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Relationship of the Presence of a Household Improved Latrine with Diarrhea and Under-Five Child Mortality in Indonesia

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Abstract. We characterized the relationship of the presence of an improved latrine with diarrhea and under-five child mortality in Indonesia. The proportion of rural and urban families, respectively, without an improved latrine was 52.1% and 16.2%, with a child with a history of diarrhea in the last 7 days was 8.2% and 9.7%, and with a history of under-five child mortality was 11.1% and 8.5%. Among rural and urban families, respectively, lack of an improved latrine was associated with a child history of diarrhea in the last 7 days (odds ratio [OR] = 1.23, 95% confidence interval [CI] = 1.18–1.29, $P < 0.0001$; OR = 1.20, 95% CI = 1.13–1.27, $P < 0.0001$) and under-five child mortality (OR = 1.29, 95% CI = 1.25–1.31, $P < 0.0001$; OR = 1.22, 95% CI = 1.12–1.32, $P < 0.0001$) in separate multivariable logistic regression models adjusting for covariates. The lack of a household improved latrine is associated with diarrhea and under-five child mortality in Indonesia.

INTRODUCTION

An estimated 2.6 billion people, or 40% of the world's population, live without adequate sanitation, and of these, about 2 billion live in rural areas.[1] Deficient environmental sanitation and hygiene are responsible for an estimated 7% of deaths in developing countries.[2] Exposure to human excreta increases the risk of diarrhea infection[3] and increased inflammation in the gut.[4–6] Diarrheal diseases contribute to stunting, reduced cognition, and increased child mortality.[7] Latrines allow for the safe disposal of human excreta and reduce transmission and ingestion of fecal-oral pathogens.[8] Defecation in open areas facilitates the transmission of diarrheal pathogens and is associated with a high risk of intestinal parasitic infections. Progress in improving sanitation in developing countries has been slow, despite studies that show latrines are effective in reducing diarrheal disease by about 30%[9] and improving child growth.[10]

The United Nations Millennium Development Goals (MDGs) include MDG 7, the reduction by one-half of the proportion of the population without sustainable access to basic sanitation, and MDG 4, the reduction by two-thirds of under-five child mortality, between 1990 and 2015. In 2004, nearly three of five rural people did not have access to a basic sanitation facility, and the current trend suggests that there will still be 1 billion urban and rural dwellers who will not have access to basic sanitation by 2015.[1] Among the strategies being advocated to reduce under-five child mortality are integrated management of childhood illnesses such as diarrhea and pneumonia, basic childhood immunizations, vitamin A supplementation, insecticide-treated bed nets, and improved breastfeeding practices. Given the relationship between sanitation and diarrheal diseases and other infectious diseases, the provision of basic sanitation would be expected to have an impact on reducing under-five child mortality. Thus, MDG 7, to provide access to basic sanitation, would impact MDG 4, the reduction of under-five child mortality.

Indonesia, with an estimated 227 million inhabitants, is the fourth most populous country in the world. The portion of the population with improved sanitation facilities ranges from 37% in rural areas to 67% in urban areas. Indonesia is ranked 66th in under-five child mortality worldwide, with a rate that is 41 per 1,000 live births.[11] We hypothesized that lack of an improved latrine was associated with higher diarrheal morbidity and high under-five child mortality among poor families in rural areas and urban slums in Indonesia. To address this *post-hoc* hypothesis, we examined the relationship of latrines with diarrheal morbidity and child mortality in surveillance data on nutrition and health collected from families in rural and urban slum areas of Indonesia.

METHODS

Study design and participants. The study subjects consisted of households that participated in the Nutritional Surveillance System (NSS) in Indonesia from 1999 to 2003. The NSS was established by the Ministry of Health, Government of Indonesia, and Helen Keller International in 1995.[12,13] The nutritional surveillance system was based on UNICEF's conceptual framework on the causes of malnutrition[14] with the underlying principle to monitor public health problems and guide policy decisions.[15] The NSS used stratified multistage cluster sampling of households in subdistricts of administrative divisions of the country in rural areas and slum areas of large cities. Data were collected from ~40,000 randomly selected households every quarter and involved five major urban poor populations from slum areas in the cities of Jakarta, Surabaya, Makassar, Semarang, and Padang, and the rural population from the provinces of Lampung, Banten, West Java, Central Java, East Java, the island of Lombok (West Nusatenggara), and South Sulawesi. In urban areas, purposive sampling was used to target poor households: within specific slum areas, poor households were considered those in which the housing location was along train tracks, rivers/gutters/swamps, underneath toll-road/highways, near "waste station/dump areas," around small alleys, and/or near the beach; and where housing conditions included "box house" composed of cardboard, galvanized tin, plywood, bamboo, house with soil/uncemented floor, house attached to other houses, and house with wood floors.

