.886, 0.978), low birth weight (0.911; 95% CI 0.844, 0.984), and especially for mortality (0.652; 95% CI 0.522, 0.814). Having a shared toilet which flushes to a septic tank shows a statistically significant protective association with stunting (0.940; 95% CI 0.906, 0.974) and underweight (0.943; 95% CI 0.908, 0.979) but was associated with a higher prevalence of diarrhea (1.086; 95% CI 1.007, 1.172).

Most households had a tube well or borehole as a water source (0.392; 95% CI 0.386, 0.399). Having a water source which is piped into yard/plot shows a statistically significant protective association for wasting (0.940; 95% CI 0.896, 0.986), anemia (0.972; 95% CI 0.952, 0.993) and especially mortality (0.857; 95% CI 0.751, 0.977). Having a water source which was piped into dwelling only shows a statistically significant association with mortality (0.724; 95% CI 0.627, 0.836).

7.2. Cooking and food storage

Panel b) in Table 4 shows results for items related to cooking and food storage. Having a pressure cooker shows a statistically significant protective association for stunting (0.973; 95% CI 0.954, 0.992), underweight (0.953; 95% CI 0.933, 0.973), anemia (0.978; 95% CI 0.965, 0.991), and low birth weight (0.944; 95% CI 0.910, 0.980). Having a refrigerator shows a statistically significant protective association for stunting (0.954; 95% CI 0.926, 0.982), being underweight (0.943; 95% CI 0.914, 0.972) and wasting (0.947; 95% CI 0.910, 0.987). A common cooking fuel was wood (0.405; 95% CI 0.399, 0.411) but using liquefied petroleum gas (LPG)/natural gas shows a statistically significant protective association for stunting (0.962; 95% CI 0.936, 0.989), being underweight (0.958; 95% CI 0.931, 0.986), and low birth weight (0.942; 95% CI 0.901, 0.985). Cooking with animal dung generally shows a harmful association, statistically significant for being underweight (1.033; 95% CI 1.006, 1.061) and diarrhea (1.085; 95% CI 1.023, 1.149).

7.3. Other consumer goods

Panel c) in Table 4 shows results for other consumer goods. Having a mobile phone had a statistically significant protective association with stunting (0.968; 95% CI 0.946, 0.991), underweight (0.946; 95% CI 0.923, 0.969), wasting (0.921; 95% CI 0.886, 0.959), anemia (0.981; 95% CI), and low birth weight (0.909; 95% CI 0.864, 0.958). Having a motorcycle/scooter had a statistically significant protective association with stunting (0.952; 95% CI 0.935, 0.970), underweight (0.957; 95% CI 0.939, 0.976), wasting (0.972; 95% CI 0.946, 0.999), diarrhea (0.937; 95% CI 0.899, 0.976), and mortality (0.885; 95% CI 0.826, 0.949). Having a bicycle had a statistically significant protective association for stunting (0.976; 95% CI 0.961, 0.990), being underweight (0.980; 95% CI 0.965, 0.996), and anemia (0.989; 95% CI 0.979, 0.998), while showing a statistically significant harmful association with wasting (1.035; 95% CI 1.011, 1.059).

7.4. Housing quality

Panel d) in Table 4 shows results for housing quality. Having more residents per bedroom shows a harmful association for stunting (1.008; 95% CI 1.004, 1.012) and being underweight (1.006; 95% CI 1.002, 1.010) but a strong protective association for mortality (0.731; 95% CI

Table 4
Results from conditional Poisson regressions.

