The use of behavioural-science informed interventions to promote latrine use in rural India: a synthesis of findings

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Abstract

Background: In 2014, the Indian government launched the Swachh Bharat Mission (SBM) to end open defecation, a historically common practice that has persisted in the country despite household latrine ownership. The majority of SBM resources targeted latrine construction; however, enabling access to sanitation but not guaranteeing use. In 2016, the International Initiative for Impact Evaluation (3ie) funded four cluster-randomized trials to assess the impact of interventions designed to increase latrine use by targeting the behavioral barriers to and facilitators of latrine use among those with household latrines in rural Bihar, Karnataka, Odisha, and Gujarat. The aim of this meta-synthesis is to estimate the combined effects of these behavioural-science informed interventions on latrine use in rural India.

Methods: The four trials were conducted by Oxford Policy Management, Swiss Federal Institute of Aquatic Science and Technology (EWAG), Emory University, and the London School of Hygiene and Tropical Medicine. All four trials used an agreed upon set of measures to assess self-reported latrine use, the primary outcome, and a household-level latrine observation index. The use of similar measurements enables comparison. For each study, we calculate an intervention treatment effect through difference-in-differences estimates, which then enables us to calculate the average treatment effect across studies through a difference-in-difference meta-analysis using the individual-participant data.

Results: Self-reported latrine use increased in most states over the course of the intervention ($\beta_{\text{Bihar}}=0.99[0.57,1.40]$, $\beta_{\text{Karnataka}}=1.24[0.51,1.97]$, $\beta_{\text{Odisha}}=0.65[0.51,0.80]$, $\beta_{\text{average effect}}=0.66[0.23,1.09]$, $\beta_{\text{Gujarat}}=-0.41[-0.93,0.12]$). The increase tended to be larger in intervention than control villages ($\beta_{\text{Gujarat}}=0.90[0.12,1.69]$, $\beta_{\text{Karnataka}}=1.05[0.04,0.36]$, $\beta_{\text{Odisha}}=0.42[0.19,0.66]$, $\beta_{\text{average effect}}=0.51[0.26,0.76]$, $\beta_{\text{Bihar}}=-0.25[-0.72,0.86]$). However, there was no difference in the change in the latrine observation index between intervention and control villages ($\beta_{\text{Bihar}}=-0.06[-0.19,0.07]$, $\beta_{\text{Karnataka}}=0.09[-0.17,0.34]$, $\beta_{\text{Odisha}}=-0.5[0.15,0.05]$, $\beta_{\text{Gujarat}}=-0.03[-0.31,0.25]$, $\beta_{\text{average effect}}=0.02[-0.06,0.09]$).

Conclusion: We show that the four behavioural-science informed interventions increase self-reported latrine use among those with latrine access beyond increases presumably attributable to SBM alone. As SBM enters its next phase, focusing on the behavioural drivers of latrine use and non-use may help to maintain latrine use behaviors and change the behaviour of those who have yet to start using latrines.

Key words: Behaviour change, open defecation, sanitation, evaluation, WaSH

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1 Background

In 2012, India was the country with the most people practicing open defecation in both absolute (626 million people) and relative (59% of the total global population) terms (WHO / UNICEF, 2012). To eradicate open defecation, the Indian government launched its flagship program the Swachh Bharat Mission (Clean India Mission; SBM) in 2014 (Department of Drinking Water & Sanitation, 2020). Although India has had a succession of sanitation campaigns, this was the first to have behaviour change, not latrine coverage, as the primary goal. To do this, the SBM focused on large-scale construction of latrines. The Government of India claimed the SBM was responsible for the construction of 10,196,733 toilets across the country from 2014-2019, reaching 100% coverage (Department of Drinking Water & Sanitation, 2020).

Although this mass construction is an incredible feat, latrine access does not guarantee latrine use. A 2013 cross-sectional study in Odisha, found that 53% of those with access to latrines did not use them at all times (Barnard et al., 2013). A 2014 panel study of households with a latrine in Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh, found that 48% of households with a working latrine had at least one member practicing open defecation (Coffey et al., 2014). A follow-up study with the same households completed in 2018 found only a slight decrease, with 40% of latrine-owning households having at least one member defecating in the open (Gupta et al., 2019). Further, they found that the proportion of those who owned a latrine yet defecated in the open remained at 23% in both 2014 and 2018, demonstrating that the behavior of latrine-owners was not changing (Gupta et al., 2019). As of February 2019, the National Annual Rural Sanitation Survey, which was conducted in the final months of the SBM, concluded that 93% of households have access to latrines and that 97% of those with latrine access use them (Agency, 2019), a finding inconsistent with the 2018 follow-up study. The gap between latrine access and latrine use is closing; however, sanitation initiatives must continue to target latrine use behavior if they are to be successful in ending open defecation and sustaining latrine use (Lahiri et al., 2017).

Commonly cited barriers to use in India, in addition to poor latrine quality and the need to fetch water (O'Reilly et al., 2017; Routray et al., 2015), are knowledge, attitudes, and habits (Lahiri et al., 2017; Routray et al., 2015). Open defecation has been viewed as easier and more practical than latrine use. Those who work far from home may not see the need to come home to defecate, especially as this would require the fetching of additional water (O'Reilly et al., 2017; Routray et al., 2015). In addition, women perceive open defecation as a social opportunity to leave their house and meet with friends (Routray et al., 2015). Deep-rooted concepts of ritualistic purity further the attitude that latrine use is undesirable (Coffey et al., 2017; Juran et al., 2019; Routray et al., 2015). Many people, especially those of higher castes, are concerned with latrine pits filling quickly and requiring emptying (Coffey et al., 2017; Lahiri et al., 2017; O'Reilly et al., 2017; Routray et al., 2015). People of higher castes may avoid using a latrine so as to also avoid having to engage with low caste individuals to empty the pit or to do so themselves (Coffey et al., 2017; Routray et al., 2015). There is variation in the perceived

convenience of pit emptying, with some people claiming no challenges in pit emptying and others, especially in remote villages, having trouble finding workers to empty pits (O'Reilly et al., 2017; Routray et al., 2015).

Launched in 2016, the International Initiative for Impact Evaluation's (3ie) Promoting Latrine Use in Rural India evidence program funded teams to use insights from behavioural science to design, pilot, and scale low-cost, context-specific interventions to increase latrine use. During the first phase of the evidence program, nine teams designed and piloted context-specific interventions in eight Indian states over a period of three months. In the next phase, 3ie funded four of the nine teams to conduct impact evaluations of the most promising interventions. The appraisal of the relative promise of the selected teams and their interventions was conducted by a set of five independent reviewers, who considered scalability, cost effectiveness, and expected impact on outcomes. Here, we present the individual and combined effects from these four impact evaluations.

We focus on the estimation of the average treatment effect achieved by the four studies. Policy makers can consider this average treatment effect when designing their own sanitation programs as it is likely to be more generalizable than the results of each separate study. Because all four studies used the same set of questions to evaluate change in latrine use and we analyze the individual participant data to calculate estimates, our combined analysis constitutes a gold standard, prospective, individual-participant, meta-analysis (Ioannidis, 2017). The prospective nature of this work reduces bias, while the use of individual participant data increases precision and allows for the harmonization of the data and analyses. We hope that researchers consider the benefits of the collaborative research design employed here in the development of future programs that require significant cross-context data in order to draw strong conclusions.

2 Methods

2.1 Project design

Four teams, from Oxford Policy Management (OPM), Swiss Federal Institute of Aquatic Science and Technology (EWAG), Emory University, and the London School of Hygiene and Tropical Medicine (LSHTM), designed the most promising interventions that are reported on here and conducted impact evaluations of those interventions over 18 months in the states of Bihar, Karnataka, Odisha, and Gujarat respectively. Each evaluation—all cluster-randomized trials—assessed interventions that were designed to target the site-specific barriers to latrine use in the manner that the study teams believed would be most effective (Table 1). All studies randomized delivery of the interventions at the Gram Panchayat or village level and included between 66 and 120 clusters. Control sites were similar in basic sociodemographic characteristics (Table 2; Caruso et al., 2019b, 2019a; Chuahan et al., 2019; Friedrich et al., 2019; International Initiative for Impact Evaluation, 2020; Viswanathan et al., 2019). Both control and intervention sites received SBM activities. Each team chose their own target populations

based on local context, including the availability of different types of latrines and open defecation rates. Additional detail regarding project activities, sampling design, and data collection is provided elsewhere (Supplemental materials 1; Caruso et al., 2019b, 2019a; Chuahan et al., 2019; Friedrich et al., 2019; International Initiative for Impact Evaluation, 2020; Viswanathan et al., 2019).

All four studies collected data pre- and post-intervention. Three of the four studies collected data on the same households at baseline and endline. The fourth, which took place in Gujarat, used a repeated cross sectional design, interviewing different households at baseline and endline due to concern about respondent fatigue (Schmidt, Wolf-peter, Chauhan et al., 2020).

Table 1: Summary of the four studies conducted to promote latrine use among those with latrine access in rural India.

State (Lead research team, implementing partner)	Eligibility criteria	Districts	Villages	Behavioural science approach	Activities	Number of individuals (households) sampled at baseline	Number of individuals (households) sampled at endline
Bihar (OPML, World Vision India)	Households with functional twin pit latrines	Jamui, Khagaria, Madhepura, Nalanda, Nawada and Saharsa	86 villages (28 ODF villages)	Nudge theory	Card game, pledge, calendar, lockbox, French drain demonstration and posters to support latrine use	6,158 (1,107)	6,046 (1,085)
Karnataka (EWAG, Water Aid India)	Households with functional latrines	Raichur	120 villages (No ODF villages)	Risks, attitudes, norms, abilities and self-regulation (RANAS)	Community, household, and mothers groups meetings and a supportive phone call	10793 (2,185)	10656 (2,021)
Gujarat (LSHTM, IIPHG2)	Households with functional government or contractor built latrines	Bhavnagar	90 villages (All ODF villages)	Behaviour center design	Social marketing campaign to support the use of a five star toilet	3496 (696)	13960 (2,492)
Odisha (Emory, Rural Welfare Institute)	Households with latrines	Puri	66 villages (6 ODF villages)	Risk perceptions, abilities, social norms, motivation, physical opportunity, and self-regulation	Palla, transect walk, wall painting, household visits, latrine repairs, community and mothers meetings, and positive deviant recognition	16827 (3,723)	16827 (3,723)

1. The same participants were not followed at baseline and endline

2.2 Measures

All four studies collected data using their own surveys and a standardized set of indicators that were common across all four teams. The four teams developed these indicators through an intensive, collaborative process. The studies used the same measures to facilitate an accurate and comparable assessment of behavior change. All four study teams collected data on latrine type, size of the pit, and demographics of the participants (Table 2).

