Implementation Science

A Multisectoral Nutrition Program in Nepal Improves Knowledge of Dietary Diversity, Sick Child Feeding, and Handwashing, but Not All Practices: a Program Impact Pathways Mediation Analysis

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ABSTRACT

Background: Few intervention studies have focused on how inputs link with outcomes.

Objectives: This study tested whether Suaahara I program inputs translated into intended outcomes and identified gaps along the theorized program impact pathway to improved nutrition, care, and water, sanitation, and hygiene behaviors.

Methods: We used household-level, cross-sectional survey data from a process evaluation of Suaahara I conducted in 2014. A total of 480 households with a pregnant woman or child aged <2 y were selected with an equal split between intervention and comparison arms. We used regression models to test associations between exposure to Suaahara I and 3 primary outcomes and 3 parallel knowledge mediators: child minimum dietary diversity, child feeding during illness, and proper handwashing during child care. We used generalized structural equation modeling using full information maximum likelihood to test whether knowledge mediated associations between exposure and outcomes.

Results: In the adjusted regression models between maternal exposure to Suaahara I and 3 behavioral outcomes, we found a small positive association for handwashing (β: 0.21; 95% CI: 0.10, 0.31), but no association with the other 2 outcomes. In the mediation analysis, maternal exposure to Suaahara I, however, was associated with the mediator (knowledge) for all 3 outcomes: handwashing with soap and water (β: 0.05 $\pm$ 0.02), child minimum dietary diversity (logit = 0.06; P = 0.03), and child feeding during illness (logit = 0.09 $\pm$ 0.02). We found a positive, significant association for the full indirect pathway of program input to output via knowledge for child feeding during illness (logit = 0.07 $\pm$ 0.03) only.

Conclusions: Exposure to Suaahara I behavior change interventions improved knowledge, but this did not always translate into improved practices. It is important to address barriers to optimal practices beyond knowledge in future nutrition programs in Nepal. *Curr Dev Nutr* 2019;4:nzz135.

Keywords: program impact pathway, nutrition, mediation analysis, process evaluation, infant and young child feeding

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Abbreviations used: BCC, behavior change communication; IR, intermediate result; IYCF, infant and young child feeding; ML, maximum likelihood; NGO, nongovernmental organization; PE, process evaluation; PIP, program impact pathway; USAID, US Agency for International Development; WASH, water, sanitation, and hygiene.

Introduction

Increasingly, policies and programs aiming to reduce undernutrition combine nutrition-specific and nutrition-sensitive approaches to simultaneously address diverse determinants of undernutrition (1). There is also an increasing call for researchers to focus on implementation science questions to help us understand what works and identify gaps in implementation, which can be particularly critical in complex, integrated nutrition interventions as the mechanisms to improve maternal and child nutrition multiply and operate across sectors (2). Generating this type of evidence helps program targeting, scale-up, or refinement of program theory (3, 4). The evidence base assessing the effectiveness of nutrition-sensitive interventions, much less integrated interventions, for addressing undernutrition is growing but limited, which is due in part to weak program design and implementation but also due to limited high-quality research (5). A variety of research studies, including randomized controlled trials but also quasiexperimental and qualitative studies are needed if evidence-based policies and programs are to be implemented (5, 6). Furthermore, impact studies need to move beyond a sole focus on main effects to answer questions about variation of impact, such as for whom, how, and under what conditions the intervention worked (7, 8).

To date, some evaluations of nutrition interventions in low- and middle-income countries have attempted to assess the assumed causal links between intervention inputs and outcomes (9–12). There has also been little documentation and use of program theory in evaluation studies (10, 13). One method that researchers have used to gain insight into the "black box" of program impact is to create and analyze program impact pathways (PIPs). PIPs map out the hypothesized mechanisms through which inputs are translated via processes into outputs and finally outcomes, and thus can guide assessment of each step in a program's intended pathways to impact (14, 15). There is a growing body of literature on the use of PIPs to plan and analyze nutrition interventions, primarily using data from process evaluation (PE) studies, and to further unpack the pathways for success or failure (15–18). PE studies have only recently been applied to nutrition interventions to identify implementation and uptake gaps (8, 13, 19–23). Although PIPs are increasingly used, they tend to focus on small-scale or relatively simplistic intervention designs; few have been used to assess large-scale or integrated nutrition programs with interventions spanning >2 sectors (24). In this article, we use a PIP and household-level PE data from Suaahara I, a large-scale integrated nutrition program in Nepal, to empirically test whether Suaahara I program inputs translated into intended outputs and in turn desired behavioral outcomes. Learning lessons about what worked and identifying gaps along Suaahara I's PIP will be important for guiding both implementation and research for similar integrated nutrition programs.

Nepal has made remarkable progress in reducing maternal and child undernutrition in the past 2 decades, including one of the largest declines in childhood stunting globally (25). This progress has been attributed to improvements in several underlying determinants, including improved access to health care, sanitation, education, and overall poverty reduction (26, 27). Despite progress, child undernutrition remains high: 36% of children aged <2 y are stunted, and 10% are wasted (28). This article presents the design and results of a PIP analysis to empirically test Suaahara I's steps from inputs to outcomes for several nutrition-specific and nutrition-sensitive determinants of nutritional status including: diets, care, and water, sanitation, and hygiene (WASH) behaviors.

