Association of Pica with Anemia and Gastrointestinal Distress among Pregnant Women in Zanzibar, Tanzania

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Abstract. The etiology of pica, the purposive consumption of non-food substances, is not understood, despite its ubiquity among gravidae. We examined correlates of pica in a representative obstetric population ($n = 2,368$) on Pemba Island, Zanzibar, Tanzania to examine proposed etiologies. Cross-sectional data were collected on socioeconomic characteristics, food intake, geophagy (earth consumption), amylophagy (raw starch consumption), anthropometry, iron status, parasitic burden, and gastrointestinal morbidities. Amylophagy was reported by 36.3%, geophagy by 5.2%, and any pica by 40.1%. There was a strong additive relationship of geophagy and amylophagy with lower hemoglobin (Hb) concentration and iron deficiency anemia. By multivariate logistic regression, any pica was associated with Hb level (odds ratio [OR] = 0.76, 95% confidence interval [CI] = 0.72–0.81), nausea (OR = 1.45, 95% CI = 1.20–1.73), and abdominal pain (OR = 1.22, 95% CI = 1.01–1.48). These striking results indicate that the nature of the relationship between pica, pregnancy, gastrointestinal distress, and iron deficiency anemia merits further investigation.

INTRODUCTION

Pica, the craving and purposive consumption of substances that the consumer does not define as food, is a widespread phenomenon that has been documented in nearly every culture.¹ The most common types of pica are geophagy (earth), amylophagy (raw starches), and pagophagy (large quantities of ice).² Several etiologies of pica have been proposed, including hunger, micronutrient deficiencies, gastrointestinal distress, and increased exposure or susceptibility to pathogens and toxins.³ Cultural explanations have also been suggested.⁴ However, the widespread occurrence of pica throughout the animal kingdom^{5,6} is a strong indication that cultural beliefs are not the sole impetus for pica. Currently, the etiology and health consequences of pica remain poorly understood.

The phenomenon of pica merits elucidation for many reasons besides its worldwide ubiquity. It has been regularly associated with both negative and positive health effects. Investigators from diverse fields have explored its causal role in conditions such as heavy metal poisoning, especially lead,^{7,8} micronutrient imbalances (by binding with consumed food or preventing adsorption in the small intestine),^{9–12} and transmission of parasites.^{13–15} Others have studied its positive health effects, such as providing micronutrients,^{12,16,17} soothing gastrointestinal upset¹⁸ or preventing harmful chemicals or pathogens from entering the bloodstream.^{18–20} An additional reason to study pica is that those who most commonly engage in pica are the most physiologically vulnerable: pregnant women and young children.^{21–24}

In this study, we characterized geophagy and amylophagy in a population that was known to engage in pica.¹⁵ We examined the cross-sectional associations of pica with socio-demographic factors, diet, parasite burden, and gastrointestinal morbidities.

METHODS

Study design and population. Pregnant women ($n = 2,368$) were recruited from 8 public antenatal health clinics in the northern part of Pemba Island, Zanzibar, Tanzania, from April 13 through December 28, 2004, to participate in a community-based trial of prevention and treatment of severe anemia in pregnancy (NCT00148629). Nearly 98% of Pemban women attend a public antenatal clinic at some point during pregnancy.²⁵ Thus, this sample is likely representative of the obstetric population. The prevalence and correlates of pica at baseline, before any intervention, are presented in this report.

In general, the culture and ecology of Zanzibar are similar to the rest of coastal eastern Africa. Swahili is the principal spoken language and the cultural group with which nearly all Pambans identify. At the time of this study, the population experienced holo-endemic *Plasmodium falciparum* malaria and endemic hookworm infection. The typical diet consists largely of cassava and rice, with only seasonal availability of vegetables and fish; red meat is largely unavailable or unaffordable.

