An Adaptation of the Food Insecurity Experience Scale (FIES) for Measuring Food Insecurity Among Women in Socially-Backward Communities

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ABSTRACT

Recent reviews on the use of experience-based food insecurity scales in the Indian context suggested the addition of "how often" related items to food insecurity modules to avoid overestimation of food insecurity, especially in underprivileged communities. Following this recommendation, we adapted the 8-item Food Insecurity Experience Scale (FIES), an official tool for measuring access to food within the Sustainable Development Goals (target 2.1), and assessed its validity and reliability in socially-backward communities in the Indian context. The polytomous Rasch model was successfully applied and soundly integrated within the probabilistic methodology already in use for the FIES, allowing the computation of comparable prevalence of food insecurity at different levels of severity and related measures of uncertainty. Data from the SWABHIMAAN programme survey, which collected information on food insecurity from mothers of children under two years of age in three Indian states (Bihar, Odisha, and Chhattisgarh), was used for analysis. Results suggest that the proposed adapted version of the FIES can be considered as a proper tool for measuring food insecurity in underprivileged communities, since it satisfies requirements of internal and external validity and reliability. Individual determinants and protective factors of food insecurity were also investigated within this methodological framework and results suggest that education, economic wealth, and homestead kitchen garden can act as a buffer against food insecurity, while the number of pregnancies seems to exacerbate a situation of food insecurity.

Keywords: Food insecurity, India, backward communities, Item Response Theory, IRT, experience-based food insecurity scale, Food Insecurity Experience Scale, FIES

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BACKGROUND

Food insecurity is a multidimensional and multifaceted phenomenon, encompassing aspects related to food accessibility, sufficiency, security, as well as sustainability (FAO 2001) and represents a major public health issue across the globe (Radimer, Olson, and Campbell 1990). It is estimated that food insecurity affects around 2 billion people across the world and that 820 million people are affected by the vicious cycle of hunger worldwide (FAO et al. 2019). India, with nearly 189 million undernourished people while comprising 14 percent of world population, accounts for about a quarter of the global hunger burden, the highest of any country (FAO et al. 2019).The Indian food security status has been consistently classified as "alarming" since 2012, according to the Global Hunger Index (Von Grebmer et al. 2020). The proportion of those suffering from moderate or severe food insecurity rose from 27.8 percent in 2014–2016 to 31.6 percent in 2017–2019 (FAO et al. 2019). On the other hand, with a GDP growth rate of 4.2 percent from 2019 to 2020, India is the world's fifth largest economy by nominal GDP. These figures show how the economic growth that started in India in the 1990s did not generally translate into immediate improvements of social conditions. Furthermore, the 2030 vision of ending hunger will not be possible unless the country effectively tackles the problem of food insecurity among poor and vulnerable populations (Narayanan 2015). Women and children are the most affected categories. Evidence from the National Family Health Survey conducted in 2015–2016 (NFHS-4) shows that 22.9 percent of women have a Body Mass Index (BMI) below normal (20.2% of men), 20.6 percent are overweight or obese (18.9% of men), and 53.1 percent of women are anemic (22.7% of men). Malnutrition and its related consequences on health are even more alarming among children, with 38.4 percent stunted and 21 percent wasted, and 58.6 percent of those between 6 and 59 months being anemic. While there is still an ongoing debate in India about the best way to guarantee the full application of the individual's right to food, as enshrined in the Indian Constitution, the difficulty in reaching targeted individuals by food aid programs highlights how the distribution of food is a challenge on its own that needs to be addressed beside food availability and food production. "Food" here specifically pertains to the dimension of "access to food". Consequently, there is a necessity for proper measures that can clearly and distinctively capture this aspect.

Although there is a dearth of studies on access to food in India, the available literature from the field agrees in voicing concern about the possibility of hunger eradication and protection of the most vulnerable ones. A more strategic and comprehensive approach needs to be implemented and the right measurement tools employed. Experience-based food insecurity scales, which measure the access dimension of food insecurity, have been widely used in the last decade in several contexts, proving to be valid and reliable instruments for measuring access to food (Jones et al. 2013; Cafiero et al. 2014).This type of scales aims at addressing the phenomenon of access to food from a behavioral perspective, by directly asking people about their own experiences and behaviors related to access to food. Among all existing experience-based food insecurity scales, the Food Insecurity Experience Scale (FIES) proposed by the Food and Agriculture Organization (FAO) in 2013 within the Voices of the Hungry (VoH) Project is designed to have cross-cultural equivalence and validity in both developing and developed countries (FAO 2016). The FIES is based on answers to eight dichotomous (yes/no) items that investigate behaviors and attitudes related to food insecurity at different levels of severity, ranging from the psychological concern about being without food, to the decreasing of food in terms of either quality or quantity. The items included in the FIES Module partly resemble those employed for other experiential food insecurity scales (such as the Latin American and the Caribbean Food Security Scale, the Households Food Insecurity Access Scale, and the Household Food Security Survey Module). The statistical methodology grounding on the Item

Response Theory (IRT) allows accounting for the uncertainty contained in the responses and makes the FIES the first food insecurity measurement system based on experiences, thereby generating formally comparable measures of food insecurity across countries. Prevalence of food insecurity based on the FIES is included as one of the official indicators for monitoring progresses toward target 2.1 of the Sustainable Development Goals and as such, the use of the FIES is commonly suggested as part of ongoing large-scale surveys (FAO 2016; FAO et al. 2019; UN 2016).