Data collection. Surveying was done in phases, and new households were selected every round. There were 16 rounds

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of data collection conducted in both urban and rural areas every 3 months, and the duration of each round was about 10 weeks. Data were collected by two-person field teams. The survey was conducted in the Indonesian language. Translation of study documents from Indonesian to English was made by the staff of Helen Keller International. A structured coded questionnaire was used to record data on children 0–59 months of age, including anthropometric measurements, date of birth, and sex. The mother of the child or other adult member of the household was asked to provide information on the household's composition, parental education, and weekly household expenditures, along with other socioeconomic, environmental sanitation, and health indicators.

Data collected that were known to be risk factors for diarrheal disease included place of defecation, socioeconomic status, maternal age, maternal education, and vitamin A supplementation.[3] The mother, father, or guardian was asked where the family members defecated, with responses being open defecation (river, pond, beach, bush, open space, garden), open unimproved pit latrine, and closed (improved) latrine (pit latrine with slab, ventilated pit latrine, flush/pour latrine). Information on vitamin A capsule receipt and use of iodized salt were collected. The interviewee was asked to provide a sample of salt that was used in the household to the interviewer, and the interviewer tested the sample for the presence of iodine using an UNICEF rapid test kit (PT Kimia Farma, Jakarta, Indonesia). The term adequately iodized salt is used to refer to salt that tested positive for ≥ 30 ppm iodine. Birth dates of the children were estimated using a calendar of local and national events and converted to the Gregorian calendar.

The participation rate of families in the surveillance system was > 97% in both urban slum and rural areas, and the main reason for non-response was that the family had moved out of the area or was absent at the time the interviews were conducted. Non-response because of refusal to participate in the surveillance system was very low (< 1%).

The relationship between presence of an improved latrine and a history of diarrhea in the last 7 days was examined in households in the NSS who had at least one child, aged 6–59 months. The question asked was "Did your child have *menceret* (diarrhea), that is, three or more episodes of loose watery stools in 1 day during the previous week?" The youngest child, aged 6–59 months, in the household was used as the index of child diarrhea for that particular household (i.e., households were not counted more than once, because diarrhea tends to cluster within households). The analyses of improved latrines and child history diarrhea were conducted for 378,175 rural families seen from March 1999 to August 2003 and 123,208 urban families from January 1999 to July 2003. The analyses of improved latrines and under-five child mortality in the family were conducted for 292,850 rural families seen from December 2000 to August 2003 and 75,186 urban families seen from February 2001 to July 2003. The questions on under-five child mortality in the family were not added to the NSS until late 2000 and early 2001.

In each household, data were gathered regarding the expenditures in the previous week on food and other commodities. Any household production and in-kind payments were converted to monetary value. Expenditure and price variables were collected in Indonesian rupiah. Data are presented in United States dollars, which were converted from Indonesian rupiahs during each data collection round.[16] The NSS did not include questions on household income or assets. In each household, data were gathered regarding the expenditures in the previous week on rice, other staple foods (cassava, sago, etc.), eggs, vegetables, and other plant sources of food (bean curd, tempeh), fruits, cooking oil, beef, chicken, fish, sugar, instant noodles, milk, snacks, clothes, housing, education, cigarettes, savings, social activities, medicine, production activities, recreation, transportation, pocket money, water, and other (gasoline, electricity, telephone, soap, seasonings, etc.).[17] Food expenditures were divided into four categories: 1) plant foods, consisting of fruits, vegetables, and other plant sources (bean curd, tempeh); 2) animal foods, consisting of beef, goat, chicken, horse, fish, milk, and eggs; 3) other non-grain foods, consisting of snacks, noodles (commonly consumed as a snack), sugar, cooking oil; and 4) grain food expenditures, consisting of rice, corn, sago, cassava, and wheat flour. Previous investigation in the NSS showed that weekly per capita expenditures on different food categories were associated with under-five child mortality.[17] Previous analyses of under-five child mortality in the NSS have not included type of latrine. Other data collected in the NSS included access to cultivable land, use of home gardens, use of garden produce, number of types of animals raised, food prices, and participation in community welfare programs.

The study protocol complied with the principles enunciated in the Helsinki Declaration.[18] The field teams were instructed to explain the purpose of the nutrition surveillance system and data collection to each child's mother or caretaker, and, if present, the father and/or household head; data collection proceeded only after written informed consent. Participation was voluntary, no remuneration was provided to subjects, and all subjects were free to withdraw at any stage of the interview. The nutritional surveillance system in Indonesia was approved by the Ministry of Health, Government of Indonesia. The plan for secondary data analysis was reviewed by the Institutional Review Board of the Johns Hopkins University School of Medicine and considered exempt from review because the data contain no identifiers and are in the public domain.