The primary outcome of interest was self-reported latrine use. To determine self-reported latrine use, information about where each household member last defecated was queried for each household member aged five years or older (Supplemental materials 2).

To determine if the latrine was actually in use, enumerators on each team observed and recorded data regarding the state of the household latrine, including if the pan was clogged, water was available, and the latrine appeared to be in use. These data were used to create a latrine use observation index. The latrine use observation index score was calculated by assigning a value of zero or one to each of the five primary latrine observation questions (Supplemental materials 2) and summing these values. The index score reflects the number of characteristic signs of latrine use observed in the household latrine, not the individual's behaviour itself. A value of zero reflects that none of the characteristic signs of latrine use were present while a value of five indicates that all characteristic signs of latrine use were seen. The mean value of this index before the intervention was 1.78 and fell slightly to 1.73 after the intervention.

2.3 Statistical methods

We use a difference-in-difference approach with clustered standard errors to estimate the impact of each study and allow for comparisons of the effects between studies (equation 1). Difference-in-differences were calculated within each of the four studies to allow for the comparison of results across studies as each team had previously conducted analysis using methods that were not comparable. The difference-in-difference was then calculated across the four studies for a prospective, individual-participant, meta-analysis. For each individual study site, a regression with robust standard errors clustered at the village level was used to evaluate the effect of the intervention (Bottomley et al., 2016). To calculate the combined effect, a separate regression was conducted across all four datasets, with robust standard errors clustered at the state level and fixed effects for state. Robust standard errors were preferred to other methods to account for clustering, such as multilevel modeling or generalized estimating equations, because they make fewer distributional assumptions. Calculations were done based on equation one in R using the mice and miceadds packages (Robitzsch and Grund, 2020; van Buuren and Groothuis-Oudshoorn, 2011).

$$\text{Equation 1: Outcome} = A + \beta_1(\text{endline}) + \beta_2(\text{treatment}) + \beta_3(\text{endline})(\text{treatment}) + C + \epsilon$$

In equation one, β_1 represents the change in control villages between baseline and endline and β_3 the difference in the change between control and intervention villages. This is the difference-in-difference term and reflects the log of the odds ratio. C represents the matrix of controls. The control variables were sex, age, household size, caste, and religion. Age and household size were standardized across the four studies so that the order of magnitude of these variables was consistent. The control variables were chosen because they are not balanced between intervention and control arms at baseline in many of the study sites and / or the literature indicates that they are likely to affect latrine use (Routray et al., 2015; Sinha et al., 2017).

Two sets of analysis were conducted. One set of analysis considered self-reported latrine use as the outcome and was calculated with a logit. A second set of analysis was conducted using the latrine observation index as the outcome of interest and was calculated with a standard regression. The value of the household latrine use observation index was applied to each person within the same household. This approach, rather than considering only one value per household, was preferred because it allows for households to be weighted by their size. Larger households have a proportionately larger effect in this analysis. Coefficients reflect the relationship between an individual's characteristics and the number of characteristics signs of latrine use seen in that person's household latrine. The approach was specified in a pre-analysis plan, with some modifications (Supplemental materials 3).

Although repeated cross sectional designs are common in difference-in-difference analysis (Models et al., 2011), several sensitivity analyses were employed due to the unique design of the Gujarat study. The difference-in-difference was first calculated according to equation one, as with the other studies. Because some villages were only sampled after the intervention, a sensitivity analysis was conducted using only villages sampled at both periods. In an additional sensitivity analysis, multiple imputation was conducted in which the pre-intervention dataset was used to impute the pre-intervention values of the individuals interviewed after the intervention and the difference-in-difference was calculated on the imputed datasets (Robitzsch and Grund, 2020; van Buuren and Groothuis-Oudshoorn, 2011). Age, sex, caste, religion, household size, village, and number of pits in the latrine were used to impute values, allowing for clustering at the village level. A level-1 logistic, generalized linear mixed effects model was used to impute the binary value for self-reported latrine use. A random forest model was used to impute the integer value for the latrine observation index. The imputation was run using 100 iterations.

Because of the different approaches used to estimate the effect of the intervention in Gujarat, sensitivity analyses were also used in the estimation of the average treatment effect. In addition to being calculated across the whole dataset, the average effect was estimated within the three states which sampled the same households at baseline and endline and using the imputed data.

Table 2: Characteristics of study participants by study arm and period. Presented as counts and means.

	Pre-intervention			Post-intervention			P-value 2
	Control	Intervention	P-value1	Control	Intervention	P-value1	
Bihar							
Villages	64	60		63	63		
Households	557	550		551	534		
Children	434	456	0.862	419	391	0.512	0.782
Adults3	2588	2676	0.807	2639	2595	0.513	0.823
Women	1323	1338	0.412	1346	1296	0.447	0.274
Age of adults4	28.337	29.283	0.062	28.987	29.938	0.074	0.011
Castes							
General category	169	336	<0.001	193	306	<0.001	0.155
OBC	2196	1910	<0.001	2060	1902	0.007	0.041
SC	581	811	<0.001	707	736	0.675	0.867
ST	70	56	0.001	87	43	0.000	0.037
Minority / other	0	0	--	0	0	--	--
Not reported	7	22	0.009	12	0	--	--
Religion							
Hindu	2734	3016	<0.001	2767	2881	0.133	0.344
Muslim	277	109	<0.001	285	106	<0.001	0.886
Christian	12	0	0.001	7	0	0.023	0.359
Other	0	10	--	0	0	--	--
Household has a single pit latrine5	0	0	--	0	0	--	--
Report that the latrine has filled5	20	34	<0.001	41	45	0.162	<0.001
Latrine observation index	1.318	1.27	0.017	1.555	1.47	<0.001	<0.001
Self-report latrine use	2120	2183	0.984	2421	2336	0.018	0.113
Report the safe disposal of child faeces	59	80	0.265	57	61	0.522	0.201
Karnataka							

Villages	54	56		54	56		
Households	1087	1098		1010	1011		
Children	361	367	0.719	370	350	0.732	1.000
Adults6	5066	4996	0.748	5033	4903	0.732	1.000
Women	2513	2471	0.911	2483	2421	0.970	0.951
Age of adults4	30.671	31.460	0.018	30.235	31.073	0.012	0.001
Castes							
General category	872	801	<0.001	876	784	<0.001	0.010
OBC	2056	1794	<0.001	2056	1755	<0.001	0.045
SC	872	1255	<0.001	839	1235	<0.001	0.004
ST	1264	1287	0.292	1285	1252	0.068	0.036
Minority / other	296	218	0.000	294	219	0.000	0.000
Not reported	69	9	0.000	53	8	0.000	0.175
Religion							
Hindu	4865	4917	0.613	4850	4816	0.714	0.394
Muslim	346	228	<0.001	342	246	<0.001	0.792
Christian	117	34	<0.001	106	14	<0.001	0.040
Other	101	185	<0.001	105	177	<0.001	0.706
Household has a single pit latrine5	1023	1060	0.508	950	976	0.897	0.508
Report that the latrine has filled5	26	18	0.000	23	21	0.012	0.000
Latrine observation index	2.338	2.33	0.415	2.343	2.45	<0.001	0.049
Self-report latrine use	3788	3704	0.390	4532	4674	<0.001	<0.001
Report the safe disposal of child faeces	24	20	0.553	139	93	0.007	0.003
Gujarat							
Number of villages	40	39		47	47		
Number of households	366	330		1214	1278		
Children	106	101	0.725	492	555	0.492	0.359
Adults	1734	1555	0.725	6217	6696	0.492	0.359
Women	897	802	0.938	3137	3355	0.701	0.664

Age of adults4	32.746	33.143	0.554	33.133	33.796	0.054	0.041
Castes							
General category	185	132	0.003	269	181	<0.001	<0.001
OBC	19	22	0.755	27	18	<0.001	<0.001
SC	267	196	0.001	1529	1822	<0.001	<0.001
ST	1344	1294	0.340	3848	4253	<0.001	<0.001
Minority / other	25	12	0.049	544	422	<0.001	0.010
Not reported	0	0	--	492	555	0.055	<0.001
Religion							
Hindu	1806	1615	0.0012	6138	6611	<0.001	<0.001
Muslim	34	41	0.4884	79	85	<0.001	--
Christian	0	0	--	0	0	--	--
Other	0	0	--	492	555	<0.001	--
Household has a single pit latrine5	312	291	0.579	33	39	0.256	0.008
Report that the latrine has filled5	3.189	3.306	0.001	2.082	2.155	<0.001	<0.001
Report latrine use	1543	1313	0.004	5255	6089	<0.001	<0.001
Latrine observation index	3.189	3.306	0.001	2.082	2.155	0.000	<0.002
Report the safe disposal of child faeces	33	19	0.051	44	52	1.000	0.175
Odisha							
Villages	33	33		33	33		
Households	1916	1807		1916	1807		
Children	581	579	0.544	581	579	0.544	0.379
Adults	7999	7668	0.544	8001	7670	0.544	0.379
Women	4041	3822	0.399	4043	3824	0.385	0.229
Age of adults4	37.221	37.335	0.716	37.218	37.339	0.699	0.595
Castes							
General category	6533	6055	<0.001	6535	6057	<0.001	<0.001
OBC	52	112	<0.001	52	112	<0.001	<0.001
SC	965	1152	<0.001	965	1152	<0.001	<0.001

ST	0	0	--	0	0	--	--
Minority / other	678	654	<0.001	678	654	<0.001	<0.001
Not reported	352	274	0.002	352	274	0.002	1.000
Religion							
Hindu	8127	7955	0.149	8129	7957	0.149	0.916
Muslim	336	158	<0.001	336	158	<0.001	0.470
Christian	0	2	--	0	--	0.016	<0.001
Other	117	132	0.899	117	132	0.899	0.303
Household has a single pit latrine ⁵	79	1807	0.595	0	1807	<0.001	<0.001
Report that the latrine has filled ⁵	85	79	0.633	83	82	0.462	0.398
Latrine observation index	1.246	1.278	0.075	1.121	1.085	0.181	0.840
Self-report latrine use	4756	4464	0.094	5767	5976	<0.001	<0.001
Report the safe disposal of child faeces	14	34	0.006	34	101	<0.001	<0.001

1. P-values were calculated as z-tests and t-tests as appropriate, comparing values between intervention and control arms within each period.