Experiential food insecurity scales have recently been considered as the royal road to measure access to food, gaining increasing popularity among researchers worldwide in different countries, including India. A study conducted in 2010–2011 among 500 low-income households from 15 slums in Kolkata (state in West Bengal) specifically investigated access to food in the urban context by application of the Kolkata Household Food Security Scale (KHFSS), an experiential scale adapted from the US HFSSM (Maitra 2017).[1] Although it is not clear if this adaptation of the US HFSSM, indeed, has the potential for working just as properly in other parts of the country, it represents an important step forward in the application of experiential food insecurity scales in India as relevant tools that can be added to the existing body of indicators. Beyond proving internal validity and reliability of the KHFSS, it also claims for the need of a multi-sectoral intervention to tackle food insecurity, by linking it with nutritional, income, employment, and education aspects. However, the KHFSS is not the only experiential scale that was tested in the Indian context. A study was recently commissioned by the United Nations Children's Fund (UNICEF) to assess the suitability of the usage of experiential scales in India (Sethi et al. 2017). The study analyzed 19 works of published and unpublished literature that were conducted in India between January 2000 and June 2015, all regarding US HFSSM applications or its adaptations. These studies generally suffered from lack of a thorough psychometric assessment. These were either in terms of an exhaustive analysis of validity of each item comprising the scale, or of deficiency in providing external validation of the resulted scale with proxy indicators. With the aim of providing recommendations over future implementations of experiential scales of food insecurity at a large scale in India, the revision brings to the attention the following important points: (1) carefully examine the validity of each item especially those referring to diet quality; (2) avoid using children-referenced items; (3) add "how often" related items to avoid overestimating the phenomenon; (4) split the "cut" and "skip" meal items; and (5) opt for a standardized set of questions in order to allow comparability.

The work in the present study stems from these recommendations and analyzes the psychometric properties of a scale of food insecurity based on the administration of an adaptation of the original FIES (hereafter referred to as the "original 8-item FIES"). Items referring to the most severe food insecurity experiences (abbreviated as "HUNGRY" and "WHLDAY" in the original 8-item FIES Survey Module and as "HUNGRY★" and "WHLDAY★" in the adapted 8-item FIES Survey Module, see Appendix) are rephrased by asking "how often" the two related experiences occurred in the last 12 months. In doing so, we show that all suggestions contained in (Sethi et al. 2017) and reported above can be accommodated and that the adapted scale (hereafter referred to as the "adapted 8-item FIES") can indeed be considered as a suitable candidate for future applications in other Indian states and incorporation in national surveys. To this end, three main technical steps are undertaken. The first one refers to the usage of the polytomous

[1] The KHFSS Survey Module employs nine dichotomous items spanning the range of experiences and attitudes already present in the US HFSSM with the addition of items referring to two extra domains: acceptability (borrowed food from relatives or neighbors to make a meal) and consequences of reduced intake (adult lost weight because did not have enough money for food). Moreover, some items were rephrased using Bengali expressions, such as for the item "adults could not eat at least two square meals a day" and the item "cooked *bhalo mondo* (rich food such as *shemai, paish,* or *polao*)".

Rasch model (also known as Partial Credit model) to build a measurement scale from responses to the adapted 8-item FIES survey module. The second one refers to soundly integrating the polytomous Rasch model within the probabilistic framework developed by VoH for the original 8-item FIES to compute comparable prevalence rates of food insecurity at different levels of severity and related measures of uncertainty. As a third original contribution, possible individual determinants and protective factors of food insecurity were identified consistently with the adopted methodology.

DATA AND METHODS

Data

This work uses baseline survey data from the SWABHIMAAN programme, a collaborative project of UNICEF India and the National Rural Livelihood Mission of Ministry of Rural Development and Panchayati Raj, Government of India (Sethi et al. 2019; Reshmi et al. 2019). The SWABHIMAAN programme covers 8,755 lactating mothers in socially-backward communities and combines interventions at both community and system-based levels. Starting as a collaborative pilot project across seven administrative revenue blocks of the three Indian states of Bihar, Odisha, and Chhattisgarh, the program is expected to improve the nutritional status and access to food among adolescent girls, pregnant women, and lactating mothers with children under two years old (UNICEF 2016).

Data have been collected from mothers of age 15–49 years with a survey capturing socioeconomic as well as demographic and food insecurity aspects with a recollecting period of 12 months. Among others, women's age, education, economic wealth and living standards, BMI, women dietary diversity score (WDDS), possession of a Below Poverty Line (BPL) card, having a kitchen garden, being a member of a self-help group (SHG) and participation in *poshan sakhi* meetings were included in the study. Food insecurity was investigated by administering an adaptation of the Food Insecurity Experience Scale (FIES) Module where the last two items, which reflect the most severe experiences related to access to food, have been rephrased. This allowed respondents to specify the frequency of occurrences (never/rarely/sometimes/often; see Appendix). The administered food insecurity module has a recall period of 12 months, thus diminishing the effects of seasonality and providing better comparability across the states.

Sampling design and ethical considerations

The sample for the SWABHIMAAN programme baseline survey was designed to provide estimates of key indicators at block levels across the states of Bihar, Odisha, and Chhattisgarh. For this purpose, a prospective, non-randomized controlled study was implemented, in which five areas (intervention arm) have been purposively allocated to community-led interventions delivered through village organizations and cluster/gram panchayat level federations since 2017 (Sethi et al. 2019; UNICEF 2016). A representative sample of 8,755 mothers (2,612 from Bihar; 3,604 from Odisha; and 2,539 from Chhattisgarh) was derived using simple random sampling after adjusting for non-response rate. The survey used pretested and bilingual (in both English and the state-specific local language) interview schedules to gather information on participants' socioeconomic, demographic as well as household characteristics. The questionnaires were administered to mothers through face-to-face computer-assisted personal interview by the investigators. Finally, quality control checks were done for 10 percent of the sampled women to maintain the quality of the data. The Institutional Ethics Committee of the All India Institute of Medical Sciences Bhubaneswar, Raipur, and Patna approved the baseline survey protocol, methodology, and tools. The baseline survey is registered with the Registry for International Development Impact Evaluations (RIDIE-STUDY-ID-58261b2f46876) and the Indian Council of Medical Research National Clinical Trials Registry of India (CTRI/2016/11/007482) (Reshmi et al. 2019). Verbal consent was obtained from all participants before conducting the interviews. However, in

the case of minor participants aged below 18 years, written and verbal consent was taken from the participants and their guardian, respectively. Personal identifiers of the participants were removed to anonymize the data.