	Stunting	Underweight	Wasting	Anemia	Diarrhea	Low birth weight	Mortality	Proportion (households)
a) Water and toilet facilities								
Water pump	0.973**	0.990	1.010	1.010	0.969	0.928***	0.968	0.172
Toilet: no facility/bush/field	RC	RC	RC	RC	RC	RC	RC	0.389
Toilet: flush to piped sewer system	0.931***	0.982	1.001	0.994	0.966	0.911**	0.652***	0.078
Toilet: shared flush to septic tank	0.940***	0.943***	0.978	0.991	1.086**	1.056*	1.010	0.054
Toilet: flush to septic tank	0.943***	0.946***	0.996	0.969***	0.977	0.950**	0.841***	0.287
Toilet: flush to pit latrine	0.976	0.996	0.968	0.962***	1.007	0.935**	0.835**	0.072
Water: tube well or borehole	RC	RC	RC	RC	RC	RC	RC	0.392
Water: piped into dwelling	0.976	1.000	0.968	0.994	0.987	1.019	0.724***	0.166
Water: piped to yard/plot	1.023	1.002	0.940**	0.972***	1.026	1.013	0.857**	0.136
Water: public tap/standpipe	1.025*	1.005	1.014	0.997	1.053	1.009	1.018	0.159
b) Food storage and preparation								
Refrigerator	0.954***	0.943***	0.947***	1.000	1.012	0.972	0.929	0.296
Pressure cooker	0.973***	0.953***	0.993	0.978***	1.045*	0.944***	0.986	0.566
Cooking: wood	RC	RC	RC	RC	RC	RC	RC	0.405
Cooking: animal dung	1.022*	1.033**	0.993	1.014	1.085***	1.021	1.092*	0.072
Cooking: LPG/natural gas	0.962***	0.958***	0.970	1.002	1.058*	0.942***	0.948	0.423
c) Other consumer goods								
Radio	0.979	1.004	1.014	1.018*	1.025	1.070***	0.966	0.081
Bicycle	0.976***	0.980**	1.035***	0.989**	0.970*	0.982	1.007	0.521
Motorcycle/scooter	0.952***	0.957***	0.972**	0.991	0.937***	0.976	0.885***	0.377
Car/truck	0.927***	0.900***	0.941*	0.988	0.947	1.048	1.009	0.060
Mobile telephone	0.968***	0.946***	0.921***	0.981**	1.015	0.909***	1.071	0.904
Watch	0.989	1.011	1.018	0.985***	0.979	1.023	0.922**	0.781
Mattress	0.985*	0.999	0.986	0.992	0.983	0.990	0.983	0.667
Chair	0.990	0.996	0.993	0.995	0.980	0.972	0.958	0.762
Cot/bed	1.012	0.998	0.982	1.013	0.943*	1.007	0.819***	0.884
Table	1.011	1.005	0.968**	0.990*	0.907***	0.969*	1.011	0.554
Electric fan	0.981*	0.984	0.962**	0.993	0.971	0.990	0.939	0.782
Color television	0.977**	0.979*	1.004	0.992	0.985	0.959**	0.957	0.635
Sewing machine	0.976**	0.984	0.996	0.991	1.020	0.981	0.898***	0.240
Computer	1.017	0.961	1.026	0.954***	0.983	0.953	0.863	0.090
Air conditioner/cooler	1.025*	1.038**	1.018	0.999	1.091***	0.977	0.925	0.179
Washing machine	0.960*	0.979	0.925***	0.980*	1.035	0.968	0.857*	0.136
d) Housing quality								
Residents per bedroom	1.008***	1.006***	0.996	1.000	0.999	1.002	0.731***	2.917
Floor: cement	RC	RC	RC	RC	RC	RC	RC	0.393
Floor: mud/clay/earth	1.026**	1.004	0.993	1.003	1.011	1.025	1.093*	0.271
Floor: ceramic tiles	1.052***	0.975	0.976	0.987	0.956	1.030	1.059	0.106
Floor: polished stone/marble/grani.	0.980	0.932***	0.977	0.962***	0.869***	0.949*	1.050	0.077
Floor: dung	1.027	1.010	0.955*	1.016	0.982	1.009	1.070	0.070
Floor: stone	1.013	0.955**	0.935**	0.967***	0.810***	0.900***	1.135	0.055
Roof: RCC/RBC/cement/concrete	RC	RC	RC	RC	RC	RC	RC	0.413
Roof: metal/GI	0.991	1.015	1.037	1.015	1.068	0.976	1.088	0.110
Roof: asbestos sheets	0.985	0.984	0.972	1.016*	0.972	1.085***	1.089	0.076
Roof: tiles	1.059***	1.030*	1.023	1.004	1.045	1.088***	1.224***	0.071
Roof: slate	1.003	1.002	0.984	0.989	0.916**	1.015	1.183***	0.081
Wall: cement/concrete	RC	RC	RC	RC	RC	RC	RC	0.379
Wall: stone with lime/cement	1.008	1.001	1.065**	1.046***	0.994	1.089***	1.035	0.059
Wall: burnt bricks	1.024*	1.016	1.026	1.011	0.958	1.035	1.063	0.252
Wall: cement blocks	0.999	1.015	1.081***	0.996	1.030	1.085***	1.206**	0.058
Wall: mud	0.990	1.000	1.039	1.046***	0.994	1.070**	1.080	0.136
e) Other								
Bank account	0.972***	0.987	0.980	0.988*	1.088***	0.943***	0.970	0.895
Electricity	0.991	0.979*	0.982	0.995	1.005	0.998	0.964	0.882
Land usable for agriculture	0.991	0.957***	0.958***	0.977***	0.962**	0.998	0.962	0.389
Internet	1.029	0.977	0.924***	1.002	1.005	0.947*	0.972	0.109
Household member owns a house	1.022**	1.004	1.001	0.994	1.022	0.958**	1.004	0.798
Observations	185,529	179,341	157,464	181,977	110,384	118,263	86,172	601,509

