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Improved Sanitation Facilities Are Associated with Higher Body Mass Index and Higher Hemoglobin Concentration among Rural Cambodian Women in the First Trimester of Pregnancy

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Abstract. Multiple factors contribute to undernutrition in Cambodian women. Our aim was to determine if type of household sanitation facility was associated with body mass index (BMI) and hemoglobin (Hb) concentration among pregnant women. Women (N = 544) from 75 villages in Kampong Chhnang Province had their height, weight, and Hb measured (HemoCue Hb 201$^+$) in the first trimester. Sociodemographic and household characteristics were collected. Multivariable linear and logistic regression models were used for analyses. Approximately 40% (N = 221) of women reported primarily using an 'improved' sanitation facility (closed pit latrine) and ~60% (N = 323) used 'non-improved' facilities (open defecation). Mean ± standard deviation (SD) BMI was higher among women with improved versus non-improved facilities (19.9 ± 3.0 kg/m^2 versus 19.4 ± 2.3 kg/m^2; P = 0.01). Mean ± SD Hb concentration was also higher among women with improved versus non-improved facilities (118 ± 12 g/L versus 114 ± 14 g/L; P = 0.001). Anemia prevalence (Hb < 110 g/L) was higher among women with non-improved facilities (34% versus 25%; P = 0.04). An improved sanitation facility was a positive predictor of BMI (β = 0.57 kg/m^2; 95% confidence interval [CI] = 0.10, 1.04) and Hb concentration (β = 2.94 g/L; 95% CI = 0.53, 5.35), adjusting for age, parity, household size, village, gestation week, source of drinking water, and iron folic acid supplementation. Poor sanitation was associated with lower BMI and Hb concentration among pregnant Cambodian women. This warrants multisectoral approaches involving the health, nutrition, water, and sanitation sectors to effectively improve maternal health in Cambodia.

INTRODUCTION

Infection and illness from repeated episodes of diarrheal and intestinal worm infections resulting from poor water, sanitation, and hygiene practices are major contributors to the global burden of undernutrition.[1] In Cambodia, undernutrition is highly prevalent among women of reproductive age and young children.[2] Anemia is of particular concern for women as the prevalence exceeds 40% and has remained relatively stagnant in recent years.[2] Causes of anemia in Cambodian women include deficiencies of iron and other micronutrients, parasitic infections, and genetic hemoglobin (Hb) disorders (e.g., thalassemia).[3] Ideally, women should be nutritionally replete and have a healthy body mass index (BMI) from the beginning of pregnancy. Those who are anemic and/or underweight are at higher risk for adverse pregnancy outcomes.

More than half of Cambodians lack access to a safe sanitation facility, one that is used only by household members and that separates fecal matter from human contact.[2] Hookworm infections are a major contributor to anemia and are endemic in Cambodia.[4] Humans contact hookworms through exposure to eggs and larvae in soil that is contaminated by fecal matter. Previous studies have shown high rates of hookworm and other helminth infections among Cambodian adults.[4,5] The Cambodian Ministry of Health recommends that pregnant women receive one dose of deworming treatment (mebendazole) after the first trimester[6]; however, the benefit of this one dose (if taken) is in question as its efficacy appears low, with a cure (egg-negative after treatment) rate of only ~18–36% for helminth infections in school-aged children in neighboring Lao People's Democratic Republic.[7] We acknowledge that the effectiveness of deworming treatments also largely depends on the types of parasitic infections present. Therefore, Cambodian women are vulnerable to helminth infections early and throughout pregnancy, with higher risks for women who do not seek prenatal care at health centers.

Though it is widely acknowledged that poor sanitation practices exacerbate the effects of poor nutrition, scientific evidence demonstrating this link is rather limited in Cambodia, a context where both sanitation standards are poor and the prevalence of undernutrition is high. We examined the associations between type of household sanitation facility and BMI, underweight (BMI < 18.5 kg/m^2), Hb concentration, and anemia (Hb < 110 g/L) among women in the first trimester of pregnancy in rural Cambodia.

MATERIALS AND METHODS

Study participants included pregnant women enrolled in a cluster-randomized efficacy trial conducted in 75 villages in two districts of Kampong Chhnang Province during 2011–2013. The objective of the trial was to examine the effects of a prenatal micronutrient-fortified corn-soya food supplement on maternal weight gain and anemia, newborn anthropometry, and preterm birth. All women who became pregnant in each village during the study period were eligible to participate. Pregnant women were enrolled in the first trimester and a monthly food supplement was provided until delivery. Written informed consent was obtained from all women. The methods and results of the trial are published in detail elsewhere.[8] Ethics approval was obtained from the Cambodia National Ethics Committee for Health Research and the University of British Columbia Clinical Research Ethics Board. The trial was registered at ClinicalTrials.gov (NCT01413776).