Statistical analysis. In the data analyses, families from rural areas and urban slums were analyzed separately, given differences in these two types of living environments. Maternal age was divided into quartiles. Maternal and paternal education was categorized as 0, 1–6 (primary), 7–9 (junior high), and ≥ 10 years (high school or greater). The proportion of mothers and fathers who had achieved greater than 12 years (high school graduate) was small and was thus included in the category ≥ 10 years. The proportion of mothers and fathers, respectively, who achieved > 12 years of education, was 2.3% and 3.8% in Indonesia. Weighting was used to adjust for urban and rural population size, by city and province, respectively, and all results are weighted. Weekly per capita household expenditure was used as the main indicator of socioeconomic status because the ways in which households spent their money was considered important to the understanding of how households used their economic resources, as used in previous analyses.[19] More than four individuals eating from the same kitchen was used as an indicator of more crowded households, as used in previous analyses.[17] The χ^2 tests were used to compare categorical variables between groups. Multivariable logistic regression models were used to examine the relationship between the presence of an improved latrine and other variables with a history of diarrhea in the last 7 days in the child and with a history of under-five child mortality in the family, respectively.

Under-five child mortality was defined as death of any of the respondent's live born children within the first 5 years of life. All variables were included in the multivariable models; $P < 0.05$ was considered significant. Covariance matrices were used to examine for multicollinearity among independent variables in the models. No collinearity was found for plant and animal food expenditures. The C statistics for discrimination tests of the model in rural and urban areas, respectively were 0.76 and 0.75 for multivariable models of under-five child mortality and 0.68 and 0.66 for multivariable models of diarrhea. Data analyses were conducted using SAS Survey (SAS Institute, Cary, NC).

RESULTS

The characteristics of the rural and urban families are shown in Table 1. The proportion of rural and urban slum families who reported practicing open defecation was 36.0% and 9.1%, respectively. The proportion of rural and urban slum families who reported using an unimproved latrine was 18.6% and 11.1%, respectively.

In families from rural areas, the proportion of children who had diarrhea in the last 7 days in those aged 6–11, 12–23, 24–35, 36–47, and 48–59 months was 10.6%, 9.9%, 7.3%, 4.8%, and 3.5%, respectively. In families from urban slum areas, the proportion of children who had diarrhea in the last 7 days in those aged 6–11, 12–23, 24–35, 36–47, and 48–59 months was 12.4%, 11.7%, 9.2%, 5.8%, and 4.6%, respectively." Univariate and multivariable models of risk factors for a child having diarrhea in the last 7 days in rural families are shown in Table 2.

Lack of an improved latrine, younger child age, male sex, lower maternal age, lower maternal education, no current breastfeeding, non-receipt of a vitamin A capsule in the last 6 months, lack of adequately iodized salt in the household, paternal

Table 1
Characteristics of families from rural areas and urban slum areas in Indonesia

Characteristic		Rural		Urban	
		N	Mean (SD) or %	*N*	Mean (SD) or %
Family has an improved latrine	Yes	203,007	45.4	114,816	79.8
	No	243,973	54.6	29,022	20.2
Child age, mos	0–5	66,925	15.0	20,279	14.1
	6–11	82,046	18.4	24,209	16.8
	12–23	127,296	28.5	39,656	27.6
	24–35	84,840	19.0	28,858	20.0
	36–47	54,446	12.2	18,532	13.6
	48–59	30,973	6.9	11,227	7.8
Child sex	Male	229,547	51.3	74,798	51.9
	Female	217,686	48.7	69,207	48.1
Maternal age, y	≤ 24	139,054	31.1	39,963	27.8
	25–	112,006	25.1	36,471	25.3
	29–32	93,784	21.0	31,765	22.0
	33+	101,889	22.8	35,815	24.9
Maternal education, y	0	26,135	5.9	6,855	4.8
	1–6	239,844	53.9	66,841	46.5
	7–9	90,967	20.4	33,692	23.5
	≥ 10	87,951	19.8	36,220	25.2
Maternal BMI (kg/m^2)	18.5 to < 25	315,727	71.0	91,583	62.3
	< 18.5	54,465	12.2	17,574	12.3
	≥ 25 to < 30	64,578	14.5	27,381	19.2
	≥ 30	10,209	2.3	5,967	4.2
Paternal education, y	0	18,891	4.4	3,078	2.2
	1–6	207,228	48.6	51,391	36.6
	7–9	83,128	19.5	34,430	24.5
	≥ 10	117,388	27.5	51,619	36.7
Child currently breastfeeding	Yes	281,072	62.9	82,258	57.2
	No	165,606	37.1	61,513	42.8
Child received vitamin A capsule in last 6 months	Yes	229,799	52.6	72,533	52.3
	No	206,797	47.4	66,296	47.7
Household has adequately iodized salt	Yes	281,920	65.6	100,557	70.7
	No	153,009	34.4	41,730	29.3
Father is a smoker	Yes	325,963	74.5	101,512	71.8
	No	111,771	25.5	39,919	28.2
Weekly per capita plant food expenditure		400,835	0.23 (0.23)	143,556	0.36 (0.28)
Weekly per capita grain food expenditure		401,018	0.34 (0.34)	143,566	0.36 (0.30)
Weekly per capita animal food expenditure		401,080	0.29 (0.39)	143,573	0.43 (0.40)
Number of household members eating from same kitchen	2–4	177,187	44.2	74,011	51.8
	> 4	223,862	55.8	68,982	48.2
Weekly per capita household expenditure, quintile†	1	80,218	20.0	28,715	20.0
	2	80,214	20.0	28,715	20.0
	3	80,225	20.0	28,717	20.0
	4	80,210	20.0	28,713	20.0
	5	80,219	20.0	28,715	20.0

* BMI = body mass index.
† Cut-offs for quintiles was $1.40, $1.94, $2.57, and $3.66 for rural families and $1.88, $2.52, $3.24, and $4.40 for families from urban slums.