2. P-values were calculated at ANOVA and chi-square as appropriate, comparing values across time and treatment status.

3. Age missing in 3 individuals who are therefore coded as neither adults nor children

4. Age and latrine observation indexes are presented as means, not counts. P-values reflect t-tests and ANOVAs.

5. Reported at the household level

6. Age missing in 6 individuals who are therefore coded as neither adults nor children

Acronyms: OBC – other backward caste, SC – schedule caste, ST – schedule tribe

3 Results

3.1 Self-reported latrine use

3.1.1 Univariate analysis

Self-reported latrine use increased in control villages in Bihar, Karnataka, and Odisha over the course of the intervention, resulting in an average increase in self-reported latrine use in control villages (Table 3, $\beta_{\text{Bihar}}=0.93[0.51,1.36]$, $\beta_{\text{Karnataka}}=1.19[0.48,1.89]$, $\beta_{\text{Odisha}}=0.164[0.49,0.74]$, $\beta_{\text{Average effect}}=0.70[0.48,0.91]$). However, there was no change in self-reported latrine use in control villages in Gujarat ($\beta=-0.44[-0.97,0.10]$). In

Karnataka, Odisha, and Gujarat, there were larger increases in self-reported latrine use in the intervention sites than the control sites ($\beta_{\text{Karnataka}}=1.03[0.05,2.02]$, $\beta_{\text{Odisha}}=0.41[0.19,0.62]$, $\beta_{\text{Gujarat}}=0.92[0.15,1.70]$). Similarly, the average treatment effect indicated that self-reported latrine use increased more in intervention sites than control sites across the four studies ($\beta=0.49[0.23,0.75]$). However, there was no difference in the change in latrine use between intervention and control sites in Bihar ($\beta=-0.24[-0.72,0.25]$).

Table 3: Unadjusted effect estimates of the intervention on self-reported latrine use

	Coefficient	P-value	CI
Bihar (n=10398)			
Period1	0.934	0.000	0.5096, 1.3574
Arm2	-0.004	0.992	-0.775, 0.7671
Treatment by period interaction	-0.236	0.336	-0.717, 0.2450
Karnataka (n=19881)			
Period	1.180	0.001	0.4759, 1.8850
Arm	-0.041	0.826	-0.402, 0.3215
Treatment by period interaction	1.033	0.039	0.0498, 2.0160
Odisha (n=30407)			
Period	0.614	0.000	0.4878, 0.7402
Arm	-0.056	0.747	-0.396, 0.2845
Treatment by period interaction	0.406	0.000	0.1932, 0.6182
Gujarat (n=16163)			
Period	-0.440	0.107	-0.974, 0.0956
Arm	-0.314	0.324	-0.938, 0.3102
Treatment by period interaction	0.922	0.020	0.1466, 1.6969
Meta-analysis (n=76849)			
Period	0.695	0.000	0.4792, 0.9099
Arm	-0.055	0.042	-0.107, -0.001
Treatment by period interaction	0.490	0.000	0.2302, 0.7506

1. Coded as 0 for pre-intervention and 1 for post-intervention

2. Coded as 0 for control and 1 for treatment

Table 3: Unadjusted effect estimates of the intervention on self-reported latrine use

	Coefficient	P-value	CI
Bihar (n=10398)			
Period ¹	0.934	0.000	0.5096, 1.3574
Arm ²	-0.004	0.992	-0.775, 0.7671
Treatment by period interaction	-0.236	0.336	-0.717, 0.2450
Karnataka (n=19881)			
Period	1.180	0.001	0.4759, 1.8850

Arm	-0.041	0.826	-0.402, 0.3215
Treatment by period interaction	1.033	0.039	0.0498, 2.0160
Odisha (n=30407)			
Period	0.614	0.000	0.4878, 0.7402
Arm	-0.056	0.747	-0.396, 0.2845
Treatment by period interaction	0.406	0.000	0.1932, 0.6182
Gujarat (n=16163)			
Period	-0.440	0.107	-0.974, 0.0956
Arm	-0.314	0.324	-0.938, 0.3102
Treatment by period interaction	0.922	0.020	0.1466, 1.6969
Meta-analysis (n=76849)			
Period	0.695	0.000	0.4792, 0.9099
Arm	-0.055	0.042	-0.107, -0.001
Treatment by period interaction	0.490	0.000	0.2302, 0.7506

1. Coded as 0 for pre-intervention and 1 for post-intervention

2. Coded as 0 for control and 1 for treatment

3.1.2 Multivariate analysis

Self-reported latrine use increased in control arms across three sites during the intervention, with a no change in Gujarat (Table 4, $\beta_{\text{Bihar}}=0.99[0.57,1.40]$, $\beta_{\text{Karnataka}}=1.24[0.51,1.97]$, $\beta_{\text{Odisha}}=0.65[0.51,0.80]$, $\beta_{\text{Average effect}}=0.66[0.23,1.09]$, $\beta_{\text{Gujarat}}=-0.41[-0.93,0.12]$). There was a larger increase in latrine use in the intervention sites than the control sites in Karnataka, Odisha, and Gujarat (Figure 1, $\beta_{\text{Karnataka}}=1.05[0.04,2.06]$, $\beta_{\text{Odisha}}=0.42[0.19,0.66]$, $\beta_{\text{Gujarat}}=0.90[0.12,1.69]$), with no changes in Bihar ($\beta=-0.25[-0.72,0.86]$). On average, intervention sites had larger increases in latrine use than control sites as well ($\beta_{\text{Average effect}}=0.51[0.26,0.76]$).

Women tended to self-report latrine use more than men ($\beta_{\text{Bihar}}=0.42[0.30,0.53]$, $\beta_{\text{Karnataka}}=0.54[0.43,0.66]$, $\beta_{\text{Odisha}}=0.51[0.45,0.57]$, $\beta_{\text{Gujarat}}=0.01[-0.08,0.10]$, $\beta_{\text{Average effect}}=0.42[0.24,0.61]$). Age had a differing relationship with latrine use across the four sites. In Odisha, older individuals were less likely to report use ($\beta_{\text{Odisha}}=-0.01[-0.01,0]$). In Karnataka and Gujarat, older individuals were more likely to report use (Karnataka= $0.031[0.03[0.02,0.04]$, $\beta_{\text{Gujarat}}=0.02[0,0.03]$). Caste had variable relationships with latrine use in the four studies. However, in general and in the meta-analysis, schedule casts had the highest reported latrine use.

In the meta-difference-in-difference, individuals from Karnataka and Odisha had lower self-reported latrine use than those from Bihar ($\beta_{\text{Karnataka}}=-0.15[-0.20,-0.10]$, $\beta_{\text{Odisha}}=-1.61[-1.77, -1.43]$). Those from Gujarat had higher self-reported latrine use than those from Bihar ($\beta=0.18[0.08,0.28]$).

3.1.3 Multivariate sensitivity analysis

The results of the analysis in Gujarat changed somewhat under alternate sample specifications (Supplemental table 2, Supplemental figure 1). When the sample was restricted to villages which were measured before and after the intervention, the primary findings were the same: latrine use did not increase significantly across time in control sites ($\beta=-0.47[-1.00,0.70]$), but there was a significant difference in the change in latrine use between intervention and control arms ($\beta=1.03[0.23,1.84]$). Latrine use still increased with age ($\beta=0.01[0.00,0.02]$). And the tendency of women to use latrines more than men remained non-significant ($\beta=0.02[-0.07,0.11]$). When the pre-intervention sample in Gujarat was used to impute the baseline latrine use of the post-intervention sample, latrine use did not increase across time ($\beta=-0.19[-1.02,0.64]$). The treatment effect became non-significant, but stayed in the same direction ($\beta=0.66[-0.29,1.62]$).

Results did not change meaningfully when Gujarat was excluded from the meta-analysis (Supplemental table 3). Latrine use increased across time in control sites ($\beta=0.83[0.48,1.18]$), and the increase over time was larger in the intervention sites than control sites ($\beta=0.43[0.16,0.70]$). Women tended to use latrines more than men ($\beta=0.51[0.47,0.54]$). Individuals in the schedule castes had the highest odds of latrine use. Those from Karnataka and Odisha had lower self-reported latrine use than those from Bihar ($\beta_{\text{Karnataka}}=-0.13[-0.15, -0.10]$, $\beta_{\text{Odisha}}=-1.69[-1.73,-1.64]$).

Results were also consistent when the imputed values were used for the Gujarat sample. Latrine use increased over time in control sites ($\beta=0.59[0.06,1.13]$), but there was a larger increase in intervention sites than control sites ($\beta=0.48[0.20,0.75]$). Women used latrines more than men ($\beta=0.36[0.07,0.66]$). And, individuals of the schedule castes had the highest reported latrine use. Individuals from Karnataka and Odisha had lower self-reported latrine use than those from Bihar ($\beta_{\text{Karnataka}}=-0.19[-0.29, -0.08]$, $\beta_{\text{Odisha}}=-1.52[-1.77,-1.25]$). However, those from Gujarat had similar self-reported latrine use to those from Bihar ($\beta=0.29[-0.19,0.77]$).