Biological data collection. For each participant, fundal height was measured to the nearest 0.1 cm in triplicate by nurses using disposable tapes. A drop of whole blood from a finger prick was used to measure hemoglobin (Hb) concentration using a HemoCue (HemoCue, Angelholm, Sweden) that was standardized every morning. Malaria parasite density was assessed by using standard methods.²⁶

In a representative subsample of 970 women,²⁷ stool samples were collected and examined by using the Kato-Katz technique to determine infection status and intensity of *Ascaris lumbricoides*, *Trichuris trichiura*, and both species of hookworm that infect humans.²⁸

Venous blood samples were taken in a subsample of 444 women to measure zinc protoporphyrin (ZPP) concentrations by using an Aviv ZP Hematofluorometer (Model 206; Aviv Biomedical, Inc., Lakewood, NJ). The first 444 women attending 4 of the 8 clinics (2 rural and 2 urban) were chosen because of their representativeness of women from urban and rural

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areas and because of ease of venous sample collection (e.g., proximity to laboratory for urban clinics and greater number of pregnant women in attendance at clinics). Iron deficiency anemia (IDA) was defined as a ZPP level $> 80 \mu\text{mol/mol}$ and an Hb level $< 11.0 \text{ g/dL}$. Data were complete on biological indices of this subsample for 435 (98.0%) women.

Survey questions and variable creation. Before the start of the study, a list of pica substances most commonly consumed on Pemba was generated using a free listing technique.³ Pembans were asked about “substances that are craved that are not normally considered food”. This longer list consisted of unripe mango, husked but uncooked rice, four types of earth, large quantities of ice, charcoal, ash, chalk, whitewash, baby powder, and powdered shell.

Survey questions were limited to the most frequently mentioned pica items: unripe mango, uncooked rice, large quantities of ice, and two most common types of earth, *udongo* and *ufue*. *Udongo* is a fine reddish-brown clay-like earth that is found close to the surface and used in making structures such as house walls. *Ufue* is much whiter than *udongo*, and is found by digging several inches or feet into the earth's surface, e.g., from the construction of wells or latrines. In Pemba, as in most parts of the world, earths are carefully selected and prepared by heating or cleaning before consumption.^{15,29} Pica behaviors were asked about at multiple time points, including at any time during the current pregnancy, at the time of the baseline interview, and two weeks after delivery. Information on current pica practices was available for 2,367 of the 2,368 women enrolled, and on post-partum pica practices for 1,578 of the sample (66.7%).

Additionally, in-depth, ethnographic interviews about pica were conducted with a purposive sample of 53 women who had professed pica behavior. The in-depth interviews lasted 30–75 minutes, and covered topics including how pica substances were identified, collected, stored, and prepared, and the attractiveness of various qualities, e.g., color, texture, flavor. After the interview, a Pemban fieldworker and/or an author (SLY) accompanied participants to the source of the pica substance if they were still engaging in pica. The consumer then collected precise amounts of the materials they consumed and a large amount for subsequent analysis.

In this report, we examine geophagy and amylophagy because these are the two most prominent and agreed-upon types of pica of concern to the scientific community. Although pagophagy has also been associated with various health outcomes, we excluded it from analyses because of the infrequent and irregular access to ice on Pemba. We have analyzed differences in correlates by geophagy versus no geophagy, amylophagy versus no amylophagy and any pica versus no pica. We also created four categories of pica behavior: no pica ($n = 1,470$), only geophagy ($n = 38$), only amylophagy ($n = 773$), and geophagy and amylophagy ($n = 86$).

In each clinic, a trained female interviewer surveyed women as they enrolled in the study. Pregnant women were asked about past and present pica behavior, past and present obstetric morbidities, reproductive history, medicine use, diet (using a non-quantitative food frequency questionnaire that covered the previous seven days), and indicators of socioeconomic status (SES). The SES indicators were selected based on previous research experience in Pemba and then pilot tested for this study. These indicators included occupation and educational level of the woman and her husband, quality of housing (type

of roof, type of lighting, toilet facilities), and household ownership of durable goods including bicycle, books other than the Koran, radio, and motorcycle. A durable goods score was created on the basis of reported household ownership of bicycle, radio, motorcycle, books, pit toilet, home lit by electric and/or glass lanterns, and a metal roof, and then weighted by frequency of ownership.³⁰

Data analyses. Data were entered into a Microsoft SQL-based (Microsoft Corp, Redmond, WA) database server. Manual and automated checks were performed to ensure data were consistent and within expected values. All statistical analyses were performed by using STATA 9.2 for Macintosh (STATA Corporation, College Station, TX).