Methods

Program description

Suaahara I, an intervention funded by the US Agency for International Development (USAID) (2011–2016), was designed to improve the nutritional status of women and children from conception through a child's second birthday by integrating nutrition-specific and nutrition-sensitive interventions across 41 of Nepal's 75 districts at the end of the program (29). An at-scale, multisectoral program, Suaahara I faced diverse programmatic, operational/management, and measurement challenges due to its scale and complexity and magnified by recurrent natural disasters including floods, earthquakes, and landslides. Suaahara I was operational in more than half of the communities of the country (which vary from lowland plains to some of the highest mountains in the world), implemented by >45 local and international organizations, dependent upon annual budget allocations from USAID, and reliant on government systems across sectors.

Specifically, Suaahara I household and community-level activities were implemented by local partner nongovernmental organizations (NGOs), hired in each district. Suaahara I had 4 intermediate results (IRs): IR1: improved household health and nutrition behaviors; IR2: greater use of quality nutrition and health services by women and children; IR3: increased consumption of diverse and nutritious foods by women and their families; and IR4: strengthened coordination on nutrition between government and other actors. In addition, Suaahara I's gender and social inclusion approach was integrated throughout all 4 IRs and led the program to explicitly target vulnerable pockets of the population with additional program activities. Suaahara I trained, supervised, and built the capacity of frontline workers, who were a combination of government and NGO volunteers and employees and were the main channel through which Suaahara I reached target households via individualized home visits and facilitation of community-level events. Suaahara I also produced a weekly radio drama called Mother Knows Best, "Bhanchhin Amma," and its related weekly call-in episode to reinforce important health and nutrition messages.

Suaahara I's process evaluation study

In 2014, 2 y after implementation of all Suaahara I program activities at the household level, a PE study to assess progress in steps along the Suaahara I PIP (**Figure 1**) was conducted (30). The PE included a household-level, cross-sectional survey to understand exposure to the program and adoption of promoted practices among Suaahara I-targeted beneficiaries. Among the 16 districts that were matched into 8 intervention-comparison pairs based on social, economic, and agroecological characteristics in 2012 for the impact evaluation, 8 districts (4 intervention-comparison pairs) were purposively selected for the PE. A total of 480 households (half from intervention and half from comparison districts) were recruited. These households were within the 4 intervention and 4 comparison districts and were an equal split between mothers of children aged <2 y and pregnant women, Suaahara I's 2 primary target populations. Participation in the study was strictly voluntary, and written informed consent was obtained from all respondents prior to the start of the survey. For this article, we used data pertinent to IR1. Additional details on the PE design, sampling strategy, and descriptive statistics have been published (31).

Measures and variables

Based on a literature review of similar studies and the programmatic focus of Suaahara I, we decided a priori which variables would be included in the analysis and statistical models (11, 25, 31, 32). Variables were constructed and assigned to each box relevant to IR1 of the PIP diagram (**Figure 2**).

The primary exposure variable—Suaahara I exposure—was a scale (0–4) comprised by summing binary variables of the 4 individual intervention components that women should have been exposed to: *1*) visited at home by Suaahara I field supervisors in the 6 mo prior to the survey (yes/no); *2*) ever participated in Suaahara I community events (yes/no); *3*) ever listened to Suaahara I's weekly, interactive Bhanchhin Amma radio program (yes/no); and *4*) ever seen Suaahara I messages on billboards/hoarding boards (yes/no).

The outcome variables, based on 3 IR1 outcome categories in the PIP, were: *1*) improved infant and young child feeding (IYCF) practices; *2*) maternal and child care; and *3*) WASH practices. We chose the following