Survey interviews were conducted with all participants upon enrollment by trained researchers from International Relief and Development, Cambodia. Information was collected on individual and household characteristics, reproductive history, food security (using the Household Food

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Insecurity Access Scale [HFIAS]),[9] source of drinking water (e.g., open or closed well, pond/river, rain water), whether the water was treated prior to consumption and the method used, and the household's primary sanitation facility (e.g., latrine, open field/pit, pond/river).

Women's height (m), weight (kg), and Hb concentration (g/L) were measured in the first trimester by trained nurse midwives during antenatal care visits at four health centers in the province. Maternal weight was measured using a non-digital scale (Nhon Hoa NHHS-120-K6; Ho Chi Minh, Vietnam) and height was measured using standard procedures. Capillary Hb concentration (finger prick) was determined using the HemoCue® Hb 201+ (Angelholm, Sweden). Identical measuring equipment was provided to each health center and weighing scales were calibrated regularly by health center staff. Gestational age was determined from the first day of the woman's last menstrual period, as reported by the woman at the prenatal visit.

BMI (kg/m^2) and Hb concentration (g/L) were analyzed as continuous dependent variables and underweight (BMI < 18.5 kg/m^2) and anemia (Hb < 110 g/L) as categorical dependent variables. The main predictor variable, type of household sanitation facility (toilet), was categorized as 'improved' (closed pit latrine) or 'non-improved' (open defecation including open pit, bush/field, or pond/river) according to the criteria defined in the Cambodia Demographic and Health Survey (CDHS).[2] Multivariable linear and logistic regression models were used to measure associations between independent variables and BMI, Hb concentration, underweight, and anemia status. Model covariates were selected based on a significant ($P < 0.05$) bivariate relationship and/or were factors known to be associated with underweight status and anemia status. The covariates included the woman's age, parity, number of household members, gestation week, the household's source of drinking water (coded as 'improved' or 'non-improved' using CDHS criteria), and whether the woman was currently taking an iron and folic acid (IFA) supplement (coded as 0 or 1; based on self-report). The regression models were adjusted for the cluster-randomized design of the trial. Results are expressed as β coefficients (95% confidence interval [CI]) for BMI and Hb concentration and as odds ratios (OR) (95% CI) for underweight status and anemia status. A two-sided 0.05 significance level was used. Analyses were conducted with IBM SPSS software Version 20.0 (IBM Corporation, Armonk, NY).

RESULTS

Height, weight, and Hb concentration were measured for 544 women. Measurements were taken during 4–12 weeks gestation (average 8.3 ± 2.3 weeks), depending on when the antenatal care visit occurred during the first trimester. Overall mean ± standard deviation (SD) BMI was 19.6 ± 2.6 kg/m^2 and mean ± SD Hb concentration was 116 ± 14 g/L. The rates of underweight (BMI < 18.5 kg/m^2) and anemia (Hb < 110 g/L) were 35.1% (N = 191) and 30.3% (N = 165), respectively. Of the anemic women, a larger proportion (N = 99; 60%) were mildly anemic (Hb = 100–109 g/L), compared with those with moderate (Hb = 70–99 g/L) anemia (N = 65; 39%), based on the World Health Organization guidelines for anemia classification.[10] One woman was severely anemic (Hb < 70 g/L). Twelve percent (N = 67) of women were both underweight and anemic. A higher prevalence of underweight (40% versus 31%; P = 0.03) occurred among women with no children, as compared with those with at least one child.

The average age of women at enrollment was 26.5 ± 5.1 years (range 18–46 years) (Table 1). Forty percent (N = 216) of women were under 25 years of age. Almost half of the participants (N = 242) were nulliparous and, among women who had given birth, the average number of children was 1.7 ± 1.1 (range 1–12 children). Approximately 20% of women had a child under 24 months of age. Most women (94%) had some formal schooling, though about 40% did not complete their primary (grade 6) education. The majority of women (~70%) were subsistence rice farmers relying on one annual harvest and median monthly household income was US $25 and US $50 in the wet and dry seasons, respectively. Land ownership was common (85%; N = 464), though about 40% of women owned less than 1 hectare. The mean ± SD HFIAS score was 4.0 ± 4.4 (median 2; range 0–21) based on a scale of 0–27, with higher scores indicating progressively greater levels of food insecurity. Despite the relatively low average and median HFIAS scores, half of the respondents worried about food availability during the previous month and 30% reported at least one household member had to eat smaller meals because of food scarcity. About 20% of the women stated that at least one household member slept hungry during the past month.