Differences between pre-pregnant and pregnant geophagy behavior within the same woman were tested by using McNemar's test for paired proportions. We used one-way analysis of variance to test for differences in correlates of pica among four categories of pica behavior. We tested for significant differences between no pica versus any pica, geophagy versus no geophagy, and amylophagy versus no amylophagy groups using either the chi-square test for categorical independent variables or two-tailed Student's *t*-test for continuous independent variables. We tested for interactions between geophagy and amylophagy and the outcome variable of interest using simple linear or logistic regression. A *P* value < 0.05 was considered statistically significant. Random-effect, multivariate logistic models of geophagy, amylophagy and any pica were created through stepwise forward addition of variables that were significant in bivariate analyses and variables that have been posited to be associated with pica in previous publications.

Ethical considerations. This study was reviewed and approved by the Committee on Human Research of the Bloomberg School of Public Health, Johns Hopkins University (Baltimore, MD), the Institutional Review Board of Cornell University (Ithaca, NY), and the Zanzibar Health Research Council (Zanzibar, Tanzania).

RESULTS

Pica behavior. One hundred twenty-four pregnant women (5.3%) reported engaging in geophagy at some point in their current pregnancy and 859 (36.3%) reported amylophagy (Figure 1). In simple logistic regressions, gestational age was associated with an increased odds of geophagy and amylophagy (odds ratio [OR] = OR 1.08, 95% confidence interval [CI] = 1.03–1.13, for geophagy per one day increase in gestational age and OR = 1.06, 95% CI = 1.04–1.08 for amylophagy) (Figure 1). Those who reported no pica were approximately two weeks less advanced in gestational age than those who practiced any pica. The mean quantity of earth consumed daily among the 53 pica practitioners participating in the ethnographic study was 26.5 grams (range = 5.1–65.9 grams), approximately 1/4 cup in dry measurement; for uncooked rice, mean daily consumption was 34.5 grams (range = 7.7–77.9 grams) or 1/3 cup.

Correlates of pica. Consumers of any pica substance did not differ from non-pica consumers by urban residence or marital status (Table 1). A smaller proportion of pica consumers had formal education and so did their husbands, but only the difference in husbands' education was statistically significant. Other measures of SES, namely ownership of durable goods

FIGURE 1. Pica behavior by pregnancy status, Zanzibar, Tanzania. Prevalence of geophagy and amylophagy was significantly higher (*) among pregnant women than among non-pregnant women ($P < 0.001$). Current pica behavior by gestational age at enrollment among 2,367 pregnant women.

and the proportion of those with a cash-earning job, did not differ significantly by pica status. Pica consumers were approximately one year younger than those who consumed no pica. There were no significant differences in parity, previous pregnancies, or the proportion who had a history of miscarriage between pica and non-pica groups.

Geophagists did not differ from non-geophagists by any dietary intake variable (Table 2). There were no differences in amylophagists versus non-amylophagists in mean daily number of meals, servings of inorganic iron, use of vitamins or iron supplements. Amylophagists weekly consumed 0.4 fewer types of food and 0.3 fewer servings of heme-rich foods than non-amylophagists. There were no differences in number of meals

consumed, servings of inorganic iron, or use of iron supplements by any pica behavior (although all women were provided with iron-folic acid supplements at the time of their baseline visit). Those women who consumed any pica substance consumed 0.5 fewer types of food weekly and 0.3 fewer servings of iron-rich food than those who consumed neither earth nor uncooked rice, and a modestly larger proportion of pica consumers used vitamin supplements that were not provided as part of the study (5.3 versus 7.4%; $P = 0.043$).