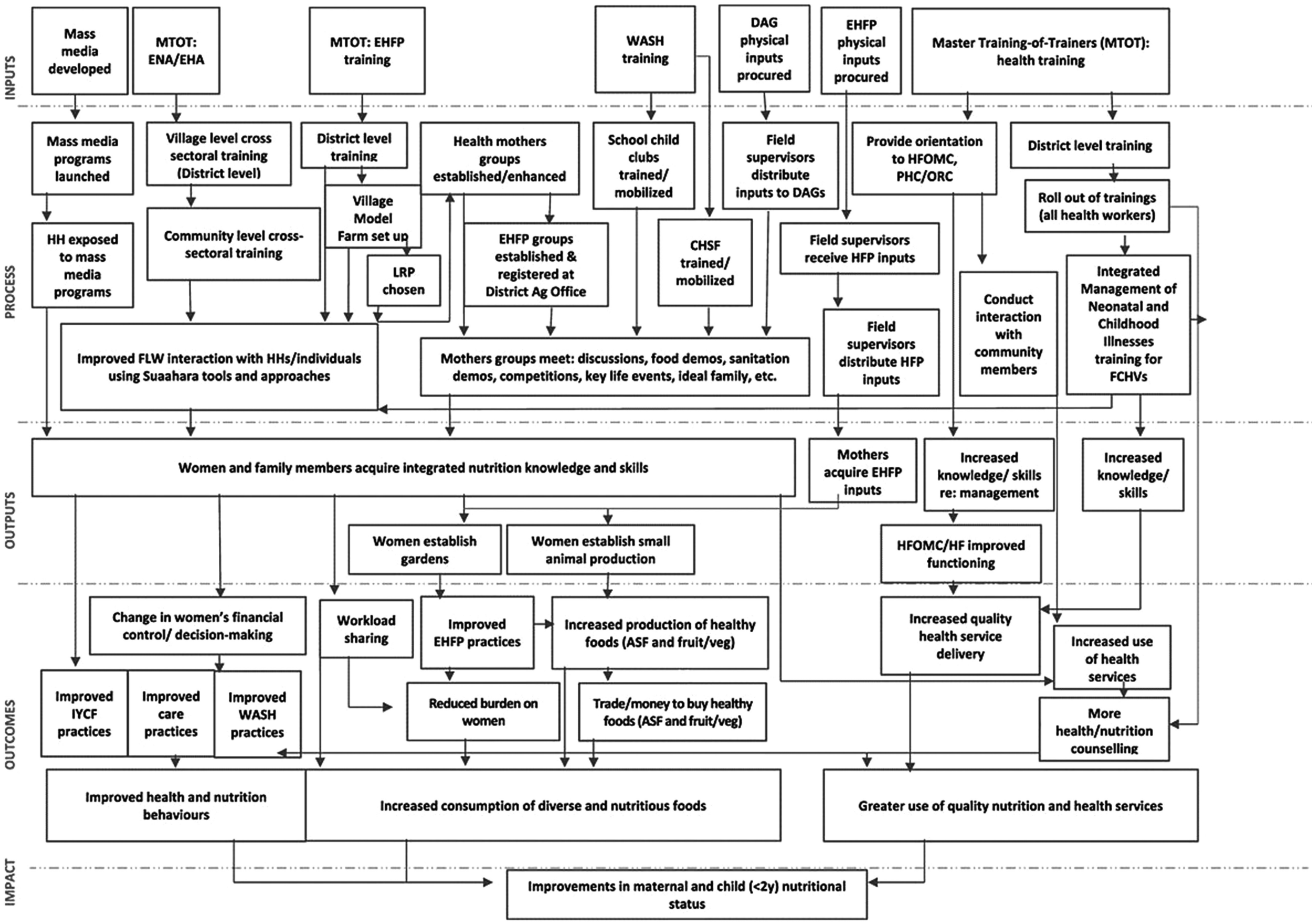

FIGURE 1 Suaahara I program impact pathway diagram. ASF, animal source food; CHSF, community hygiene and sanitation facilitator; DAG, disadvantaged group; EHA, essential hygiene action; EHFP, enhanced homestead food production; ENA, essential nutrition action; FCHV, female community health volunteer; FLW, frontline worker; HF, health facility; HFOMC, health facility operations and management committee; HFP, homestead food production; HH, household; IYCF, infant and young child feeding; LRP, local resource person; MTOT, master training of trainers; PHC/ORC, primary health care outreach; WASH, water, sanitation, and hygiene.

practices as the outcome variable for these 3 categories, in part because complementary data related to knowledge were available in the dataset and thus analyzing the pathway was possible:

- IYCF practices: minimum child dietary diversity was used for children aged 6–23.9 mo, because the WHO recommends this proxy for measuring diet quality and predicting child growth in low-income countries (17, 33). Child dietary data were collected by administering a semiquantitative 24-h recall to mothers. Child dietary diversity was constructed as a 7-point score (0–7) and then converted into a binary variable with a cut-off of consumption of foods from ≥4 of the 7 food groups, as per WHO recommendations (33).
- Care: a binary variable was created for the child care practice of providing extra to eat or drink during child illness. The survey question asked mothers what they usually do for child feeding during illness. This question was only asked of mothers who were not in their first pregnancy due to a coded skip-pattern in the survey; this explains the smaller sample size ($n = 363$). Feeding a child more during illness is a recommended practice included in the WHO Essential Nutrition Actions for improving infant and young child nutrition (34).
- WASH: a score was constructed indicating how many of the 5 key times for handwashing—after defecation, after cleaning a child's bottom, before food preparation, before eating, and before child feeding—were reported by the mother. During the survey, mothers were asked to list out when they usually wash their hands. Proper handwashing behavior is a component of the WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation list of indicators (35) and has been used in other nutrition intervention studies (13).

The mediator variables were related to knowledge because Suaahara I household and community activities focused on improving

