Original Research Article

A Test of Three Hypotheses of Pica and Amylophagy Among Pregnant Women In Tamil Nadu, India

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Objectives: Pica has been studied in India and elsewhere for more than 100 years, yet no compelling and empirically well-supported explanation for it has emerged. Amylophagy, sometimes considered a type of pica and sometimes studied separately, is less frequently investigated and also lacks a convincing explanation. This study used a biocultural approach to test three hypotheses of pica and amylophagy: protection, hunger/nutrition, and psychological distress.

Methods: The research took place in Tamil Nadu, India. In study 1, a cultural investigation was carried out among nonpregnant, adult women ($n = 54$) to determine nonfood substances that are consumed in this region and perceptions of health consequences. Next, using the substances identified in Study 1, three hypotheses of pica and amylophagy were tested in a cross-sectional study of pregnant women (Study 2, $n = 95$). Logistic regression analysis was used to analyze the presence or absence of engaging in pica and amylophagy. A series of bivariate analyses were used to examine the variation in amount and frequency of consumption.

Results: Study 1 revealed that cultural attitudes strongly shape the selection of nonfood substances. In Study 2, the presence or absence of pica was not predicted by any of the variables included in the study, whereas the frequency and amount of consumption of pica substances were primarily explained by the psychological distress and hunger/nutrition hypotheses. Both the presence or absence of amylophagy as well as the frequency and amount of consumption were best explained by the protection hypothesis.

Conclusions: This research provided partial support for the protection and hunger/nutrition hypotheses for amylophagy, and also provided some evidence for the role of psychological distress and hunger or nutrition in pica. Am. J. Hum. Biol. 00:000–000, 2013. © 2013 Wiley Periodicals, Inc.

Pica is the compulsive craving and ingestion of culturally defined "nonfood" items. From an etic perspective, nonfood substances include, but are not limited to: earth (geophagy), unprocessed starches (amylophagy), ash (stachtophagia), and charcoal (Corbett et al., 2003; Young, 2010, 2011; Young et al., 2010). Although consumption of nonfood items has been documented in many cultures and across numerous species (Anell and Lagercrantz, 1958; Krishnamani and Mahaney, 2000; Laufer, 1930; Young et al., 2011), no compelling and empirically well-supported explanation for it has yet emerged.

Amylophagy is the ingestion of raw starch, including laundry starch, cornstarch, raw cassava, raw potatoes, and raw rice (Golden et al., 2012; Jackson and Martin, 2000; Young et al., 2008). Amylophagy is often considered a form of pica because some studies have indicated that when clays are unavailable individuals consume raw starches (e.g., raw rice) that have a similar texture to some geophageous substances (Hunter and de Kleine, 1984; Vermeer and Frate, 1979; Young et al., 2010). Other research, however, treats amylophagy separately because it involves consumption of substances that are classified as foods by the study population (Golden et al., 2012). Many amylophagy studies are limited to case studies and clinical samples of pregnant women in the United States (Corbett et al., 2003; Ephros and Lee, 1988), with a few recent exceptions (Golden et al., 2012; Young et al., 2010).

Numerous hypotheses have been proposed to explain pica and/or amylophagy. These include hunger, psychopathology, culture, and biological adaptation (American Psychological Association, 2011; Geissler, 2000; Young, 2010; Young et al., 2011).

Earth has been consumed at different points in time to quell hunger (Bourne, 2008; Laufer, 1930; Young, 2011). This hypothesis is not considered a universal explanation of pica, however, because individuals often claim that their motivations for consuming pica substances are due to intense cravings and desires, not hunger (Young, 2010). Furthermore, individuals tend to consume pica substances in-between meals and in small quantities (around 30 g), which indicates that pica is not a means to cope with hunger (Young, 2011). Although the hunger hypothesis is not widely supported, it warrants continued investigation because pica substances are sometimes capable of satiating hunger pains (Bourne, 2008). In addition, raw starches provide substantial calories per gram, so hunger must be considered as a possible explanation for amylophagy.

In Western psychology, general pica behavior is considered a psychopathology requiring intervention (American Psychological Association, 2011). Pica is typically associated with high levels of stress, anxiety, depression, and developmental disorders (Danford et al., 1982; Stiegler, 2005; Stroman et al., 2011). Cravings for substances, in some instances, are comparable to those for opium and alcohol, with consumption alleviating psychological discomfort (Edwards et al., 1994, Young, 2011).

Contract grant sponsor: Washington State University's Graduate and Professional Student Association (GPSA).

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Received 13 February 2013; Revision received 20 August 2013; Accepted 21 August 2013

DOI: 10.1002/ajhb.22456
Published online 00 Month 2013 in Wiley Online Library (wileyonlinelibrary.com).

Numerous studies have also demonstrated the role that culture plays in influencing pica behavior (Laufer, 1930). Geophagy often has religious significance, and is related to healing, fertility, and childbearing (Danford et al., 1982; Prince, 1989; Young, 2010). The Luo of Kenya, for example, consume soil during pregnancy because it "adds to the blood" and has the capacity to improve health of women (Geissler, 2000). In Esquipulas, the Black Christ cult is traditionally known for promoting the consumption of white clay tablets to alleviate pregnancy sickness and ease childbirth (Hunter and de Kleine, 1984). The tablets are blessed by the Catholic Church and sold at local markets. Followers of this cult believe this particular clay has divine healing properties (Hunter and de Kleine, 1984; Prince, 1989). An Aka informant from Central African Republic stated that cravings for clay were caused by the desires of the infant (Hewlett, 2013). In North India, cravings for pica substances are used as a means to predict the sex of an unborn child. If a woman craves ash, people believe she will have a girl, whereas dust cravings indicate that she is pregnant with a boy (Jeffrey et al., 1989).