A sensitivity analysis was conducted for the meta-analysis in which 25% of those who self-reported latrine use was randomly assigned to be non-users to simulate misreporting. The results of the meta-analysis maintained statistical significance even if 25% of those who self-reported latrine use were not actually latrine users.

Table 4: Adjusted effect estimates of the intervention on self-reported latrine use

	Coefficient	P-value	CI
Bihar (n=10364)			
Period ¹	0.985	0.000	0.567, 1.401
Arm ²	0.049	0.906	-0.76, 0.862
Treatment by period interaction	-0.249	0.308	-0.72, 0.229

Female	0.417	0.000	0.303, 0.529
Non-Hindu	0.188	0.675	-0.69, 1.066
Age ³	-0.003	0.704	-0.01, 0.010
Age squared	0.000	0.119	-0.00, 3.312
Household size ³	-0.043	0.039	-0.08, -0.00
Caste - Schedule Caste as referent			
Scheduled tribe	-0.773	0.050	-1.54, -0.00
General category	-1.180	0.007	-2.03, -0.32
Other backward category	-0.720	0.046	-1.42, -0.01
Karnataka (n=19752)			
Period	1.240	0.001	0.507, 1.973
Arm	0.012	0.948	-0.33, 0.359
Treatment by period interaction	1.049	0.042	0.036, 2.061
Female	0.544	0.000	0.430, 0.656
Non-Hindu	-0.012	0.954	-0.40, 0.379
Age	0.029	0.000	0.018, 0.039
Age squared	0.000	0.000	-0.00, -0.00
Household size	-0.012	0.190	-0.03, 0.005
Caste - Schedule Caste as referent			
Scheduled tribe	-0.538	0.002	-0.88, -0.19
General category	-1.140	0.000	-1.51, -0.76
Other backward category	-1.388	0.000	-1.73, -1.04
Minority / other	-0.268	0.333	-0.81, 0.274
Odisha (n=29271)			
Period	0.654	0.000	0.510, 0.797
Arm	-0.053	0.748	-0.37, 0.272
Treatment by period interaction	0.423	0.000	0.189, 0.655
Female	0.509	0.000	0.445, 0.572
Non-Hindu	-0.107	0.650	-0.56, 0.353
Age	-0.010	0.008	-0.01, -0.00
Age squared	0.000	0.558	-0.00, 5.966
Household size	-0.001	0.901	-0.01, 0.016
Caste - Schedule Caste as referent			
General category	-1.150	0.005	-1.94, -0.35
Other backward category	-1.140	0.000	-1.49, -0.78
Minority / other	-0.565	0.000	-0.79, -0.33
Gujarat (n=16163)			
Period	-0.410	0.126	-0.93, 0.115
Arm	-0.296	0.347	-0.91, 0.321
Treatment by period interaction	0.904	0.023	0.122, 1.685
Female	0.005	0.917	-0.08, 0.097
Non-Hindu	1.758	0.095	-0.30, 3.824

Age	0.015	0.006	0.004, 0.025
Age squared	0.000	0.095	-0.00, 1.983
Household size	-0.019	0.491	-0.07, 0.035
Caste - Schedule Caste as referent			
Scheduled tribe	-0.388	0.724	-2.54, 1.770
General category	-0.163	0.591	-0.75, 0.429
Other backward category	-0.532	0.052	-1.06, 0.003
Minority / other	-0.788	0.028	-1.48, -0.08
Meta-analysis (n=75550)			
Period	0.660	0.003	0.225, 1.093
Arm	-0.048	0.101	-0.10, 0.009
Treatment by period interaction	0.509	0.000	0.257, 0.761
Female	0.425	0.000	0.238, 0.611
Non-Hindu	0.101	0.512	-0.20, 0.404
Age	0.005	0.625	-0.01, 0.027
Age squared	0.000	0.097	-0.00, 2.556
Household size	-0.011	0.110	-0.02, 0.002
Caste - Schedule Caste as referent			
Scheduled tribe	-0.598	0.000	-0.84, -0.35
General category	-1.067	0.000	-1.31, -0.81
Other backward category	-1.238	0.000	-1.60, -0.87
Minority / other	-0.669	0.000	-0.97, -0.36
State - Bihar as referent			
Karnataka	-0.151	0.000	-0.20, -0.10
Odisha	-1.606	0.000	-1.77, -1.43
Gujarat	0.176	0.001	0.076, 0.275

1. Coded as 0 for pre-intervention and 1 for post-intervention
2. Coded as 0 for control and 1 for treatment
3. Measure was standardized across the entire sample

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Age ³	-0.003	0.704	-0.01, 0.010
Age squared	0.000	0.119	-0.00, 3.312

Household size ³	-0.043	0.039	-0.08, -0.00
Caste - Schedule Caste as referent			
Scheduled tribe	-0.773	0.050	-1.54, -0.00
General category	-1.180	0.007	-2.03, -0.32
Other backward category	-0.720	0.046	-1.42, -0.01
Karnataka (n=19752)			
Period	1.240	0.001	0.507, 1.973
Arm	0.012	0.948	-0.33, 0.359
Treatment by period			
interaction	1.049	0.042	0.036, 2.061
Female	0.544	0.000	0.430, 0.656
Non-Hindu	-0.012	0.954	-0.40, 0.379
Age	0.029	0.000	0.018, 0.039
Age squared	0.000	0.000	-0.00, -0.00
Household size	-0.012	0.190	-0.03, 0.005
Caste - Schedule Caste as referent			
Scheduled tribe	-0.538	0.002	-0.88, -0.19
General category	-1.140	0.000	-1.51, -0.76
Other backward category	-1.388	0.000	-1.73, -1.04
Minority / other	-0.268	0.333	-0.81, 0.274
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Treatment by period			
interaction	0.423	0.000	0.189, 0.655
Female	0.509	0.000	0.445, 0.572
Non-Hindu	-0.107	0.650	-0.56, 0.353
Age	-0.010	0.008	-0.01, -0.00
Age squared	0.000	0.558	-0.00, 5.966
Household size	-0.001	0.901	-0.01, 0.016
Caste - Schedule Caste as referent			
General category	-1.150	0.005	-1.94, -0.35
Other backward category	-1.140	0.000	-1.49, -0.78
Minority / other	-0.565	0.000	-0.79, -0.33
Gujarat (n=16163)			
Period	-0.410	0.126	-0.93, 0.115
Arm	-0.296	0.347	-0.91, 0.321
Treatment by period			
interaction	0.904	0.023	0.122, 1.685
Female	0.005	0.917	-0.08, 0.097
Non-Hindu	1.758	0.095	-0.30, 3.824
Age	0.015	0.006	0.004, 0.025
Age squared	0.000	0.095	-0.00, 1.983
Household size	-0.019	0.491	-0.07, 0.035
Caste - Schedule Caste as referent			

Scheduled tribe	-0.388	0.724	-2.54, 1.770
General category	-0.163	0.591	-0.75, 0.429
Other backward category	-0.532	0.052	-1.06, 0.003
Minority / other	-0.788	0.028	-1.48, -0.08
Meta-analysis (n=75550)			
Period	0.660	0.003	0.225, 1.093
Arm	-0.048	0.101	-0.10, 0.009
Treatment by period interaction	0.509	0.000	0.257, 0.761
Female	0.425	0.000	0.238, 0.611
Non-Hindu	0.101	0.512	-0.20, 0.404
Age	0.005	0.625	-0.01, 0.027
Age squared	0.000	0.097	-0.00, 2.556
Household size	-0.011	0.110	-0.02, 0.002
Caste - Schedule Caste as referent			
Scheduled tribe	-0.598	0.000	-0.84, -0.35
General category	-1.067	0.000	-1.31, -0.81
Other backward category	-1.238	0.000	-1.60, -0.87
Minority / other	-0.669	0.000	-0.97, -0.36
State - Bihar as referent			
Karnataka	-0.151	0.000	-0.20, -0.10
Odisha	-1.606	0.000	-1.77, -1.43
Gujarat	0.176	0.001	0.076, 0.275

-
1. Coded as 0 for pre-intervention and 1 for post-intervention
 2. Coded as 0 for control and 1 for treatment
 3. Measure was standardized across the entire sample

Figure 1: Effects of the four interventions on self-reported latrine use. Presented as odds ratios as calculated by the difference-in-difference.

Note: Squares represent estimates for individual studies and circles are for summary estimates. The size is inversely proportional to the width of the confidence interval.

3.2 Latrine observation index

3.2.1 Univariate analysis

Latrine observation index scores increased in control villages over the course of the intervention in Bihar ($\beta=0.24[0.16, 0.32]$). However, they decreased in Odisha and Gujarat ($\beta_{\text{Odisha}}=-0.14[-0.21, -0.8]$, $\beta_{\text{Gujarat}}=-1.11[-1.30, -0.92]$). There was no change in Karnataka or the average effect ($\beta_{\text{Karnataka}}=0.01[-0.15, 0.17]$, $\beta_{\text{Average effect}}=-0.7[-0.24, 0.11]$). There was no difference in the change in the latrine observation index scores between intervention and control sites ($\beta_{\text{Bihar}}=-0.5[-0.18, 0.08]$, $\beta_{\text{Karnataka}}=0.09[-0.17, 0.34]$, $\beta_{\text{Odisha}}=-0.05[-0.15, 0.05]$, $\beta_{\text{Gujarat}}=-0.03[-0.31, 0.26]$, $\beta_{\text{Average effect}}=0.04[-0.05, 0.13]$).