Methods

Following the conceptual framework and statistical methodology developed by VoH for the dichotomous FIES (FAO 2016; Nord, Cafiero, and Viviani 2016) along with addressing the polytomic nature of the employed food insecurity module, the Partial Credit Model (PCM), also known as the polytomous Rasch model—an extension of the Rasch model for items with polytomous responses—was used to measure food insecurity in the three Indian states. As in the Rasch model case, two separate sets of parameters are involved in the analytical expression of the model, one referring to items (item-category parameters) and one referring to respondents (ability parameters, i.e., the person's food insecurity latent parameter), both lying on the same latent trait continuum. Relying on these two sets of parameters, the PCM expresses the probability of endorsing a certain category of an item as a step logistic function between adjacent categories. Moreover, as a member of the Rasch models family, the PCM is subject to the associated assumptions of unidimensionality, local independence, and monotonicity (Masters 1982).

While the Rasch model has been widely used to assess the psychometric properties of diverse dichotomous experience-based food insecurity scales (Knueppel, Demment, and Kaiser 2010; Sahyoun et al. 2014; FAO 2016), a smaller number of works have been engaged with assessing validity and reliability of food insecurity scales built from responses to polytomic items (Na, Gross, and West 2015). In this study, we aim to assess the psychometric properties of the adapted 8-item FIES in the context of backward communities in the Indian states of Bihar, Odisha, and Chhattisgarh. Specifically, we developed the following analysis:

1) ***Internal validity and reliability assessment*** of the adapted 8-item FIES by performing the following two sub-tasks:
   a. PCM parameters estimate and fit assessment
   b. PCM assumptions check by means of the Mokken Scale Analysis (MSA)
2) ***External validation*** of the obtained scale by assessing significant association with proxies of food insecurity.
3) ***Computation of comparable prevalence rates of food insecurity and related measures of uncertainty*** in the three Indian states at different levels of severity, by integrating the PCM with the probabilistic framework developed by the VoH for the original 8-item FIES.
4) ***Investigation of possible determinants and protective factors of food insecurity*** at the individual level, consistently with the methodology employed in the previous steps.

All aspects of the analysis are illustrated in the following sections. The Stata SE 15 and the R 3.1.1 software (The R Foundation for Statistical Computing) were used to conduct the analysis. The RM.weights R package was used for fitting the PCM and the "mokken" R package for the MSA.

Internal validity and reliability assessment

PCM parameters estimate and fit assessment

The operation of fitting the PCM to data produces estimates for both items and person's parameters. Item-category severity parameters are technically defined as the intersection between adjacent category probability curves (Masters 1982). Nonetheless, in place of the item-category parameters, it is common practice to report on the so called Thurstonian thresholds, defined as the points on the latent trait (expressed in the logit scale) that corresponds to a probability of 0.5 of endorsing a category or above of a certain item. Thurstonian thresholds are generally preferred over their more technical counterpart since they are more similar in meaning to the item severity parameters of the Rasch model.

In the Rasch models family, goodness-of-fit is generally assessed by means of Infit statistics, a Chi-squared type standardized item statistic that assesses the fit of each item comprising the scale by comparing the observed answers and the expected ones under the considered model (Nord 2014; Rasch 1960). Infit statistics quantify the "good behavior" of each item and can be considered as a measure of each item's discrimination power, given the other items in the scale. Item infit in the range of 0.7 and 1.3 are considered acceptable for an item to be retained in the scale, and values in the range of 0.8 and 1.2 are considered optimal. Furthermore, overall model fit can be assessed by the flat Rasch reliability statistics corresponding to the proportion of the total variation in the sample that is accounted for by the model. Values greater than 0.7 indicate a good model fit for an 8-item scale (FAO 2016; Nord 2014). Beside the Rasch reliability statistics, Cronbach's alpha is also commonly reported as a measure of the internal consistency for a psychometric test and 0.7 is a common cutoff for an acceptable level (Bland and Altman 1997).

PCM assumptions check

Belonging to the Rasch models family, the PCM requires assumptions of unidimensionality, local independence and monotonicity to be met. Unidimensionality deals with the requirement that the scale built from a set of items indeed measures a unidimensional phenomenon (in the context of this study, the access to food). To validate data with respect to this assumption, it is common practice to verify that the residual correlation matrix submitted to the Principal Component Analysis (PCA) does not show any latent residual trait (Nord, Cafiero, and Viviani 2016). In practice, unidimensionality holds if the percentage of explained residual variance is not substantial (e.g., less than 50%–60%) or, referring to the pictorial decision criterion of the scree-test (Cattell 1966), if the scree-plot does not show any relevant residual component.

Assumption of conditional (or local) independence of the items is in a way connected to the unidimensional assumption and assesses that, conditioning on the food insecurity level of a person, responses to items must be statistically independent. This would ensure that the items comprising the scale are not redundant. Local independence is assessed in this study by verifying that residual correlation among each pair of items is not greater than 0.4 in absolute value (FAO 2016).

Finally, hypothesis of (latent) monotonicity is met if the probability of endorsing an item is an increasing function of the latent food insecurity trait. In the specific case of the PCM, we assessed this assumption by testing the so-called *manifest monotonicity* in the context of the MSA (Sijtsma et al. 2002) that inspects the probability of endorsing a certain category or above of an item, given the sum score of the remaining items (rest score). A practical issue may occur if the number of respondents with a certain value of the rest score is too small for an accurate estimation of the above-mentioned probability. To avoid incurring such an estimation drawback, a parameter called *minsize* is set up and respondents with adjacent rest scores are grouped until the size of the rest score group is greater than the set *minsize*. For large datasets (greater than 500) a *minsize* value equal to one tenth of the sample size is recommended to get accurate estimates. Another practical issue concerning the procedure for testing manifest monotonicity concerns the possibility that a violation of it might be too small to be relevant. For this reason, another parameter, called *minvi* is set up (usually *minvi* = 0.03), so that only violations greater than *minvi* are considered and, for the violations reported, a significance test at level $\alpha = 0.05$ is performed.