The longest standing adaptive hypothesis for pica is that it provides micronutrients such as iron, calcium, or zinc (Vermeer, 1966; Wiley and Katz, 1998; Young, 2010, 2011). However, although pica substances, such as clays, often contain iron and calcium, few studies have examined if these micronutrients are bioavailable to individuals after consumption (Seim et al., 2013; Young, 2010). Many pica substances actually bind micronutrients in the gastrointestinal tract, further depleting an individual (Hooda et al., 2002; Thomas et al., 1976). Raw rice, for example, contains higher levels of phytic acid than cooked rice (Agte et al., 1999). Phytate limits iron absorption, often leading to iron deficiency in vulnerable populations (Zimmerman and Hurrell, 2007). Furthermore, Young et al. (2011) show that pica during pregnancy is less likely to occur when women need micronutrient support, but is instead often linked to iron deficiency and iron deficiency anemia (see also Giudicelli and Combes, 1992; Libnoch, 1984; Roselle, 1970; Shahverdi and Nekoie, 2001).

One adaptive hypothesis gaining recent attention is that pica has a role in protecting against toxins or pathogens (Young et al., 2011). Several lines of evidence support the "protection" hypothesis. First, pica commonly occurs during childhood and pregnancy, when components of the immune system are suppressed and the fetus or child is vulnerable to teratogens, and individuals thus need increased protection from pathogens and toxins (Abrams and Miller, 2011; Bogin et al., 2007; Ellis et al., 2009; Young, 2010; but see Golden et al., 2012 for prevalence of pica among men). Second, several studies have shown that pica substances can provide protection by either binding directly to pathogens or toxins or by reducing permeability of the gut wall to prevent transmission (Hladik and Gueguen, 1974; Mahaney et al., 1999; Profet, 1992; Young et al., 2011). For instance, certain pica substances can bind to viruses, bacteria, and plant secondary compounds owing to a high cation-exchange capacity (Barr, 1957; Hooda et al., 2002; Johns, 1986; Johns and Duquette, 1991; Lipson and Stotzky, 1983). Third, because raw rice can limit iron absorption, as noted above, and iron is a limiting resource for bacteria, raw rice consumption might help combat bacterial infections (Fessler, 2002). Numerous studies have also illuminated the ability of pica substances to quell feelings of nausea and reduce vomiting sensations (Geissler et al., 1999; Hunter and de Kleine, 1984; Young et al., 2008, 2010).

Finally, pica is hypothesized to impact immune function. Callahan (2003), for instance, posits that aluminum present in commonly consumed clays acts as an adjuvant, or natural "vaccination," to help reduce pathogen burden of consumers. Regarding amylophagy, raw starches are obviously rich sources of both carbohydrates and protein. Raw rice, for instance, is 82% carbohydrates and 7–8% protein by weight, whereas cooked rice, which has absorbed a great deal of water, contains only 21% carbohydrates and 2% protein by weight (USDA, 2013). Research in humans and non-human animals shows that immune challenges can alter diet choice or the allocation of available macronutrients to immunity vs. growth and reproduction (Blackwell et al., 2010; Cotter et al., 2011; Ponton et al., 2011; Povey et al., 2009; Venesky et al., 2012). Thus, immune challenges might motivate increased consumption of nutrient-rich substances like raw rice.

The protection hypothesis for pica and amylophagy is comparable to broader research on the psychological and behavioral mechanisms used by humans and other animals to mitigate the costs associated with mounting an immune response (Huffman, 1997; Parker et al., 2011; Schaller and Duncan, 2007; Sullivan and Hagen, 2002). In particular, behavioral immunologists, who focus on human populations, hypothesize that psychological and behavioral mechanisms are activated when individuals are faced with increased risk of infection (Schaller and Park, 2011). More specifically, disgust and perceptions of disease vulnerability are heightened during periods of increased immunological demand (Navarrete and Fessler, 2006; Navarrete et al., 2007; Oaten et al., 2009; Schaller et al., 2010). Pregnancy, a period of decreased investment in cell-mediated immunity, is noted for eliciting behavioral immune responses such as disgust, nausea, and vomiting (Fairweather, 1968; Fessler et al., 2005; Flaxman and Sherman, 2000; Patil, 2012; Verberg et al., 2005). These behaviors are also hypothesized to protect the unborn infant from teratogenic substances (Fessler, 2002; Flaxman and Sherman, 2000; Hook, 1976; Profet, 1988).

THE CURRENT STUDY

This study had two aims. First, similar to the many previous studies reviewed above, it investigated how cultural norms influence the selection of nonfood substances. Second, it tested the recent protection hypothesis against two long-standing hypotheses for pica/amylophagy: hunger/nutrition and psychological distress. When discussing protection from pathogens specifically, we also refer to the protection hypothesis as the behavioral immune hypothesis.

Predictions

This study tested the following predictions of the behavioral immune hypothesis: (1) immune activation will increase consumption of pica substances and (2) increased exposure to pathogens will increase pica behavior. For the protection hypothesis (pathogens or toxins), we predicted (3) pica will be associated with nausea and vomiting, (4) women will report relief from nausea and/or vomiting as the primary reason for engaging in pica or amylophagy, and (5) pica and amylophagy will commence more often in the first trimester than the second and third trimesters.