Table 5: Unadjusted effect estimates of the intervention on the latrine observation index scores

	Coefficient	P-value	CI
Bihar (n=10498)			
Period ¹	0.238	0.000	0.1590, 0.3176
Arm ²	-0.050	0.621	-0.247, 0.1479
Treatment by period interaction	-0.049	0.472	-0.181, 0.0838
Karnataka (n=19547)			
Period	0.012	0.883	-0.149, 0.1735
Arm	-0.017	0.874	-0.225, 0.1915
Treatment by period interaction	0.088	0.497	-0.166, 0.3436
Odisha (n=28327)			
Period	-0.145	0.000	-0.212, -0.077
Arm	0.030	0.661	-0.102, 0.1624
Treatment by period interaction	-0.052	0.327	-0.154, 0.0515
Gujarat (n=16202)			
Period	-1.109	0.000	-1.302, -0.915
Arm	0.119	0.357	-0.134, 0.3728
Treatment by period interaction	-0.026	0.856	-0.309, 0.2572
Meta-analysis (n=74574)			
Period	-0.067	0.457	-0.242, 0.1092

Arm	-0.004	0.871	-0.047, 0.0404
Treatment by period interaction	0.040	0.380	-0.048, 0.1284

1. Coded as 0 for pre-intervention and 1 for post-intervention

2. Coded as 0 for control and 1 for treatment

Table 5: Unadjusted effect estimates of the intervention on the latrine observation index scores

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Treatment by period interaction	0.040	0.380	-0.048, 0.1284

1. Coded as 0 for pre-intervention and 1 for post-intervention

2. Coded as 0 for control and 1 for treatment

3.2.2 Multivariate analysis

The latrine observation index scores increased in control villages in Bihar over the intervention period (Table 6, $\beta=0.25[0.16,0.33]$); however, the index scores decreased in Odisha and Gujarat ($\beta_{\text{Odisha}}=-0.14[-0.20,-0.07]$, $\beta_{\text{Gujarat}}=-1.10[-1.29,-0.90]$). There was

no change in Karnataka or the average effect estimate ($\beta_{\text{Karnataka}}=0.01[-0.14,0.18]$, $\beta_{\text{Average effect}}=-0.20[-0.58,0.20]$). There were no significant differences in the change in index scores between intervention and control arms in any of the studies ($\beta_{\text{Bihar}}=-0.6[-0.19,0.7]$, $\beta_{\text{Karnataka}}=0.08[-0.17,0.34]$, $\beta_{\text{Odisha}}=-0.05[-0.15,0.5]$, $\beta_{\text{Gujarat}}=-0.03[-0.31,0.25]$, $\beta_{\text{meta}}=0.02[-0.06,0.09]$).

In Karnataka and Odisha, older individuals tended to inhabit households with lower latrine observation index scores ($\beta_{\text{Karnataka}}=0.01[0.00,0.01]$, $\beta_{\text{Odisha}}=0.01[0.00,0.01]$), but this was not seen in Bihar, Gujarat, or the average effect estimate ($\beta_{\text{Bihar}}=-0.00[-0.00,0.00]$, $\beta_{\text{Gujarat}}=0.00[-0.00,0.00]$, $\beta_{\text{Average effect}}=0.00[-0.00,0.01]$). Individuals of scheduled castes tended to inhabit households with the highest latrine observation index scores. Households with higher latrine observation index scores tended to be in Karnataka and Gujarat ($\beta_{\text{Karnataka}}=0.98[0.95,1.01]$, $\beta_{\text{Gujarat}}=1.11[1.01,1.20]$) rather than Bihar. Households with lower latrine observation index scores tended to be in Odisha rather than Bihar ($\beta=-0.32[-0.39,-0.25]$).

3.2.3 Multivariate sensitivity analysis

These results remained the same under alternate sample specifications for the Gujarat data (Supplemental table 4, Supplemental figure 2). When the sample was restricted to villages sampled both before and after the intervention, latrine observation index scores decreased over the course of the intervention in control sites ($\beta=-1.11[-1.29,-0.91]$), with no significant difference in the decrease between intervention and control sites ($\beta=-0.01[-0.09,0.08]$). Similarly, when pre-intervention values were imputed for individuals sampled after the intervention, latrine observation index scores were found to decrease over time in control sites ($\beta=-1.15[-1.22,-1.06]$), with no significant difference in the decrease between intervention and control sites ($\beta=-0.01[-0.07,0.06]$).

Alternate sample specifications did not affect the primary findings of the meta-analysis (Supplemental table 5). When Gujarat was removed from the analysis there were no significant changes in latrine observation index scores over time in control sites ($\beta=-0.02[-0.19,0.16]$) or differences in the change between intervention and control villages ($\beta=-0.01[-0.09,0.03]$). Households with higher latrine observation index scores tended to be in Karnataka rather than Bihar ($\beta=0.99[0.98,1.02]$), and households with lower scores tended to be in Odisha rather than Bihar ($\beta=-0.36[-0.39,-0.32]$). Similarly, when imputed values were used for the estimation of the pre-intervention values of individuals sampled in Gujarat after the intervention, there were no significant changes in latrine observation index scores over time in control sites ($\beta=-0.36[-0.98,0.26]$) or differences in the change between intervention and control villages ($\beta=-0.01[-0.01,0.07]$). Households with higher latrine observation index scores tended to be in Karnataka or Gujarat rather than Bihar ($\beta_{\text{Karnataka}}=0.98[0.96,1.01]$, $\beta_{\text{Gujarat}}=1.41[1.35,1.47]$). Households with lower scores tended to be in Odisha rather than Bihar ($\beta=-0.31[-0.40,-0.21]$).

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Household size ³	-0.043	0.039	-0.08, -0.00
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Scheduled tribe	-0.773	0.050	-1.54, -0.00
General category	-1.180	0.007	-2.03, -0.32
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Female	0.544	0.000	0.430, 0.656
Non-Hindu	-0.012	0.954	-0.40, 0.379
Age	0.029	0.000	0.018, 0.039
Age squared	0.000	0.000	-0.00, -0.00
Household size	-0.012	0.190	-0.03, 0.005
Caste - Schedule Caste as referent			
Scheduled tribe	-0.538	0.002	-0.88, -0.19
General category	-1.140	0.000	-1.51, -0.76
Other backward category	-1.388	0.000	-1.73, -1.04
Minority / other	-0.268	0.333	-0.81, 0.274
Odisha (n=29271)			
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Female	0.509	0.000	0.445, 0.572
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Age	-0.010	0.008	-0.01, -0.00
Age squared	0.000	0.558	-0.00, 5.966
Household size	-0.001	0.901	-0.01, 0.016
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General category	-1.150	0.005	-1.94, -0.35
Other backward category	-1.140	0.000	-1.49, -0.78

Minority / other	-0.565	0.000	-0.79, -0.33
Gujarat (n=16163)			
Period	-0.410	0.126	-0.93, 0.115
Arm	-0.296	0.347	-0.91, 0.321
Treatment by period interaction	0.904	0.023	0.122, 1.685
Female	0.005	0.917	-0.08, 0.097
Non-Hindu	1.758	0.095	-0.30, 3.824
Age	0.015	0.006	0.004, 0.025
Age squared	0.000	0.095	-0.00, 1.983
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Caste - Schedule Caste as referent			
Scheduled tribe	-0.388	0.724	-2.54, 1.770
General category	-0.163	0.591	-0.75, 0.429
Other backward category	-0.532	0.052	-1.06, 0.003
Minority / other	-0.788	0.028	-1.48, -0.08
Meta-analysis (n=75550)			
Period	0.660	0.003	0.225, 1.093
Arm	-0.048	0.101	-0.10, 0.009
Treatment by period interaction	0.509	0.000	0.257, 0.761
Female	0.425	0.000	0.238, 0.611
Non-Hindu	0.101	0.512	-0.20, 0.404
Age	0.005	0.625	-0.01, 0.027
Age squared	0.000	0.097	-0.00, 2.556
Household size	-0.011	0.110	-0.02, 0.002
Caste - Schedule Caste as referent			
Scheduled tribe	-0.598	0.000	-0.84, -0.35
General category	-1.067	0.000	-1.31, -0.81
Other backward category	-1.238	0.000	-1.60, -0.87
Minority / other	-0.669	0.000	-0.97, -0.36
State - Bihar as referent			
Karnataka	-0.151	0.000	-0.20, -0.10
Odisha	-1.606	0.000	-1.77, -1.43
Gujarat	0.176	0.001	0.076, 0.275

1. Coded as 0 for pre-intervention and 1 for post-intervention

2. Coded as 0 for control and 1 for treatment

3. Measure was standardized across the entire sample

Table 6: Adjusted effect estimates of the intervention on the latrine observation index scores

Bihar (n=10462)	Coefficient	P-value	CI
Period ¹	0.245	0.000	0.163, 0.325
Arm ²	-0.034	0.734	-0.23, 0.164
Treatment by period interaction	-0.059	0.374	-0.19, 0.071
Female	0.008	0.409	-0.01, 0.028
Non-Hindu	0.040	0.679	-0.15, 0.232
Age ³	-0.001	0.415	-0.00, 0.001
Age squared	0.000	0.899	-3.49, 3.977
Household size ³	-0.010	0.092	-0.02, 0.001
Caste - Schedule Caste as referent			
Scheduled tribe	-0.252	0.003	-0.41, -0.08
General category	-0.433	0.000	-0.62, -0.24
Other backward category	-0.173	0.265	-0.47, 0.131
Karnataka (n=19418)			
Period	0.014	0.865	-0.14, 0.177
Arm	-0.004	0.971	-0.20, 0.198
Treatment by period interaction	0.085	0.517	-0.17, 0.340
Female	-0.008	0.482	-0.02, 0.013
Non-Hindu	-0.064	0.417	-0.21, 0.090
Age	0.006	0.009	0.001, 0.010
Age squared	0.000	0.009	-0.00, -2.05
Household size	-0.002	0.685	-0.01, 0.007
Caste - Schedule Caste as referent			
Scheduled tribe	-0.094	0.024	-0.17, -0.01
General category	-0.285	0.000	-0.39, -0.17
Other backward category	-0.376	0.000	-0.50, -0.24
Minority / other	0.012	0.923	-0.23, 0.256
Odisha (n=27213)			
Period	-0.139	0.000	-0.20, -0.07
Arm	0.024	0.707	-0.10, 0.151
Treatment by period interaction	-0.054	0.301	-0.15, 0.048
Female	-0.006	0.439	-0.02, 0.009
Non-Hindu	-0.131	0.060	-0.26, 0.005
Age	0.005	0.000	0.003, 0.007
Age squared	0.000	0.009	-6.76, -9.46
Household size	0.006	0.134	-0.00, 0.013
Caste - Schedule Caste as referent			
General category	-0.453	0.002	-0.73, -0.16