TABLE 2
Univariate and multivariable models of potential risk factors and history of diarrhea in children from rural families in Indonesia*

Characteristics		Univariate			Multivariable†		
		OR	95% CI	*P*	OR	95% CI	*P*
Family does not have an improved latrine		1.43	1.39–1.49	< 0.0001	1.23	1.18–1.29	< 0.0001
Child age, mos	6–11	1.00	–	–	1.00	–	–
	12–23	0.90	0.86–0.94	< 0.0001	0.92	0.88–0.96	0.0003
	24–35	0.66	0.63–0.70	< 0.0001	0.64	0.60–0.68	< 0.0001
	36–47	0.45	0.42–0.48	< 0.0001	0.44	0.41–0.48	< 0.0001
	48–59	0.31	0.29–0.35	< 0.0001	0.30	0.27–0.34	< 0.0001
Child, male		1.16	1.12–1.20	< 0.0001	1.18	1.13–1.22	< 0.0001
Maternal age, y	≤ 24	1.00	–	–	1.00	–	–
	25–28	0.86	0.82–0.90	< 0.0001	0.96	0.91–1.01	0.08
	29–32	0.79	0.76–0.83	< 0.0001	0.89	0.85–0.94	< 0.0001
	33+	0.79	0.75–0.83	< 0.0001	0.86	0.81–0.91	< 0.0001
Maternal education, y	0	1.80	1.66–1.94	< 0.0001	1.45	1.30–1.61	< 0.0001
	1–6	1.45	1.38–1.52	< 0.0001	1.25	1.18–1.33	< 0.0001
	7–9	1.19	1.12–1.26	< 0.0001	1.10	1.03–1.17	0.003
	≥ 10	1.00	–	–	1.00	–	–
Paternal education, y	0	1.57	1.43–1.71	< 0.0001	1.08	0.97–1.20	0.17
	1–6	1.28	1.22–1.33	< 0.0001	1.07	1.01–1.13	0.02
	7–9	1.14	1.08–1.20		1.02	0.96–1.08	0.51
	≥ 10	1.00	–	–	1.00	–	–
Maternal BMI (kg/m^2)	18.5 to < 25	1.00	–	–	1.00	–	–
	< 18.5	1.10	1.04–1.15	0.0003	1.02	0.96–1.07	0.56
	≥ 25 to < 30	0.93	0.88–0.97	0.002	1.02	0.97–1.07	0.46
	≥ 30	0.80	0.71–0.89	< 0.0001	0.90	0.80–1.02	0.09
Child currently breastfeeding		1.35	1.30–1.40	< 0.0001	0.96	0.94–0.98	< 0.0001
Child received vitamin A capsule in last 6 months		0.76	0.73–0.78	< 0.0001	0.92	0.88–0.95	< 0.0001
Household has adequately iodized salt		0.68	0.66–0.70	< 0.0001	0.86	0.83–0.90	< 0.0001
Father is a smoker		1.26	1.21–1.31	< 0.0001	1.08	1.04–1.13	0.0004
More than 4 individuals eating from same kitchen		1.10	1.06–1014	< 0.0001	1.06	1.02–1.11	0.002
Weekly per capita plant food expenditure		0.45	0.41–0.50	< 0.0001	0.83	0.73–0.93	0.002
Weekly per capita grain food expenditure		1.01	0.97–1.07	< 0.0001	1.06	1.01–1.11	0.04
Weekly per capita animal food expenditure		0.89	0.85–0.93	< 0.0001	0.95	0.89–1.00	0.07
Weekly per capita household expenditure, quintile†	1	1.00	–	–	1.00	–	–
	2	0.85	0.80–0.89	< 0.0001	0.99	0.94–1.06	0.87
	3	0.80	0.76–0.84	< 0.0001	0.99	0.93–1.06	0.96
	4	0.81	0.77–0.86	< 0.0001	1.05	0.99–1.13	0.09
	5	0.81	0.77–0.85	< 0.0001	1.05	0.98–1.13	0.16

* OR = odds ratio; CI = confidence interval; BMI = body mass index.
† Full multivariable model is adjusted for all variables in the table and location.

smoking, more than four household members eating from the same kitchen, lower weekly per capita plant food expenditure, and higher weekly grain food expenditure were associated with a history of diarrhea in the multivariable model for rural families.

Univariate and multivariable models of risk factors for a child having diarrhea in the last 7 days in urban slum families are shown in Table 3. In the multivariate model, risk factors that were significantly associated with child diarrhea were the same as for the previously mentioned rural families, but also included lower weekly per capita food expenditure.