The psychological distress hypothesis predicts (1) symptoms of psychological distress, such as depression, hopelessness, anxiety, and lethargy, will correlate with pica and amylophagy, and (2) women will report engaging in these behaviors to reduce feelings of psychological distress. The hunger/nutrition hypothesis predicts: (1) food insecurity will correlate with pica and amylophagy; (2) anthropometric indices of nutrition will correlate with pica and amylophagy; and (3) women will report hunger as the primary motivation for engaging in pica and amylophagy (cf. Young, 2011).

The Washington State University Institutional Review Board approved both the studies reported here.

Study population

Pica has been studied in India for more than 100 years (Hooper and Mann, 1906; Laufer, 1930; Nag, 1994; Rao, 1985; Thurston, 1906). Most studies have investigated the social pressures and psychological dysfunctions associated with pica (Khanum and Umpathy, 1976; Singhi and Singhi, 1983; Srinath et al., 2005), with surprisingly few examining the current cultural significance of the practice or biological explanations (Boatin et al., 2012; Jeffrey et al., 1989; Nisar et al., 2012).

The study took place from June to August 2012 in 13 villages outside of Tiruvannamalai district, Tamil Nadu, India (12°N, 79°E). The estimated total population of the 13 villages is 13,000. Tamil is the primary spoken language in the region. This is a farming community, practicing mostly rice and groundnut cultivation. Although rice composes a large portion of the diet, villagers also consume milk, eggs, chicken, and various dhals and curries.

This project used the ethnographic "funnel" approach, which begins by defining a research question and then hones in on a more specific set of questions suitable for quantitative analyses (Agar, 1996).

STUDY 1: CULTURAL INVESTIGATION OF PICA

The goal of Study 1 was to learn about common cravings and aversions women in this population experience during pregnancy, and to identify possible pica substances, the social norms regulating their consumption, and the perceived positive and negative health consequences of consumption. This information would then be used to create a structured survey to assess pica behavior specifically among a representative sample of pregnant women in Study 2.

Participants

Participants were nonpregnant adult women located in five villages ($n = 54$). Convenience sampling was used to recruit participants because the goal of Study 1 was simply to identify common cravings and aversions and not to infer their distribution in the population (e.g., no P-values would be computed for Study 1); a woman translator and the first author (C.D.P.) went door to door and asked women to participate in the study. Participants were compensated with an amount in accordance to local norms (a gift of food).

Semistructured interview

After providing informed consent, participants were asked to (1) freelist (Quinlan, 2005) "nonfood substances commonly consumed during pregnancy"; (2) report potential health consequences of consuming pica substances; and (3) state whether the practice was accepted in the region. Women in Study 1 were not asked about their personal pica behavior.

Analysis

Salience analysis, a method to determine the primary items in a cultural domain, was used to assess freelist data from semistructured interviews (Quinlan, 2005; Smith et al., 1995). This method computes a salience score for each substance that reflects both its frequency of mention as well as the order in which it was mentioned. Specifically, the salience score of a substance mentioned by a participant is

$$\text{score} = (N + 1 - \text{rank})/N,$$

where N is the number of substances mentioned by that participant, and rank is its rank order (e.g., if a participant mentions five substances, the substance mentioned first has rank = 1 and score = 1 and the one mentioned last has rank = 5 and score = 0.2). To compute the composite salience score, the scores for each substance are then averaged across all participants (Quinlan, 2005).

Study 1 results and discussion

The average age of women respondents for semistructured interviews was 38.3 (range: 19–80). Women listed 10 total "nonfood" substances.

Salience. Unripe mango was the most salient item (0.62), followed by ash (0.38) and mud or clay (0.27). The remaining items listed by participants had very low salience; these included: *esel* (a type of insect), *kungumapoo* (milk mixed with saffron powder), unripe tamarind, charcoal, toothpowder, *vibuthi* (ceremonial ash), and raw rice. All substances were included in the structured interview used in Study 2 except for *kungumapoo*. *Kungumapoo* is consumed once by women late in pregnancy in hope that it will lighten the skin of the unborn child. For this study, *kungumapoo* is not considered a pica substance because it is consumed only once in pregnancy, whereas most definitions of pica require compulsive and/or repeated consumption of a nonfood substance.

Cultural acceptance of substances. Participants were asked if the most salient pica items were accepted for consumption in the community. Unripe mango was acceptable to consume in pregnancy (76%). Ash and mud, on the other hand, were not culturally accepted; 67% of respondents stated that ash was unacceptable to consume, whereas 58% reported that women should not eat mud. For the latter two substances, a few participants further stated that women are scolded if caught eating ash or mud.

Health effects of consuming substances. Participants were asked about the health effects of consuming pica substances for mother and infant. For unripe mango, 47.4% stated that there were no adverse health effects of consumption, 34.3% said that unripe mango can lead to

excess heat in the body, 5.2% claimed that unripe mango consumption leads to stomach pain, and 5.2% said consumption causes *Manthai*—a local term for an illness where the infant is born with blue or black patches on skin, and 7.9% did not respond.

Regarding the health effects of consuming ash and mud, 10 respondents (36%) reported that there were no negative health consequences of consuming ash, five respondents (18%) were not sure, and 13 (46%) gave a variety of negative health consequences. These included: cancer, swelling in the body, hepatitis, stomach pain, "reduced blood content," death of infant, and *Manthai*. For mud, 10 (42%) of respondents said that there were no negative health consequences of consuming it, three participants (12.5%) were unsure, and the remaining responses were similar to the consequences of consuming ash. Responses included: "unhealthy," may get "stuck" to baby, causes swelling in body, stomach pain, blood loss, death of infant, and *Manthai*. Overall, results suggest that consuming unripe mango in pregnancy is more culturally accepted, perhaps because the perceived health consequences of consumption are less severe than consuming ash and mud.