The main source of household drinking water was an open ring well (45%; N = 245), followed by a tube well (35%; N = 189) and closed ring well (8%; N = 43). When considering water treatment practices (e.g., boiling, filtration), which were reported by about 90% of women, most households were considered to have an improved source of drinking water for the purpose of our analysis (Table 1). With regard to sanitation practices, about 40% (N = 221) of the study population used an improved sanitation facility

TABLE 1

Women's individual and household characteristics on enrollment*

	Mean ± SD or n (%)
Age (years)	26.5 ± 5.1
Parity (number of children previously born)	
0	242 (45)
1–2	249 (46)
3–4	50 (9)
> 4	3 (< 1)
Education level completed†	
None	32 (6)
Primary	274 (50)
Secondary	233 (43)
Post-secondary	5 (1)
Household size	4.0 ± 1.6
HFIAS score‡	4.0 ± 4.4
Sanitation facility	
Improved (closed pit latrine)	221 (41)
Non-improved (open defecation)	323 (59)
Source of drinking water	
Improved (treated regardless of source)	487 (90)
Non-improved (untreated)	57 (10)
Currently taking iron and folic acid (self-reported)§	
Yes	446 (83)
No	94 (17)

HFIAS = household food insecurity access scale; SD = standard deviation.
*Total N = 544.
†Indicates full or partial completion in each category.
‡HFIAS score based on range of 0–27 with 27 indicating maximum food insecurity.
§540 women reported receiving iron and folic acid at the prenatal visit.

TABLE 2
Mean BMI and Hb concentration and rates of underweight and anemia according to type of household sanitation facility*

	Improved sanitation facility†	Non-improved sanitation facility‡	*P* value
Total, *n* (%)	221 (41)	323 (59)	
BMI (kg/m^2)	19.9 ± 3.0	19.4 ± 2.3	0.013
Hb (g/L)	118 ± 12	114 ± 14	0.001
Underweight (BMI < 18.5 kg/m^2)	74 (34)	117 (36)	0.511
Anemia (Hb < 110 g/L)	56 (25)	109 (34)	0.036

BMI = body mass index; Hb = hemoglobin.
*Total *N* = 544. Values are mean ± standard deviation or *n* (%). *t* tests and χ^2 tests were used to compare means and proportions between groups, respectively.
†Closed pit latrine.
‡Open defecation.

TABLE 4
Associations between independent variables, all anemia, and moderate anemia*

Variable	Any anemia† (*N* = 165) OR (95% CI)	Only moderate anemia‡ (*N* = 65) OR (95% CI)
Age (years)	1.00 (0.96, 1.05)	0.97 (0.90, 1.04)
Parity	1.09 (0.88, 1.34)	1.11 (0.83, 1.47)
Household size	1.04 (0.92, 1.17)	1.12 (0.95, 1.32)
Gestation (weeks)	1.07 (0.98, 1.16)	1.02 (0.91, 1.15)
Water source (ref: non-improved)§	0.55 (0.30, 1.00)	1.23 (0.49, 3.11)
Taking IFA	1.07 (0.64, 1.79)	0.92 (0.45, 1.89)
Toilet type (ref: non-improved)‖	0.81 (0.54, 1.22)	0.35 (0.18, 0.68)

CI = confidence interval; Hb = hemoglobin; IFA = iron and folic acid; OR = odds ratio.
*Categorical reference variables: non-improved (untreated) water source, not taking IFA, and non-improved sanitation facility. Continuous variables: parity and household size.
†Hb < 110 g/L.
‡Hb = 70–99 g/L; excluding those women with no anemia, mild or severe anemia.
§Improved: treated water supply; non-improved: untreated water supply.
‖Improved: closed pit latrine; non-improved: open defecation.

(closed latrine), with the remainder (~60%) practicing open defecation in a field, pond, river, or stream (non-improved sanitation facility). As participant characteristics have been published elsewhere,[8] only those relevant to this analysis are presented here.