We considered alternative multivariable models of risk factors for a child having diarrhea in the last 7 days, which included all previously mentioned covariates but excluded weekly per capita plant, animal, and grain food expenditures. For rural and urban families, respectively, lack of an improved latrine was associated with the child having diarrhea in the last 7 days (odds ratio [OR] = 1.26, 95% confidence interval [CI] = 1.21–1.31, $P < 0.0001$; OR = 1.23, 95% CI = 1.16–1.30, $P < 0.0001$).

The percent of children who died within 1 month, 2–12 months, and 13–59 months of age, respectively, was 42.9%, 35.1%, and 22.0% for urban families and 45.7%, 38.1%, and 16.2% in rural families. Risk factors for a history of under-five child mortality in rural families are shown in univariate and multivariable analyses in Table 4. In the multivariable model, lack of an improved latrine, greater maternal age, lower maternal education, lower paternal education, maternal body mass index (BMI), lack of adequately iodized salt in the household, paternal smoking, more than four household members eating from the same kitchen, lower weekly per capita plant food expenditure, and higher weekly per capita grain food expenditure were associated with a history of under-five child mortality for rural families. Mean weekly per capita expenditure on plant foods, grain-foods, animal foods, and other foods, in rural families with and without a history of under-five child mortality were US$0.25 and $0.33, $0.38 and $0.36, $0.26 and $0.33, and $0.47 and $0.51, respectively (all $P < 0.0001$).

Risk factors for a history of under-five child mortality in families in urban slums are shown in univariate and multivariable analyses in Table 5. In the multivariable model, risk factors that were significantly associated with under-five child mortality were the same as for the previously mentioned rural families. Mean weekly per capita expenditure on plant foods, grain-foods, animal foods, and other foods, in families from urban slums with and without a history of under-five child mortality were US$0.32 and $0.41, $0.32 and $0.30, $0.42 and $0.49, and $0.32 and $0.41, respectively (all $P < 0.0001$).

TABLE 3
Univariate and multivariable models of potential risk factors and history of diarrhea in children from families from urban slums in Indonesia*

Characteristics		Univariate			Multivariable†		
		OR	95% CI	*P*	OR	95% CI	*P*
Family does not have an improved latrine		1.35	1.28–1.42	< 0.0001	1.20	1.13–1.27	< 0.0001
Child age, mos	6–11	1.00	–	–	1.00	–	–
	12–23	0.94	0.88–0.99	0.03	1.02	0.96–1.09	0.43
	24–35	0.71	0.66–0.76	< 0.0001	0.78	0.71–0.84	< 0.0001
	36–47	0.41	0.38–0.45	< 0.0001	0.45	0.41–0.50	< 0.0001
	48–59	0.31	0.28–0.35	< 0.0001	0.33	0.29–0.38	< 0.0001
Child, male		1.14	1.09–1.19	< 0.0001	1.13	1.07–1.18	< 0.0001
Maternal age, y	≤ 24	1.00	–	–	1.00	–	–
	25–28	0.79	0.74–0.84	< 0.0001	0.87	0.82–0.93	< 0.0001
	29–32	0.71	0.67–0.76	< 0.0001	0.80	0.74–0.85	< 0.0001
	33+	0.72	0.67–0.76	< 0.0001	0.78	0.73–0.84	< 0.0001
Maternal education, y	0	1.45	1.30–1.61	< 0.0001	1.26	1.10–1.44	< 0.0001
	1–6	1.30	1.22–1.38	< 0.0001	1.17	1.08–1.26	< 0.0001
	7–9	1.11	1.03–1.18	0.003	1.04	0.96–1.12	0.34
	≥ 10	1.00	–	–	1.00	–	–
Paternal education, y	0	1.54	1.33–1.79	< 0.0001	1.15	0.97–1.37	0.09
	1–6	1.22	1.16–1.29	< 0.0001	1.02	0.95–1.08	0.65
	7–9	1.15	1.08–1.22	< 0.0001	1.03	0.96–1.10	0.37
	≥ 10	1.00	–	–	1.00	–	–
Maternal BMI (kg/m^2)	18.5 to < 25	1.00	–	–	1.00	–	–
	< 18.5	1.14	1.07–1.22	0.0001	1.03	0.96–1.11	0.36
	≥ 25 to < 30	0.91	0.86–0.97	0.004	1.05	0.98–1.12	0.14
	≥ 30	0.83	0.74–0.83	0.002	0.99	0.88–1.13	0.98
Child currently breastfeeding		1.43	1.37–1.50	< 0.0001	0.93	0.87–0.98	0.02
Child received vitamin A capsule in last 6 months		0.66	0.63–0.70	< 0.0001	0.80	0.76–0.84	< 0.0001
Household has adequately iodized salt		0.81	0.77–0.85	< 0.0001	0.90	0.86–0.95	0.0004
Father is a smoker		1.10	1.05–1.16	0.0002	1.04	0.98–1.10	0.16
More than 4 individuals eating from same kitchen		1.10	1.05–1.15	< 0.0001	1.01	0.95–1.07	0.89
Weekly per capita plant food expenditure		0.46	0.41–0.51	< 0.0001	0.68	0.60–0.78	< 0.0001
Weekly per capita grain food expenditure		1.21	1.14–1.29	< 0.0001	1.30	1.19–1.42	< 0.0001
Weekly per capita animal food expenditure		0.76	0.72–0.81	< 0.0001	0.90	0.83–0.98	0.01
Weekly per capita household expenditure, quintile†	1	1.00	–	–	1.00	–	–
	2	0.92	0.86–0.89	0.03	1.00	0.92–1.08	0.99
	3	0.82	0.77–0.88	< 0.0001	0.96	0.88–1.05	0.42
	4	0.77	0.71–0.82	< 0.0001	0.93	0.85–1.02	0.13
	5	0.66	0.61–0.71	< 0.0001	0.89	0.80–0.99	0.03