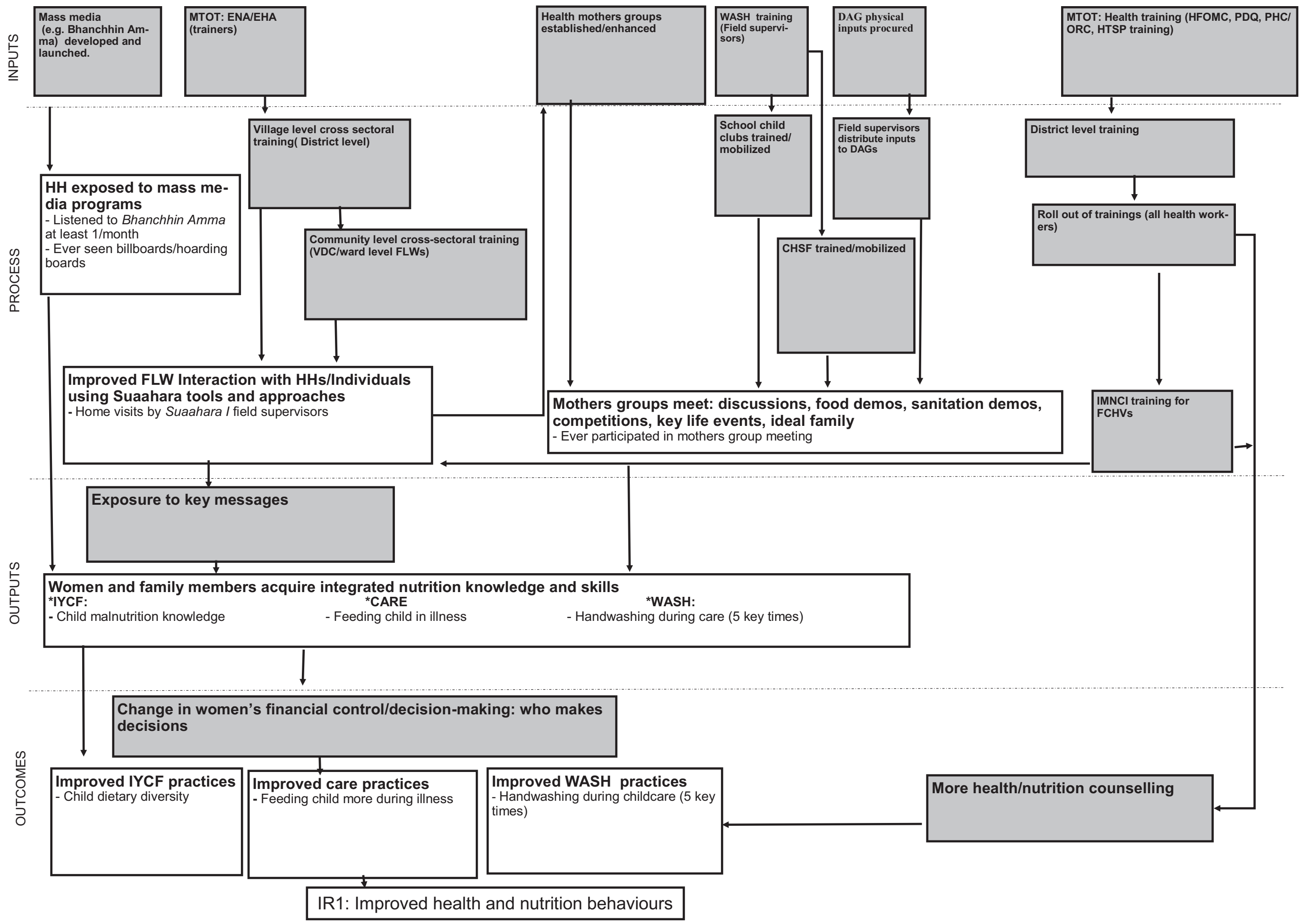

FIGURE 2 Suaahara I impact pathway (IR) 1 variables. CHSF, community hygiene and sanitation facilitator; DAG, disadvantaged group; EHA, essential hygiene action; ENA, essential nutrition action; FCHV, female community health volunteer; FLW, frontline worker; HFOMC, health facility operations and management committee; HH, household; HTSP, healthy timing and spacing of pregnancies; IMNCI, integrated management of newborn and child illness; IYCF, infant and young child feeding; MTOT, master training of trainers; PDQ, partnership defined quality; PHC/ORC, primary health care outreach; VDC, Village Development Committee; WASH, water, sanitation, and hygiene.

knowledge to drive social and behavior change and data were available for this PIP component for all 3 behaviors. Knowledge was assessed by asking open-ended questions to mothers about each of the 3 practices. The 3 mediator variables were then constructed in similar ways to the corresponding 3 outcome variables:

- IYCF knowledge: because dietary diversity knowledge was not explicitly collected, we used introduction of complementary food knowledge as a proxy for maternal knowledge of young child diets. Mothers were asked at what age a young child should be given 6 types of foods: *1*) water or other clear liquids; *2*) milk or other milk products other than breast milk; *3*) semisolid foods; *4*) solid foods; *5*) eggs; and *6*) animal meat/fish. A score (0–6) was created where 1 point was given for each correct answer (6–8.9 mo).
- Care knowledge: mothers were asked what should be done for a child to recover from illnesses. A binary variable (0/1) was created to differentiate those who gave any correct answer compared with none. Correct answers were any mention of providing an extra meal, giving more to eat, or giving more to drink during child illness.
- WASH knowledge: mothers were asked when caretakers of infants and young children should wash their hands. A score (0–5) was created based on how many of the 5 key times for handwashing, the same reported for practice variables, were reported by the mother.

Socioeconomic status, a potential confounder included in regression models, was constructed using principal component analysis to aggregate household assets and sociodemographic characteristics into wealth quintiles. Other confounders included in all models were: maternal age

TABLE 1 Background characteristics of Suaahara process evaluation study sample, 2014[1]

		Comparison arm (n = 240) %/mean ± SD	Intervention arm (n = 232) %/mean ± SD	*P* value
Child sex	Female	47.9	47.0	0.20
Child age (completed months) (range: 0 to 58)		16.9 ± 14.6 (n = 197)	16.9 ± 15.6 (n = 166)	0.98
Women's age (completed years) (range: 16 to 46)		24.1 ± 5.1	24.3 ± 4.8	0.77
Women's schooling (completed years)	None	30.0	21.1	0.002
	Grades 1–6	32.5	25.0	
	7+	37.5	53.9	
Household number of children aged <5 y	0	22.5	31.0	0.14
	1	52.9	44.8	
	>1	24.6	24.1	
Household caste/ethnicity	Dalit	19.6	19.4	0.98
	Muslim/Janajati	37.1	35.3	
	Brahmin/Chhetri	43.3	45.3	
Household socioeconomic status[2]	Lowest	27.9	12.1	0.02
	Lower	33.3	7.3	
	Middle	15.8	23.3	
	Higher	11.3	28.9	
	Highest	11.7	28.5	
Household agroecological zone of residency	*Terai*	25.00	25.9	0.94
	Hills	25.00	23.7	
	Mountains	50.00	50.4	
Knowledge of introduction to complementary food (range: 0–6)		2.8 ± 1.5	3.7 ± 0.7	<0.001
Knowledge of proper child feeding during illness (yes/no)		18.8	49.1	<0.001
Knowledge of proper handwashing during child care (yes/no)		8.3	22.0	<0.001
Child minimum dietary diversity[3] (≥4 food groups)		51.6	77.9	0.01
Proper child feeding during illness (yes/no)		23.4	39.8	0.03
Handwashing during child care (range: 0–5)		2.73 ± 1.1	3.25 + 0.95	<0.001
Number of Suaahara I components exposed to	0	80.3	28.9	
	1	17.9	27.6	
	2	1.3	27.2	<0.001
	3	0.0	15.1	
	4	0.0	1.3	