External validation

External validation is conducted either by Pearson or Spearman correlation tests to assess association between the adapted 8-item FIES and the following indicators that are often considered as proxy of food insecurity: WDDS, BMI, mid-upper arm circumference measure (MUAC), and Wealth Index (WI). The WDDS is an indicator specifically meant to measure micronutrients adequacy in diets of women of reproductive age. It is based on nine food groups and the indicator

counts the number of food groups that have been consumed (in this survey, with a recall period of one day). The higher the value, the more complete the diet (Kennedy, Ballard, and Dop 2010). The BMI is an indicator of nutritional status, and is computed by dividing the weight by the height squared (Coates, Webb, and Houser 2003) and it is commonly categorized into underweight (BMI <18.5), normal (18.5< = BMI <25), overweight (25< BMI< = 30), and obese (BMI >30). The MUAC is an anthropometric measurement that relates to body weight and fat and that corresponds to the length of the arm circumference. Finally, the WI is an indicator of economic wealth and living standards built from information about asset ownership and housing characteristics combined by means of PCA (Hjelm et al. 2017). The WI is commonly conceived as an ordinal scale of five levels (poorest, poor, middle, rich, and richest) with respect to the four quintiles of the distribution of the first PC and, although not strictly measuring food insecurity, is often used as a proxy indicator, due to the strong relationship between economic deprivation and access to food.

Estimation of prevalence rates of food insecurity

After estimating person and item Rasch Thurstonian parameters and assessing the fit of the model to the data, prevalence rates of food insecurity can be computed. Following the VoH methodology, two prevalence rates are considered: *Prevalence of Experienced Food Insecurity at moderate-or-severe levels* ($FI_{Mod+Sev}$) and *Prevalence of Experienced Food Insecurity at severe level* (FI_{Sev}). Both indicators represent percentages of population that are beyond specific thresholds on the latent trait, and the two thresholds considered for $FI_{Mod+Sev}$ and FI_{Sev} differ from each other in that the one used for FI_{Sev} reflects a more severe level of food deprivation. Computation of the two indicators is carried out separately for each of the three Indian states and, to make prevalence rates comparable, a preliminary equating procedure is undertaken with the aim of calibrating the three scales on a common metric. The FIES Global Standard was chosen as such a common metric and pairs of scales are calibrated in turn by equating the mean and the standard deviation of the set of items that are common to the two scales (FAO 2016; Onori, Viviani, and Brutti 2020). In this application, the Rasch-Thurston parameters estimated between the first two categories (namely "no" against "yes" for dichotomous items and "no" against "rarely" for polytomous items) were employed to perform the scale equating, with all six dichotomous items being considered as "in common" and the remaining two polytomous items being considered as "unique", in all three states.

Once the Thurstonian parameters have been scaled to the FIES Global Standard, it is possible to compute indicators of food insecurity by adopting the probabilistic framework developed by the VoH methodology. The methodology employed for the two indicators is extensively described in (FAO 2016) and here we will only convey the main concepts underlying the procedure. First of all, a raw score is computed for each respondent by summing up the codified responses to all items according to the following codification: 0 = No, 1 = Yes for dichotomous items and 0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Often for the polytomous items. For the adapted 8-item FIES (as it has been considered and defined in this study), the raw score will thus be one of the thirteen possible integers comprised between 0 and 12 (extreme values included). Each respondent is assigned a gaussian probability distribution of his/her food insecurity along the latent trait according to his/her raw score. The true food insecurity trait is modelled as a mixture of gaussian distributions with a mixture component for each class of raw scores, and as weights of the different proportions of raw scores in the sample. As a final step, percentage of population whose severity is beyond a fixed threshold is calculated as the complementary to one of the cumulative distribution functions of the mixture distribution. Uncertainty around estimated prevalences is handled by taking into account two sources of error: sampling error and measurement error. The two are combined to form the Margin of Error (MoE)—at a certain confidence level—of the estimated prevalence of food insecurity at a specific level of severity

(FAO 2016). For comparison purposes, the two prevalences are computed using both the original and adapted 8-item FIES. To prevent the usage of cumbersome notation, the same names and symbols for these two indicators are used, it being clear from the context whether it refers to one or the other.

Possible determinants and protective factors of food insecurity

The analysis described so far aims at measuring food insecurity at an aggregated level. Nevertheless, the tools provided by VoH also allow an individual level analysis. In fact, since each respondent is assigned a probabilistic normal distribution of his/her food insecurity along the latent trait, it is also possible to compute the probability for each respondent being food insecure beyond a fixed threshold. This value will be a number between 0 and 1 that can be interpreted as the extent to which the respondent can be considered as food insecure at that level of severity. Consistently with the approach adopted for the aggregated analysis, we consider the same two thresholds already used to compute $FI_{Mod+Sev}$ and FI_{Sev} and each respondent will be therefore assigned two values between 0 and 1, corresponding to the probability of her being food insecure at either moderate-or-severe and severe levels. We can then codify this measure in a binary way, by attributing 1 if the probability of being food insecure at a specific level of severity is equal to or greater than 0.5, and 0 if otherwise (FAO et al. 2019). Consequently, possible determinants and protective factors for individual food insecurity as measured by the adapted 8-item FIES can be investigated by means of logistic regression models where the dependent variable is the binary individual variable just described.

It is therefore natural to carry out two distinct regression analysis, one for each threshold used to compute $FI_{Mod+Sev}$ and FI_{Sev}. Based on the literature reviews and considering the location of study areas, we have included selected background characteristics (both modifiable and non-modifiable factors) which have been found to impact on household food insecurity (see, among others, Asghar and Muhammad 2013). Specifically, socio-demographic variables (age, school attendance, religion, number of pregnancies) and housing characteristics variables (number of members in the household, possibility of using a kitchen garden) were tested as possible covariates in the binary logistic analysis. Both unadjusted and adjusted logistic regression were considered and only those covariates that emerged to be significantly associated with the binary outcome in the unadjusted analysis were retained and used as covariate in the adjusted analysis.

