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## Determinants of Latrine Use Behavior: The Psychosocial Proxies of Individual-Level Defecation Practices in Rural Coastal Ecuador

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**Abstract.** There is increasing appreciation that latrine access does not imply use—many individuals who own latrines do not consistently use them. Little is known, however, about the determinants of latrine use, particularly among those with variable defecation behaviors. Using the integrated behavior model of water, sanitation, and hygiene framework, we sought to characterize determinants of latrine use in rural Ecuador. We interviewed 197 adults living in three communities with a survey consisting of 70 psychosocial defecation-related questions. Questions were excluded from analysis if responses lacked variability or at least 10% of respondents did not provide a definitive answer. All interviewed individuals had access to a privately owned or shared latrine. We then applied adaptive elastic nets (ENET) and supervised principal component analysis (SPCA) to a reduced dataset of 45 questions among 154 individuals with complete data to select determinants that predict self-reported latrine use. Latrine use was common, but not universal, in the sample (76%). The SPCA model identified six determinants and adaptive ENET selected five determinants. Three indicators were represented in both models—latrine users were more likely to report that their latrine is clean enough to use and also more likely to report daily latrine use; while those reporting that elderly men were not latrine users were less likely to use latrines themselves. Our findings suggest that social norms are important predictors of latrine use, whereas knowledge of the health benefits of sanitation may not be as important. These determinants are informative for promotion of latrine adoption.

### INTRODUCTION

Sanitation interventions, alongside clean water and good hygiene, are important strategies to reduce the incidence of pediatric diarrheal disease and malnutrition, particularly in low- and middle-income countries.<sup>1–4</sup> In the Latin American region, most countries have met the World Health Organization's outlined goals for sanitation under the millennium development goals. Yet disparities in sanitation access persist across the region.<sup>5</sup> Upon examining national estimates of sanitation coverage in the Andes region of South America, for example, the proportion of households that have a sanitation facility that separates human excreta from contact with individuals (i.e., an “improved” sanitation facility) is heterogeneous, with Venezuelan households (95%) and Ecuador households (86%) experiencing the highest levels of access to improved sanitation and those in Bolivia the lowest (53%).<sup>6</sup> Likewise, within countries similar disparities are observed. For example, although access to improved sanitation in Ecuador is high, among rural households, improved sanitation access drops to 80%.<sup>6</sup> Furthermore, neighborhood-level sanitation access is highly variable: some rural Ecuadorian communities have improved sanitation coverage in fewer than 50% of households.<sup>7</sup> Although sanitation access is indeed important, it may not be sufficient to ensure latrine use and therefore improve child health. For example, results from recent randomized control trials of latrine construction interventions have shown no effect on diarrhea, child growth, or helminth infections, largely because of limited coverage of latrines and low uptake of latrine use.<sup>8,9</sup> Within both of these intervention studies, use of sanitation facilities was variable—approximately 60% of households in one trial reported that their latrines were used,<sup>8</sup> whereas approximately 40% of households in the other study

reported that an adult living at home still practiced open defecation after the intervention.<sup>9</sup> To effectively mitigate enteric pathogens transmission, we need to understand the drivers of latrine use behavior.

Studies of latrine use behavior have been primarily focused in South Asia and Africa. Existing studies in India,<sup>10</sup> Ghana, Mali, Niger, and Nigeria<sup>11</sup> have identified latrine construction and maintenance as key factors associated with latrine use. In addition, because individual-level behavior is influenced by social processes,<sup>12</sup> studies primarily conducted in India that have identified sociocultural factors associated with latrine use behavior are also presented within the literature. These sociocultural drivers of defecation behaviors reflect a wide array of determinants, such as enhancement of social status, community norms of latrine use,<sup>13,14</sup> or a preference to practice open defecation rather than defecate in a latrine.<sup>15</sup> Moreover, both the combination of sociocultural drivers of behavior and the construction of the latrine have been shown to influence defecation patterns. For example, a 2015 study by Dreibelbis et al.,<sup>16</sup> examining the intersection of sociocultural factors with physical components of latrines among Indian households noted that open defecation was predicted by perceptions of latrine attributes and the convenience of latrine use. In their study, Dreibelbis and others show that defecation behavior is indeed a product of a complex system with multidimensional determinants. We add to this literature by providing data on the determinants of individual sanitation practices in rural Ecuadorian communities with distinct cultural practices from each. Like Dreibelbis and others, we also conceptualize defecation as a complex behavior driven by personal and societal determinants in which latrine ownership, construction, and maintenance play key roles. Broadly, in combination with results from prior studies, the research presented here provides insight into whether drivers of defecation behavior are generalizable across regions of the globe.

