Online supplement

Maternal and child nutrition services delivered through the Integrated Child Development Services scheme of India are associated with nutritional knowledge and practices

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Appendix S1. Detailed methodology

This methodological note is complementary to the Methods presented in the main manuscript. A complete account of all methodological information requires reference to both this Appendix and the main manuscript text.

Multi-stage sampling of Anganwadi centers

At the first stage, districts within each of the 11 states were stratified according to whether the district had implemented the ICDS-Common Application Software (ICDS-CAS; a mobile-based job support application introduced through POSHAN Abhiyaan). Since some states had entirely implemented or not implemented ICDS-CAS across all districts, stage 1 resulted in 16 strata. Within each strata, six to eight districts were selected with probability proportional to population size using the 2011 census of India. In the second stage, five to ten AWCs were chosen via simple random selection using computer-assisted randomization from a register of all AWCs in each district identified during stage 1. In the third stage, ICDS beneficiaries from the selected AWCs were randomly selected to be called using computer-assisted telephonic interview software. The target groups for sampling were pregnant women (n=1,100; 100 per state), women with children aged zero to five months (n=1,100; 100 per state), and women with children aged six to 23 months (n=2,200; 200 per state). The sample size for this study was selected so that estimates of prevalence for a given indicator in each of the 11 states would have a 95% margin of error of less than ±5 percentage points, using the formula: margin of error $= Z * \sqrt{[(p*(1 - p)) / n]}$.

Out of 880 AWCs selected for sampling, beneficiary contact information was received for 745 AWCs (84.7%). Phone numbers were obtained for 20,244 beneficiaries, of which 16,145 were randomly selected for contact. Of those selected, 8,874 (55.0%) had phones that were not in service, switched off, or no one answered the call; this left 7,271 available contacts. Among those successfully contacted, 995 were incorrect numbers, 1,258 were not available for interview, 454 were no longer eligible for the survey, and 164 refused to participate. The final sample size, by design, was 4,400 respondents, with 400 selected in each of the 11 states.

Quality assurance

Survey tools were pre-tested and accordingly revised. Questionnaires were designed to be completed in 15 to 20 minutes, to ensure participant completion of the interview. Survey staff received six full days of training, including instruction from a team of nutrition specialists on assessment methods for nutrition practices. Before surveyors were approved to begin data collection for the study, they were required to complete a pilot interview with an ICDS beneficiary and receive a satisfactory review by an expert supervisor. When the call connected, the surveyor confirmed if she was speaking with the correct beneficiary. Follow-up calls were made to beneficiaries if they did not respond after multiple attempts. A minimum of three attempts were made before abandoning the respondent from the list. Following informed consent, interviews with survey respondents were audio recorded for quality assurance. A subset of the interviews (23.6%) were reviewed by data collection coordinators, who then briefed the interviewers on a daily basis on any improvements needed.

Sociodemographic variable categorizations

Seven sociodemographic indicators were used in the analysis: age at time of interview (<20 y, 20-24 y, 25-29 y, ≥30 y), age at time of marriage (<15 y, 15-19 y, 20-24 y, ≥25 y), highest year of education achieved (no education, primary school [grades 1-5], middle school [grades 6-8], junior high school [grades 9-10], senior high school [grades 11-12], and more than high school), religion (Hindu, Muslim, other), caste or tribe (scheduled caste or tribe, other backwards class, general class), whether the household has a Below Poverty Line card, and number of children (none, one, two, three or more).

Regression model specification

Regression models for risk ratios used the following general specification:

$$Pr[Y=1|A,L] = \beta_0 + \beta_1 A + \beta_2 L$$

where Y is the model outcome (i.e. a binary indicator of either (i) whether a given message was received, or (ii) whether a given nutrition behavior was practiced); A is the treatment variable of interest (i.e. a binary indicator of a given ICDS service); L is a vector of covariates (i.e. age at time of interview, age at time of marriage, highest year of education achieved, religion, caste or tribe, whether the household has a Below Poverty Line card, and number of children); β_0 is the probability that Y=1 when A and L are all set to zero; β_1 is the coefficient associated with the treatment variable (this coefficient is used to calculate the risk ratios reported in the tables); and β_2 is a vector of coefficients associated with each covariate. One regression model was run for every unique combination of treatment and outcome. The findings reported in Tables 3 and 4 can be interpreted as the risk ratio for the probability of the outcome that is associated with the presence of the treatment (compared to no treatment), after controlling for the covariates in the model. For example, in the upper-left corner of Table 3, the coefficient can be interpreted as: "women who received THR for more than 21 days had a 5% higher probability of having received the message that they should take one iron-folic acid tablet at night after dinner".