[1]Means and SD for continuous variables, percentages for categorical variables; all analysis adjusted for clustering at the VDC level. VDC, Village Development Committee.
[2]Wealth quintiles constructed using primary component analysis.
[3]Confined to children aged 6–24 mo; comparison: n = 95; intervention: n = 86.

(in completed years), maternal education level (categories of completed years of schooling: none, 1–6, ≥7), number of children in the household aged <5 y (0, 1, >1), caste/ethnicity, and agroecological zone of residence (mountains, hills, and *terai)*. Child age (in completed months) was an additional confounder included in the child diet and sick child feeding models.

Statistical modeling

Bivariate analysis included chi-square test for categorical data and *t* test statistics to compare means between intervention and comparison groups (**Table 1**). Both unadjusted and adjusted regressions were run to test associations between exposure to the intervention and the 3 primary outcomes. All models were adjusted for clustering at the village development committee level, because most intervention components were delivered at this level. ORs for binary variables and regression coefficients for continuous variables, CIs, and *P* values are reported. Associations were considered significant at $P < 0.05$. Data were analyzed using Stata version 14 (StataCorp) and Mplus version 8.2 (https://www.statmodel.com/).

We then used generalized structural equation modeling to empirically test the direct and indirect effects between exposure to Suaahara I and the 3 outcomes based on the PIP using Mplus software (version 8.2). Structural equation modeling allows for evaluating multiple mediated effects for different outcomes simultaneously compared with traditional regressions used in path analysis, which only allow for 1 fixed exposure (36, 37); for this reason, it is increasingly being used to understand impact pathways of nutrition interventions (38, 39). We estimated mediation effects by using maximum likelihood (ML) estimates and assumed data were missing at random. The direct and indirect effects reported are ML estimates and are accompanied by SEs. We evaluated the direct effects from the exposure to the outcome (c'), the indirect effect of exposure to knowledge (a), and knowledge to outcome (b), and the total effect, which includes the direct plus the indirect effect (**Figure 3**).

Ethical approval for the PE was received from the Nepal Health Research Council (reg. no. 232/2014). For the additional analyses in this

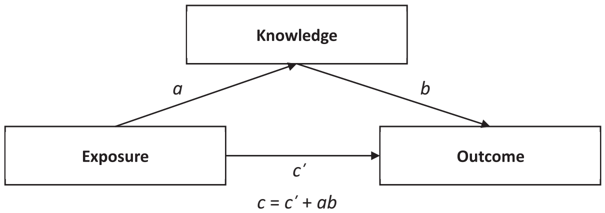

FIGURE 3 Suaahara I hypothesized pathways to impact on nutrition and WASH outcomes. WASH, water, sanitation, and hygiene.

publication, ethical approval was also obtained from the London School of Hygiene and Tropical Medicine in 2016.

Results

Sample characteristics

In the study sample, households in the comparison and intervention arms were similar (Table 1). Children were on average aged 17 mo, nearly half (47%) were female, and only 25% of households had >1 child aged <5 y. Women were on average aged 24 y in both areas, but mothers in the intervention arm had more schooling compared with the control arm (54% compared with 38% had ≥7 y of schooling; $P = 0.002$). Even though caste did not differ by study arm, socioeconomic status was significantly higher in the intervention arm ($P < 0.05$). By study design, half of the population sample lived in the mountains, with the remainder spread equally between hills and the *terai*.

Mothers in the intervention arm scored on average 1 point higher on the IYCF knowledge question, and 30% and 14% more mothers answered care and WASH knowledge questions correctly, respectively, with all differences being statistically significant. Around three-quarters of the children in the intervention arm met the minimum dietary diversity standards, compared with half in the comparison arm ($P = 0.01$). More mothers in the intervention arm reported proper child feeding during illness compared with mothers in the comparison arm ($P = 0.03$). Mothers in intervention areas, compared with comparison areas, reported more times for handwashing during childcare ($P < 0.001$). Additional descriptive statistics have been published and discussed in more detail elsewhere (31).

More than 60% of mothers in the intervention area had some exposure to Suaahara I, whereas this was the case for only ∼20% of mothers in the control villages.

Associations between exposure to Suaahara I interventions and child feeding and WASH outcomes

In the unadjusted regression models testing the association between degree of exposure to Suaahara I interventions and the 3 outcomes, only the association with handwashing during childcare was statistically significant: minimum dietary diversity for children (OR: 1.51; 95% CI: 0.93, 2.43; $P = 0.10$), child feeding during illness (OR: 1.23; 95% CI: 0.96, 1.58; $P = 0.11$), and handwashing during child care (β: 0.24; 95% CI: 0.13, 0.35; $P < 0.001$). After adjusting for all confounders and clustering, the lack of a statistically significant association remained for minimum dietary diversity for children and child feeding during illness. The significant association between exposure to Suaahara I interventions and handwashing during childcare also remained (β: 0.21; 95% CI: 0.10, 0.31; $P = 0.001$) (**Table 2**).