Mean ± SD BMI was 19.9 ± 3.0 kg/m^2 among women with an improved sanitation facility and 19.4 ± 2.3 kg/m^2 among those with a non-improved facility (*P* = 0.01) (Table 2). No difference was observed in the rate of underweight between women with an improved and non-improved sanitation facility. Mean ± SD Hb concentration was 118 ± 12 g/L among women with an improved sanitation facility and 114 ± 14 g/L among those with a non-improved facility (*P* = 0.001) (Table 2). Further, women with a non-improved facility had a higher prevalence of anemia, as compared with women with an improved facility (34% versus 25%; *P* = 0.04). Among the 165 anemic cases, the proportion of moderate anemia (Hb = 70–99 g/L) was higher among women with a non-improved facility, as compared with women with an improved sanitation facility (48%; *N* = 52 versus 23%; *N* = 13; *P* = 0.002).

An improved sanitation facility was a positive predictor of both BMI and Hb concentration in linear regression models that adjusted for age, parity, household size, village cluster, gestation week, source of drinking water (improved or non-improved), and whether the woman was taking a prenatal IFA supplement at the time of the survey. The β coefficients for sanitation facility were 0.57 kg/m^2 (95% CI = 0.10, 1.04; *P* = 0.02) and 2.94 g/L (95% CI = 0.53, 5.35; *P* = 0.02) for BMI and Hb concentration, respectively (Table 3). Multicollinearity was not evident due to a low variance inflation factor (< 2) for all variables in both models.

Having an improved sanitation facility was not a significant predictor for underweight (OR = 0.87; 95% CI = 0.60, 1.28) or general anemia (OR = 0.81; 95% CI = 0.54, 1.22) in the logistic regression models adjusted for age, parity, household size, village cluster, gestation week, source of drinking water (improved or non-improved), and IFA supplementation. However, women with an improved facility had a much lower chance of being moderately anemic (OR = 0.35; 95% CI = 0.18, 0.68) than women who had a non-improved sanitation facility (Table 4). Consumption of improved (treated) drinking water had a borderline protective effect on any anemia (OR = 0.55; 95% CI = 0.30, 1.00), though this result was not observed in the analysis for moderate anemia, likely due to the much smaller sample size (*N* = 65) of this subgroup of women.

DISCUSSION

In this study among rural Cambodian women, those who resided in households with an improved sanitation facility had a significantly higher BMI and Hb concentration than women without an improved facility. Further, the prevalence of anemia was almost 10% higher among women with a non-improved facility. Given the low level of household food insecurity in this population, as measured by the HFIAS, we speculate the observed associations between sanitation facility and BMI, Hb concentration, and anemia were due to a

TABLE 3
Associations between independent variables and BMI and Hb concentration*

Variable	BMI (kg/m^2) β (95% CI)	BMI *P* value	Hb concentration (g/L) β (95% CI)	Hb *P* value
Age (years)	0.07 (0.02, 0.13)	0.01	0.01 (−0.27, 0.28)	0.96
Parity	−0.03 (−0.27, 0.22)	0.83	−0.51 (−1.77, 0.75)	0.43
Household size	−0.09 (−0.23, 0.05)	0.20	−0.18 (−0.89, 0.54)	0.63
Gestation (weeks)	0.04 (−0.05, 0.14)	0.38	−0.46 (−0.96, 0.04)	0.07
Water source (Ref: non-improved)†	−0.12 (−0.85, 0.62)	0.75	1.28 (−2.47, 5.03)	0.50
Taking IFA	−0.40 (−0.99, 0.19)	0.19	−0.18 (−3.21, 2.84)	0.91
Toilet type (Ref: non-improved)‡	0.57 (0.10, 1.04)	0.02	2.94 (0.53, 5.35)	0.02

BMI = body mass index; CI = confidence interval; Hb = hemoglobin; IFA = iron and folic acid.
*Total *N* = 544. Categorical reference variables: non-improved (untreated) water source, not taking IFA, and non-improved sanitation facility. Continuous variables: parity and household size.
†Improved: treated water supply; non-improved: untreated water supply.
‡Improved: closed pit latrine; non-improved: open defecation.

reduction in infection risk in households practicing improved sanitation behaviors.

Contaminated drinking water is an underlying cause of poor nutrition.[1] In our study, the majority of households (~90%) reported treating their water supply (by boiling or filtration) before consumption, which likely attenuated the effect of drinking water source on BMI and Hb concentration. Further, as more than 80% of women reported taking an IFA supplement at the time of the survey, the lack of association between IFA supplementation and Hb concentration was unexpected. Though we did not measure biochemical markers of iron status (e.g., serum ferritin, transferrin saturation, and soluble transferrin receptor), the weak associations between IFA and Hb concentration and IFA and anemia in our study support the growing evidence[11,12] that iron deficiency may not be the primary cause of anemia in Cambodian women.