Mediation algorithm

Mediation analyses were performed to estimate the proportion of the total direct effect between ICDS services and nutrition practices which are mediated by nutrition messages received.[1] In this approach, the following algorithm is used: (1) two logistic regression models are specified – one for the mediator (i.e. the indicator of a given message received) and one for the outcome (i.e. and indicator of a given nutrition behavior that was practiced); (2) model parameters are simulated from their sampling distribution; (3) the following three steps are repeated for each draw of the model parameters, (i) simulate the potential values of the mediator, (ii) simulate the potential outcomes given the simulated values of the mediator, (iii) compute the average causal mediation effect; and (4) compute mean point estimates and confidence intervals.[2] The proportion of the total direct effect mediated can be interpreted as the proportion of the association of a given ICDS service with a given nutrition practice that is statistically attributable to the change in the relevant nutrition message. Although multiple nutrition messages were at times relevant for a given practice, the statistical approach for mediation used in this analysis required that a single variable be selected as a mediator. Based on their experience in the implementation of nutrition behavior change programs, the authorship team selected what was in their judgement the single best message to be used as a mediator. The nutrition messages used as mediators are listed in Table S1 of the Online Supplement. All regression and mediation models are multivariate adjusted for the following categorical variables using the coding defined above: age at time of interview, age at time of marriage, highest year of education achieved, religion, caste or tribe, possession of a Below Poverty Line card, and number of children.

Missing data

The only variable which contained missing data was for beneficiaries who did not know how many days' worth of take-home rations they had received (n=99 out of 4,400); these respondents were excluded from analyses which used take-home rations as the independent variable.

Confidentiality and participant risk

Confidentiality was ensured by minimizing the collection of data that could potentially be used to identify participants (e.g. names and birth dates were not collected) and by securing data in a password-protected server. The risk to beneficiaries of data collection was assessed to be minimal, due to: (1) ICDS program participation is widespread and not considered sensitive by local communities, and (2) infant and young child feeding practices are not stigmatized and therefore not a source of potential risk to the participants. This research did not provide direct benefits to individual

[1] Imai K, Keele L, Tingley D. A general approach to causal mediation analysis. Psychological methods. 2010;15(4):309-34. Epub 2010/10/20.

[2] Hicks R, Tingley D. Causal mediation analysis. Stata Journal. 2011;11(4):605-19.

participants, but the ICDS program and its beneficiaries more broadly can benefit from programmatic insights generated by this research.

Appendix S2. Discussion of study limitations and risk of bias

Cross-sectional design

Cross sectional study designs are sometimes limited in that they cannot identify the directionality of causation. However, the specifics of implementation in the ICDS program indicate that this is not a major concern for this study. Service delivery in the ICDS program is conducted by Anganwadi Workers according to programmatic protocols; it is therefore independent of the knowledge or practices of beneficiaries. So, knowledge and practices cannot be a "reverse cause" of service delivery in the ICDS program. As a result, the flow of causality underlying the associations found in this study are likely in line with the logic model of the ICDS program (Figure 1, main text).

Use of telephonic data collection approach

The use of telephonic data collection and high non-response rate poses the question of whether the results of this survey are generalizable to the population of ICDS beneficiaries. Mobile phone penetration in India is high. According to the NFHS-5, 93.3% of the overall population has access to a mobile phone in the household. Furthermore, all beneficiaries at the Anganwadi Center are expected to provide contact information, even if this is a phone number from a relative or neighbor who does not live in the household. As a result, ICDS beneficiaries can in principle be contacted by mobile phone. In order to assess whether poorer households may have been less likely to respond to the survey, the authors conducted a primary data analysis of the nationally representative NFHS-5 survey in India as a comparison. According to NFHS-5 data, 47.8% of ICDS beneficiaries in the 11 states covered in the present study had a BPL card (authors' calculations). In comparison, the population-weighted proportion of beneficiaries who had a BPL card in our study was 53.2%. These figures are qualitatively similar, and if any bias exists in the present study, it is in the direction of oversampling the poor. As a result, it is unlikely that there is substantial bias in the generalizability of the results.