* OR = odds ratio; CI = confidence interval; BMI = body mass index.
† Full multivariable model is adjusted for all variables in the table and location.

We considered alternative multivariable models of risk factors for under-five child mortality, which included all previously mentioned covariates but excluded weekly per capita plant, animal, and grain food expenditures. For rural and urban families, respectively, lack of an improved latrine was associated with under-five child mortality (OR = 1.38, 95% CI = 1.33–1.44, $P < 0.0001$; OR = 1.27, 95% CI = 1.17–1.38, $P < 0.0001$).

To gain further insight into the risks of child diarrhea and under-five child mortality with defecation in open areas, and unimproved latrines, we examined multivariate models that adjusted for the same covariates as used in the previous analyses in Tables 2–5, where an improved latrine was the reference. In families in rural areas, open defecation and unimproved latrines, respectively, were associated with child diarrhea (OR = 1.32, 95% CI = 1.26–1.37, $P < 0.0001$; OR = 1.13, 95% CI = 1.08–1.20, $P < 0.0001$). In families from urban slums, open defecation and unimproved latrines, respectively, were associated with child diarrhea (OR = 1.22, 95% CI = 1.13–1.32, $P < 0.0001$; OR = 1.19, 95% CI = 1.11–1.29, $P < 0.0001$). In rural families, open defecation and unimproved latrines, respectively, were associated with under-five child mortality (OR = 1.43, 95% CI = 1.38–1.49, $P < 0.0001$; OR = 1.26, 95% CI = 1.20–1.32, $P < 0.0001$). In families from urban slums, open defecation and unimproved latrines, respectively, were associated with under-five child mortality (OR = 1.30, 95% CI = 1.16–1.45, $P < 0.0001$; OR = 1.21, 95% CI = 1.09–1.34, $P < 0.0001$)

We calculated the attributable risks (ARs) for child diarrhea in the last 7 days and for under-five child mortality caused by various binary risk factors. In rural areas, the ARs for child diarrhea in the last 7 days caused by lack of an improved latrine, paternal smoking, adequately iodized salt, and receipt of a vitamin A capsule in the last 6 months were 2.9%, 1.6%, 2.6%, and 2.6%, respectively. In urban slum areas, the ARs for child diarrhea in the last 7 days caused by lack of an improved latrine, paternal smoking, adequately iodized salt, and receipt of a vitamin A capsule in the last 6 months were 2.3%, 1.1%, 3.1%, and 3.7%, respectively. In rural areas, the ARs for under-five child mortality caused by lack of an improved latrine, paternal smoking, and adequately iodized salt were 6.2%, 3.4%, and 4.7%, respectively. In urban slums areas, the AR for under-five child mortality caused by lack of an improved latrine, paternal smoking, and adequately iodized salt were 3.8%, 1.8%, and 2.7%, respectively.

DISCUSSION

This study shows that families that do not have an improved latrine have higher odds both of a child with a history of diarrhea in the previous 7 days and a history of under-five child

TABLE 4
Univariate and multivariable models of potential risk factors and under-five child mortality in rural families in Indonesia*