Follow-up interviews were conducted to crosscheck findings. Despite one informant who claimed that raw rice was a nonfood substance, most other informants indicated that raw rice was considered a food because it is often used to prepare *dosas* and other popular South Indian dishes. Women are often encouraged not to eat it, however, for fear that it will get stuck to the unborn child. Thus, raw rice cannot be considered "pica" *per se*, but is etically categorized as amylophagy, the consumption of unprocessed starches (Corbett et al., 2003; Golden et al., 2012).

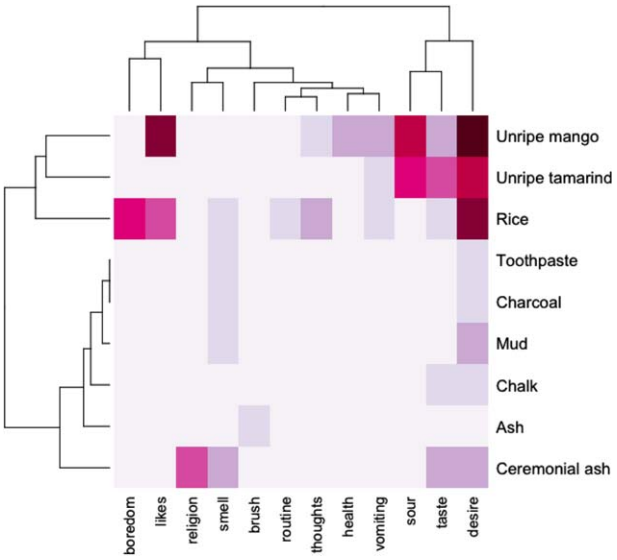

Fig. 1. Heat map of frequencies of motivations endorsed for consuming each substance. Darker, more saturated colors represent higher frequencies. For example, many participants stated they consumed unripe mango because they had a "desire" for it; a small number of participants stated they consumed ash to brush their teeth. Dendrograms were computed using the hclust package for R with the standard Euclidean distance function for individual vectors and the complete-linkage method for clustering. The left dendrogram displays clustering of the rows (pica substances), whereas the top dendrogram displays clustering of the motivations. Frequencies log transformed to better display differences between low-frequency items. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.].

STUDY 2: BIOLOGICAL INVESTIGATION OF PICA

Study design and construction of surveys

Study 2 used a cross-sectional design to test the protection/behavioral immunity, hunger/nutrition, and psychological distress hypotheses for pica and amylophagy in pregnant women. It also examined emic motivations for consumption of the substances by pregnant women.

Participants

Participants for structured interviews ($n = 95$) were recruited from Primary Health Centers (PHCs) located in the villages. This sample is likely representative of the general pregnant population because women are given a substantial monetary incentive (about USD 200) to register with the PHCs when becoming pregnant. All pregnant women who registered with PHCs at the 13 villages in the study region were included in the study regardless of trimester. Therefore, we believe we included nearly all women in the region who were pregnant during the study.

A woman translator from the region assisted the first author (C.D.P.) for all data collection. The translator and C.D.P. privately interviewed pregnant women at the respective PHC locations. Women were given monetary compensation for participation (USD 1.50). Each interview took ~25 min to complete. Informed consent was obtained before each interview.

Outcome measures. The goal of Study 2 was to help explain pica. Some studies have grouped raw starches together with other pica substances, whereas others have considered amylophagy separately from pica. Study 1 found that raw rice was considered food, and thus did not meet the definition of a pica substance. In addition, raw rice contains substantial macronutrients, unlike the other pica substances studied here, which is relevant to the hunger hypothesis. Finally, a surprisingly large percentage of participants in Study 2 reported eating raw rice, but few reported consuming the other substances, suggesting that raw rice played a separate and special role. To test our intuition, we performed a hierarchical cluster analysis of the frequencies with which participants endorsed 12 motivations for consuming each of nine substances (Fig. 1). This analysis found that the motivations for consuming mud, ash, *vibuthi*, chalk, charcoal, and toothpaste were similar (formed a cluster), and differed from those for consuming raw rice. In what follows, we therefore consider amylophagy separately from pica.

The outcome measures were presence or absence of any pica and amylophagy, amount of pica and amylophagous substances consumed, and the frequency of pica and amylophagy. Amount was measured using four local containers (small = 26 g, medium small = 100 g, medium large = 200 g, and large = 300 g), and frequency was measured on a seven-point scale ranging from never to daily. Pica substances were the nonfood items listed by nonpregnant women in Study 1: mud, ash, *vibuthi*, chalk, charcoal, and toothpaste. Unripe mango and unripe tamarind were not included because they were generally acceptable to consume, and thus technically not pica substances, and because they contain plant secondary metabolites

(Obulesu and Bhattacharya, 2011; Palafox-Carlos et al., 2012), which in some theories of pica are considered substances to which pica substances bind (Hladik and Gueguen, 1974). Finally, in the hierarchical cluster analysis (Fig. 1), unripe mango and tamarind formed a cluster, and were distinct from raw rice and the pica substances. Raw rice was the only amylophagous substance studied.

Behavioral immune hypothesis. The principal explanatory variable for the behavioral immune hypothesis was immunological activation, as indexed by number of tetanus-toxoid vaccinations received during pregnancy. Delivery of noninfectious vaccines (e.g., tetanus-toxoid and diphtheria-tetanus vaccines) is one method used to activate the immune system without exposing the organism to an actual pathogen. Numerous experimental studies with non-human animals have used vaccines to examine trade-offs between immunity, growth, and reproductive effort (Bonneaud et al., 2004; Ekblom et al., 2005; Råberg et al., 2000; Soler et al., 2003). Unlike the cited animal studies, we did not randomize participants into a vaccine treatment and placebo control group. Instead, ours was an observational study that simply measured the number of vaccines received.