There were no differences in the prevalence or intensity of geohelminth infection by current geophagy status (Table 3). However, the proportion of women with hookworm infection was significantly higher among amylophagists (40.6%) than non-amylophagists (28.8%), but intensity of hookworm infection was not significantly different by pica status. A similar pattern of increased proportion with hookworm infection appeared in no pica versus any pica comparisons. There were no differences in malaria infection by pica status. Similar relationships emerged when changes in parasite burden were examined by pica behavior at any point in current pregnancy.

Differences in mean Hb concentration by pica behavior at any point in current pregnancy were statistically and medically significant in linear regression models after controlling for hookworm and malaria infections and gestational age, the strongest predictors of maternal anemia on Pemba (Figure 2). Geophagists had 0.08 g/dL lower Hb concentrations than non-pica eaters (not significant), amylophagists had 0.59 g/dL lower Hb concentrations ($P < 0.001$), and those who consumed uncooked rice and earth had 1.05 g/dL lower Hb concentrations ($P < 0.001$). A similar negative association existed between Hb concentration and pica behavior at time of the baseline interview.

Similarly, ZPP concentration, a biomarker that increases with iron deficiency, was significantly positively associated with pica status during current pregnancy, after controlling for hookworm and malaria infection and gestational age (Figure 2). In linear regression models, ZPP concentrations in exclusive amylophagists were higher than those who consumed neither earth nor rice by 20.1 $\mu\text{mol/mol}$ heme ($P < 0.001$) and 25.7 $\mu\text{mol/mol}$ heme ($P = 0.085$) for those who ate both substances. A similar relationship existed between ZPP concentration and pica behavior at time of the baseline interview.

TABLE 1

Association between demographic and socioeconomic characteristics and pica behavior at any point in current pregnancy among 2,367 pregnant women in Zanzibar, Tanzania

Characteristic	Pica status					P*
	No pica n = 1,470 (61.0%)	Earth only n = 38 (1.6%)	Rice only n = 773 (32.7%)	Earth and rice n = 86 (3.6%)	Any pica n = 897 (37.9%)	
Urban, %	27	21	29	29	29	0.258
Married, %	98	100	98	98	98	0.919
Sole wife, %	71	71	69	71	71	0.490
Women with any formal education (%)	56	47	52	58	52	0.071
Husbands with any formal education, %	68	57	64	64	64	0.037
Durable goods score†	4.4 (12.2)	3.0 (10.4)	3.7 (11.3)	5.7 (13.7)	3.9 (11.5)	0.285
Women with a cash-earning job, %	8	8	6	6	6	0.087
Husband with cash-earning job, %	64	63	65	65	65	0.693
Age (years)†	28.8 (6.8)	28.6 (7.0)	27.5 (6.3)	28.1 (6.2)	27.6 (6.3)	< 0.001
Gestational age at enrollment, weeks†	23.6 (4.9)	26.7 (4.9)	25.2 (5.2)	26.4 (5.3)	25.4 (5.2)	< 0.001
Primiparous, %	12	8	11	10	11	0.277
No. of previous pregnancies†	4.4 (3.1)	4.3 (2.6)	4.2 (3.0)	4.5 (3.1)	4.2 (3.0)	0.124
Ever miscarried, %	25	26	26	24	26	0.564

* Indicates significance of difference by *t*-tests between no pica and any pica groups.

† Values are mean (SD).

TABLE 2

Comparisons between recalled dietary intake and pica behavior at any point during current pregnancy among 2,367 pregnant women, Zanzibar, Tanzania

Dietary intake	Pica status					
	No geophagy n = 2,243	Geophagy n = 124	No amylophagy n = 1,508	Amylophagy n = 859	No pica n = 1,470	Any pica n = 897
No. of meals per day*	2.6 (0.6)	2.5 (0.5)	2.6 (0.6)	2.6 (0.6)	2.6 (0.6)	2.6 (0.6)
No. of foods eaten in last 7 days*	11.1 (3.1)	10.8 (3.3)	11.3 (3.1)	10.9† (3.0)	11.3 (3.1)	10.8‡ (3.0)
Servings of heme-rich food in past 7days*§	7.7 (3.1)	7.3 (2.9)	7.8 (3.0)	7.5† (3.1)	7.8 (3.0)	7.5‡ (3.1)
Servings of food high in inorganic iron in past 7days*¶	4.8 (2.8)	4.6 (3.2)	4.8 (2.8)	4.7 (2.9)	4.8 (2.8)	4.7 (2.9)
Vitamins during current pregnancy, %	5.9	8.0	5.4	7.3	5.3	7.4‡
Iron supplements during current pregnancy, %	11.9	12.9	11.2	13.3	11.2	13.2

*Values are mean (SD).