Other backward category	-0.317	0.000	-0.42, -0.20
Minority / other	-0.366	0.000	-0.47, -0.25
Gujarat (n=16202)			
Period	-1.097	0.000	-1.28, -0.90
Arm	0.119	0.359	-0.13, 0.373
Treatment by period interaction	-0.030	0.838	-0.31, 0.254
Female	0.006	0.420	-0.00, 0.022
Non-Hindu	0.115	0.507	-0.22, 0.453
Age	0.000	0.749	-0.00, 0.001
Age squared	0.000	0.170	-6.89, 3.914
Household size	-0.005	0.528	-0.02, 0.010
Caste - Schedule Caste as referent			
Scheduled tribe	-0.060	0.788	-0.49, 0.378
General category	0.031	0.722	-0.14, 0.203
Other backward category	-0.011	0.891	-0.17, 0.148
Minority / other	-0.192	0.040	-0.37, -0.00
Meta-analysis (n=7329)			
Period	-0.195	0.328	-0.58, 0.195
Arm	0.005	0.722	-0.02, 0.034
Treatment by period interaction	0.016	0.696	-0.06, 0.094
Female	-0.001	0.906	-0.01, 0.009
Non-Hindu	0.036	0.555	-0.08, 0.157
Age	0.002	0.187	-0.00, 0.005
Age squared	0.000	0.364	-4.98, 1.829
Household size	-0.001	0.735	-0.00, 0.005
Caste - Schedule Caste as referent			
Scheduled tribe	-0.138	0.000	-0.21, -0.06
General category	-0.318	0.000	-0.37, -0.25
Other backward category	-0.301	0.001	-0.47, -0.13
Minority / other	-0.369	0.000	-0.52, -0.20
State - Bihar as referent			
Karnataka	0.981	0.000	0.952, 1.009
Odisha	-0.324	0.000	-0.39, -0.25
Gujarat	1.105	0.000	1.009, 1.200

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3. Measure was standardized across the entire sample

Figure 2: Effects of the four interventions on observed latrine use. Presented as odds ratios as calculated by the difference-in-difference.

Squares represent estimates for individual studies and circles are for summary estimates. The size is inversely proportional to the width of the confidence interval.

4. Discussion

Through a difference-in-difference meta-analysis using the individual-participant data, we found that the four behavioural-science informed interventions, when considered collectively, had a positive average effect on self-reported latrine use ($\beta_{\text{Average effect}}=0.51[0.26,0.76]$). However, there was no collective effect on use when using the household-level latrine observation index. The Swachh Bharat Mission is likely responsible for the increase in self-reported latrine use in control areas, but the increase in the intervention arms that was beyond that observed in the control arms can be attributed to the evaluated interventions. This finding is consistent with the results the individual studies reported in their independent analyses, which indicated positive effects on latrine use in Karnataka, Odisha, and Gujarat, with null effects in Bihar (Caruso et al., 2019b; Chuahan et al., 2019; Friedrich et al., 2019; International Initiative for Impact Evaluation, 2020; Schmidt, Wolf-peter, Chauhan et al., 2020; Viswanathan et al., 2019). However, the calculation of the average effect across all four studies has the added benefit of being both statistically more powerful and applicable to a broader set of contexts. This average effect may more closely reflect the impact that policy makers could expect should they attempt to introduce tailored and piloted behaviour-science informed interventions in their own, local context.

This study builds on the work of the four independent impact (Caruso et al., 2019b; Chuahan et al., 2019; Friedrich et al., 2019; International Initiative for Impact Evaluation, 2020; Schmidt, Wolf-peter, Chauhan et al., 2020; Viswanathan et al., 2019). By using a common analytical approach to synthesize findings across studies, we are able to identify similarities in predictors of latrine use, such as sex and caste, and differences in predictors of latrine use, such as age, across these four states. We are also able to directly compare the treatment effects of the four different interventions. Our use of a novel methodology (prospective, individual-participant meta-analysis) allows us to quantify an average treatment effect. These analyses would not have been possible if the studies had not been designed from the beginning to allow for comparison by using the same measures. This co-creation of four unique research projects was a considerable effort for each research team, but ultimately resulted in a rich body of data that allows for deeper cross-context conclusions than would have been possible had each study been conducted fully independently. Future programs that would like to understand cross-context effects of interventions can adopt a similar, collaborative approach.

By analyzing each of the four studies using a common method, we are able to identify heterogeneity in results that would not have been seen otherwise because the results of each impact evaluation have been presented separately using different methods. The average treatment effect shows that, across studies, age has no effect on latrine use. However, by taking the same analytical approach to quantifying impact across the four studies, we find that age, in fact, has a different relationship with latrine use in the four

settings. In Odisha, older individuals are less likely to use latrines, consistent with previous work (Sinha et al., 2017). In contrast, in Karnataka and Gujarat, older individuals are more likely to use latrines. The variation in our results reflect the immense diversity of India in terms of socioeconomic traits and culture. This variation also indicates the benefit of calculating individual study effects in addition to average effects. However, even this may not capture the true variation in open defecation behaviour, which is related to a complex interaction between age, sex, and social status (Routray et al., 2015).

Consistent with other work, we find that women self-report latrine use more than men on average and in most of the states considered. In India, especially in the rural areas, men perceive open defecation to be an expression of masculinity, intra-household power, health, and convenience (Coffey et al., 2014). The higher rate of latrine use among women may be initially viewed as positive, reflecting value of women's dignity and safety and indicating social inclusion. However, millions of women in rural India use the time they spend walking to the fields to be away from their in-laws, household chores, and other daily burdens and socialize with their friends or other women in the village (Routray et al., 2015; Vyas et al., 2019). While the reduction in open defecation is important, efforts must be made to avoid the reduction in women's freedom of movement that may accompany it. Further, efforts need to be made to normalize latrine use among men. Latrine use is not just for women, and use by all is necessary if positive health impacts are to be achieved.

We find that lower caste individuals are more likely to use latrines compared to higher caste individuals in our sample. This may be because socio-cultural beliefs regarding ritual purity, cleanliness, and disgust in rural areas of India can cause higher castes to not use latrines (Coffey et al., 2014). Higher castes in India perceive emptying their own latrines as extremely degrading (Coffey et al., 2017). This results in latrines with full pits being abandoned rather than emptied (Coffey et al., 2017). In order to maintain low rates of open defecation, interventions will need to target the combined and interacting barriers of caste and fear of latrine pits filling in India (Lahiri et al., 2017; Routray et al., 2015; Vyas et al., 2019). Efforts should also be made to protect the dignity of dalits, who have traditionally been employed in pit emptying (Coffey et al., 2017; Prasad and Ray, 2019, 2018).

We find no average effect of the interventions on scores of the latrine observation index. This is likely because scores increased in Odisha and decreased in Bihar and Gujarat. In other words, over time, the characteristic signs that a latrine was in use became more common in Odisha and less common in Bihar and Gujarat. The decrease in the latrine observation index scores in two states was not expected given results from self-reported latrine use. In Gujarat, different survey firms were used before and after the intervention, which may have resulted in variation in the enumerators' scoring practices. There were no consistent patterns across states in the relationship between an

individual's demographic characteristics and the number of characteristic signs of latrine use observed in that person's household latrine.

The two measures, self-reported latrine use and the latrine observation index, each have different strengths, limitations, and interpretations. Through self-reported latrine use, we measure the behaviour of each individual separately, allowing for a more precise measure than the latrine observation index. However, unlike the latrine observation index, it is prone to reporting bias. To address this, we conducted a sensitivity analysis in which we randomly re-assigned 25% of those who reported latrine use to be true non-users. Because the intervention highlighted the social desirability of latrine use, this bias could increase more in the intervention sites than control sites, resulting in an inflation of the intervention effect estimate that would not have been addressed through our sensitivity analysis. The latrine observation index, while not prone to self-reporting and social desirability biases, can have biases related to variation in observer reliability and detection bias because observers knew treatment status. Furthermore, this approach fails to capture the known heterogeneity in behaviour within households (Vyas et al., 2019). It is not sensitive to scenarios in which only the women, sick, or elderly use the latrine. It is likely that a latrine that was regularly used by only a small portion people in a household would have the characteristic signs of use.

We acknowledge several other limitations. The use of a two-step implementation process in which nine formative evaluations were conducted and the most promising four were ultimately implemented, induces a form of publication bias. We do not know what the effects of the other five studies would have been. Therefore, our average treatment effect does not reflect the average effect that could be expected of *any* behavioural-science informed intervention. Rather, it reflects the average effect of these promising interventions. We hope that the positive average effects found through this approach motivate others to adopt an extended scoping process in which multiple interventions are tested and only the most promising are carried forwards. In order to respond to the variations in local context, the interventions implemented in each location were different. The strength of this approach is that it allows for the evaluation of appropriately designed and locally relevant, behavioural-science informed interventions. However, it also means that we do not know if variations in results are due to variation in local context or the design of the interventions. Finally, this work is a secondary data analysis and is prone to all the limitations of such analysis.

5. Conclusion

Through this meta-analysis, we show that behavioural-science informed interventions that are designed through a rigorous formative process modestly increased self-reported latrine use on average. While the individual evaluations show that some of the interventions increase self-reported latrine use, this combined analysis indicates that these impacts can be expected and are not isolated incidents. However, there was no

impact on the household-level, latrine observation index scores. Although results appear promising, we are not able to conclusively demonstrate that these interventions increased the behaviour of latrine use.