Notes: ***p < 0.01, **p < 0.05, *p < 0.1. Prevalence ratios are shown. All estimates were weighted and tests for statistical significance were done using robust standard errors. All estimates in each column were obtained from a single model. Control variables: sex, age, maternal age at birth, birth order, birth interval, firstborn, twin, vaccination status (except for mortality and low birth weight), born at home, maternal education, caste/tribe, and wealth index quintiles. Models were further adjusted for unobserved PSU-level factors. Proportions are for all households interviewed. Prevalence ratios are only shown for items which are observed in over 5% of households. Full outputs are shown in Table A9 in the supplementary appendix. Acronyms and abbreviations: liquefied petroleum gas (LPG), reinforced cement concrete (RCC), reinforced brick concrete (RBC), galvanized iron (GI), granite (grani.), reference category (RC).

0.716, 0.747). The most common type of floor material was cement (0.393; 95% CI 0.388, 0.397). Having a stone floor shows a statistically significant protective association for five outcomes; being underweight (0.955; 95% CI 0.916, 0.996), wasting (0.935; 95% CI 0.881, 0.992), anemia (0.967; 95% CI 0.943, 0.991), diarrhea (0.810; 95% CI 0.732, 0.897), and low birth weight (0.900; 95% CI 0.845, 0.959). Having polished stone/marble/granite floor shows a statistically significant

protective association for being underweight (0.932; 95% CI 0.891, 0.974), anemia (0.962; 95% CI 0.941, 0.984), and diarrhea (0.869; 95% CI 0.799, 0.946). The most common type of roof material was reinforced cement concrete (RCC)/reinforced brick concrete (RBC)/cement/concrete (0.413; 95% CI 0.408, 0.419). Having a roof made of tiles shows a statistically significant harmful association with stunting (1.059; 95% CI 1.027, 1.093), low birth weight (1.088; 95% CI 1.027, 1.152), and

especially mortality (1.224; 95% CI 1.072, 1.397).

7.5. Other results

Panel e) in Table 4 shows results for other items. Having land usable for agriculture shows a statistically significant protective association for four outcomes; being underweight (0.957; 95% CI 0.941, 0.974), wasting (0.958; 95% CI 0.934, 0.983), anemia (0.977; 95% CI 0.967, 0.988), and diarrhea (0.962; 95% CI 0.926, 1.000). Having a bank account shows a statistically significant protective association for two outcomes; stunting (0.972; 95% CI 0.954, 0.991) and low birth weight (0.943; 95% CI 0.905, 0.982), while showing a statistically significant harmful association for diarrhea (1.088; 95% CI 1.035, 1.144).