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Universal access to adequate and equitable sanitation facilities, and implied use of said facilities with the goal of ending open defecation, is a global priority noted in sustainable development goal (SDG) 6.2.<sup>17</sup> Considering both this SDG and the inequalities present in latrine access throughout Latin America, it is of paramount importance to understand the potential variability of drivers of latrine use behavior in distinct cultural settings throughout the globe. Responding to this need, we aim to characterize the psychosocial drivers of latrine use in rural, coastal Ecuadorian communities. First, we use an ethnography describing defecation practices in communities in the Esmeraldas Province to design and implement a survey tool to measure specific social norms, perceptions, and attitudes related to latrine use and open defecation. Second, we use data-reduction techniques drawn from machine learning to eliminate survey questions that may not reflect common drivers of behavior at the population-level associated with self-reported latrine use. Through this approach, we identify a subset of latrine use determinants within communities, where latrine ownership is common but latrine use is variable. Such drivers of behavior provide important context for the promotion of latrine use and behavior change, which are central to SDG successes.

## METHODS

**Questionnaire development.** *Setting.* This research builds on a 15-year longitudinal study in Esmeraldas, Ecuador, that examines enteric pathogen transmission.<sup>18</sup> Esmeraldas, the northernmost coast province within Ecuador, is home to indigenous communities, a growing number of *Mestizos*, and a predominant Afro-Ecuadorian population. As an area undergoing social and economic development, the 21 study communities have a gradient of access to sanitation infrastructure (ranging from no facility to a toilet with a septic tank), with construction and maintenance of facilities varying across communities. Likewise, multiple defecation practices also occurred within the communities, such as the use of latrines or various forms of open defecation (e.g., defecation in a river or on the ground). Such variability in the physical components of latrines and defecation behaviors, as well as distinct cultural values and practices between communities, presented a unique setting for the study.

*Ethnography and questionnaire design.* From early 2012 until mid-2013, a full-time field anthropologist, who has lived in the area for nearly two decades, developed the ethnography as part of a research project examining the influence of road development on diarrheal disease.<sup>18</sup> The primary focus of the ethnography was as follows: 1) to assess which defecation practices are included in the academic definition of “open defecation”; 2) to assess where people are defecating; 3) to assess if there is variability in defecation practices (including place and time); and 4) to assess how latrine ownership may influence one’s defecation practices. To answer these questions, the anthropologist interviewed both community leaders and other residents of various ages, and spent weeks observing sanitation behaviors, infrastructure, and their effects on the environment. He summarized his findings in the form of written reports.

To design survey questions for a quantitative interview, we first read the anthropologist’s reports. Next, we applied the integrated behavior model of water, sanitation, and hygiene (IBM-WASH)<sup>19</sup> as a basis for interpreting the ethnography. The IBM-WASH framework presents intersecting dimensions of

technology, context, and psychosocial factors as the intrinsic drivers of behavior. In our conceptual model (see Figure 1), we examined the intersection of technology and psychosocial factors as they are related to latrine use behavior. We addressed contextual factors through the inclusion of individual-level demographic information. Age and gender were the main contextual factors included. Household roles were not included as they are highly correlated with age and gender, and household wealth was not included given its limited variability.

The IBM-WASH framework’s psychosocial and technological dimensions operate through five nested but interdependent ecological levels: habitual, individual, interpersonal, community, and societal. We excluded the community and societal IBM-WASH levels as these data were not available from the ethnography and would be more difficult to obtain in individual-level interviews. In addition, because behavior change was not the focus on this study, we did not examine favorable environments for changing latrine use habits. Using this conceptual framework as a guide (two dimensions and three ecological levels), one study team member reread the anthropologist’s reports to identify potential determinants of latrine use behavior and drafted questions to reflect these determinants. A second study team member independently read the report and drafted additional survey questions. The draft survey questions from each study team member were combined into one set of questions.

Survey questions were drafted across the interpersonal, intrapersonal/individual, and habitual levels. Interpersonal questions reflected *descriptive* and *injunctive* social norms of defecation across age, gender, and seasons (*Descriptive* norms are reports of others’ behaviors, whereas *injunctive* norms are perceptions of how others should behave.<sup>20</sup>). Here, we included an injunctive norm question about embarrassment of open defecation in the rainy season. We also included interpersonal questions that solicited attitudes regarding latrine sharing but did not ask about aspirations of latrine ownership/use or nurture, as these themes did not emerge in