Per McDade et al. (2009), number of household members was used as an index of exposure to infectious pathogens. Our measure differs from that of McDade et al. in that it does not include number of rooms per house, but there was little variation in household size among participants in this study; most reside in one to two bedroom houses.

Protection hypothesis (toxins or pathogens). Self-reported nausea and vomiting were measured to evaluate this hypothesis for pica and amylophagy (Young et al., 2008). Timing of commencement of pica and amylophagy was measured to examine if the behavior started during the first trimester when women are at increased risk of pathogen infection and fetal development is at increased risk from teratogens (Abrams and Miller, 2011; Fessler, 2002; Profet, 1992).

Hunger hypothesis. The principal explanatory variable under the hunger hypothesis was food insecurity, measured with the short-form food insecurity measure, which assesses one's access to sufficient foods, and has been shown to be both reliable and valid (Blumberg et al., 1999; World Health Organization, 2013). Body mass index (BMI) and bicep and tricep skinfold thicknesses were measured as indices of nutritional status. Although BMI includes the weight of the baby, studies have shown that it is nevertheless a reliable indicator of nutritional status in pregnancy (Anderson and Krasovec, 1991; Pike, 2000) and is significantly correlated with a number of pregnancy outcomes such as intrauterine growth rate and low birth weight (Kelly et al., 1996). Skin fold thicknesses, which measure skin and adipose tissue, correlate well with overall body fat (de Onis et al., 2007; Lohman, 1981; Sarria et al., 1998) and are thus informative indexes of nutritional status.

Psychological distress hypothesis. Psychological distress was measured with the total score from the Kessler-6 (K-6). The K-6 is a six-item measure that assesses serious mental illness in World Health Organization surveys (Kessler et al., 2010). Studies using the K-6 in India have demonstrated adequate internal consistency (Patel et al., 2007).

Finally, emic motivations for pica and amylophagy were measured by asking participants why they consumed each item.

Control variables. Income, age, and education were measured because these have predicted pica behavior in previous studies (Bruhn and Pangborn, 1971; Corbett et al., 2003; Young et al., 2010). Number of months pregnant was also included because previous research shows that pica commonly occurs early in pregnancy (Young et al., 2010). In addition, tetanus-toxoid vaccination involves two to three vaccines during pregnancy, and thus could be confounded with month of pregnancy. Total fertility rate was included because women with a previous pregnancy often received the tetanus-toxoid vaccine then, rather than during the current pregnancy. Thus, zero vs. nonzero vaccines is potentially confounded with total fertility. Finally, we analyzed the relationship between pica/amylophagy and use of Western medicine and traditional medicine because the latter might reflect a tendency to self-medicate or engage in other health-related behaviors, and therefore confound vaccinations received with pica/amylophagy. Participants were asked to report their use of both Western medicine and traditional medicine on a four-point scale ranging from never to almost always.

Surveys instruments were translated into Tamil and back-translated to English to confirm reliability (Nasser, 2005). Hypotheses were tested by examining descriptive data, and by using correlation tests and logistic regression. Statistical analyses were conducted with STATA/IC v. 10 for Macintosh.

Results

Descriptive statistics for all variables are displayed in Table 1. On an average, women were 23 years old, had one living child, made approximately $115 USD (6,257 INR) a month, and had completed school up to the ninth standard (~14 years of age).

Presence or absence of pica and amylophagy. Only 15% (14/95) of participants reported using a pica substance during pregnancy, whereas 46% (44/95) reported eating raw rice. Table 2 shows the prevalence of consumption for each pica substance among the sample of pregnant women.

We assessed commencement of pica and amylophagy in two ways. First, we asked women if and when they started to consume each pica substance and raw rice. Restricting our analysis to the 46 women in our sample who were in their third trimester (because women earlier in pregnancy still had many months in which to commence consumption), we found that 38 never consumed pica substances (83%), four commenced before pregnancy (9%), one during the first trimester (2%), two during the second trimester (4%), and one during the third trimester (2%). For amylophagy, we found that 22 (48%) never consumed raw rice, eight (17%) commenced before pregnancy, six (13%) during the first trimester, five (11%) during the

TABLE 1. Variable descriptions and descriptive statistics

Variable	Description	Present/Yes	Absent/No			
Rawrice	Raw rice consumption (presence/absence)	44	51			
Pica	Pica consumption, including: charcoal, ash, vibuthi, mud, toothpaste powder, and chalk consumption (presence/absence)	14	81			
Vomit	Any vomiting in pregnancy (yes/no)	74	21			
Nausea	Any nausea in pregnancy (yes/no)	61	34			
		Mean	**Median**	**SD**	**Min**	**Max**
Rawriceamt	Amount of uncooked rice consumed (0: small; 4: large), see text for details	0.68	0	0.85	0	3
Rawrice freq	Frequency of uncooked rice consumption per month	1.73	0	2.32	0	6
Picaamt	Amount of consumption for all pica substances (0: small; 4: large), see text for details	0.23	0	0.64	0	4
Picafreq	Frequency of consumption for all pica substances per month	1.08	0	3.33	0	24
Vaccines	Number of tetanus-toxoid vaccinations received during pregnancy	1.16	1	0.76	0	3
FStotal	Total score from Food Security scale	2.39	1	3.09	0	13
Ktotal	Total score from Kessler-6	9.81	9	2.61	6	17
BMI	Body mass index (kg/m^2)	22.64	22.1	3.66	15.2	31.8
Tricep	Skinfold thickness at tricep (mm)	13.0	12	4.3	5	24
Bicep	Skinfold thickness at bicep (mm)	8.3	7	3.8	3	21
Income	Income in rupees	6,337	5,000	8,354	500	50,000
Education	Years of education	9.19	10	3.69	0	18
Age	Age in years	23.28	23	3.13	19	35
Faminhouse	Number of household members	4.99	5	1.95	2	10
MonthsPreg	Months pregnant	6.40	7	2.04	2	9
TFR	Total fertility rate	0.62	1	0.67	0	3
Western meds	Use of Western medicine (0: never; 4: always)	3.53	4	1.24	0	4
Traditional meds	Use of traditional medicine (0: never; 4: always)	0.28	0	0.96	0	4