There were some noteworthy results from our sensitivity analysis. First, Table A1 in the supplementary appendix shows results for models where each wealth index item was entered separately, excluding covariates for SES, maternal factors, and health care use. Table A1 shows that most wealth index items show a statistically significant association with child health outcomes. After a full set of covariates was added, shown in Table A2 in the supplementary appendix, the results are similar to our main models, despite each wealth index item being entered separately. Table A4 in the supplementary appendix shows that when fixed-effects (PSU or district) are not applied, there are more statistically significant relationships found, for example, the relationship between type of toilet facilities and diarrhea, and electricity and stunting, underweight, diarrhea, and mortality.

8. Discussion

In this paper, we used nationally representative household survey data to explore relationships between household assets and amenities and diverse child health outcomes in India. We used all items used to construct the DHS wealth index, which was derived from households' ownership of durable consumer goods and productive assets, housing quality, water and sanitation facilities, and other amenities. Specifically, we explored which items had an independent association with child health, adjusted for common measures of SES, maternal factors, health care use, and community-level factors. Some of these wealth index items are simple markers of SES, while others may have a direct effect on the major proximate determinants of child health, nutrition and exposures to infections (Filmer & Scott, 2012; Houweling, Kunst, & Mackenbach, 2003).

Our results indicated that most items used to construct the DHS wealth index reflect SES, rather than being independently associated with child health on their own. Yet, a few common items emerged as having the most consistent protective association with child health, showing a statistically significant association for four or five outcomes; having a flush toilet instead of no toilet, pressure cooker, mobile phone, motorcycle/scooter, a floor made of stone instead of cement, and owning land usable for agriculture. Several common items also showed a statistically significant protective association for three outcomes; refrigerator, bicycle, cooking with LPG/natural gas instead of wood, having piped water into yard/plot instead of tube well or borehole, and having RCC/RBC/cement/concrete roof instead of tile roof. The association with type of toilet facilities and water source was particularly strong for mortality, showing a 16–35% and 14–28% lower mortality, respectively.

This analysis has limitations. First, the design of this study was explorative; associations may, for example, reflect unobserved measures of SES and additional studies are needed to determine a causal relationship between assets and amenities, and child health. Nevertheless, we controlled for confounders, most importantly unobserved community-level factors and various measures of SES. Second, the data only recorded households' ownership of wealth index items at the time of the survey, which may differ from ownership during other important periods, such as the neonatal period or infancy. We did, however, limit

our analysis to children born less than five years before a survey, and dramatic changes in item ownership were less likely to have occurred over such a short period.

Inadequate access to clean water and unhygienic toilet facilities increase exposure to harmful pathogens and infection and are the primary cause of diarrhea - a major cause of undernutrition and mortality. A previous study found the quality of toilet facilities and the source of water to be negatively associated with under-five mortality, stunting, and the prevalence of diarrhea in 70 LMICs (Fink, Günther, & Hill, 2011). Good sources of drinking water include piped water, public taps or standpipes, and protected wells (WHO, 2009). In our study, having water piped into dwelling had a strong protective association with mortality, but not for other outcomes. Having water piped into yard/plot had a protective association with wasting, anemia, and especially mortality. Proper toilet facilities include flush toilets and composting toilets (WHO, 2009) which can reduce exposure to fecal germs (Mbuya & Humphrey, 2016). Almost 40% of households had no toilet facilities. However, almost 30% of households had a toilet which flushes to a septic tank, and they were associated with a 3–6% lower prevalence of stunting, underweight, anemia, and low birth weight, and 16% lower mortality. Fewer households had a toilet that flushes to a piped sewer system, which was associated with 7% lower prevalence of stunting, 9% lower prevalence for low birth weight, and especially mortality, which was reduced by 35%.

We did not find a consistent association between common types of toilet facilities and diarrhea, which was surprising, as unhygienic toilet facilities, as well as water source, have been cited as the most important cause of diarrhea globally (WHO, 2009). A possible explanation is the reliance on mother's diagnosis of diarrhea cases. It may also be that the type of toilet facility operates at the community-level rather than the household-level (Geruso & Spears, 2018), and models which did not adjust for PSU or district fixed-effects showed a protective association.