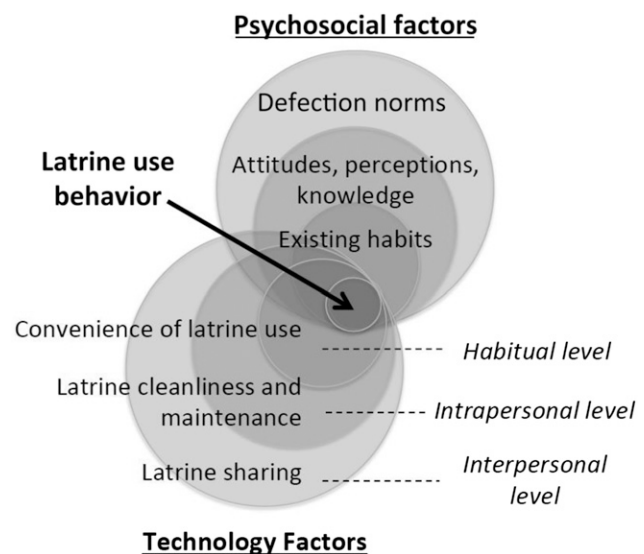


FIGURE 1. Conceptual Framework. Our framework is a modified integrated behavior model of water, sanitation, and hygiene model. Here, we measure the determinants of latrine use that intersect at two domains (technology and psychosocial) across three levels (interpersonal, intrapersonal, and habitual). This diagram provides example themes of the types of questions included in the survey.

the ethnography. Intrapersonal/individual questions assessed the benefits of latrine use and attitudes regarding latrine cleanliness, maintenance, and personal safety. Disgust of open defecation or feces did not emerge as an important theme in the ethnography, nor did self-efficacy, and were thus excluded from the questionnaire. Other questions assessed daily habits, convenience of latrine use, and open defecation. These survey questions were designed to reflect cultural values as driving forces of latrine use behavior. All survey questions are presented in Supplemental Material 1. This final set of drafted survey questions were reviewed and revised by local field staff; the local field staff edited the translation of questions to improve respondent understanding. As summarized previously, we have used a variety of approaches to ensure that we are capturing the underlying constructs that govern latrine use. Our ethnographic data allowed us to draft relevant questions, while the work by our local field staff enhanced the content validity of the survey questions.

**Survey implementation and analyses.** *Data collection.* Survey data were collected in January and February of 2016. Three communities were preselected for the study based on size, racial/ethnic makeup of the population, and representativeness of the study region in terms of access to clean water and improved sanitation facilities and sanitation practices. Households in communities A and B were censused, whereas a convenience sampling was carried out in community C because of its large size and the associated complex logistics of field visits. All households included in this present study had access to a latrine, either privately owned by their household or shared with another household. We sought to include more than one adult (i.e., those 18 years or older) per household interviewed to capture within-household variability and an equal number of men and women. Individuals were selected for interview if they were present at the time of the field visit; however, household clustering was not recorded during fieldwork. See Supplemental Material 2 for background characteristics of the communities.

*Data cleaning and manipulation.* Each psychosocial question in the survey included three possible response categories: “yes,” “no,” or “don’t know/no response.” Questions were removed from analysis if 1) 10% or more of those surveyed responded that they did not know/did not provide a response to the survey question (deemed to reflect that these questions were not drivers of latrine use in this population); or 2) the percentage of individuals agreeing or disagreeing with a specific question was 90% or greater (deemed to poorly reflect variability in survey questions that would predict latrine use). Sensitivity analyses exploring the effects of these cut points are presented in Supplemental Material 3.

Following the removal of some survey questions, the remaining questions were recoded as indicator variables. For questions in which all three of the possible responses were provided, the “don’t know” response was chosen as the referent category. This referent group was chosen to reflect the likely null association between a neutral response to the survey question and consistent latrine use. With “don’t know” as the reference category, we were able to make separate inferences for “yes” responses and for “no” responses to the same question. For those questions where only “yes” or “no” responses were provided, the “no” response was used as the referent category. Hence, the final study results will reflect whether each selected indicator is associated with consistent latrine use, the outcome variable of interest, relative to the respective referent group response (i.e., no

association). Those respondents reporting that they always use a latrine for defecation were considered consistent latrine users, whereas those reporting that they sometimes or never used a latrine for defecation were considered inconsistent latrine users. Individuals with missing data were excluded from the analyses.