Characteristics		Univariate			Multivariable†		
		OR	95% CI	*P*	OR	95% CI	*P*
Family does not have an improved latrine		1.91	1.85–1.97	< 0.0001	1.29	1.25–1.35	< 0.0001
Maternal age, y	≤ 24	1.00	–	–	1.00	–	–
	25–28	1.91	1.80–2.02	< 0.0001	1.97	1.86–2.09	< 0.0001
	29–32	3.09	2.93–3.26	< 0.0001	3.21	3.02–3.39	< 0.0001
	33+	5.88	5.59–6.17	< 0.0001	5.30	5.01–5.60	< 0.0001
Maternal education, y	0	10.76	10.03–11.53	< 0.0001	3.76	3.43–4.11	< 0.0001
	1–6	3.39	3.21–3.58	< 0.0001	2.36	2.20–2.52	< 0.0001
	7–9	1.42	1.33–1.52	< 0.0001	1.48	1.37–1.59	< 0.0001
	≥ 10	1.00	–	–	1.00	–	–
Paternal education, y	0	7.31	6.82–7.85	< 0.0001	1.91	1.75–2.08	< 0.0001
	1–6	2.70	2.58–2.83	< 0.0001	1.51	1.43–1.60	< 0.0001
	7–9	1.41	1.33–1.50	< 0.0001	1.16	1.08–1.23	< 0.0001
	≥ 10	1.00	–	–	1.00	–	–
Maternal BMI (kg/m^2)	18.5 to < 25	1.00	–	–	1.00	–	–
	< 18.5	0.85	0.81–0.89	< 0.0001	0.99	0.94–1.05	0.86
	≥ 25 to < 30	1.05	1.01–1.09	0.02	0.94	0.89–0.98	0.005
	≥ 30	1.09	0.99–1.19	0.07	0.91	0.82–1.01	0.08
Household has adequately iodized salt		0.61	0.59–0.63	< 0.0001	0.83	0.80–0.87	< 0.0001
Father is a smoker		1.49	1.43–1.54	< 0.0001	1.16	1.11–1.21	< 0.0001
More than 4 individuals eating from same kitchen		1.59	1.54–1.64	< 0.0001	1.02	0.98–1.06	0.31
Weekly per capita plant food expenditure		0.21	0.19–0.23	< 0.0001	0.70	0.61–0.80	< 0.0001
Weekly per capita grain food expenditure		1.15	1.11–1.20	< 0.0001	1.13	1.07–1.19	< 0.0001
Weekly per capita animal food expenditure		0.62	0.58–0.66	< 0.0001	1.02	0.98–1.06	0.24
Weekly per capita household expenditure, quintile†	1	1.00	–	–	1.00	–	–
	2	0.75	0.72–0.79	< 0.0001	0.95	0.89–1.00	0.49
	3	0.66	0.63–0.69	< 0.0001	0.95	0.89–1.01	0.09
	4	0.59	0.57–0.63	< 0.0001	0.95	0.89–1.02	0.15
	5	0.54	0.52–0.57	< 0.0001	0.97	0.90–1.05	0.49

* OR = odds ratio; CI = confidence interval; BMI = body mass index.
† Full multivariable model is adjusted for all variables in the table and location.

mortality in the family. To our knowledge, this is the first population-based study to show an independent association between lack of an improved latrine and under-five child mortality. These findings are consistent with other observational studies that showed an association between lack of latrine and child mortality in rural Mozambique.[20] The presence of toilets or latrines was associated with lower child mortality in Eritrea[21] and Bangladesh.[22] In a review of 46 studies of the impact of sanitation on diarrheal diseases, Fewtrell and colleagues[9] found an overall impact of about a 30% reduction in diarrheal disease morbidity. A recent meta-analysis of observational studies by Norman and colleagues[23] showed that piped sewerage systems are associated with a 30% lower incidence of diarrhea and up to 60% lower diarrheal incidence when the starting sanitation conditions are extremely poor. In Kenya, lack of a latrine was associated with greater risk of helminth infection.[24] Lack of a latrine was associated with an increased risk of diarrheal disease in a case-control study from Tanzania.[25]

In this study, we adjusted the analyses for other risk factors that have been shown to be associated with child diarrhea such as low maternal education,[3] low maternal age,[3] greater household size,[3] lack of breastfeeding,[3] and vitamin A supplementation.[26] To our knowledge, this is the first study to show a relationship between paternal smoking and child diarrhea, and between lack of adequately iodized salt and child diarrhea. These two risk factors are known to be associated with increased child mortality.[27,28]

The strengths of this study are the large sample size, the population-based sampling, and careful adjustment for other covariates that are known to be associated with diarrheal disease and with under-five child mortality. The results were generally consistent between rural areas and urban slum areas, even though there were a much higher proportion of rural families that lacked an improved latrine compared with families in urban slum areas.

One of the limitations of the study was that the data were available on presence of a household latrine and not actual monitoring of use of a household latrine. The field team members also did not do a visual inspection of each latrine in the nearly 870,000 households visited in the study.

Intervention studies have shown that latrines reduce rates of diarrheal disease in children. In a controlled field study in the Philippines, provision of improved toilets reduced the incidence of cholera.[29] In Lesotho, ventilation improved pit latrines that were provided in a district as part of a rural sanitation project.[30] Cases of diarrheal disease in children, < 5 years of age, who presented at the local health facilities, were matched by age and other factors with control children who did not have diarrheal disease. Households with a latrine had about one-quarter fewer episodes of diarrhea in their children than households without a latrine.[30] In Bangladesh, a water, sanitation, and hygiene intervention project was evaluated before and after the intervention from an intervention and control area. The intervention project area had one-quarter fewer episodes of diarrhea in children than the control area.[31]

A cluster-randomized control trial showed that provision of latrines for trachoma control in The Gambia reduced the number of flies caught from children's eyes.[32] Although the