TABLE 2. Prevalence of pica behavior, per item, among pregnant women (N = 95)

Pica substance	Population prevalence (%)
Raw rice (*arisi*)	46
Ceremonial ash (*vibuthi*)	12
Toothpaste (*paṟpacai*)	3
Mud (*maṇ*)	3
Chalk (*cīmaiccuṇṇāmpu*)	2
Charcoal (*marakkari*)	2
Ash (*cāmpal*)	1

second, three (7%) during the third, and two (4%) were unsure. Thus, more women commenced consumption before or after the first trimester than during it. Second, we examined presence or absence of current consumption in our sample, which included women in all trimesters. The fraction of consuming pica substances in the first trimester (3/9 = 33%) was marginally significantly more than the fraction consuming pica substances in the second and third trimesters (11/86 = 13%), $X^2 = 2.74$, $P = 0.09$. The fraction of consuming rice in the first trimester (3/13 = 23%) was not significantly different than the fraction consuming raw rice in the second and third trimesters (41/86 = 48%), $X^2 = 0.67$, $P = 0.41$. Thus, there was little evidence that pica or amylophagy preferentially commenced, or was practiced, during the first trimester.

We used logistic regression to determine whether hunger/nutrition, protection, or psychological distress best predicted the presence or absence of pica and amylophagy. We first tested each hypothesis separately with logistic regression models that included all explanatory variables for a particular hypothesis.

For pica, none of the models of presence or absence approached statistical significance, and are therefore not reported. Amylophagy presence or absence was significantly predicted only by variables from the protection hypothesis: number of vaccines and number of household members, with vomiting marginally significant (Table 3, Model 1).

Even though only the protection hypothesis for amylophagy was supported (Table 3, Model 1), we wanted to see if the protection variables remained significant when variables from the hunger and psychological distress hypotheses were included in the regression, and, conversely, whether the latter variables became significant when combined with protection hypothesis variables. We therefore tested a model that included number of vaccines, number of household members, vomiting, BMI, and the Kessler-6. All variables except the Kessler-6 were significant. We therefore present a model with only the significant predictors (Table 3, Model 2). (Models with food insecurity and skinfold thickness found no support for these variables. Therefore, results were not reported.) A higher number of vaccinations, an increased number of family members in the household, and less vomiting increased the odds of consuming raw rice; higher BMI reduced the odds of consuming raw rice.

Next, we explored models of amylophagy presence or absence as a function of vaccines, controlling for likely confounding variables. Numbers of vaccines did correlate with months pregnant ($r_s = 0.59$, $P < 0.001$), total fertility ($r_s = 0.35$, $P < 0.001$), and use of Western medicines ($r_s = 0.36$, $P < 0.001$), but not with use of traditional medicines ($r_s = 0.15$, $P = 0.16$). With all these potentially confounding variables in the model, number of vaccines remained a significant predictor (Table 3, Model 3).

Finally, we looked at all of our significant predictors, controlling for income and education. All original predictors remained significant, with education and income having no significant effect (Table 3, Model 4). Age was very

TABLE 3. Logistic regression models of amylophagy (presence/absence)

	Estimate	OR	Standard error	*Z*-value	$P > \|z\|$	95% Confidence interval for OR	Model statistics
Model 1: Amylophagy							
Vaccines	1.14	3.14	0.33	3.42	0.00	1.63–6.05	LR X^2 (4) = 22.85
Faminhouse	0.35	1.42	0.13	2.65	0.01	1.09–1.83	Prob > X^2 = 0.0001
Vomit	−1.03	0.36	0.60	−1.71	0.09	0.11–1.16	Pseudo R^2 = 0.17
Nausea	0.19	1.21	0.50	0.37	0.71	0.45–3.25	N = 95
(Intercept)	−2.57		0.88	−2.90	0.00		H-L prob > X^2 = 0.51
Model 2: Amylophagy							
Vaccines	1.70	5.47	0.42	4.02	0.00	2.39–12.52	LR X^2(4) = 34.01
Faminhouse	0.32	1.37	0.13	2.41	0.01	1.06–1.78	Prob > X^2 = 0.0000
Vomit	−1.27	0.28	0.63	−2.02	0.04	0.08–0.96	Pseudo R^2 = 0.26
BMI	−0.26	0.77	0.09	−3.01	0.00	0.64–0.91	N = 95
(Intercept)	3.24		1.99	1.63	0.10		H-L prob > X^2 = 0.06
Model 3: Amylophagy							
Vaccines	1.24	3.45	0.46	2.70	0.01	1.40–8.47	LR X^2(4) = 15.91
Months_preg	−0.09	0.91	0.15	−0.62	0.54	0.67–1.23	Prob > X^2 = 0.0031
TFR	−0.29	0.75	0.30	−0.98	0.33	0.42–1.34	Pseudo R^2 = 0.12
Western_meds	−0.17	0.84	0.21	−0.83	0.41	0.56–1.27	N = 95
(Intercept)	−0.15		0.96	−0.16	0.87		H-L prob > X^2 = 0.87
Model 4: Amylophagy							
Vaccines	1.97	7.17	0.47	4.15	0.00	2.83–18.19	LR X^2(4) = 36.36
Faminhouse	0.30	1.35	0.14	2.21	0.03	1.03–1.76	Prob > X^2 = 0.0000
Vomit	−1.11	0.33	0.64	−1.73	0.08	0.09–1.16	Pseudo R^2 = 0.29
BMI	−0.27	0.76	0.09	−2.94	0.00	0.64–0.91	N = 92
Income	−5.21	0.99	0.00	−0.17	0.86	0.99–1.00	H-L prob > X^2 = 0.96
Education	0.12	1.12	0.08	1.52	0.13	0.97–1.30	
(Intercept)	1.92		2.13	0.90	0.37		