†P < 0.05 versus no amylophagy group.

‡P < 0.05 versus no pica group.

§Defined as seafood, chicken, beef, goat, large fish, and whitebait.

¶Defined as eggs, greens, and beans.

The prevalence of IDA followed a similar pattern, with the prevalence of IDA significantly higher among amylophagists than among those who reported no pica at any point in pregnancy (52.6% versus 36.1%; $P < 0.001$) and highest among women who ate both pica substances (57.0% versus 36.1%; $P < 0.001$) (Figure 2). The effect of uncooked rice and earth on iron status was independent; there was no evidence of interaction between the two types of pica behavior on Hb or ZPP.

A significantly higher proportion of women who had eaten earth in the current pregnancy had experienced abdominal pain and constipation than non-geophagic women (Table 4). A significantly higher proportion of pregnant women who had consumed uncooked rice at some point in the current pregnancy had experienced nausea and abdominal pain than those who had not. More women who had engaged in any form of pica had experienced nausea, abdominal pain, and constipation in this pregnancy than those who had not. There were no significant differences in loss of appetite, diarrhea, or vomiting between the pica versus non-pica group.

Statistical models of pica. We built a multivariate logistic regression model of any pica to examine the relative strength of the association of the correlates of pica when considered jointly (Table 5). Hookworm was not included for three reasons: it greatly limited the sample size, the effects of hookworm on iron status are largely captured by the inclusion of Hb, and we have already established that geophagy is not a vector for hookworm transmission in this population.¹⁵

Women with lower Hb concentrations, women who were later in gestation, and women who had experienced abdominal pain or nausea were more likely to engage in pica. Older women and women whose husbands had received formal education were less likely to engage in pica. The variable with the strongest association with any pica was nausea (OR = 1.45, 95% CI = 1.20–1.73), followed by Hb. For every g/dL decrease in Hb concentration, the likelihood of engaging in pica increased by 31.5% (OR = 0.76, 95% CI = 0.73–0.81).

We then examined how the predictors of any pica determined geophagy and amylophagy separately (Table 5). The ORs in logistic models of geophagy and amylophagy separately were consistently in the same direction and of similar magnitude as they were for any pica.

DISCUSSION

Of the 2,367 pregnant women, 897 (37.9%) had engaged in geophagy by the time of their enrollment into the larger study of the prevention of severe anemia in pregnancy. Of these, 36.3% were amylophagists, 5.2% were geophagists, and 3.6% had eaten raw rice and earth.

The prevalence of geophagy among pregnant women in Africa has been reported to range from 28% to 100%^{31–40}; the prevalence on Pemba Island was markedly lower (5.2%). However, the amounts of earth consumed in Pemba (26.5 grams/day) were comparable to those reported in other

TABLE 3

Comparisons between parasite burden and pica status at time of baseline interview among 2,367 pregnant women, Zanzibar, Tanzania*

Geohelminth	Pica status					
	No geophagy n = 929	Geophagy n = 41	No amylophagy n = 635	Amylophagy n = 335	No pica n = 620	Any pica n = 350
<i>Ascaris</i> , %	5.6	4.9	5.4	6.0	5.3	6.0
Median intensity						
<i>Ascaris</i> , eggs/g (IQR)†	2,052 (552–3,264)	504 (72–936)	1,752 (672–2,640)	1,644 (372–4,764)	1,752 (672–2,640)	1,644 (372–4,764)
<i>Trichuris</i> , (%)	33.2	34.2	31.7	36.1	31.8	35.7
Median intensity						
<i>Trichuris</i> , eggs/g (IQR)†	144 (72–384)	180 (72–648)	144 (72–288)	168 (72–480)	144 (72–288)	168 (72–480)
Hookworm, %	32.3	46.3	28.8	40.6‡	28.4	40.9§
Median intensity						
hookworm, eggs/g (IQR)†	360 (120–948)	360 (144–1,536)	312 (120–792)	396 (120–1,176)	312 (120–792)	396 (120–1,176)
Malaria, %	n = 2,243 6.8	n = 96 6.3	n = 1,648 7.0	n = 691 6.2	n = 1,615 7.1	n = 724 6.1