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Supplemental materials 1

Description of interventions and study design

Bihar intervention – Improving households' attitudes and behaviours to increase toilet use (HABIT)

Conducted by Oxford Policy Management

Based on nudge theory, this team attempted to change attitudes and practices around toilet use. They used a combination of household and community level meetings in which they encouraged latrine use through posters, a French drain demonstration, and a card game. They also used tools to encourage commitment to the adoption of the behaviour such a pledge and a calendar for a reminder. The intervention had high levels of coverage and almost all households received the intervention in the treatment group.

The team had extensive quality control measures for quantitative and qualitative surveys which included: field supervision and quality assurance; daily data consistency checks; data back checks; daily debriefs and revisit interviews where necessary.

86 villages were selected where World Vision has presence in Bihar. 43 were randomly assigned to treatment and rest to control. From the list of villages, 44 treatment wards and 44 control wards were selected by Probability proportion to size sampling. A sample of 12 households were selected randomly from a list of eligible households in each ward.

Karnataka intervention – RANAS

Conducted by the Swiss Federal Institute of Aquatic Science and Technology (EWAG)

This intervention addressed perceived risks, attitudes, norms, abilities, and self-regulation (RANAS) through community meetings and household visits over a span of 7-8 days. There were two community sessions and two household visits, with the two household visits between the two community sessions. They also conducted a meeting at *anganwadi* centers to promote the safe disposal of child feces. During this intervention, a supportive phone call was used to remind individuals to use the latrine. The intervention reach was assessed at 83% in the treated villages.

The data collection team comprised on 21 members, which included 7 supervisors and 14 enumerators. Each supervisor was responsible for 2 to 4 enumerators. Two tools were used- a structured quantitative face-to-face questionnaire and a spot-check observations of household latrine. The supervisors conducted back-checks. The data was collected on a CAPI platform and data was regularly checked for consistency and quality.

250 villages of 1071 villages were eligible (More than 30% latrine coverage). 120 villages were randomly selected. Out of the households with functioning latrines, randomly select 2328 households for baseline. In the endline 10 villages were dropped as latrine coverage was 99%. The final sample was 2169 households from 110 villages.

Gujarat intervention – The 5 Star Toilet Campaign

Conducted by the London School of Hygiene and Tropical Medicine

Based on the theory and process of behaviour centered design, this team developed a social marketing campaign to promote latrines as smart and modern. The intervention used community events including a World of Toilets activity, a virtual reality tool, skits and films, a toilet board, songs, a composting guessing game, a life sized demonstration pit, certificates and stickers, and a SMART wi-fi network. All participants in the target population could have been exposed to treatment.

The two tools in the data collection process were administered through CAPI tools by trained enumerators. There was a span of 5-7 days in between the administration of two tools. The quality of data collection was closely monitored by supervisors.

94 villages/clusters were randomly selected from 137 eligible (latrine coverage > 70%) clusters. 47 villages were randomly assigned to treatment and the rest to control. 10 Households from each village were randomly selected for the baseline survey. There households were not included in endline. In the endline 30 other households were randomly selected. All members of the household were interviewed for the main survey and two members for the physical activity survey.

Odisha intervention – Sundra Grama

Conducted by Emory University

Emory addressed perceptions of risk, ability, social norms, motivation, physical opportunity, and self-regulation in order to promote latrine use. They used community meetings and household visits. A special meeting for mothers was used to promote the safe disposal of child feces. *Pallas* and transect walks were used to promote latrine use in an engaging manner. Paintings and positive deviant recognition attempted to change perceptions of social norms. Minor latrine repairs were done as well.

The intervention reach was assessed at 85% in the treated villages.

A team of data collectors supervised by a field manager and a PI conducted the quantitative data collection. Periodic data quality checks were conducted. Data quality checks were performed periodically. The team put into action effective strategies to ameliorate different biases such as social desirability bias.

To select the villages, the research team carried out a rapid assessment by visiting 282 villages across 3 blocks. From this the team 72 villages based on village size, latrine coverage, ODF status. 6 villages were purposively selected for qualitative research and remaining 66 for quantitative survey. 33 were randomly assigned in treatment and rest in control. In total there were 3978 households at baseline and 4280 households at endline.

Supplemental materials 2

Latrine observation questions

1. Is the latrine being used for some other purpose?
2. Is the squatting pan clogged with leaves / dirt / other materials?
3. Water container, like lota, mug, or coke bottle (for washing after defecation) in the latrine?
4. Slippers outside or inside the latrine?
5. Are there supplies to clean the latrine pan (i.e. toilet brush, cleaning fluid like Harpic)?
6. According to your (enumerator's) judgement, does the latrine look like it is likely being used?

Latrine use question

For every household member five or older, as part of a household roster (where household is defined as living under this roof): the last time {NAME} defecated, did {NAME} defecate in the open or use the latrine?

Supplemental materials 3: Quantitative synthesis report pre-analysis plan

1 Overview

The Sustainable Development Goals (SDG 6.2) target the ending of open defecation by 2030. 60% of those defecating in the open reside in India. In an effort to eradicate open defecation by October 2019, the Indian government launched its flagship program the Swachh Bharat Mission (Clean India Mission; SBM) in 2014. Given that most Indian households did not have access to toilets, the primary focus of the program was the large scale construction of toilets. Yet, several studies suggest that access to a toilet does not necessarily imply use.

In 2016, the International Initiative for Impact Evaluation (3ie) launched a thematic window to supplement the work being done under the SBM. 3ie's Promoting Latrine Use in Rural India thematic window used insights from behavioural science to generate evidence on the design and implementation of context-specific, low-cost interventions that can be implemented and scaled-up with the resources available through the Government of India's Swachh Bharat Mission (Clean India Mission; SBM) and/or any voluntary household contributions. During the three-month formative phase of the window, nine teams tested interventions in eight Indian states to develop context-specific, mature interventions. Based on these findings, 3ie funded four impact evaluations of interventions to promote latrine use in rural India. The four teams conducted impact evaluation studies over 18 months in the states of Bihar, Odisha,

Gujarat and Karnataka. Additional information on the teams and their interventions can be viewed [here](#).

We aim to synthesize quantitative findings across these studies. Because we have access to individual level data from this set of prospective studies, each of which used the same questions, our analysis is novel in that it will be a prospective, individual-level meta-analysis (Ioannidis 2017). Such an analysis is considered the gold standard of meta-analysis. Although the specific interventions are different, they all had similar, two-stage designs: a three-month formative window in which specific, behavioural barriers to latrine use were identified within a target population, and then a behavioural science informed intervention to support latrine use among their target populations was implemented. Because the impact evaluations of these interventions use a pre-specified and similar set of questions, *this analysis can evaluate the impact of a two-stage, behavioural science approach on improving latrine use in rural India among the identified target populations*. This quantitative pre-analysis plan provides the details for this synthesis.

2 Sample

At baseline, the sampling across the studies began with the selection of districts. Three studies operated in one district each, while the Bihar study identified six districts. The districts were usually selected due to the implementing partners' prior experience of working in these areas. Eligibility at the village level was determined on factors such as current latrine coverage rates (to ensure there were adequate households with latrines), village size, and non-Open Defecation Free (ODF) status (Odisha). Eligible villages were then randomly assigned to treatment or control. The selection of households varied by team. Three of the teams re-interviewed the same households at endline, while Gujarat interviewed a different set of households. Study descriptions are presented in table 1.

3 Data aggregation and common variables across studies

All four impact evaluations focus on latrine use (in rural India, among household members who are age 6+) as the primary outcome. In the case of children aged 5 and below, the safe disposal of feces is the primary outcome. The data used for this synthesis was extracted from four impact evaluations datasets. We merged these datasets to construct an aggregated dataset. This is possible because, from the outset, a set of standardized questions was developed in collaboration with the four teams. All four teams were free to include additional questions. The list of standardized questions is presented below in table 2.

Table 1: Baseline study samples and eligibility across projects

State	Eligibility criteria	Districts	Villages	Number of individuals sampled at baseline	Number of individuals sampled at endline
Bihar	Households with functional twin pit latrines	6 districts (Jamui, Khagaria, Madhepura, Nalanda, Nawada and Saharsa)	86 quantitative villages 6 qualitative villages (28 ODF villages)	6,158	6,046
Gujarat	Households with functional government or contractor built latrines	1 district (Bhavnagar)	90 quantitative villages 4 qualitative villages (All ODF villages)	NA ¹	13,960
Karnataka	Households with functional latrines	1 district (Raichur)	120 quantitative and qualitative villages (No ODF villages)	10,793	10,656
Odisha	Households with latrines	1 district (Puri)	66 quantitative villages 6 qualitative villages (6 ODF villages)	16,827	16,827

Gujarat sampled different households at baseline and endline. The baseline data may not be appropriate for use

Table 2: Standardized Questions

		Variable Name
	Latrine Observation	
1	Is the latrine being used for some other purpose? [Other purpose indicates non-use.]	latrine_use_other
2	Is the squatting pan clogged with leaves/dirt/other materials? [Leaves/dirt/other materials indicate non-use.]	latrine_nonuse
3	Water container, like lota, mug, or coke bottle, (for washing after defecation) in the latrine? [Water container indicates use.]	latrine_use_water
4	Slippers outside or inside the latrine? [Slippers indicate use.]	latrine_use_slipper
5	Are there supplies to clean the latrine pan (i.e. toilet brush, cleaning fluid like Harpic)? [Cleaning supplies indicate use.]	latrine_use_clean
6	According to your (enumerator's) judgment, does the latrine look like it is likely being used?	latrine_use_obs
	Latrine Use	
7	For every household member five or older, as part of a household roster (where household is defined as living under this roof): "The last time [NAME] defecated, did [NAME] defecate in the open or use the latrine?"	defecate_where_adult
8	For children younger than five: The last time [NAME of child under 5] defecated, where did [NAME of child under 5] defecate?	defecate_where_child
9	(For children younger than 5 and if child went somewhere other than "In latrine"): What was done to dispose of the stools?	defecate_child_dispose
	Household Latrine	
10	For all households:	
	a. Have you received any money or materials from the government or an NGO to construct a latrine?	latrine_construct_receipt
	b. (If materials in a) Did the government or NGO give you materials, or did it construct the latrine for you?	materials_provide_who
11	For households that have a latrine:	
	a. How long ago was construction completed on the latrine?	latrine_construct_time
	b. Does the latrine have one pit, two pits, or a septic tank?	latrine_pit

c. How big is the pit? [Instructions: For pits that are cylindrical, either record the number of rings if rings have been used, or record the diameter and depth. If the latrine has a septic tank, record the dimensions of the tank under first pit and leave second pit blank.]	latrine_pit_size
d. Has the pit of your latrine ever filled up?	latrine_pit_fill
e. (If yes to d) What did you do with the pit after it filled up? Did you get it emptied, did you dig a new pit or start using second pit, or did some people stop using?	latrine_pit_empty
f. (If emptied in e) How was it emptied?	latrine_pit_howempty

We identified the following primary and secondary outcomes, and list of indicators. We have extracted information on these outcomes and indicators from the four studies.