Vaccines, number of tetanus-toxoid vaccines received in pregnancy; Faminhouse, number of household members; Vomit, any vomiting during pregnancy (yes/no); Nausea, any nausea during pregnancy (yes/no); BMI, body mass index; TFR, total fertility rate; Western_meds, use of Western medicine; Income, income measured in Indian rupees; Education, education measured in number of years spent in school.

homogenous: three participants were 19, five were in their early 30s, and the remaining 87 were in their 20s. Age was not significant when added to Model 4, nor did it significantly alter the coefficients of the other variables (results not reported). Pica was modeled with control variables and findings did not approach statistical significance (results not reported).

Diagnostic tests were conducted for each model to test for goodness-of-fit and multicollinearity. Goodness-of-fit was examined using a Hosmer–Lemeshow test, a common diagnostic method for Logistic regression, with values presented in Table 3. The Hosmer–Lemeshow X^2 values were nonsignificant, indicating that the models fit the data well. Variance inflation factors for all models were below 2.0 and condition numbers were less than 30, indicating that variables were not highly correlated.

Frequency of pica and amylophagy

There was considerable variation in amount and frequency of pica substances and raw rice consumed that could potentially be modeled by our explanatory variables. However, the number of pica substance users was too small ($n = 14$) to use multivariate models. The number of raw rice consumers was larger ($n = 44$), but this small sample would still pose a risk of overfitting in a multivariate model. [We used penalized regression techniques (lasso regression) with k-fold cross-validation (Friedman et al., 2010) in an attempt to obtain parsimonious multivariate models for the frequency and amount of raw rice consumption. This attempt failed to produce parsimonious models.]

We therefore restricted analyses to bivariate correlations of our four outcome variables (amount and frequency of pica and amylophagy) vs. all of the explanatory variables from our hunger, protection, and psychological distress hypotheses. We also included the correlations between our outcome variables and control variables. We present these results in Table 4, and summarize them in the Discussion section.

Emic explanations for pica and amylophagy

Across all nonfood substances, women reported that "desire" (*acai*) was the primary motivation for consumption. Desire clustered with "sour" and "taste" as motivations for consuming substances (Fig. 1). Thus, in pregnancy, chemoreceptors, such as sour and bitter taste receptors, might be playing a role in pica/amylophagy (Fessler, 2002, Young, 2011). Not surprisingly, reducing vomiting and improving health formed a cluster. Nevertheless, unripe mango (*manga*) was the only item that women claimed provided health benefits in pregnancy. Very few women reported that nonfood substances (specifically raw rice, unripe tamarind, and unripe mango) provided relief from vomiting. The health/vomiting cluster formed a larger cluster with tooth brushing and other routines. Other clusters were more difficult to interpret, such as the one with religion and smell. *Vibuthi*, ash used in religious ceremonies, was the only substance reported to have religious significance.

Discussion of Study 2

Pica did not appear to commence more frequently in the first trimester than in other trimesters, or before pregnancy. Amylophagy commenced more before or after the first trimester than during it. These results contrast with previous research that suggests pica happens more frequently in the first trimester when women experience shifts in cell-mediated immunity (Young et al., 2011).

The presence or absence of pica behavior was not significantly predicted by any of our explanatory variables. The

TABLE 4. Rank correlation table of total pica and raw rice amount and frequency vs. all explanatory variables, and significant control variables (nonusers of pica substances excluded for pica analyses; nonraw rice consumers excluded for raw rice analyses)

	Pica amount	Pica frequency	Raw rice amount	Raw rice frequency
Vaccines	0.44 (0.06)†	0.12 (0.68)	−0.02 (0.44)	0.10 (0.25)
F. I.	0.49 (0.04)*	0.56 (0.19)	0.11 (0.23)	0.09 (0.29)
Nausea	−0.14 (0.31)	−0.09 (0.38)	0.31 (0.02)*	0.08 (0.30)
Vomiting	−0.20 (0.24)	0.20 (0.24)	−0.11 (0.24)	0.26 (0.04)*
Months_preg	0.17 (0.28)	0.12 (0.34)	0.04 (0.41)	0.32 (0.03)*
Kessler-6	0.47 (0.05)*	0.53 (0.03)*	−0.04 (0.41)	0.15 (0.16)
Bicep	0.06 (0.42)	−0.00 (0.50)	0.22 (0.08)†	−0.06 (0.35)
Tricep	0.08 (0.47)	−0.11 (0.36)	0.24 (0.06)†	0.04 (0.41)
BMI	0.23 (0.21)	−0.16 (0.30)	0.23 (0.06)†	0.09 (0.27)
Trad_Meds	0.51 (0.03)*	0.10 (0.16)	0.03 (0.39)	0.05 (0.30)
Western_Meds	0.01 (0.46)	0.00 (0.48)	0.02 (0.39)	0.04 (0.34)
Total fertility	−0.07 (0.24)	−0.07 (0.24)	−0.18 (0.04)*	0.33(0.01)*
Income	−0.02 (0.43)	−0.02 (0.44)	0.05 (0.31)	0.03 (0.40)
Education	0.02 (0.42)	0.02 (0.42)	0.10 (0.16)	0.10 (0.16)

* $p<0.05$; † $p<0.10$

presence or absence of raw rice consumption, however, was consistently predicted by the number of tetanus-toxoid vaccines received during pregnancy, supporting the behavioral immune hypothesis for amylophagy. It was also significantly predicted by number of household family members, which has been used as an index of pathogen exposure, further supporting the behavioral immune hypothesis.