TABLE 2 Adjusted associations between exposure scale and Suaahara I outcomes[1]

	Minimum dietary diversity for children aged 6–23.9 mo (*n* = 181)		Child feeding during illness (*n* = 363)		Handwashing practices during child care (score) (*n* = 469)	
	Adjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value	Adjusted β (95% CI)	*P* value
Suaahara I exposure scale	1.31 (0.80, 2.14)	0.28	1.33 (0.97, 1.84)	0.08	0.21 (0.10, 0.31)	0.001
Child age (completed months)	1.08 (0.98, 1.18)	0.12	1.03 (1.01, 1.05)	0.001	N/A	N/A
Women's age (completed years)	0.95 (0.90, 1.01)	0.10	0.97 (0.93, 1.02)	0.23	0.003 (−0.02, 0.02)	0.77
Women's schooling (completed years)						
Grades 1–6	0.67 (0.31, 1.48)	0.33	0.60 (0.31, 1.15)	0.13	0.10 (−0.22, 0.42)	0.53
7+	1.60 (0.57, 4.53)	0.37	0.50 (0.24, 1.05)	0.07	0.24 (−0.06, 0.53)	0.12
Caste/ethnicity						
Muslim/Janjati	2.26 (0.81, 6.27)	0.12	1.55 (0.88, 2.74)	0.13	− 0.09 (−0.40, 0.23)	0.58
Brahmin/Chhetri	1.71 (0.67, 4.38)	0.26	1.75 (0.70, 4.39)	0.22	0.08 (−0.25, 0.41)	0.62
Wealth quintile						
2	0.91 (0.43, 1.95)	0.81	6.21 (2.55, 15.15)	<0.001	0.18 (−0.19, 0.54)	0.34
3	6.30 (2.04, 19.52)	0.001	7.48 (2.82, 19.82)	<0.001	0.32 (−0.08, 0.73)	0.12
4	1.94 (0.55, 6.86)	0.30	7.40 (2.89, 18.94)	<0.001	0.11 (−0.40, 0.62)	0.67
5	4.44 (1.64, 12.02)	0.003	9.82 (3.89, 24.74)	<0.001	0.40 (−0.09, 0.90)	0.11
Agroecological zone						
Hill	1.00 (0.28, 3.56)	0.99	0.25 (0.11, 0.53)	<0.001	− 0.77 (−1.20, 0.34)	0.001
Terai	0.70 (0.20, 2.47)	0.58	0.15 (0.07, 0.34)	<0.001	− 0.34 (−0.90, 0.22)	0.23
Total number of children aged <5y						
>1	0.58 (0.26, 1.28)	0.88	0.33 (0.07, 1.62)	0.55	0.06 (−0.20, 0.32)	0.65

[1]All values are ORs. Adjusted for clustering at VDC level. N/A, not applicable; VDC, Village Development Committee.

TABLE 3 Direct, indirect, and total effect of exposure to Suaahara I and minimum dietary diversity of children aged 6–24 mo (n = 181)

	Minimum dietary diversity for children: estimate (logit ± SE)[1]	*P* value	Knowledge of introduction of CF: estimate (logit ± SE)[1]	*P* value
Suaahara I exposure	0.25 ± 0.19	0.18	0.06 ± 0.03	0.022
Knowledge of introduction of complementary feeding	0.12 ± 0.38	0.76	N/A	N/A
Child age (completed months)	0.08 ± 0.04	0.035	0.003 ± 0.002	0.10
Women's age (completed years)	− 0.03 ± 0.04	0.50	− 0.01 ± 0.01	0.02
Women's schooling level (completed years)	0.28 ± 0.24	0.23	− 0.09 ± 0.04	0.01
Caste/ethnicity	0.31 ± 0.24	0.21	0.01 ± 0.04	0.77
Wealth quintile	0.40 ± 0.16	0.01	0.09 ± 0.02	<0.001
Agroecological zones	− 0.19 ± 0.24	0.42	0.06 ± 0.04	0.07
Total number of children aged 0–59 mo	− 0.68 ± 0.36	0.06	0.04 ± 0.05	0.45
	Estimate ± SE[1]	*P* value		
Indirect effect	0.01 ± 0.02	0.76		
Total effect	0.25 ± 0.18	0.16		

[1]All values are maximum likelihood estimates. CF, complementary feeding; N/A: not applicable.

Exposure to Suaahara I interventions and minimum dietary diversity for children: mediation analysis

As a mother was exposed to an additional Suaahara I intervention, the likelihood of her child aged 6–24 mo meeting minimum dietary diversity increased by 0.25, although this was not statistically significant (logit = 0.25 ± 0.19; P = 0.18) (Table 3). The pathway from exposure to knowledge (a) was positive and statistically significant (logit = 0.06 ± 0.03; P = 0.02), but there was no significant effect from knowledge to meeting minimum dietary diversity for children (logit = 0.12 ± 0.38; P = 0.76). Thus, there was neither a direct nor indirect pathway found for exposure to Suaahara I interventions and children meeting minimum dietary diversity.