*IQR = interquartile range.

†Intensity is calculated as eggs per gram of stool for infected women only. Significant differences are calculated by using the logged values of intensity, but untransformed values are listed for ease of interpretation.

‡P < 0.05 versus no amylophagy group.

§P < 0.05 versus no pica group.

FIGURE 2. Predicted means of (A) hemoglobin and (B) zinc protoporphyrin (ZPP) and (C) proportion with iron deficiency anemia (IDA) for mean gestational age and having no hookworm or malaria infection by pica behavior at any point in pregnancy and at time of baseline interview, Zanzibar, Tanzania. *Significant ($P < 0.05$) in regression model. **Significant differences were calculated based on the logged values of ZPP, but unlogged values are reported for ease of interpretation. ***IDA defined as ZPP > 80 $\mu\text{mol/mol}$ and hemoglobin < 11.0 g/dL.

studies. In contrast to the low prevalence in geophagy, amylophagy was much higher than previously reported in obstetric populations in Africa. To our knowledge, this is the first report of widespread amylophagy anywhere in Africa. Raw starch consumption has been reported among populations elsewhere; cornstarch has been commonly consumed in the United States,^{41–43} and the consumption of raw flour, laundry starch and uncooked rice has been reported in North America, South America, Europe, and Asia.^{44–47}

Fear of chastisement may have led to some underreporting of pica, especially geophagy, which is considered more

objectionable than amylophagy in Pemba. However, ethnographic interviews and participant observation confirmed the low prevalence of geophagy and high prevalence of amylophagy, leading us to believe that the numbers reported here are reasonably accurate.

It is possible that Pemban women use raw rice as a substitute for earth, just as persons elsewhere have reported using raw starches as a replacement for the clay no longer available or socially unacceptable.^{23,45} A number of Pembans commented on how clay and rice have similar dry, adsorptive, and crunchy textures and similar smells, particularly after they become damp (Young SL, unpublished data). The similarity of the predictors of geophagy and amylophagy in the multivariate logistic regression models (Table 5) may be a further indication of similar use or function.

In addition to the high prevalence of amylophagy, a second interesting finding was the strong additive effect of geophagy and amylophagy on Hb concentration, even after controlling for the effects of hookworm, gestational age, and malaria (Figure 2). Compared with those who did not engage in any pica, Hb concentration was 1.05 g/dL lower among those who engaged in both picas ($P < 0.001$), 0.59 g/dL among those who engaged in amylophagy ($P < 0.001$), and 0.08 g/dL lower among those who engaged in geophagy only (not significant). A similar dose response to pica was apparent in ZPP concentration and in the proportion of women with IDA in each pica category.

Differential iron intake among pica groups can only partially explain the large difference in iron indices between pica groups. Those who engaged in amylophagy consumed significantly fewer servings of iron-rich foods (Table 2). However, from a biological point of view, the difference was small (0.4 fewer servings per week). A greater proportion of women who engaged in pica used vitamins, although this difference was also small (7.4% versus 5.3%). Differences in prevalence of anemia-causing conditions did not fully explain the association either; Hb concentrations were lower among those who engaged in pica even after controlling for hookworm, malaria, and gestational age.

In many, but not all, epidemiologic studies, there has been a positive association between geophagy and anemia among pregnant women in Africa^{32,48–50} and elsewhere.^{23,42} However, in prior population-level studies, the relationship between amylophagy and anemia in pregnant women has been less consistent.^{41,42,51}

The correlates of pica may offer some insight into the posited etiologies of pica: hunger, micronutrient deficiency, gastrointestinal distress and protection from pathogens and toxins.