RESULTS

Sample Profile

Responses containing missing values were omitted and analyses were carried out on a total of 7,835 respondents (31% in state of Bihar, 41% in Odisha, and 28% in Chhattasgarh). Socioeconomic as well as demographic characteristics of the women who entered the study are listed in Table 1 and Table 2. Beside some similarities, the three sub-samples show distinct features that, on a high level, depict a less privileged condition in the state of Bihar. Women in their thirties or older represent 25 percent of the subsample in Odisha and Chhattisgarh and 40 percent in Bihar. Bihar also has the highest percentage of women who never attended school (60.3%, against 53.2% in Odisha and 39.6% in Chhattisgarh) and the biggest percentage of women who had more than 3 pregnancies (around 40% against 20% in both Odisha and Chhattisgarh). Moreover, only around 15 percent of women in this state has a kitchen garden (38.3% in Odisha and 37.6% in Chhattisgarh). Likewise, the WI describes a more difficult economic situation in Bihar where more than 80 percent of women fall under the lowest quantiles (being classified as either "poorest" or "poor"), while in the other two states the same holds for around 60 percent of the respondents. Still, women in Bihar have the smallest average of the WDDS while, regarding anthropometric measurements such as BMI and MUAC, the three sub-samples show very similar results. Hindu is the

Table 1. Socio-demographic profile of the sample (mothers of children under age two years)

Characteristics	Bihar N=2398 %	Odisha N=3246 %	Chhattisgarh N=2191 %	Total N=7835 %
Age				
15–19	0.02	0.09	0.05	0.06
20–29	0.58	0.70	0.70	0.65
30 and above	0.40	0.25	0.25	0.29
Education				
Never attended	60.0	53.5	39.3	51.5
Ever attended	40.0	46.5	60.7	48.5
Religion				
Hindu	40.4	95.1	97.5	79.1
Others	59.6	4.9	2.5	20.9
Caste				
Scheduled Caste (SC)	19.4	20.2	2.4	15.0
Scheduled Tribe (ST)	5.1	53.3	65.9	42.1
Other Backward Classes (OBCs)	65.9	18.1	27.1	35.3
General	9.5	8.3	4.6	7.6
Number of pregnancies				
Between 1 and 3	0.59	0.80	0.78	0.73
Between 4 and 6	0.29	0.19	0.20	0.22
More than 7	0.11	0.02	0.02	0.05
Wealth quintile				
Poorest	35.4	25.8	30.4	30.0
Poor	45.2	34.1	35.6	37.9
Middle	15.1	22.9	20.7	19.9
Rich	3.0	12.8	9.6	8.9
Richest	1.2	4.5	3.7	3.3
Household having kitchen garden				
No	84.9	61.4	63.9	69.3
Yes	15.1	38.6	36.1	30.7
Own BPL ration card				
No	47.3	15.7	12.4	24.5
Yes	52.7	84.3	87.6	75.5
Membership in the SHG group				
No	69.6	62.0	65.6	65.4
Yes	30.4	38.0	34.4	34.6
Attendance in *poshan sakhi* meeting				
No	97.5	80.0	89.0	87.9
Yes	2.5	20.0	11.0	12.1

Table 2. Profile of proxies of food insecurity in the sample (mothers of children under age two years)

Measure	Mean	Median	SD	Min	Max
BMI					
Bihar	19.1	18.8	2.6	14.0	35.2
Odisha	19.1	18.7	2.6	9.2	36.8
Chhattisgarh	18.6	18.3	2.3	9.8	47.0
MUAC					
Bihar	22.3	22.0	2.4	17.0	40.0
Odisha	23.7	23.4	2.5	14.4	41.3
Chhattisgarh	23.4	23.3	2.2	12.0	40.0
WDDS					
Bihar	3.6	4	1.6	0	9
Odisha	4.4	4	1.3	1	9
Chhattisgarh	4.4	4	1.1	0	9

predominant religion in both Chhattisgarh and Odisha (97.6% and 95.1%, respectively), while only around 40 percent of the sample in Bihar reported on embracing this religion. Regarding the caste, around two thirds of the sub-sample belongs to "other backward classes" (OBCs) in Bihar and to either "scheduled caste" (SCs) or "scheduled tribe" (STs) in both Odisha and Chhattisgarh.

Results from Fitting the PCM

Fitting of the PCM to the adapted 8-item FIES Modules' responses yielded overall statistically valid and reliable results in all three Indian states (Table 3 and Table 4). The 12-item infit statistics computed for each Indian state (for a total of 36 infit statistics estimates) all fall in the acceptability range 0.7–1.3, except for four values that lie slightly outside this range that, however, seem not to jeopardize the general good fit of the PCM (Table 5). Overall reliability of the scale is confirmed by a (flat) Rasch reliability statistic greater than or equal to 0.81 and a Cronbach's alpha greater than or equal to 0.82 in all three states (Table 4).

Regarding the assessment of model assumptions, unidimensionality is assessed in all three states, with the first principal component from the residual correlation matrix not accounting for a substantial percentage of the residual total variance (54% in Bihar, 39% in Odisha, and 45% in Chhattisgarh; see Figure 1 and Table 6), confirming the absence of any strong second dimension.The assumption for local independence is also generally confirmed in all three Indian states, due to residual correlations between pairs of items being all smaller than 0.4 (in absolute value) or very close to it, with the only exception of the items WORRIED and WHLDAY* in Chhattisgarh, which show a residual correlation of

Table 3. Responses to the adapted 8-item FIES Module in the three states

Item Name	Bihar (N = 2,398)				(Odisha N = 3,246)				Chhattisgarh (N = 2,191)			
	NO (%)		YES (%)		NO (%)		YES (%)		NO (%)		YES (%)	
WORRIED	23.2		76.8		27.9		72.1		39		61	
HEALTHY	26.9		73.1		27.3		72.7		49		51	
FEWFOOD	29.0		71.0		32.1		67.9		59		41	
SKIPPED	42.6		57.4		58.6		41.4		81		19	
ATELESS	50.0		50.0		32.6		67.4		72		28	
RUNOUT	54.8		45.2		61.3		38.7		82		18	
	Never	Rarely	Sometimes	Often	Never	Rarely	Sometimes	Often	Never	Rarely	Sometimes	Often
HUNGRY*	53.2	12.0	26.4	9.1	69.3	7.0	17.1	6.6	83	2	3	12
WHLDAY*	63.8	8.5	19.7	8.0	72.9	6.4	14.7	6.1	91	2	1	6