*Data reduction.* Using the cleaned dataset, we fit logistic regression models to assess the association between latrine use and the psychosocial predictors. As identified in the ethnography, factors influencing latrine use behavior are interrelated (see Supplemental Material 4 for assessment of correlation). If strong correlation between survey questions, and the domains they represent, is present, standard regression model results will most likely overinflate the variance of each predictor, leading to poor prediction and limited interpretation of final models.<sup>21</sup> To avoid an erroneous increase in the variance of the estimated regression coefficients, we used supervised principal component analysis (SPCA) and adaptive elastic nets (ENET), two data-reduction techniques that explicitly incorporate covariance matrices within their algorithms, and thus account for correlation among the predictors (see Supplemental Material 5 for details regarding the modeling).<sup>22,23</sup> Through the use of these models, we sought to remove questions that were not instrumental in explaining the total variability in the set of questions that predict latrine use behavior, thus reducing the number of predictors to include in the logistic regression models for latrine use.

Given our anticipated small sample size and because each modeling approach uses a different algorithm, we compared results from these two data-adaptive analytical approaches to increase our confidence that the observed associations were not spurious. In each of these analytical approaches, we used *k*-fold cross-validation to select model-tuning parameters (specifically, 8-fold validation for SPCA and 5-fold validation for adaptive ENET). The model-tuning parameters enhance the performance of each model and reduce the variance of the included variables. Because the adaptive ENET model selects and shrinks the estimates of the unnecessary regression coefficients to zero, the *P*-values do not have a standard interpretation.<sup>24</sup> Here, the *P*-values are not absolute but are a relative reflection of the adjusted strength of associations within the entire dataset. Thus, it is important to examine all selected variables in the adaptive ENET model. The SPCA model, on the other hand, ranks the importance of selected variables by producing a relative score. To ease comparison of model results, variables selected by SPCA were subsequently used as predictors in a logistic regression model to quantify the relationship between the selected variables and latrine use.

To assess the extent to which the selected predictors from each of the two models were discordant, we compared the questions deemed relevant by each model using the McNemar’s test. The McNemar’s test statistic, which has a chi-squared distribution and one degree of freedom, provides an assessment of marginal homogeneity between two tests. We categorized whether each question in the total dataset was selected by each model or by both models; then, we tested for discordance. We also assessed which model identified a better set of questions that predict latrine use. We ran two different logistic regression models, each using the SPCA or adaptive ENET predictors, respectively, to assess the association with consistent latrine use and compared each model’s Akaike information criterion (AIC) values. To assess the internal validity of each analysis, we compared each model’s

predictive mean squared error (PMSE), a metric of model accuracy that accounts for the squared difference between the fitted values of predicted outcomes and the observed fitted values (i.e., the dataset).<sup>25</sup> The predicted outcome reflects the odds of expected latrine use for each person in the sample given the relationships observed within the dataset. Because the data are binary, the PMSE value falls within a range of zero to one, with a value close to zero indicating a high level of accuracy.

Analyses were conducted using R (version 3.0.2) and R-packages *superpc*, *gcdnet*, *GMCM*, and *matrixStats*. The University of Michigan Institutional Review Board and the Universidad San Francisco de Quito Bioethics Committee approved data collection methods and study procedures.

## RESULTS

**Ethnography and questionnaire development.** Based on ethnographic data, we found that defecation practices in the study site varied between and within communities. On the one hand, most households had access to a latrine—located within their own home, at a neighbor's home, or within the community—and reported defecating in the latrine(s) to which they had access. Open defecation, on the other hand, was practiced regardless of latrine ownership. Multiple forms of open defecation occurred as follows: within a leaf or plastic bag (which is not disposed of safely), on the ground within community boundaries, outside of community boundaries, within nearby rivers, and within the boundaries of their households. Demographic characteristics, such as age, gender, place in the family hierarchy, and time spent outside of the home, had some influence on the types of defecation behavior practiced. For example, those who were confined to the household, such as the elderly or the sick, were consistent latrine users, whereas individuals who were able to leave the house practiced some form of open defecation in addition to using the household's latrine. Those working in agricultural fields, most commonly men in Afro-Ecuadorian communities and women in Chachi communities, reported they often defecated on the way to their farms or within their farmlands, which lacked latrines. Once mobile and out of diapers, young children defecated wherever and whenever the need arose, frequently on the ground within the community, which was viewed as a nuisance to community members. Overall, there was variability in defecation behavior observed within households and on the individual level, regardless of latrine access.

Multiple factors specific to the study site also influenced defecation practices. During the rainy season, latrines were used less frequently. The influence of seasonality on defecation patterns intersects with descriptive defecation norms in unique ways. Some individuals with latrines located outside of their home, most commonly adult men, preferred not to leave their homes and become wet en route to the latrine. They defecated in a receptacle, with the contents disposed of at a later time in a variety of locations, including the latrine, the yard, or the river. Thus, men, who more often defecate on the ground on the farms, are less likely to use a latrine at home during the rainy season. Moreover, seasonality also influences the preference for river defecation. The individuals who normally defecated in the river reported that high water levels in the rainy season resulted in fecal matter quickly sinking out of sight, which was cited as a positive outcome. Defecating in a body of water was thought to avoid contact with feces and, importantly, reduce the likelihood that others would encounter feces.