Exposure to Suaahara I interventions and child feeding during illness: mediation analysis

As the number of Suaahara I interventions mothers were exposed to increased by 1, the likelihood of a mother feeding her child aged 0–24 mo more during illness increased by 0.22, although this was not statistically significant (logit = 0.22 ± 0.14; P = 0.12) (Table 4). There was a positive, significant indirect pathway, however, via knowledge. Mothers with more program exposure were more likely to have accurate knowledge (logit = 0.09 ± 0.02; $P < 0.001$), and those with accurate knowledge were more likely to engage in proper child feeding during illness (logit = 0.78 ± 0.29; P = 0.008).

Exposure to Suaahara I interventions and handwashing at critical times: mediation analysis of direct and indirect pathways

As the number of Suaahara I components mothers were exposed to increased by 1, the likelihood of mothers practicing handwashing at 5 key times during child care increased (β: 0.22 ± 0.05; $P < 0.001$) (Table 5). The pathway from the exposure to knowledge was small, but positive and significant (β: 0.05 ± 0.02; P = 0.002), but there was no statistically significant effect from knowledge to handwashing at 5 key times during childcare (β: 0.17 ± 0.13; P = 0.20).

TABLE 4 Direct, indirect, and total effects of exposure to Suaahara I and feeding a child aged <2 y during illness (n = 363)

	Child feeding during illness: estimate (logit ± SE)[1]	*P* value	Knowledge of child feeding during illness: estimate (logit ± SE)[1]	*P* value
Suaahara I exposure	0.22 ± 0.14	0.12	0.09 ± 0.02	<0.001
Knowledge of child feeding during illness	0.78 ± 0.29	0.008	N/A	
Child age (completed months)	0.03 ± 0.01	<0.001	− 0.003 ± 0.002	0.050
Women's age (completed years)	− 0.03 ± 0.03	0.23	0.004 ± 0.01	0.39
Women's schooling level (completed years)	− 0.46 ± 0.19	0.02	0.02 ± 0.03	0.44
Caste/ethnicity	0.31 ± 0.19	0.10	0.001 ± 0.03	0. 97
Wealth quintile	0.36 ± 0.11	0.001	0.06 ± 0.02	0.001
Agroecological zones	− 0.75 ± 0.18	<0.001	− 0.14 ± 0.03	<0.001
Total number of children aged 0–59 mo	− 0.51 ± 0.26	0.05	− 0.04 ± 0.04	0.34
	Estimate ± SE[1]	*P* value		
Indirect effect	0.07 ± 0.03	0.028		
Total effect	0.29 ± 0.14	0.037		

[1]All values are maximum likelihood estimates. N/A, not applicable.

TABLE 5 Direct, indirect, and total effects of exposure to Suaahara I and handwashing during care of a child aged <2 y (n = 469)

	Handwashing during child care: estimate ($\beta \pm$ SE)[1]	P value	Knowledge of handwashing during child care: estimate ($\beta \pm$ SE)[1]	P value
Suaahara I exposure	0.22 ± 0.05	<0.001	0.05 ± 0.02	0.002
Knowledge of handwashing during childcare	0.17 ± 0.13	0.20	N/A	N/A
Women's age (completed years)	−0.001 ± 0.01	0.94	0.01 ± 0.004	0.15
Women's schooling level (completed years)	0.02 ± 0.07	0.77	0.06 ± 0.02	0.006
Caste/ethnicity	0.10 ± 0.07	0.15	−0.03 ± 0.02	0.15
Wealth quintile	0.05 ± 0.04	0.18	0.02 ± 0.01	0.21
Agroecological zones	−0.13 ± 0.06	0.044	−0.03 ± 0.02	0.22
Total number of children aged 0–59 mo	0.01 ± 0.07	0.85	−0.002 ± 0.02	0.94
	Estimate ($\beta \pm$ SE)[1]	P value		
Indirect effect	0.01 ± 0.01	0.24		
Total effect	0.23 ± 0.05	<0.001		

[1]All values are maximum likelihood estimates. N/A, not applicable.

Discussion

In this study, we empirically tested several hypothesized causal links between Suaahara I interventions and behavioral outcomes via a specific output (knowledge). In the adjusted models, we found maternal exposure to Suaahara I to have a small, positive association with proper handwashing during child care (β: 0.21; 95% CI: 0.10, 0.31; $P = 0.001$), but no associations with minimum dietary diversity for children and proper child feeding during illness. In the mediation analysis, we also only found a direct association between exposure and the handwashing outcome and not the other 2 outcomes. However, maternal exposure to Suaahara I was associated with the mediator (knowledge) for all 3 outcomes: handwashing (β: 0.05; $P = 0.002$), child minimum dietary diversity (logit = 0.06; $P = 0.022$), and child feeding during illness (logit = 0.09; $P < 0.001$). For child feeding during illness, because knowledge was also positively associated with practices, we also found a positive, significant association for the full indirect pathway of program input to output (logit = 0.07; $P < 0.028$).

For all hypothesized pathways to impact that we tested, being exposed to intervention components was positively associated with improved knowledge. This is encouraging because Suaahara I interventions were primarily behavior change communication (BCC) activities. The effect sizes found for knowledge, however, were quite small. This could be because "some" exposure to Suaahara I does not ensure exposure to specific topics. For example, listening to the Bhanchhin Amma radio program once a month, or ever attending women's group sessions, does not necessarily ensure any or enough exposure to specific messages about child feeding or all required WASH messages. This points to a need for more sophisticated measures of exposure to specific messages (40), which is a challenge for evaluations and other implementation studies given concerns of response bias and also time constraints for administering surveys. Also, variations in content or way of delivering messages in the different intervention components might have also occurred. For example, even if the same thematic areas are discussed on Bhanchhin Amma episodes, in mothers' group meetings, and during frontline worker home visits, the exact content might vary. It could be that the content, frequency of delivery, or delivery style and quality need to be improved (41, 42). Other studies have highlighted the usefulness of information about beneficiaries' opinions of tools and materials used in interactions (8, 23, 43) and were able to pinpoint that frontline workers who did not retain information during training did not communicate the topics during counseling sessions (44, 45).