Table 4. Estimates of the Rasch-Thurstone thresholds from the PCM

Item	Bihar			Odisha			Chhattisgarh		
WORRIED	−3.76 (0.18)	–	–	−1.90 (0.07)	–	–	−2.79 (0.09)	–	–
HEALTHY	−2.33 (0.12)	–	–	−1.97 (0.07)	–	–	−1.78 (0.07)	–	–
FEWFOOD	−1.79 (0.10)	–	–	−1.44 (0.06)	–	–	−0.94 (0.07)	–	–
SKIPPED	−0.01 (0.08)	–	–	0.75 (0.05)	–	–	1.10 (0.07)	–	–
ATELESS	0.80 (0.07)	–	–	−1.38 (0.06)	–	–	0.21 (0.07)	–	–
RUNOUT	1.30 (0.07)	–	–	0.96 (0.05)	–	–	1.18 (0.08)	–	–
HUNGRY*	1.39 (0.09)	2.30 (0.08)	4.23 (0.10)	1.58 (0.07)	1.97 (0.08)	3.62 (0.10)	0.73 (0.11)	0.87 (0.12)	1.14 (0.12)
WHLDAY*	2.31 (0.08)	2.78 (0.08)	4.26 (0.11)	1.82 (0.07)	2.17 (0.08)	3.65 (0.11)	1.96 (0.11)	2.08 (0.13)	2.22 (0.14)

Table 5. Item infit statistics for each Rasch-Thurstone thresholds, Rasch reliability statistics and Cronbach's alpha from the estimation of the PCM to the adapted 8-item FIES responses in the three states

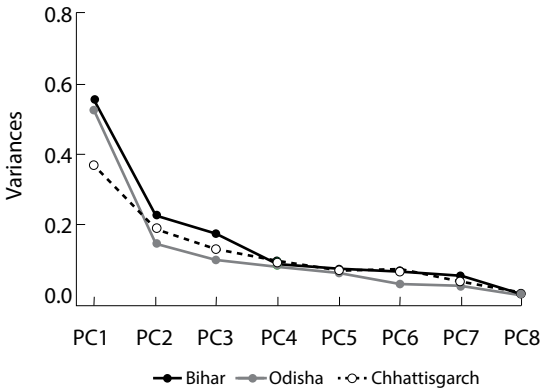
Item	Item Infit Statistics								
	Bihar			Odisha			Chhattisgarh		
WORRIED	1.0			1.16			1.15		
HEALTHY	0.87			0.93			0.81		
FEWFOOD	1.16			0.80			1.07		
SKIPPED	0.86			0.74			0.81		
ATELESS	0.86			1.18			0.87		
RUNOUT	0.66			0.80			0.90		
HUNGRY*	0.51	1.27	1.09	0.60	1.03	1.01	0.84	1.30	1.54
WHLDAY*	0.99	0.66	0.96	1.02	1.12	0.90	1.00	0.93	0.84
Rasch Reliability		0.86			0.84			0.81	
Cronbach's alpha		0.88			0.83			0.82	

−81. Such a high value, although not inflating the general good behavior of the scale, could reveal specificities of the phenomenon of food insecurity in this state or, perhaps more likely, the need for either a more effective translation of these items into the local language or a more exhaustive explanation of the meaning of the item when administering the survey. Finally, monotonicity of the scale is confirmed in all three sub-samples with no significant violations of manifest monotonicity detected by means of the MSA (with parameter *minsize* set to one tenth of the sub-sample size and parameter *minvi* set to 0.03, see Table 7).

External Validation

Raw scores from the adapted 8-item FIES resulted in being inversely associated with the four proxies of food insecurity, proving the external validity of the proposed scale (Pearson correlation of 0.07 with BMI and −0.11 with MUAC; Spearman correlation of −0.14 with WDDS and −0.29 with the WI, all $p < 0.001$).

Figure 1. Scree plot of the PCA on the residual correlation matrix to assess local independence of the items



Note: Shown are the percentages of explained variance related to each Principal Component (PC) in each state.

Estimates of Prevalence Rates of Food Insecurity

Finally, after assessing validity and reliability of the adapted 8-item FIES, an equating procedure is conducted to adjust the Rasch-Thurston parameters estimates from the PCM to the FIES Global Standard and compute the food insecurity indicators $FI_{Mod+Sev}$ and FI_{Sev} in the three Indian states (Table 8). Bihar and Odisha had the bigger prevalence of severe food insecurity (7.6% and 7.7%, respectively) with Bihar also having the largest prevalence of moderate-or-severe food insecurity (66.8% against 60.8% in Odisha). In Chhattisgarh on the other side, 32.7 percent of the sub-sample was moderately to severely food insecure and 0.5 percent was severely food insecure. MoE between 0.22 percent and 0.93 percent confirm the very good degree of accuracy of the measurement tool. Finally, a comparison with the estimates of such prevalence rates obtained by

Table 6. Percentage of explained variance from the PCA on the residual correlation matrix from fitting the PCM to the adapted 8-item FIES responses in the three states

	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8
Bihar	54	15	10	9	6	3	3	0
Odisha	39	20	13	10	7	7	4	0
Chhattisgarh	45	18	14	7	6	5	5	0

Table 7. Monotonicity hypothesis assessment through of the MSA: Number of active comparisons and number of violations for each Indian state

	Bihar		Odisha		Chhattisgarh	
	N° active comparisons	N° violations	N° active comparisons	N° violations	N° active comparisons	N° violations
WORRIED	10	0	15	0	10	0
HEALTHY	6	0	21	0	10	0
FEWFOODS	10	0	15	0	10	0
SKIPPED	10	0	21	0	15	0
ATELESS	10	0	15	0	15	0
RUNOUT	10	0	15	0	15	0
HUNGRY*	26	0	45	0	45	0
WHLDAY*	30	0	45	0	40	0

Table 8. Prevalence of moderate-or-severe food insecurity ($FI_{Mod+Sev}$), prevalence of severe food insecurity (FI_{Sev}) form both the original 8-item FIES and the adapted 8-item FIES in the three states and corresponding MoE