In addition to seasonality, key drivers of latrine use behavior were related to the latrine itself as well as one's safety and privacy during use. It was commonly reported that dirty latrines and latrines with poor construction were less likely to be used. Poor latrine maintenance was noted as both a safety and privacy concern (i.e., a lack of a door or cracks in a wall). Some individuals noted that nighttime use of latrines outside of the household was dangerous. Walking to the latrine in the dark posed a hazard, as did the potential for animals or insects in the pit of the latrine that could bite them. Given these threats, river defecation or defecation in a receptacle was noted as a preference, should one have to defecate at night.

These ethnographic results were used to both develop new survey questions as well as modify questions obtained from studies previously conducted in India.<sup>16,26</sup> The questionnaire was meant to reflect important constructs in the ethnographic data and test the generalizability of the Indian questions in a Latin American context. In total, 70 questions were included, along with questions about the frequency of self-reported latrine use and open defecation practice (see Supplemental Material 1 for a complete list of questions).

**Survey implementation and analyses.** *Survey and data cleaning.* Of the 202 individuals approached, 197 consented to participate in the survey. Examining the responses from these 197 people, 25 of the 70 psychosocial questions were removed from the analysis: 18 questions were removed because of lack of variability in the responses and seven were removed because > 10% of the population responded "did not know" to a specific question. From the remaining 45 survey questions, 17 questions had yes/no responses and 28 had yes/no/don't know response; thus, 73 indicator variables were created. Three demographic variables (individual's gender, age, and race/ethnicity) were also included in the final dataset alongside the psychosocial indicator variables.

Of 197 individuals who participated in the survey, data from 154 subjects with complete records (those who answered every survey question) were analyzed. We found no difference in latrine use among those with complete data and those without complete records in terms of self-reported latrine use (chi-squared = 0.16, *P*-value = 0.69), gender (chi-squared = 0.44, *P*-value = 0.40), or race/ethnicity (chi-squared = 1.3, *P*-value = 0.25). Approximately, 76% of the 154 individuals self-reported always using a latrine, whereas the remainder of the study participants reported not always using a latrine (Table 1). A higher proportion of women, participants aged 18–40, and individuals living in Afro-Ecuadorian communities report consistent latrine use.

*Data reduction.* Using SPCA, the dataset was reduced to six questions of importance, whereas the adaptive ENET identified five questions as having an association with reported latrine use (Table 2). The 11 questions selected by these models included psychosocial factors, but not demographic variables, as independent drivers of consistent latrine use. These models did not, however, include all of the different types of psychosocial questions that were included in the survey. Examples of questions that did not have an association with consistent latrine use behavior include those related to injunctive social norms and individual-level knowledge of the benefits of latrine use. Rather, questions reflecting descriptive social norms of defecation, attitudes about latrine sharing, cleanliness, and maintenance, as well as personal safety, habitual latrine use, and convenience of latrine use were deemed

TABLE 1  
Percent distribution of the study population and percent individuals that use a latrine by background characteristics

Background characteristics	Percent distribution of population (%)	Percent latrine users (%)	Number of people in each category
Gender			
Female	50	78	77
Male	50	74	77
Age			
18–30 years	47	79	72
31–40 years	15	78	23
41–50 years	16	72	25
51–60 years	15	70	23
61+ years	7	72	11
Race/ethnicity			
Afro-Ecuadorian	81	78	124
Chachi	20	67	30
Total population	100	76	154

important by the modeling approaches. Specific questions within these constructs are discussed in more detail in the following paragraphs.

Three questions reflecting determinants of latrine use on each of the IBM-WASH domains (interpersonal, individual, and habitual levels) were selected by both approaches and were included in the logistic regression models. Of the common questions, daily latrine use and perceived cleanliness of the latrine had the strongest association with self-reported consistent latrine use. By contrast, when asking about latrine use norms within the community, disagreement with the statement “During the dry season, I think that majority of the elderly men in my village regularly use a latrine” reflected lower odds of consistent latrine use among individuals, although at varying strengths between the adaptive ENET model and the SPCA model.