Limitations of the mediation analysis

There are several potential explanations that may contribute to the low levels of mediation observed. First, only one related nutrition message was used to estimate the proportion of mediation. For some nutrition practices, a combination of multiple messages may contribute to behavior change. A second explanation is that the use of a passive recall indicator for nutrition messages did not adequately capture the depth of knowledge that a beneficiary may have, and that those beneficiaries with deeper familiarity with the messages were the ones more likely to practice the behavior. Third, it is likely that knowledge must be combined with an enabling environment for some indicators. For example, knowledge alone is insufficient to ensure a diverse diet; access to diverse foods must also be present. Data from India on household expenditures demonstrates that the proportion of total household spending allocated to food increased sharply by 16-18% during the nationwide COVID-19 lockdown in March through May 2020.[3] Prices declined somewhat after the lockdown but remained elevated compared to pre-pandemic levels. This suggests that, during the time period of the present study, food access may have been an especially constrained factor in achieving an adequate diet.

Recall of nutrition messages

This study was only able to assess passive recall, and therefore is not able to comment on the degree to which beneficiaries had fully comprehended and retained the messages. The implication of this limited granularity regarding the depth of nutrition knowledge is primarily a limitation with respect to the mediation models. A larger proportion of the effect of services on practices may have been mediated by knowledge if we were able to define a variable for more robust knowledge.

Interaction between ICDS services

[3] Kaicker, N., Gupta, A., & Gaiha, R. (2022). Covid-19 pandemic and food security in India: Can authorities alleviate the disproportionate burden on the disadvantaged? *J Policy Model, 44*(5), 963-980. doi:10.1016/j.jpolmod.2022.08.001

This study does not investigate the combined effects of multiple services. The ICDS scheme aims to deliver several concomitant interventions. Since the associations estimated in this study are for single services, the joint effects of multiple services together cannot be assumed to be cumulative. A moderate to weak correlation was seen between service delivery indicators (i.e. correlation coefficients <0.5), which suggests that correlation between services would not fully explain the associations observed in this study between services and knowledge or practices (Table S5).

Assessment of intervention quality

The frequency and quality of interventions (e.g. the quality of nutrition counseling) was not assessed, so the results should be interpreted as representative of the average frequency and quality of interventions in the programmatic setting.

Generalizability

A further note regarding the interpretation of this analysis is that the counterfactual comparison is not between ICDS beneficiaries and non-beneficiaries. It is rather between ICDS beneficiaries who received key services versus those who did not. As a result, the impacts seen in this study cannot be assumed to generalize to non-beneficiaries, though qualitatively they may be of interest when considering an expansion of the program.

Table S1. Message variable used as mediator in regression models for each nutrition practice

Practice (outcome variable)	Message used as mediator
Achieved the minimum dietary diversity for pregnant women (≥5 food groups)	Consume green and yellow/orange colored fruits and vegetables and drink milk daily
Breastfeeding initiated in the first hour of life	Breastfeed the baby within one hour of birth
Child exclusively breastfed in the first 6 months of life	Exclusively breastfeed until six months of age
Children aged 6-8 months of age receiving solid or semi-solid food and breastmilk	Initiate complementary feeding at age 6 months, along with breastfeeding
Minimum dietary diversity	Initiate complementary feeding at age 6 months, along with breastfeeding
Minimum meal frequency	From 6-8 months of age, child should be fed 2 bowls of complementary foods daily
Increase food quantity or breastfeeding following illness	After a child's illness, increase the quantity of food fed

Table S2. Median effect sizes for Table 3.

	N estimates	Median risk ratio
Service		
THR for more than 21 days	18	1.09
Nutrition information received from AWW during pregnancy	18	1.25
Home visit by AWW in past month	10	1.13
Ever attended CBE	18	1.19
Attended VHSND in the past month	18	1.10
Growth monitoring received in past year	10	1.30
ICDS-CAS application used by AWW	18	1.10
Message received		
Take one iron-folic acid tablet at night after dinner	6	1.10
Take one iron-folic acid tablet daily for at least 100 days	6	1.23
Consume green and yellow/orange colored fruits and vegetables and drink milk daily	6	1.04
Increase the quantity of food during pregnancy	6	1.11
Take frequent meals during the day (5-6 small meals rather than 3)	6	1.09
Rest for 1 to 2 hours in a day	6	1.08
Non-vegetarians should include non-vegetarian items in the diet	6	1.25
Feed colostrum immediately after birth	6	1.18
Breastfeed the baby within one hour of birth	7	1.17
Exclusively breastfeed until six months of age	7	1.10
Initiate complementary feeding at age 6 months, along with breastfeeding	6	1.09
From 6-8 months of age, child should be fed 2 bowls of complementary foods daily	6	1.17
From 9-11 months of age, child should be fed 3 bowls of complementary foods daily	6	1.28
From 12-24 months of age, child should be fed 4 bowls of complementary foods daily	6	1.27
Feed the child from a separate bowl	6	1.25
Play with the child while feeding	6	1.17
After a child's illness, increase the quantity of food fed	6	1.24
Wash hands before preparing food and feeding the baby	6	1.08