		Bihar (MoE)	Odisha (MoE)	Chhattisgarh (MoE)
$FI_{Mod+Sev}$	Original 8-item FIES	66.9% (±0.72%)	59.7% (±0.76%)	33.7% (±0.95%)
	Adapted 8-item FIES	66.8% (±0.71%)	60.8% (±0.74)	32.7% (±0.93%)
FI_{Sev}	Original 8-item FIES	20.7% (±1.04%)	15.3% (±0.75%)	4.7% (±0.55%)
	Adapted 8-item FIES	7.6% (±0.68%)	7.7% (±0.54%)	0.5% (±0.22%)

implementing the original 8-item FIES clearly shows that the latter produces estimates with no or minimal differences for moderate-or-severe food insecurity but clearly larger estimates for severe food insecurity (20.7% in Bihar, 15.3% in Odisha, and 4.7% in Chhattisgarh).

Determinants and Protective Factors of Food Insecurity

Possible determinants of food insecurity were investigated by means of multiple logistic regressions after controlling for the variables State and Caste. As expected, adjusted odds for the case of moderate-or-severe food insecurity (second column of Table 9) show that the economic status (here measured with the WI) is negatively associated with food insecurity (OR 0.62, CI 0.59–0.66, p-value <0.001). Also, women who attended school have a lower risk of being moderate-or-severe food insecurity (OR 0.66, CI 0.60–0.74, p-value <0.001), and the number of pregnancies is positively associated with being food insecure (OR 1.45, CI 1.29–1.63, p-value <0.001). It was noted too that having a kitchen garden might act as a buffer against food insecurity (OR 0.73, CI 0.65–0.82, p-value < 0.001). Moreover, and perhaps unexpectedly, women who live in households with more than six members have lower risk to be food insecure (OR 0.81, CI 0.72–0.92, p-value < 0.001). This result could possibly be explained by considering that in numerous households there might be more working members, which would create the conditions for more economic stability if compared to households with only one or two working adults. Finally, having a BPL (OR 1.35, CI1.19–1.54, p-value <0.001) or being a member of an SHG (OR 1.18, CI 1.07–1.32, p-value<0.01) are both associated with a bigger risk of being food insecure at a moderate-or-severe level. This result is not unforeseen, since women who are already targeted for assistance of some kind (be it with a BPL card or by joining an SHG) are expected to be coping with a disadvantaged condition with possible consequences on the access to food.

On the other hand, analysis for severe food insecurity (third column of Table 9) shows that only economic status (OR 0.67, CI 0.57–0.78, p-value < 0.001) and size of the households (OR 0.61, CI 0.44–0.85, p-value < 0.01) are significantly associated with food insecurity, with the same sign in these relationships—and thus the same interpretation of the relationship—as to those just discussed for the moderate-or-severe insecurity. Finally, variation inflation factors always below 2.7 confirm the absence of multicollinearity among the predictive variables (common rule of thumb is 5), while C-statistics between 0.74 and 0.75 confirm the reasonable fit of the two multiple logistic models to the data.

DISCUSSION AND POLICY IMPLICATIONS

The analysis conducted in this study was mainly directed toward assessing suitability of the adapted 8-item as a tool for measuring access to food in underprivileged communities in the Indian context. To this end, and to the best of the authors' knowledge, this work introduces three technical novelties in the field of food insecurity measurement in backward communities in India. The first contribution refers to the employment

Table 9. Protective factors for moderate-or-severe and severe food insecurity in the population

Characteristics	Moderate-or-Severe FI	Severe FI
	OR (95% CI)	OR (95% CI)
State		
Bihar	Reference	
Odisha	**1.20* [1.01–1.41]**	0.87 [0.61–1.25]
Chhattisgarh	**0.27***[0.23–0.32]**	0.00 [0.00–0.00]
Caste		
General	Reference	
OBC	**0.64***[0.52–0.79]**	0.80 [0.51–1.31]
Scheduled Caste (SC)	0.90[0.72–1.13]	0.83 [0.51–1.39]
Scheduled Tribe (ST)	**0.81*[0.66–0.99]**	0.96 [0.60–1.59]
WI	0.62***[0.59–0.66]	**0.67***[0.57–0.78]**
Age	1.01 [0.91–1.12]	Not included
Education		
Never attended	Reference	
Ever attended	**0.66***[0.60–0.74]**	0.86 [0.65–1.13]
Religion		
Hindu	Reference	
Other	0.53 [0.81–1.12]	0.91[0.63–1.31]
Number of Pregnancies	**1.41 ***[1.25–1.59]**	1.07 [0.98–1.15]
Size of the household		
Less than 6	Reference	
More or equal to 6	**0.77***[0.68–0.87]**	0.61**[0.44–0.85]
Household having kitchen garden		
No	Reference	
Yes	**0.72***[0.64–0.80]**	0.83 [0.61–1.12]
Membership of SHG		
No	Reference	
Yes	**1.18**[1.07–1.32]**	Not included
Household with a BPL card		
No	Reference	
Yes	**1.35***[1.19–1.54]**	Not included
Intercept	**3.77***[2.71–5.27]**	0.15***[0.09–0.26]

Notes: FI - Food Insecurity, OR - Odds Ratio, CI - Confidence Interval, *** $p < 0.001$, ** $p < 0.01$ level of significance

of the polytomous Rasch model to analyze an adaptation of the 8-item FIES obtained from the original dichotomous FIES, by rephrasing the two most severe items to allow for the specification of the frequency of occurrences. Secondly, the polytomous Rasch model was soundly integrated with the probabilistic methodology developed by VoH for the original dichotomous FIES, allowing the computation of comparable prevalence rates of food insecurity at different levels of severity. As a third original contribution, possible individual determinants and protective factors of food insecurity in backward Indian communities were identified consistently with the suggested methodological framework. Results from the estimation of the PCM to the adapted 8-item FIES Module's responses show that the obtained scale is a valid and reliable measuring tool (both internally and externally). In fact, statistical assumptions of unidimensionality, local independence and monotonicity, assessed by means of parametric and nonparametric techniques, show Infit statistics and residual correlations mainly in the acceptable range. The only exception is made for the pair of items WORRIED and WHLDAY*, whose residual correlation in Chhattisgarh show a peculiar high value, which however does not inflate the overall good behavior of the scale. Nonetheless, further investigation in future administration of the Survey is recommended, specifically by ensuring an effective translation of the two items into the local language. The adapted 8-item FIES raw scores were also negatively associated with indicators commonly used as proxies for food insecurity (WDDS, BMI, MUAC, and WI), proving its external validity, while Rasch reliability statistics greater than 0.81 and Cronbach's alpha greater than 0.82 indicate that the scale is reliable. Therefore, the adapted version of the 8-item FIES, as it is described in this work, can be successfully used to compute both aggregated and individual measurements of food insecurity.