In addition to the three common questions, five other psychosocial determinants were identified by the two data-reduction approaches and included in the logistic regression models. These determinants have large standard errors (SE), which limits any possible interpretation of the association between the predictors and the outcome. Nevertheless, the selected predictors

unique to the SPCA model reflect attitudes about latrine attributes (small cabin size and low walls) and convenience of latrine use at night as important drivers of behavior. On the other hand, the adaptive ENET model selected the following determinants of individual-level latrine use: convenience of returning to home to defecate and the perception that household size is too large for one latrine (Table 2).

The low PMSE values for both models (less than 15%) imply that each model exhibits good internal validity. The two models did not yield statistically different results (McNemar’s chi-squared statistic = 0.20, *P*-value = 0.65) and showed comparable fit (AIC value of 133 for the regression model using the adaptive ENET predictors relative to 143 AIC value for the model using the SPCA selected predictors).

## DISCUSSION

Understanding individual-level latrine use is an important step toward integrating behavior change into sanitation interventions. To this end, we used social theories, based on the IBM-WASH framework, to guide our initial selection of potential latrine use determinants identified in a previously collected ethnography.

TABLE 2  
Data Reduction. Logistic regression models derived from SPCA and adaptive ENET approaches

SPCA model				Adaptive ENET model			
Response to corresponding question	Beta estimate	SE	<i>P</i> -value	Response to corresponding question	Beta estimate	SE	<i>P</i> -value
Yes to, “The latrine is clean enough to use.”**	2.4	0.62	0.0001	Yes to, “The latrine is clean enough to use.”**	1.2	0.18	< 0.0001
Yes to, “I use the latrine everyday.”**	2.5	0.62	< 0.0001	Yes to, “I use the latrine everyday.”**	1.4	0.17	< 0.0001
No to, “During the dry season, I think that majority of the elderly men in my village regularly use a latrine.”†	–1.6	0.78	0.04	No to, “During the dry season, I think that majority of the elderly men in my village regularly use a latrine.”†	–0.15	0.23	0.51
Yes to, “The cabin of the latrine is too small for me to use.”**	–0.81	0.56	0.15	No to, “For the type of work I do, it is more convenient to defecate outside of the house.”†	0.10	0.12	0.40
Yes, to “It is more convenient to use the latrine at night than to defecate in a container within my household.”†	0.61	0.63	0.33	Yes, to “There are too many people in this household for one latrine.”**	0.14	0.12	0.23
Yes to, “The walls of the latrine are too small to provide enough privacy while using the latrine.”**	0.57	0.59	0.33				
PMSE		0.13		PMSE		0.14	

ENET = adaptive elastic nets; PMSE = predictive mean squared error; SE = standard errors; SPCA = supervised principal component analysis. Both models present the list of estimated beta coefficients, SEs, and *P*-values for variables predictive of self-reported consistent latrine use. The PMSE is shown below the results of each respective model. Variables selected by both modeling approaches are in bold.

\* Referent group is “No.”

† Referent group is “Don’t know.”

We then used dimension reduction techniques to narrow down these variables to a select set of latrine use determinants. Overall, we found that determinants of latrine use are not solely individual-level psychosocial factors or personal characteristics (gender, age, and race/ethnicity). Daily latrine use, perceived latrine cleanliness, and a descriptive norm about latrine use among elderly men were also drivers of individual-level behavior for our field site. This constellation of questions provides insight into the sociocultural drivers of behavior to exemplify that individual behavior is a by-product of dynamic social and psychological processes. First and foremost, daily latrine use reflects a personal habit. Habit formation is impacted by a variety of factors, including ease of repeating behavior<sup>27</sup> and sociocultural norms (including other people's behavior) that impact how individuals process information.<sup>28,29</sup> Latrine cleanliness has been associated with overall satisfaction of a sanitation facility.<sup>30,31</sup> Thus, we conclude that cleanliness creates a favorable environment for latrine use to become habitual. Indeed, latrine cleanliness, among other factors, was identified as an important driver of latrine adoption in a systematic review of the impact of sanitation interventions in South Asia and sub-Saharan Africa.<sup>32</sup> Outside of an intervention setting, latrine cleanliness is consistently cited as a driver of latrine use in places such as India,<sup>33</sup> Benin,<sup>34</sup> South Africa,<sup>35</sup> and Uganda.<sup>36</sup> Cleanliness, however, is only one factor that leads to daily latrine use. The social environment, which is also included in the study results, greatly influences how behavior patterns form and change.