Home appliances have not been studied sufficiently as potential determinants of child health. In general, household appliances make housework more efficient (Brenneman, 2014, p. 2002; Fay, Leipziger, Wodon, & Yepes, 2005). Cooking equipment can also facilitate the storage and preparation of food. Refrigerators can reduce food contamination and improve nutrition by allowing families to consume more high-protein foods, rather than relying exclusively on grains and vegetables (Meckel, 1990; Nickles, 2002; The Economist, 2014). We find that households with refrigerators had more favorable child health for most outcomes, although only statistically significant for stunting, being underweight, and wasting, or about 5–6% lower prevalence. Since only 30% of households had a refrigerator there is large room for improvements.

Ownership of efficient cooking equipment may affect child health since ninety-five percent of food requires cooking (Dfid, 2002; IEA, 2002). Furthermore, indoor air pollution from cooking fuel is a major cause of pneumonia, one of the leading causes of child deaths and morbidity (WHO, 2014, p. 292). In our study, wood was found to be one of the most commonly used cooking fuel (41%), but those using other biofuels, such as animal dung, generally showed worse child health outcomes. Notably, using LPG/natural gas showed protective association for stunting, being underweight, and low birth weight, with about 4–6% lower prevalence. Another study from India found the use of biofuel (e.g., wood, crop residue, or dung cakes) as opposed to cleaner fuels (e.g., electricity, liquid petroleum gas, biogas, or kerosene) to be associated with a higher incidence of anemia and stunting (Mishra & Retherford, 2007). In addition, our study observed that owning a pressure cooker, which is another clean way to prepare food, had a protective association with stunting, being underweight, anemia, and low birth weight, between 2 – 6% reduced prevalence.

Other wealth index items could possibly affect child health. Access to electricity provides a multitude of benefits for communities and households by improving access to pumped drinking water, powering water and sanitation infrastructure, and making agricultural and

domestic work more efficient (Kjellstrom et al., 2007). Previous studies have also suggested that access to electricity is associated with child health (Akachi, Steenland, & Fink, 2017). But this association was less robust in our study. The fixed-effects may capture the impact of electricity in our study since excluding fixed-effects (PSU or district) resulted in a statistically significant associations with several outcomes. Although access to electricity was observed for 88% of households, it may be unreliable for many households.

Number of residents per bedroom can indicate crowding which can affect hygiene and exposures to infection and was found to be positively associated with stunting in a previous study (Shah, Selwyn, Luby, Merchant, & Bano, 2003). We found number of residents per bedroom to have a harmful association with stunting and being underweight, but a strong protective association with mortality.

Having a motorcycle/scooter, a mobile phone, and land usable for agriculture was also consistently associated with several outcomes. These assets and amenities may affect child health; mobile phones can provide information, for example through mhealth applications (LeFevre, Agarwal, Chamberlain, Scott, & Godfrey, 2019) and motorcycle/scooter may facilitate travel, for example to health facilities. These assets can, however, also be markers for SES confounders not captured by our covariates.

9. Conclusion

To our knowledge, this is the first research to explore the association between all items used to construct the widely used DHS wealth index and child health outcomes. Most items appear to be markers of SES, rather than exposures with direct influence on child health, while a few common items show a consistent association with child health outcomes. The main contribution of this study is in highlighting the specific assets and amenities that may be important exposures with direct influence on child health on their own; some are well-established factors such as type of toilet facilities and source of water, while other are less known, such as assets used for cooking and storing food.

Contributors

All authors contributed to the study concept and design, the interpretation of findings, and the drafting of the manuscript. OK acquired the data and performed the statistical analysis. OK is the guarantor for the overall content of this article. All authors approved the final version of the submitted manuscript.

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Compliance with ethical standards

This analysis was reviewed by the Harvard T.H. Chan School of Public Health Institutional Review Board and was considered exempt from full review because the study was based on an anonymous public use dataset with no identifiable information on the survey participants. Procedures and questionnaires were approved by the ICF International Review Board and the International Institute for Population Sciences (IIPS) Institutional Review Board, and protocols were reviewed by U.S. Centers for Disease Control and Prevention (CDC).

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2019.100513>.