Recent research has shown that hemoglobinopathies may be a larger contributor to the anemia burden in the Cambodian context. In a study involving 420 non-pregnant women in Prey Veng Province, Karakochuk and others[11] found that more than half of the women had a genetic hemoglobinopathy (predominantly Hb E variants and α-thalassemia). Further, only 2% had low iron stores (ferritin < 15 μg/L) and the prevalence of iron deficiency anemia was ~14% in women with a hemoglobinopathy, compared to only ~1.5% in women without a hemoglobinopathy.

Evidence from high-quality studies supporting the link between sanitation and health outcomes in women is limited. Studies involving children have shown the lack of proper sanitation is associated with increased childhood illness and mortality and is a key determinant of stunted growth. Open defecation has shown to be a major factor in the rate of childhood stunting in Cambodia[13] and India[14] and a large cluster-randomized trial showed improved latrine use reduced childhood stunting in Mali from 41% to 35%.[15] Moreover, an analysis of data obtained from > 100 Demographic and Health Surveys conducted in 65 developing countries revealed positive associations between the frequency of open defecation and stunting rates.[16] Specifically, more than half of the variation in child height across countries was attributed to differences in household defecation practices. In contrast, evidence suggests that there is no association between latrine promotion and child health outcomes in India.[17] This conflicting finding is attributed to inadequate coverage and inconsistent use of provided latrines resulting in continued exposure to fecal pathogens and, second, to the need for other household measures such as handwashing to interrupt the disease transmission cycle.

Open defecation and unsafe excreta disposal affect human health through fecal-oral transmission of disease-causing pathogens and through the promotion of disease vectors such as soil-transmitted helminths.[1] Resulting infections and illnesses inhibit the intestinal absorption of nutrients, which is especially deleterious for young children and pregnant women who have increased nutritional requirements. A recent meta-analysis by Ziegelbauer and others[18] that included 39 studies showed the availability and use of sanitation facilities had a highly protective effect against the three most common types of soil-transmitted helminth infections (OR = 0.51; 95% CI = 0.44, 0.61). Repeated exposure to fecal microbial and parasitic hazards has been hypothesized to produce an inflammatory response leading to environmental enteropathy (EE), a chronic enteric dysfunction associated with a 'leaky' gut.[19] EE is hypothesized to be the causal link between poor sanitation and undernutrition.[20] Recent research from Nepal[21] also suggests open defecation is associated with low hemoglobin concentrations and a higher prevalence of anemia in children, with the authors speculating this is partly because of the reduced absorption of micronutrients (e.g., iron, folate, and vitamin B12) in children with enteropathy, as these nutrients are necessary for Hb production.

As women in our study sought antenatal care at a health facility in the first trimester of pregnancy, it is likely they also engaged in other health-fostering behaviors. Therefore, associations between sanitation and nutritional status may be more pronounced in the broader population of Cambodian women. Though study participants were women enrolled in a food supplementation trial, supplements were provided after baseline height, weight, and Hb measurements used in this analysis were taken, thereby eliminating any effect of the supplement on these nutritional indicators. As we accounted for the cluster effect in the analysis, any confounders related to geographic grouping were removed.

Though this study was nested in a cluster-randomized trial, we explored the relationship between household sanitation facility and women's nutritional status at one point of time. This cross-sectional approach prevents the inference of causal relationships. One limitation of this study is that we did not investigate women's handwashing practices, a known contributor to poor nutrition.[22] We acknowledge that any intervention designed to improve sanitation facilities should also incorporate the promotion of handwashing as a complementary measure.

As one-third of the world's population lack improved sanitation facilities,[23] nutrition-focused efforts that do not address sanitation, along with safe water and hygiene improvements as complementary priorities, will make little sustained impact. The high percentage of Cambodians that lack access to a proper sanitation facility is concerning. This study is one of the first to our knowledge to examine the associations between sanitation, underweight, and anemia in pregnancy. Our findings suggest that improving sanitation, through a reduction in the practice of open defecation, is associated with less maternal underweight and anemia in Cambodian women. Cross-sectoral and integrated programming is needed to effectively improve maternal health and nutrition in Cambodia and elsewhere.

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