TABLE 5
Univariate and multivariable models of potential risk factors and under-five child mortality in families from urban slums in Indonesia*

Characteristics		Univariate			Multivariable†		
		OR	95% CI	*P*	OR	95% CI	*P*
Family does not have an improved latrine		1.59	1.47–1.71	< 0.0001	1.22	1.12–1.32	< 0.0001
Maternal age, y	≤ 24	1.00	–	–	1.00	–	–
	25–28	1.87	1.65–2.10	< 0.0001	1.97	1.73–2.22	< 0.0001
	29–32	2.92	2.61–3.27	< 0.0001	3.01	2.66–3.40	< 0.0001
	33+	6.09	5.49–6.76	< 0.0001	4.89	4.35–5.50	< 0.0001
Maternal education, y	0	9.37	8.23–10.65	< 0.0001	3.80	3.24–4.44	< 0.0001
	1–6	3.16	2.87–3.46	< 0.0001	2.17	1.95–2.43	< 0.0001
	7–9	1.47	1.32–1.65	< 0.0001	1.41	1.24–1.59	< 0.0001
	≥ 10	1.00	–	–	1.00	–	–
Paternal education, y	0	6.86	5.82–8.09	< 0.0001	2.03	1.68–2.44	< 0.0001
	1–6	2.56	2.37–2.77	< 0.0001	1.37	1.25–1.51	< 0.0001
	7–9	1.47	1.33–1.61	< 0.0001	1.12	1.02–1.24	0.02
	≥ 10	1.00	–	–	1.00	–	–
Maternal BMI (kg/m^2)	18.5 to < 25	1.00	–	–	1.00	–	–
	< 18.5	0.81	0.72–0.80	0.0002	0.96	0.84–1.07	0.46
	≥ 25 to < 30	1.25	1.16–1.35	< 0.0001	1.01	0.92–1.09	0.86
	≥ 30	1.50	1.32–1.71	< 0.0001	1.07	0.92–1.22	0.37
Household has adequately iodized salt		0.74	0.69–0.79	< 0.0001	0.91	0.84–0.98	0.01
Father is a smoker		1.26	1.17–1.36	< 0.0001	1.08	1.01–1.17	0.05
More than 4 individuals eating from same kitchen		2.05	1.93–2.18	< 0.0001	1.09	1.01–1.17	0.04
Weekly per capita plant food expenditure		0.36	0.31–0.41	< 0.0001	0.71	0.59–0.84	0.0001
Weekly per capita grain food expenditure		1.18	1.07–1.31	0.001	1.24	1.08–1.41	0.001
Weekly per capita animal food expenditure		0.59	0.54–0.64	< 0.0001	0.93	0.84–1.03	0.16
Weekly per capita household expenditure, quintile†	1	1.00	–	–	1.00	–	–
	2	0.84	0.75–0.93	0.001	0.92	0.82–1.04	0.17
	3	0.70	0.63–0.78	< 0.0001	0.89	0.79–1.01	0.07
	4	0.63	0.57–0.70	< 0.0001	0.92	0.81–1.04	0.20
	5	0.59	0.54–0.65	< 0.0001	0.98	0.86–1.12	0.79

* OR = odds ratio; CI = confidence interval; BMI = body mass index.
† Full multivariable model is adjusted for all variables in the table and location.

aim of the trial was to determine the effect of an intervention with latrines on flies and trachoma, the findings have implications for diarrheal disease, because contamination of weaning food by flies increases the risk of diarrheal diseases in children.[33]

In this study, the analyses were adjusted for other factors that were previously known to be associated with under-five child mortality, such as household use of adequately iodized salt,[28] paternal smoking,[27] and food expenditures on grain (mostly rice).[17] The iodine deficiency disorders are characterized by higher perinatal and infant mortality.[34] Among poor families, paternal smoking diverts precious household income from food to tobacco, with a resulting higher risk of child malnutrition, maternal underweight, and neonatal, infant, and under-five child mortality in the family.[27,35] Households that spend more money on plant source foods (fruits and vegetables) and less on grain foods have a greater intake of micronutrients and have a lower risk of child mortality.[17]

In Indonesia, from 1990 to 2004, the proportion of the rural population that had improved sanitation increased from 37% to 40%, and the proportion of the urban population that had improved sanitation increased from 65% to 73%.[1] Overall in South-eastern Asia, the proportion of the population that had improved sanitation increased from 49% to 67% from 1990 to 2004.[1] Although the importance of improved sanitation is well established, progress has been slow because sanitation is not a priority for central or regional governments in Indonesia, as reflected in limited budget allocations for sanitation.[36]

Improved access to sanitation facilities such as improved latrines has a highly favorable cost-benefit ratio[37] and cost-effectiveness.[38] Interventions such as provision of improved latrines should be considered as an integrated strategy with other interventions aimed at improving child health and survival, such as vitamin A supplementation, iodized salt, insecticide-treated bed nets, tobacco control, hand washing, and promotion of breastfeeding.[39] Latrines should be given a high priority among interventions to reducing child mortality in developing countries

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