Table S3. Median effect sizes for Table 4.

	N estimates	Median risk ratio
Service		
THR for more than 21 days	9	1.09
Nutrition information received from AWW during pregnancy	9	1.32
Home visit by AWW in past month	1	1.35
Ever attended CBE	9	1.21
Attended VHSND in the past month	9	1.09
Growth monitoring received in past year	8	1.21
ICDS-CAS application used by AWW	9	1.02
Practice		
Consumed iron-folic acid tablets for 100 or more days during pregnancy	6	1.23
Achieved the minimum dietary diversity for pregnant women (≥5 food groups)	6	1.23
Breastfeeding initiated in the first hour of life	7	1.12
Child exclusively breastfed in the first 6 months of life	7	1.07
Children aged 6-8 months of age receiving solid or semi-solid food and breastmilk	7	1.08
Minimum dietary diversity	7	1.63
Minimum meal frequency	7	1.12
Minimum acceptable diet	7	1.69
Increase food quantity or breastfeeding following illness	7	1.14

Figure S1. Box and whisker plot of relative risk estimates from Table 3 for the association between services and knowledge indicators.

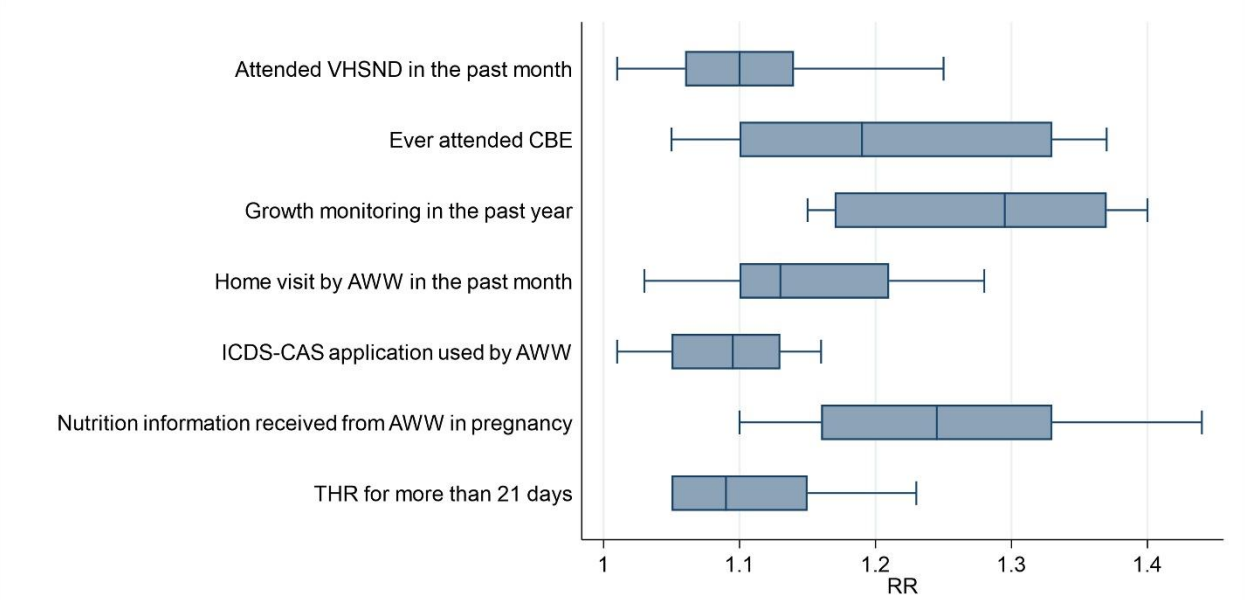

Figure S2. Box and whisker plot of relative risk estimates from Table 4 for the association between services and practice indicators.