Other researchers have also noted the influence of social norms on sanitation practices.<sup>37–39</sup> In rural Ethiopia, for example, shared values around latrine use and open defecation were strong indicators of individual defecation behavior; open defecation was practiced more often in communities that noted strong barriers to latrine use, whereas in communities with taboos against open defecation latrine use was practiced commonly.<sup>37</sup> O'Reilly and Louis' examination of latrine use behavior in India noted that proximate social pressures to use latrines were important drivers of behavior.<sup>38</sup> This is also echoed by Shakya et al.'s social network analysis of latrine access, a precursor to latrine use, which showed latrine ownership was higher among more centrally connected individuals.<sup>39</sup> Within our study, we found that a descriptive norm specific to defecation behavior among elderly men during the dry season predicted individual-level latrine use. Men, particularly male elders, are highly respected in the study communities, and because of seasonal flooding, rain often affects activities of daily living. This highlights the intersectional influence of power dynamics (social position, described by age, and gender) with temporal factors, such as seasonality, on individuals. Our results, alongside these other studies, highlight the importance of sociocultural determinants of behavior because individuals are likely to exhibit the same behavior as those around them.<sup>40</sup>

Our findings differ from other studies examining latrine use in two fundamental ways. First, we did not find personal characteristics to be independent determinants of latrine use behavior. Nearly all studies examining defecation practices have noted distinct patterns by age, seasonality, and gender.<sup>14,41,42</sup> Although personal characteristics were not selected within our model, it is of note that themes of seasonality were imbedded in the questions that asked about normative behaviors within the communities (i.e., defecation patterns by demographic groups in the wet and dry seasons). In addition, our findings deviate from

a core principle in early health behavior theories—knowledge as a propagator of behavior change.<sup>43–46</sup> Based on this core principle, many sanitation campaigns, most notably the community-led total sanitation program, often rely on knowledge of disease transmission and health benefits of latrine uptake to promote latrine use.<sup>47</sup> In our study, however, questions related to the knowledge of benefits resulting from latrine use were not selected. Knowledge of benefits stemming from latrine use was high, even among nonusers. The fact that people chose to not use latrines even when they understood the health benefits associated with latrine use has been observed elsewhere. In a recent study examining latrine use behavior in Ethiopia, community members identified that latrines could be beneficial for health and simultaneously chose not to use latrines.<sup>37</sup> In addition, Barnard et al. 2013 found similar findings in their assessment of latrine uptake following a large-scale latrine construction intervention.<sup>10</sup> Increasingly, health behavior change approaches are relying less on knowledge as a primary driver of behavior.<sup>48</sup> Because knowledge alone does not predict behavior, additional work is required to further test whether the generalizable determinants identified in our study site—latrine cleanliness and use of latrines by people with power in the community—are targets for behavior change programs across a wide array of contexts.

One approach to enhance our abilities to determine whether indicators of latrine use behavior generalize across populations is to expand studies to include heterogeneous populations. Latrine use studies, particularly those conducted in India, commonly sampled one person per household and almost exclusively women.<sup>16,26</sup> Within-household variability of psychosocial factors or behaviors was not accounted for in their results, nor were the identified psychosocial factors reflective of defecation determinants within the general population. One strength of our approach is the diversity of the study population. Not only did we attempt to sample more than one adult per household, but also we intentionally sampled both men and women from communities with different cultural values and primary languages spoken. For example, as described in the ethnography, open defecation was less stigmatized in Chachi communities than in Afro-Ecuadorian communities and latrine access varied between the two ethnic groups. Yet, latrine cleanliness was a driver of latrine use among both groups. If we had limited our sample to either type of community, we would likely present different results with limited generalizability. In addition, we also observed households in which individuals practiced defecation behaviors different from their family members. For example, one individual primarily openly defecated whereas others were consistent latrine users. If we had estimated only household-level drivers of latrine use, the variability in individual-level behavior would have been missed. Thus, sampling homogeneous populations presents challenges for assessing whether common psychosocial determinants of latrine use exist between and within populations.

Beyond the issue of generalizability, a few caveats with our approach are important to highlight. First, as noted in the results section, the PMSE value is low. This suggests that the selected predictors present a near perfect proxy of latrine use. It is improbable that the questionnaire captured all of the psychosocial determinants of latrine use behavior, and we would thus expect a higher margin of error, which is common in questionnaire-based proxies of measurement.<sup>49</sup> Two common limitations of survey-based research may play a role here. First, as is always the case in face-to-face interviews and particularly when asking



about defecation, the predictors may be subject to misclassification. This may occur if a question is perceived as sensitive. Perceived sensitivity of survey questions can lead to social desirability bias in responses<sup>50</sup>; and if this social desirability bias results in most people responding to a question in the same manner, there would be minimal variability in predictor variables. We argue that misclassification inherent in the selected determinants is minimal because these questions were perceived to be less sensitive than self-reported defecation questions. Second, survey-based research often suffers from limitations in content validity, as the survey questions may not reflect the underlying constructs we are interested in better understanding. Although we cannot say with certainty how the survey questions were interpreted by the survey respondents and whether their answers reflect the underlying construct of latrine use, we feel that our approach to survey design, which was rooted in qualitative data and relied on local staff to translate and fine-tune questions, helped increase the validity of the survey questions. Our confidence that the group of identified questions truly reflect drivers of behavior is supported by an out-of-sample analysis. In this analysis, we compared two datasets containing six common psychosocial variables and self-reported latrine use by fitting logistic regression models to test the association between these variables. The model PMSE values were similar, providing evidence that the variables selected in this study have some degree of external validity (see Supplemental Material 6 for details).