References

- Akachi, Y., Steenland, M., & Fink, G. (2017). Associations between key intervention coverage and child mortality: An analysis of 241 sub-national regions of sub-Saharan Africa. *International Journal of Epidemiology*, 47(3), 740–751.
- Almond, D. V., Chay, K. Y., & Lee, D. S. (2002). *Does low birth weight matter? Evidence from the US Population of Twin Births*. Working paper NO. 53. Center for Labor Economics. Retrieved from <http://cle.berkeley.edu/wp/wp53.pdf>.
- Barros, A. J., & Hirakata, V. N. (2003). Alternatives for logistic regression in cross-sectional studies: An empirical comparison of models that directly estimate the prevalence ratio. *BMC Medical Research Methodology*, 3(1), 21.
- Borchers, M., & Ilne-Mari, H. (1997). *Rural electrification supply options to support health, education, and SMME development*. Energy & Development Research Centre: University of Cape Town.
- Brenneman, A. (2014). *Infrastructure & poverty linkages: A literature review*. Washington, DC: World Bank.
- Corsi, D. J., Neuman, M., Finlay, J. E., & Subramanian, S. V. (2012). Demographic and health surveys: A profile. *International Journal of Epidemiology*, 41(6), 1602–1613.
- Desai, S. (2000). Maternal education and child health: A feminist dilemma. *Feminist Studies*, 26(2), 425–446.
- DHS. (2019). Wealth index construction. Retrieved February 19, 2019, from The DHS Program website: <https://dhsprogram.com/topics/wealth-index/Wealth-Index-Construction.cfm>.
- DfID. (2002). *Energy for the poor: Underpinning the Millennium development goals*. London: Department for International Development.
- Doza, S., Jabeen Rahman, M., Islam, M. A., Kwong, L. H., Unicomb, L., Ercumen, A., et al. (2018). Prevalence and association of Escherichia coli and diarrheagenic Escherichia coli in stored foods for young children and flies caught in the same households in rural Bangladesh. *The American Journal of Tropical Medicine and Hygiene*, 98(4), 1031–1038. <https://doi.org/10.4269/ajtmh.17-0408>.
- Fay, M., Leipziger, D., Wodon, Q., & Yepes, T. (2005). Achieving child-health-related Millennium development goals: The role of infrastructure. *World Development*, 33(8), 1267–1284.
- Filmer, D., & Pritchett, L. H. (2001). Estimating Wealth Effects Without Expenditure Data—Or Tears: An Application To Educational Enrollments In States Of India. *Demography*, 38(1), 115–132. <https://doi.org/10.1353/dem.2001.0003>.
- Filmer, D., & Scott, K. (2012). Assessing asset indices. *Demography*, 49(1), 359–392. <https://doi.org/10.1007/s13524-011-0077-5>.
- Fink, G., Günther, I., & Hill, K. (2011). The effect of water and sanitation on child health: Evidence from the demographic and health surveys 1986–2007. *International Journal of Epidemiology*, 40(5), 1196–1204. <https://doi.org/10.1093/ije/dyr102>.
- Fraser, A. M., Brockert, J. E., & Ward, R. H. (1995). Association of young maternal age with adverse reproductive outcomes. *New England Journal of Medicine*, 332(17), 1113–1118.
- Galobardes, B., Lynch, J., & Smith, G. D. (2007). Measuring socioeconomic position in health research. *British Medical Bulletin*, 81(1), 21.
- Geruso, M., & Spears, D. (2018). Neighborhood sanitation and infant mortality. *American Economic Journal: Applied Economics*, 10(2), 125–162.
- Greenwood, J., Seshadri, A., & Yorukoglu, M. (2005). Engines of liberation. *The Review of Economic Studies*, 72(1), 109–133.
- Gwatkin, D. R., Rutstein, S., Johnson, K., Suliman, E., Wagstaff, A., & Amouzou, A. (2007). *Socio-Economic Differences in Health, Nutrition, and Population Within Developing Countries*. The World Bank. <https://siteresources.worldbank.org/INTPAH/Resources/IndicatorsOverview.pdf>.
- Hoddinott, J., Alderman, H., Behrman, J. R., Haddad, L., & Horton, S. (2013). The economic rationale for investing in stunting reduction. *Maternal and Child Nutrition*, 9(S2), 69–82.
- Houweling, T. A., Kunst, A. E., & Mackenbach, J. P. (2003). Measuring health inequality among children in developing countries: Does the choice of the indicator of economic status matter? *International Journal for Equity in Health*, 2(1), 8. <https://doi.org/10.1186/1475-9276-2-8>.
- Howard, C. T., de Pee, S., Sari, M., Bloem, M. W., & Semba, R. D. (2007). Association of diarrhea with anemia among children under age five living in rural areas of Indonesia. *Journal of Tropical Pediatrics*, 53(4), 238–244.
- Howe, L. D., Galobardes, B., Matijasevich, A., Gordon, D., Johnston, D., Onwujekwe, O., et al. (2012). Measuring socio-economic position for epidemiological studies in low and middle-income countries: A methods of measurement in epidemiology paper. *International Journal of Epidemiology*, 41(3), 871–886. <https://doi.org/10.1093/ije/dys037>.
- IEA. (2002). Energy and poverty. *IAEA Bulletin*. International Energy Agency.