Moving along the pathway, the inconsistent findings of the 3 models on the effect of knowledge on outcomes is consistent with the literature, which shows that knowledge does not always translate into practices in nutrition programs. Some of the reasons for poor translation of knowledge into practices include time constraints, influence of family members, and lack of resources (31, 44, 46, 47). This is an important finding for donors, implementers, and researchers to begin to move toward understanding and addressing barriers to optimal practices beyond knowledge (48–50). Widespread global and local campaigns promoting WASH and dietary diversity, but not necessarily sick child feeding, could help explain why improved knowledge was related to practices for sick child feeding but not the other 2 outcomes (51). The barriers to adoption of optimal WASH and dietary diversity practices are also known to go beyond lack of knowledge to include access and availability of goods and services.

Among the 3 outcomes of interest, only handwashing at key times had a direct significant association with programmatic exposure. Arguably, WASH facilities and practices require more resources than diet, especially among primarily agricultural households where eating more food (but not necessarily better quality) can be easier than improving WASH facilities and practices (building a toilet, buying soap, having regular access to water). This is consistent with a similar finding and hypothesis in another recent Nepal study (11). Moving forward, data collection investments should focus more on the role of enabling environments in supporting ideal practices; community-level surveys of markets, facilities, and availability of goods would provide insights to help interpret these household-level survey findings (49). Moreover, it is also important to recognize general challenges with changing diets and hygiene practices (even in the presence of improved knowledge), which are influenced by deeply rooted cultural norms (52). More qualitative studies would shed light on how to better ensure interventions are culturally appropriate and able to overcome sociocultural barriers to uptake of promoted practices. It has been shown that women's abilities to allocate resources and make decisions related to WASH affect

WASH practices within the household. The literature from South Asia (53), specifically Nepal (32, 44) and Bangladesh (54), shows that different aspects of empowerment—freedom of movement, decision-making power, financial control—can relate differently to different nutrition, health, and WASH outcomes.

Additionally, it is important to consider how Suaahara I fits into Nepal's health system and daily life in intervention communities; the fairly low reported exposure to Suaahara I interventions likely had implications for the results. For example, mothers' groups existed long before Suaahara I, and the program aimed to restart deactivated groups and encourage participation in these groups, whereas other intervention components were created by Suaahara I and were more intense, although also designed to be streamlined within ongoing systems to enable sustainability. This suggests measurement challenges because interventions strengthening pre-existing platforms might not be perceived by respondents as program interventions.

This study has some limitations. First, the data are cross-sectional, which provides limitations both for assigning causality as well as inherent issues for mediation analysis (55). However, because it is unlikely that improved practices resulted in increased exposure to Suaahara I, we believe that the data satisfy the temporal ordering required for mediation analysis (55). Some of our findings could be due to small sample size and related limited statistical power to detect effects, particular for the dietary outcome, which excluded all children aged <6 mo. Meeting the required sample size to draw conclusions about program pathways to impacts on nutritional status is increasingly discussed (5). Sample size is also important when conducting generalized structural equation modeling due to multiple simultaneous analyses occurring (56). Sample size limitations also prevented examination of individual intervention components, which would help shed light on which components were contributing to the results. Finally, additional measured and unmeasured confounding cannot be ruled out. Creating a PIP and then using it to test how program inputs relate to anticipated outcomes is an ideal way for implementation science in nutrition to guide program learning and adaptation. The PIP documents the complexity of the program and helps to create a unified understanding of expected pathways to desired impact (57, 58) and also enables research teams to design studies and include measures for each step along the pathway. A PIP analysis, in turn, is informative for implementers (19). Nutrition BCC programs in Peru (23) and the Alive & Thrive programs in Ethiopia, Bangladesh, and Vietnam (22) also included PE studies that used PIPs. Similar research has also been done in western Kenya, where a PIP was used to plan an integrated agriculture and health program for women and children in the 1000-d period (42).

To our knowledge, Suaahara I is one of the first large-scale, multisectoral nutrition programs to apply similar methods to design its PIP and PE. The analyses use mediation methods, thereby overcoming limitations of most of the prior PIP analyses to date, which use various separate models each with error terms. Furthermore, by exploring pathway analyses for both significant and insignificant initial regression results, we shed light on the value of treating null findings as relevant instead of as nonfindings (55), which can better inform programs by gaining insights into where in the hypothesized pathway the breakdown happens rather than just whether exposure is associated with a specific outcome. A somewhat obvious but often overlooked issue in program evaluations worth mentioning is that most PIP phrasing is generic (i.e., improved WASH practices), but for analyses, researchers choose specific indicators along the PIP. This highlights how what gets measured (and what does not) matters. Program implementers and researchers need to be as specific as possible when creating PIPs to determine exactly which exposures, processes, outcomes, and outputs are anticipated if they intend to map pathways across the entire PIP with sufficient sample size (24). If this is done, PIPs can be extremely useful for designing, monitoring, and evaluating complex nutrition programs to explore pathways of intervention effects.

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