Second, the current R-packages we used for data reduction do not account for the nested clustering we observed in our data. If the outcomes are correlated and their correlation is ignored in the analysis, the SEs presented in Table 2 are narrower than they would otherwise be. A sensitivity analysis examining this question is presented in Supplemental Material 6 and the results suggest that clustering of behaviors is unlikely to impact our results.

Third, there is no gold standard measurement of individual latrine use. Although we are using psychosocial determinants to predict behavior, it is likely that our outcome variable, self-reported latrine use, is subject to social desirability bias with overreporting of latrine use behavior. It should also be noted that self-reported defecation behavior has not been previously validated as a metric of latrine use. Thus, misclassification of latrine use behavior may have influenced which attitudes, norms, habits, etc. were associated with latrine use behavior. The use of multiple cross-validation methods to select questions predicting latrine use, however, mitigates errors in variable selection.

Fourth, our analysis presents psychosocial factors influencing latrine use behavior at the population level and was not powered to disaggregate by gender, ethnicity, or age. This limitation prevents us from examining interactions between demographic characteristics and psychosocial factors. Contextual factors, in particular gender, are likely associated with unique psychosocial factors that influence sanitation practices and are not included within our analyses (see Supplemental Material 7 for a gender-related sensitivity analysis). For example, women require latrines to be sufficiently outfitted for menstrual hygiene management.<sup>51</sup> In addition, women consistently report that privacy and safety are of concern and are, therefore, important determinants of latrine use for women more so than for men.<sup>14,52</sup> For these reasons, SDG 6.2 specifically notes the importance of considering the needs of girls and women while improving latrine access for the entire population. Importantly,

our study does not address individual drivers of behavior among children but rather focuses on determinants of latrine use among adults. As highlighted in Supplement Material 7, future latrine use behavior work should explicitly examine how contextual factors (such as gender, ethnicity, age, class, etc.) interact with specific psychosocial factors to influence latrine use behavior.

Achieving universal access to WASH, the stated goal of SDG 6, will require a focus on equity across different populations. One implication of this goal is the need to refocus on regions such as Latin America, where coverage is overall high but pockets of low coverage still exist. In addition to this regional variation, there is growing evidence that individuals exhibit a variety of sanitation practices, including both open defecation and latrine use, even when a household has access to a sanitation facility.<sup>53,54</sup> These studies highlight the fact that access does not equate to use. However, we still need to know what—beyond sanitation access—influences latrine use. Notably, latrine cleanliness and the influence of those with power in the community, variables identified within our study as well as elsewhere, should be harnessed by sanitation programming to promote habitual latrine use—possibly in conjunction. In fact, some evidence suggests that it may not be enough to only focus on cleaning programs and that targeting community power structures may play a role in ultimately changing latrine use behavior. For example, a school-based latrine cleanliness intervention did not increase latrine use among pupils (an outcome not included in other latrine cleanliness studies), despite an increase in cleaner latrines.<sup>55</sup> On the other hand, several latrine cleanliness interventions have shown evidence of cleaner latrines,<sup>56–59</sup> and latrine coverage interventions cite cleaner latrines as being used more often.<sup>32</sup> Cleaning behavior, like latrine use, is complex and influenced by a host of factors, such as, psychosocial factors,<sup>60</sup> commitment to cleaning,<sup>57</sup> seasonality,<sup>59</sup> and the physical structure of the latrine.<sup>56</sup> Most often, women are regulated to cleaning tasks.<sup>58</sup> Thus, cleaning programs that target community power structures may play a role in ultimately changing latrine use behavior as well. Unfortunately, there are few examples of this in the literature. We need to continue to stress the importance of interventions to assess 1) behavior change processes of both latrine cleaning- and defecation-related social norms, 2) the appropriate agents of changes for said processes within a community and 3), and their integration. Overall, our study provides an important first step in this process by teasing apart the complicated relationship between individual-level behavior and sociocultural and technological determinants among individuals with latrine access.

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