- International Institute for Population. (2018). *India national family health survey (NFHS-3), 2015-16*. International Institute for Population Sciences.
- Islam, M. A., Ahmed, T., Faruque, A. S. G., Rahman, S., Das, S. K., Ahmed, D., et al. (2012). Microbiological quality of complementary foods and its association with diarrhoeal morbidity and nutritional status of Bangladeshi children. *European Journal of Clinical Nutrition*, 66(11), 1242.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning* (Vol. 112). Springer.
- Kamal, S. M. (2011). Socio-economic determinants of severe and moderate stunting among under-five children of rural Bangladesh. *Malaysian Journal of Nutrition*, 17(1).
- Kjellstrom, T., Friel, S., Dixon, J., Corvalan, C., Rehfuess, E., Campbell-Lendrum, D., et al. (2007). Urban environmental health hazards and health equity. *Journal of Urban Health*, 84(1), 86–97.
- Kotecha, P. V. (2011). Nutritional anemia in young children with focus on Asia and India. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine*, 36(1), 8.
- LeFevre, A., Agarwal, S., Chamberlain, S., Scott, K., & Godfrey, A. (2019). Are stage-based health information messages effective and good value for money in improving maternal newborn and child health outcomes in India? Protocol for an individually randomized controlled trial. *Trials*, 20(1), 1011–1020. <https://doi.org/10.1186/s13063-019-3369-5>.
- Lewis, J. (2018). Infant health, women's fertility, and rural electrification in the United States, 1930–1960. *The Journal of Economic History*, 78(1), 118–154. <https://doi.org/10.1017/S0022050718000050>.
- Mbuya, M. N., & Humphrey, J. H. (2016). Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: An opportunity for stunting reduction in developing countries. *Maternal and Child Nutrition*, 12, 106–120.
- Meckel, R. A. (1990). In , Vol. 32. *Save the babies: American public health reform and the prevention of infant mortality, 1850-1929*. University of Michigan Press.
- Miller, G., & Urdinola, B. P. (2010). Cyclicity, mortality, and the value of time: The case of coffee price fluctuations and child survival in Colombia. *Journal of Political Economy*, 118(1), 113–155.
- Million Death Study Collaborators. (2010). Causes of neonatal and child mortality in India: A nationally representative mortality survey. *The Lancet*, 376(9755), 1853–1860.
- Mishra, V., & Retherford, R. D. (2007). Does biofuel smoke contribute to anaemia and stunting in early childhood? *International Journal of Epidemiology*, 36(1), 117–129. <https://doi.org/10.1093/ije/dyl234>.
- Mokyr, J. (2000). Why “more work for mother?” Knowledge and household behavior, 1870–1945. *The Journal of Economic History*, 60(1), 1–41.
- Montgomery, M. R., & Hewett, P. C. (2005). Urban poverty and health in developing countries: Household and neighborhood effects. *Demography*, 42(3), 397–425.
- Mosley, W. H., & Chen, L. C. (1984). An analytical framework for the study of child survival in developing countries. *Population and Development Review*, 25–45.
- Nickles, S. (2002). “Preserving women”: Refrigerator design as social process in the 1930s. *Technology and Culture*, 43(4), 693–727.
- de Onis, M., & Blössner, M. (1997). *WHO global database on child growth and malnutrition*. Geneva: World Health Organization.
- Rutstein, S. O., & Johnson, K. (2004). *The DHS wealth index. DHS comparative reports no. 6*. Calverton: ORC Macro.