Regarding its employment as an aggregate tool, the probabilistic framework developed by VoH for the FIES for computing comparable prevalence rates of food insecurity could soundly be adapted for the polytomous version of the scale. It could be employed to compute comparable prevalence rates of food insecurity at two levels of severity (moderate-or-severe and severe) in the three Indian states. Moreover, the adapted 8-item FIES can indeed provide individual measurements of food insecurity that can be used to investigate determinants and protective factors of food insecurity, possibly suggesting insights for policy strategies. In this regard, and when considering moderate-or-severe food insecurity, results show that education of women should be facilitated. This finding is corroborated by evidence from the related literature showing that women's education is intrinsically related to food security since women are the family members who mostly produce, process, and prepare the food, especially in the rural context (Agarwal 1986; Narasimhan 1999). It is in fact also acknowledged that empowering women translates into better understanding and adoption of improved technologies for food management, food wastage control, and better nutritional knowledge (Olumakaiye and Ajayiet 2006). Secondly, rural households should be encouraged to establish a kitchen garden. Studies from rural areas in Uttar Pradesh (Arya et al. 2018) and southern India (Nithya and Bhavaniet 2018) also concluded that kitchen garden could provide families with direct access to fresh products, thus empowering food security that can be sustained through crop diversification. However, it is important to impart training through homestead kitchen garden (Tripathi and Selvanet 2016). Thirdly, being member of a household with more members (here, the cutoff of six members was identified) seems to be a protective factor against moderate-or-severe food insecurity. This result, although apparently counterintuitive, could be partially due to the presence of more working adults in households of bigger size, which would translate into a more stable economic situation. Additionally, high labor out-migration from these states might also have contributed leaving behind smaller families, which result in being more food insecure compared to bigger families (Choithani 2019). This aspect might deserve further investigation in future research and, if confirmed, could possibly suggest that knowledge

of the economic structure of the households (for example by asking how many working adults are in the household) could help identify those households that are more in need for assistance programs due to the presence of only one or too few working adults. This would ultimately be consistent with findings in Agarwal et al. (2009), where the authors point to a high unemployed/employed member ratio as being a characteristic of food insecure households. As per our last finding related to moderate-or-severe food insecurity, as expected, the number of pregnancies seems to exacerbate a situation of food insecurity, suggesting that nutrition programs should specifically target pregnant women. On the other hand, if looking at severe food insecurity, size of the households and economic deprivation seem to be the main factors that, amongst the ones considered, are significantly associated to food insecurity. This would suggest a relationship between size of households, economic situation, and food insecurity in agreement to what was prospected above for moderate-or-severe food insecurity. Finally, it is worth mentioning that both being a member of an SHG and owning a BPL card were positively associated with moderate-or-severe food insecurity. This is an expected result, since SHG programs and the public distribution system through BPL cards are targeted to poor sections of the society. Additionally, participation in *poshan sakhi* meetings (women's group meetings) appears not to be associated with food insecurity (at any level of severity). However, in order not to run into misleading conclusions, it must be taken in consideration that when baseline data were collected, the SWABHIMAAN programme interventions have yet to be fully rolled out. Therefore, the assessment of the effect of *poshan sakhi* meeting on food insecurity at a midline or endline survey is recommended.

Finally, with regards to guidelines suggested in Sethi et al. (2017), it is noteworthy that the adapted 8-item FIES does fulfill all of them. This is because (1) the validity of each item comprising the scale was carefully examined and resulted in good psychometrics performance for each of them; (2) children-referenced items are not included in the module (being so already in the original 8-item FIES); (3) "how often" related items have been added in order not to overestimate the phenomenon; (4) the "cut" and "skip"' meal items are split (being so already in the original 8-item FIES); and (6) comparability is guaranteed by opting for a standardized set of questions that refer to the common experiences related to food insecurity, regardless of the specific cultural context (being so already in the original 8-item FIES). In light of this, the adapted 8-item FIES can indeed be considered as a suitable candidate for future applications in other Indian states as well as incorporation in national surveys.

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APPENDIX

Appendix Table 1. Survey module of the adapted 8-item FIES

Item Ordering	Item Phrasing	Item Abbreviation
	Was there a time when…	
1	…you were ever worried that you would not be able to get enough food to eat?	WORRIED
2	…you were unable to eat healthy and nutritious food because of a lack of money or other resources?	HEALTHY
3	…you ate only a few kinds of foods because of a lack of money or other resources?	FEWFOOD
4	…you had to skip a meal because there was not enough money or other resources to get food?	SKIPPED
5	…you ate less than you thought you should because of a lack of money or other resources?	ATELESS
6	…your household ran out of food because of a lack of money or other resources?	RUNOUT
	How often did happen in the last 12 months that…	
7	…you were hungry but did not eat because there was no food at home and there was not enough money or other resources for food?	HUNGRY*
8	…you did not eat for a whole day because there was no food at home and there was not enough money or other resources for food?	WHLDAY*

Notes: For the first six items, the item abbreviations are the same as in the original 8-item FIES Survey Module. To distinguish the phrasing of the last two items from that of the corresponding items in the original 8-item FIES Survey Module, these items are here referred to in a slightly modified way, namely as HUNGRY* and WHLDAY* instead of HUNGRY and WHLDAY.