Table 3 lists all the indicators and outcomes.

Table 3: Outcomes (definitions list) and key indicators

Outcomes	Type of Outcome
Primary	
Latrine use ²	I
Safe disposal of child faeces ³	I
Observed latrine use	H
Secondary	
Correlation between latrine observation and reported use	H
Predictors of use	Type of Indicator
Type of latrine ⁴	H
Size of pit	H
Sources of funding	H
Latrine age	H
Education of the head of household ⁵	I
Caste	H, I
Sex	I
Household Size	H
Note: "I" is Individual level indicator, "H" is household level indicator	

² Self-reported latrine use among individuals over five years of age

³ Safe disposal: faeces disposed or rinsed in latrine

⁴ The type of latrine differs by team. For example, the Bihar team only considered twin pit latrines.

⁵ For Odisha we can only disaggregate by education at the household level, as we know the household head's education.

4 Hypotheses

The goal of this analysis is to quantify the impact of the approach taken by 3ie to address latrine use in rural India among the identified target populations. This approach involved a two-stage intervention design in which local, behavioural barriers were first identified through a three-month formative phase and then behavioural science informed projects were implemented to address these barriers. By testing the following hypotheses, we will demonstrate the extent of the impact of the interventions on latrine use in rural India among the identified target population. The hypotheses are first presented here, then details on the analytical approach are presented in the following section.

Primary outcome 1: Self-reported latrine use among individuals older than five years of age.

There will be a larger increase in self-reported latrine use rates in intervention sites than control sites

Primary outcome 2: Observed latrine use as measured through an observation index reflecting if the latrine appears to be in use

There will be a larger increase in household level latrine use rates measured through observation in intervention sites than control sites

Primary outcome 3: Safe disposal child faeces

There will be a larger increase in the rates of the safe disposal of child faeces in intervention sites than control sites

Secondary outcome 1: Correlation between self-reported latrine use and observed latrine use

Households whose latrines appear to be in use will be more likely to have at least one member who reports latrine use than households whose latrine does not appear to be in use

5 Predictors of latrine use

Household demographics

Across intervention and control sites, individuals in households with more people will be less likely to use latrines

Across intervention and control sites, individuals in households whose household heads have lower education levels will be less likely to use latrines

Individual demographics

Across intervention and control sites, men will be less likely to use latrines than women
Across intervention and control sites, middle-aged individuals will be most likely to use latrine

Across intervention and control sites, individual-level latrine use rates will be lower among scheduled castes and scheduled tribes

Latrine characteristics

Across intervention and control sites, individuals in households with twin pit latrines will be more likely to use latrines

Across intervention and control sites, individuals in households with smaller latrine pits will be less likely to use latrines

Across intervention and control sites, individuals in households that contributed their own resources to latrine construction will be more likely to use latrines

Across intervention and control sites, individuals in households that use older latrines will be less likely to use the latrine

6 Analysis

Latrine Observation Index

This index will be created using the latrine spot check observations of toilets conducted by the researchers in different states. The index will range between 0 and 1, with 0 indicating none of the spot check items suggest latrine use and 1 indicating all of the spot check item suggests use.

Index construction

Item selection: The items for the index are a component of the standardized questions. There are 6 items in the latrine observation index. Each of these items measure latrine usage at the household level. The items are listed in table 1 under Latrine Observation.

Empirical relationships

We will inspect the correlation between the items before inclusion. From our review of the baseline data, the items are positively correlated across data from all four teams

Index scoring

All the items are coded “0” and “1”, with “0” indicating No and “1” indicating Yes. All the responses (six items) are added together for each household to arrive at household level score of observed latrine use. The score is standardized to interpret it as observed latrine use. We use the following mathematical model to standardize the scores.

$$\text{Latrine observation index} = \frac{\text{Score}_i - \text{Score}_{\min}}{\text{Score}_{\max} - \text{Score}_{\min}}$$

Because item six is likely to be affected by the scores of the other items and, therefore, is not an independent measure, a sensitivity analysis will be conducted in which this item is dropped from the development of the latrine observation index.

Sample descriptions

See attached table 1 and supplemental table 1 for the table shell that will be filled in and presented.

Meta-analysis

We propose an individual level meta-analysis in which the data from the individual participants from each of the studies will be analyzed. Individual-level and prospective meta-analyses are now being viewed as gold standards. We are able to achieve this gold standard, but a few challenges still exist to data harmonization and interpretation. These are described with potential solutions here. After, the proposed analyses are outlined.

7 Expected challenges and solutions

Variation in study context and design

Challenge: Each study had slightly different criteria for inclusion and exclusion. These differences range from the identification of eligible households to the identification of eligible villages. Furthermore, India is a highly diverse country. Each state is different, with a unique culture, history, socioeconomic profile, and set of barriers to latrine use. Therefore, what is effective for one population or state may not have the same effect in another. If treatment effects vary by factors related to the different inclusion criteria or state, it would be inappropriate to calculate a single treatment effect across the four studies.

Solution: This is the reason that the same intervention was not implemented in all four studies. We acknowledge that what works for one population in one area may not work in another. We are testing if this two-stage, behaviour science informed intervention approach can be effective across different contexts within identified target populations; therefore, these differences in context are necessary to answer the question. Because the goal of this analysis is to understand if the interventions are effective within their target populations, differences in target population are acceptable.

Missing baseline data

Challenge: A different set of households was interviewed at baseline and endline in Gujarat. In the other three studies, the same households were interviewed at both times.

Solution: Data for latrine observation variables will be imputed for baseline values using the available baseline data. This is not possible for latrine use as the question was not asked at the individual level.

Potential for selection bias

Challenge: 3ie originally commissioned nine formative studies and then only funded the four that were believed the most likely to have an impact. As such, these studies are likely to have somewhat larger effects than if studies had been chosen at random.

Solution: There is no statistical approach that will allow us to correct this selection bias. It is simply a limitation of our study. We must acknowledge that our summary effect size may overestimate the effects expected from any randomly chosen behaviour change study.

8 Proposed analyses

We will estimate the effect size of each of the following analyses individually and then calculate a combined effect, reflecting the meta-analysis. These effects will be visually reflected in a forest plot. Based on analysis from the Measurement Study, also commissioned by 3ie but using a different sample of households, the following variables were significantly related to latrine use at baseline and endline in at least one state and will therefore be included as controls: sex, age, education, occupation, caste, latrine age, latrine type, and latrine financing. Standard errors will be clustered at the state level (Bottomley et al 2016). Data analysis will be conducted in STATA and R. For the sake of clarity, each hypothesis is re-stated here, and the proposed analysis is outlined below.

Primary outcome 1: Self-reported latrine use

There will be a larger increase in reported latrine use rates in intervention sites than control sites

Analysis: Examine the difference in latrine use between intervention and control arms at endline.

Primary outcome 2: Observed latrine use

There will be a larger increase in latrine use rates measured through observation in intervention sites than control sites

Analysis: Difference-in-difference analysis examining the change in latrine use rates as measured through observation between intervention and control sites

Primary outcome 3: Safe disposal of child faeces

There will be a larger increase in the rates of the safe disposal of child faeces in intervention sites than control sites

Analysis: Difference-in-difference examining the change in the rates of safe disposal of child faeces between intervention and control sites

Secondary outcome 1: Correlation between self-reported latrine use and observed latrine use

Households whose latrines appear to be in use will be more likely to have at least one member who reports latrine use than households whose latrine does not appear to be in use

Analysis: Logit comparing the rates of latrine use measured through observation among *households* in which at least one person self-reports latrine use at baseline

Predictors of latrine use

Household demographics

Across intervention and control sites, individuals in households with more people will be less likely to use latrines

Analysis: Logit considering the individual-level latrine use rates as a function of the continuous measure of the number of individuals in the household

Across intervention and control sites, individuals in households whose household heads have lower education levels will be less likely to use latrines

Analysis: Logit considering the individual-level latrine use rates as a function of the education level of the head of household

Individual demographics

Across intervention and control sites, men will be less likely to use latrines than women

Analysis: Logit considering the individual-level latrine use rates as a function of sex

Across intervention and control sites, middle-aged individuals will be most likely to use latrine

Analysis: Logit considering the individual-level latrine use rates as a function of age and age²

Across intervention and control sites, individual-level latrine use rates will be lower among scheduled castes and scheduled tribes

Analysis: Logit considering the individual-level latrine use rates as a function of caste

Latrine characteristics

Across intervention and control sites, individuals in households with twin pit latrines will be more likely to use latrines

Analysis: Logit considering the individual-level use rates as a function of latrine type

Across intervention and control sites, individuals in households with smaller latrine pits will be less likely to use latrines

Analysis: Logit considering the individual-level use rates as a function of latrine pit size

Across intervention and control sites, individuals in households that contributed their own resources to latrine construction will be more likely to use latrines

Analysis: Logit considering the individual-level use rates as a function of reported self-funding of latrine construction

9 References

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