- Sahn, D. E., & Stifel, D. (2004). Exploring alternative measures of welfare in the absence of expenditure data. *Family Economics and Nutrition Review*, 16(1), 61.
- Schmidt, L., Sobotka, T., Bentzen, J. G., Nyboe Andersen, A., & ESHRE Reproduction and Society Task Force. (2012). Demographic and medical consequences of the postponement of parenthood. *Human Reproduction Update*, 18(1), 29–43.
- Shah, S. M., Selwyn, B. J., Luby, S., Merchant, A., & Bano, R. (2003). Prevalence and correlates of stunting among children in rural Pakistan. *Pediatrics International*, 45(1), 49–53. <https://doi.org/10.1046/j.1442-200X.2003.01652.x>.
- Subramanian, S. V., Ackerson, L. K., Smith, G. D., & John, N. A. (2009). Association of maternal height with child mortality, anthropometric failure, and anemia in India. *Jama*, 301(16), 1691–1701.
- Takanashi, K., Chonan, Y., Quyen, D. T., Khan, N. C., Poudel, K. C., & Jimba, M. (2009). Survey of food-hygiene practices at home and childhood diarrhoea in Hanoi, Viet Nam. *Journal of Health, Population and Nutrition*, 27(5), 602–611.
- The Economist. (2014, May 31). Cool developments. *The Economist*. Retrieved from <https://www.economist.com/international/2014/05/31/cool-developments>.
- Urke, H. B., Bull, T., & Mittelmark, M. B. (2011). Socioeconomic status and chronic child malnutrition: Wealth and maternal education matter more in the Peruvian Andes than nationally. *Nutrition Research*, 31(10), 741–747.
- Van Malderen, C., Van Oyen, H., & Speybroeck, N. (2013). Contributing determinants of overall and wealth-related inequality in under-5 mortality in 13 African countries. *Journal of Epidemiology & Community Health*, 67(8), 667–676.
- Victora, C. G., Wagstaff, A., Schellenberg, J. A., Gwatkin, D., Claeson, M., & Habicht, J.-P. (2003). Applying an equity lens to child health and mortality: More of the same is not enough. *The Lancet*, 362(9379), 233–241. [https://doi.org/10.1016/S0140-6736\(03\)13917-7](https://doi.org/10.1016/S0140-6736(03)13917-7).
- Wagstaff, A., & Watanabe, N. (2003). What difference does the choice of SES make in health inequality measurement? *Health Economics*, 12(10), 885–890.
- WHO. (2001). Iron deficiency anemia. Assessment, prevention, and control. Retrieved from World Health Organization website https://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/WHO_NHD_01.3/en/, 114.
- WHO. (2006). *WHO child growth standards: Length/height for age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age, methods and development*. Retrieved from <https://www-cabdirect-org.ludwig.lub.lu.se/cabdirect/abstract/20063123347>.
- WHO. (2009). *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva: World Health Organization.
- WHO. (2014). *Household air pollution and health*. Fact Sheet. <https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health>.
- WHO. (2017). Diarrhoeal disease: Key facts. Retrieved May 4, 2019, from World Health Organization website: <https://www.who.int/en/news-room/fact-sheets/detail/diarrhoeal-disease>.
- World Bank. (2018). Prevalence of stunting, height for age (% of children under 5) | Data. Retrieved August 25, 2017, from http://data.worldbank.org/indicator/SH.STA.STNT.ZS?locations=ZG&name_desc=false.
- Zou, G. (2004). A modified Poisson regression approach to prospective studies with binary data. *American Journal of Epidemiology*, 159(7), 702–706.