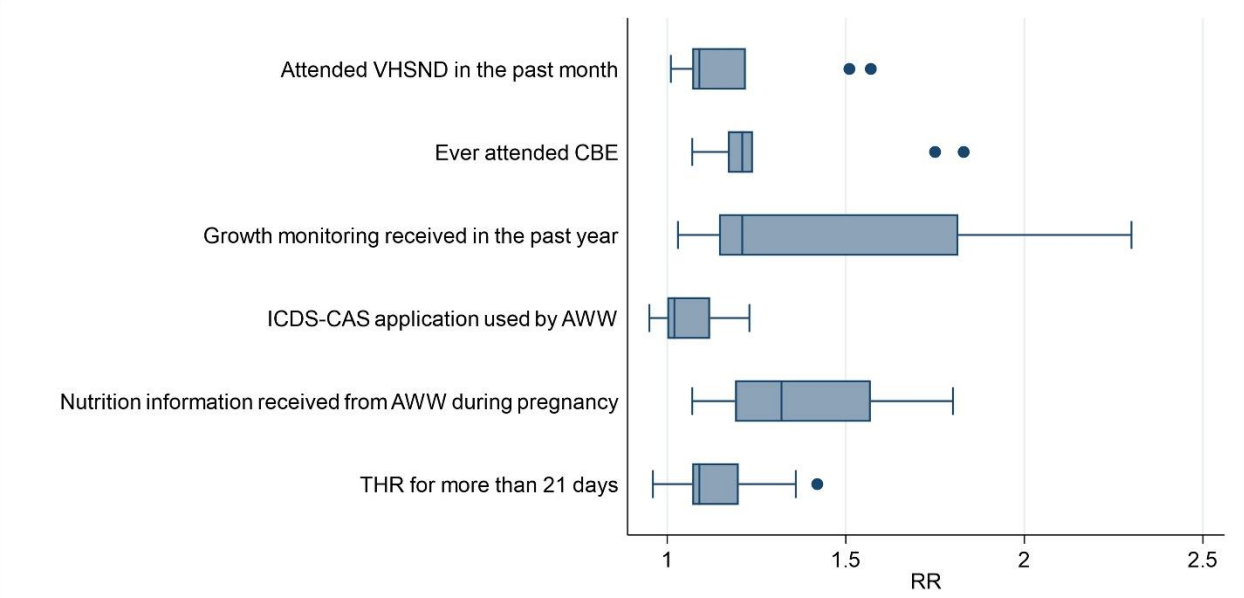

Table S4. Median effect sizes for Table 5.

	N estimates	Median percent of total effect mediated
Service		
THR for more than 21 days	7	13.0
Nutrition information received from AWW during pregnancy	7	20.9
Home visit by AWW in past month	1	5.3
Ever attended CBE	7	18.7
Attended VHSND in the past month	7	24.2
Growth monitoring received in past year	7	24.9
ICDS-CAS application used by AWW	7	17.4
Practice		
Achieved the minimum dietary diversity for pregnant women (≥5 food groups)	6	17.3
Breastfeeding initiated in the first hour of life	6	36.2
Child exclusively breastfed in the first 6 months of life	6	11.0
Children aged 6-8 months of age receiving solid or semi-solid food and breastmilk	6	24.9
Minimum dietary diversity	6	11.1
Minimum meal frequency	6	13.2
Increase food quantity or breastfeeding following illness	6	37.9

Table S5. Tetrachoric correlation coefficients for Integrated Child Development Services scheme services.

	THR for more than 21 days¶	Nutrition information received from AWW during pregnancy	Home visit by AWW in past month†	Ever attended CBE	Attended VHSND in the past month	Growth monitoring received in past year‡	ICDS-CAS application used by AWW
THR for more than 21 days¶	1.00						
Nutrition information received from AWW during pregnancy	0.28	1.00					
Home visit by AWW in past month†	0.42	0.47	1.00				
Ever attended CBE	0.23	0.48	0.42	1.00			
Attended VHSND in the past month	0.3	0.32	0.38	0.44	1.00		
Growth monitoring received in past year‡	0.20	0.46	n/a	0.46	0.41	1.00	
ICDS-CAS application used by AWW	0.25	0.14	-0.02	0.15	0.20	0.12	1.00