Number of vaccines was potentially confounded with total fertility, month of pregnancy, and use of Western medicines. However, in a logistic regression model that controlled for all of these (Table 3, Model 3), only number of vaccines was a significant predictor of the presence or absence of amylophagy, strengthening the interpretation of vaccine number as an index of immune activation. Nausea and vomiting, on the other hand, were not significant predictors, which undercuts the protection hypothesis. Thus, factors associated with immunity specifically, but not protection more generally, were significantly correlated with the odds of engaging in amylophagy.

The hunger/nutrition hypothesis also received some support: Low BMI was associated with higher odds of amylophagy. Despite the fact that BMI was a significant predictor, the possible role of hunger/nutrition is questionable because neither food security nor bicep and tricep skinfold thicknesses were significant predictors (Table 3, Model 2). In addition, women who consumed raw rice ate, on average, 23 g/day, which provides 25 calories and about 1.8 g of protein. This is unlikely to provide sufficient macronutrients to significantly alleviate hunger or improve immune function. Nevertheless, hunger or immune challenge might still have motivated raw rice consumption.

The results from the frequency and amount analyses provided a different picture for the consumption of pica substances and raw rice. Pica amount and frequency were significantly correlated with food insecurity, psychological distress, and use of traditional medicines, whereas raw rice amount and frequency were significantly associated with nausea and vomiting, (similar to previous studies), and total fertility (Table 4). However, only one woman reported eating raw rice to reduce vomiting (Fig. 1). Raw rice frequency was also positively and significantly associated with month of pregnancy, perhaps indicating that frequency of raw rice consumption is a response to increased nutritional demands.

Women's own explanations for pica and amylophagy (Fig. 1) conform to cultural models that describe pregnancy as a time of increased cravings and desires. These emic perspectives provided little support for the etic models tested here.

Limitations

Cultural proscriptions against pica may have led to underreporting of consumption of some of these substances. This study also had an observational design, which prevents assigning causality to the significant correlations we found. In particular, although we interpret number of vaccines as an index of immune activation, and we ruled out some potential confounds, this variable could be confounded with a number of other factors influencing amylophagy. The same can be said of our other variables, including number of household members, which we used as an index of pathogen exposure, per McDade et al. (2009). For instance, BMI could potentially be confounded with household members because family size can inversely correlate with nutritional status (Hagen et al., 2001, 2006). BMI and skinfold thicknesses were also measured only once during pregnancy, but our pica and amylophagy measures were retrospective, and thus indexed these behaviors across the previous months of pregnancy. Current nutritional status therefore might not indicate whether hunger was driving pica behavior earlier in pregnancy.

Additionally, the correlation of amylophagy with number of vaccines could reflect anxiety about health rather than behavioral immunity (although this relationship persisted after controlling for use of medicines and psychological distress). Finally, our results might not generalize to other populations or even to nonpregnant women in this population.

Because of limited number of consumers of pica substances and raw rice, we could only report bivariate correlations of our explanatory variables vs. frequency and amount (multivariate models would have been preferable because they allow for controls). The significant correlations we found might reflect confounds with our control variables or other factors, and should therefore be treated with caution. We failed to find parsimonious multivariate models of the frequency and amount of raw rice

consumption. The small number of users of pica substances vs. the variety of substances used also limited our ability to discriminate among our hypotheses.

CONCLUSION

This research contributes to the integration of cultural and biological perspectives on pica and amylophagy. Study 1 found that unripe mango (*manga*), ash, and mud were the most culturally salient "nonfood" items consumed by pregnant women. Participants claimed that unripe mango was acceptable for consumption during pregnancy, whereas ash and mud could lead to detrimental health effects for the mother and infant. Respondents further indicated that raw rice is culturally considered a food substance, thereby leading to us to consider it separately from pica.

The cultural proscriptions discovered in Study 1 were borne out in Study 2, which found that pica in this population occurred less frequently (15%) than amylophagy (46%). Pica was related to two types of stress: food insecurity and psychological distress. Amylophagy was associated with infectious disease and toxin factors: indices of immune response, including number of vaccines, pathogen exposure, nausea, and vomiting (but was not more common in the first trimester than at other times during pregnancy). Pregnant Tamil women themselves explain the consumption of pica and amylophagic substances as motivated by "desires." Taken together, these findings indicate that multiple factors drive the consumption of nonfood items. To shed further light on the etiology and health costs and benefits of pica and amylophagy, future research should therefore take a multifaceted biocultural approach.

ACKNOWLEDGMENT

The authors would like to thank anonymous reviewers for their helpful comments and suggestions throughout the review process. Special thanks are owed to Xavier and Hushmija Mariadoss for their hospitality and assistance during the data collection process. We also give our sincere gratitude to the National Folklore Support Centre in Chennai, Tamil Nadu.

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