TABLE 4

Association between gastrointestinal morbidities and pica behavior at any point in current pregnancy among 2,367 pregnant women, Zanzibar, Tanzania

Morbidities, %	Pica status					
	No geophagy n = 2,243	Geophagy n = 124	No amylophagy n = 1,508	Amylophagy n = 859	No pica n = 1,470	Any pica n = 897
Loss of appetite	62.3	71.0	63.0	62.4	62.8	62.8
Nausea	35.7	41.9	33.6	40.2*	33.5	40.1†
Abdominal pain	69.8	79.8‡	68.6	73.2*	68.4	73.4†
Constipation	20.4	29.8‡	20.0	22.5	19.7	23.0†
Diarrhea	8.0	11.3	7.7	9.0	7.6	9.1
Vomiting	42.8	46.8	43.2	42.7	43.0	43.0

* $P < 0.05$ versus no amylophagy group.

† $P < 0.05$ versus no geophagy group.

‡ $P < 0.05$ versus no pica group.

TABLE 5

Multiple logistic regression models for any form of pica, geophagy, and amylophagy at any point in pregnancy among 2,367 pregnant women, Zanzibar, Tanzania*

Feature	Any pica		Geophagy		Amylophagy	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Nausea†	1.45 (1.20–1.73)	< 0.001	1.34 (0.92–1.96)	0.132	1.42 (1.19–1.71)	< 0.001
Hb, g/dL	0.76 (0.73–0.81)	< 0.001	0.77 (0.69–0.86)	< 0.001	0.77 (0.72–0.81)	< 0.001
Abdominal pain†	1.22 (1.01–1.48)	0.043	1.63 (1.03–2.57)	0.037	1.20 (0.99–1.46)	0.064
Husband education†	0.88 (0.80–0.97)	0.010	0.81 (0.65–1.02)	0.068	0.88 (0.89–0.98)	0.015
Woman's age, years	0.97 (0.96–0.99)	< 0.001	1.00 (0.97–1.03)	0.953	0.97 (0.96–0.99)	< 0.001
Duration of gestation, weeks	1.08 (1.06–1.10)	< 0.001	1.10 (1.06–1.14)	< 0.001	1.07 (1.05–1.09)	< 0.001

*OR = odds ratio; CI = confidence interval; Hb = hemoglobin. Controlling for random effects of clinic attended.

†None as referent.

Neither geophagy or amylophagy were associated with most indicators of poor SES status or reduced food availability, e.g., dietary diversity or number of meals consumed. Furthermore, if rice was available to be eaten raw, it could have been eaten after cooking. Thus, these data suggest that pica is not motivated by hunger in this population.

Although causality cannot be claimed in cross-sectional studies, the positive relationship between pica and iron deficiency and anemia could be interpreted as consistent with the hypothesis that pica is motivated by a micronutrient deficiency. The greater prevalence of pica in later pregnancy, when micronutrient needs are higher, also supports this hypothesis (Figure 1).³⁹ Several studies have presented evidence to suggest that geophagic earth can act as a micronutrient supplement,^{52,53} but more rigorous laboratory studies in rats and humans have shown that earth and uncooked starch actually inhibit iron adsorption, especially when they are consumed before a meal.^{10,11,54,55} Putative mechanisms for this include the increase of gut pH (which would reduce the bioavailability of inorganic iron) and the adsorption of dietary iron into pica substances, rendering it unavailable. We know that Pemban pica substances are unlikely vectors for geohelminths; parasitologic analyses of geophagic earths on Pemba indicated no viable *Trichuris*, *Ascaris*, or hookworm eggs.¹⁵ Moreover, the desiccating effect of uncooked rice on hookworm eggs makes it unlikely that uncooked rice would harbor viable hookworm eggs (Goodman D, unpublished data, 2006).

We explored the possibility of differential effects of pica on heme versus non-heme iron absorption by testing for interactions between number of servings of heme and inorganic iron foods and pica behavior on Hb concentration, but no significant interactions were found. This finding could be an indication that pica substances affect adsorption of both types of iron similarly or do not affect it at all. Consideration of the physical and chemical structure of soils and starch provides some evidence that these dry, powdery substances may reduce micronutrient absorption by consumers. Pemban geophagic soils contain clay,²⁹ and clays often have a high cation exchange capacity, which means they are good at binding cations such as Fe²⁺.⁵⁶ However, the capacity of Pemban clays to bind heme or the binding capacity of raw rice for inorganic or heme iron have not yet been determined.

The few *in vitro* studies of the bioavailability of iron in geophagic earth have reported mixed results.^{8,54,57} No study has looked at the bioavailability of micronutrients in uncooked rice, but it is highly unlikely that more nutrients would be available in uncooked than cooked rice, and the white rice consumed in Zanzibar, which is not enriched, is low in most micronutrients.⁵⁸

A third possibility is that pica and anemia are not causally related, but instead merely associated via a third factor, for example, chronic gastrointestinal inflammation causing both diarrhea (which is quelled by kaolin ingestion) and anemia. Examination of the bioavailability of micronutrients and iron binding capacity in Pemban soils would be useful for determining if the relationship between pica and anemia is a causal one.

It has been suggested that geophagy is a response to gastrointestinal distress, that is has a palliative effect on gastroesophageal reflux disease (by increasing gut pH) and diarrhea (by reducing rapid passage of fluids). This suggestion is plausible for geophagy; a number of clays have been established as efficacious at treating diarrhea, e.g., kaolin was the original active ingredient in the over-the-counter medicine Kaopectate. The palliative effects of amylophagy are not known.

More pregnant women who engaged in pica reported nausea and abdominal pain than those who did not, which is consistent with this hypothesis. Furthermore, mineralogic analyses of 12 samples of Pemban geophagic earth indicated the presence of kaolin, which is consistent with this hypothesis.²⁹ Finally, the association between hookworm and both types of pica (Table 3) could be interpreted as consistent with this hypothesis. It may be that pica is a response to parasitic infection, as is thought to be the case among various species of free-living primates.⁵ However, geophagy as a palliative response to endoparasites is not consistent with the patterns of infection; Pemban women experience chronic, rather than acute infection. One possible explanation of the sudden increase in pica during pregnancy is that women become more sensitive to their parasitic infections when pregnant, mediated by hormonal changes, but this is only speculative. Pica may also cause gastrointestinal distress; it has been associated with constipation. It would be useful for other researchers to examine the association between gastrointestinal distress and pica in future studies, ideally noting the temporality of the relationship.

The detoxification and protection hypothesis posits that pica prevents harm from pathogens or plant chemicals by either binding with them directly or by binding with the mucin layer, thereby preventing their passage into the bloodstream. It is closely related to the gastrointestinal distress hypothesis because nausea, vomiting, and diarrhea are frequently a consequence of ingestion of harmful substances.^{59,60}

The striking increase in prevalence of amylophagy (8% versus 37%) and geophagy (0.03% versus 3.6%) (Figure 1) during pregnancy is consistent with this protection hypothesis, as is the dry, adsorptive texture of raw rice and earth. Both starch and clays have been demonstrated to be effective in adsorbing viruses,⁶¹ bacteria,^{62,63} and chemical poisons.^{18–20,61}

They have also been shown to adhere to and reinforce the intestinal mucin layer,^{64,65} another possible mechanism for protection. An *in vivo* study of the pathogen and toxin binding capacity of geophagic and amylophagic substances would be highly useful in understanding this relationship.

In conclusion, amylophagy and geophagy are strongly positively associated with iron deficiency, anemia, and some gastrointestinal morbidities. From a public health perspective, the relationship between these factors merits elucidation because of the worldwide prevalence of pica, the strong association with iron deficiency and anemia, and the potential for some pica substances to reduce gastrointestinal distress and harm from pathogens and toxins. There is a clear need for further research to understand this enigmatic ingestive behavior.

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