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RESEARCH

Exploring the determinants of malnutrition in 2–5 year Iranian children using structural equation modeling: national food and nutrition surveillance

Samira Rabiei[1], Samira Ebrahimof[1], Hamid Rasekhi[1], Maryam Amini[1], Delaram Ghodsi[1], Zahra Yari[1], Zahra Abdollahi[2], Mina Minaie[2], Bahareh Nikooyeh[1*] and Tirang R. Neyestani[1*]

Abstract

Background Childhood malnutrition remains a critical public health challenge in low- and middle-income countries, contributing significantly to morbidity and mortality among children aged 2–5 years. This study was undertaken to assess the nutritional status of 2–5 y children and to explore the main determinants of child malnutrition in eight food insecure provinces of Iran.

Methods In each province, participants were invited to attend the health house/center to complete the questionnaire on the pre-appointed day. In this study, an android application comprising electronic questionnaires was employed for data collection. Anthropometric, dietary, food security and socioeconomic status (SES) assessments were performed. Structural equation modeling (SEM) was done to assess the structural relationship of malnutrition indicators (z-score of height to age (HAZ), z-score of weight to age (WAZ) and z-score of weight to height (WHZ)) with other variables.

Results Overall, 2247 children aged 42.2 ± 0.3 months were enrolled in the study, of whom 1048 (46.6%) were female and 1438 (64%) were urban residents. Based on Z score criteria, 216 (10.1%) of the studied children had less than − 2SD HAZ, 193 (8.4%) had lower than − 2SD WHZ and 188 (8.1%) had lower than − 2SD WAZ. The prevalence rates of stunting, wasting and underweight were not significantly different between boys and girls. Nevertheless, the occurrence of stunting was significantly higher in children residing in rural than in urban areas ($p = 0.025$). SEM analysis revealed that higher SES had a positive relationship with HAZ (0.089), WAZ (0.163) and WHZ (0.109). The effect of SES was greatest on WAZ, indicated by the highest absolute value of a path coefficient. There were specific indirect effects of father's education on HAZ (0.032, $p = 0.001$), WHZ (0.045, < 0.001) and WAZ (0.061, < 0.001) through effect on SES and DDS. SES had a direct effect on DDS (0.202).

*Correspondence:
Bahareh Nikooyeh
nikooyeh11024@yahoo.com; nikooyeh@sbmu.ac.ir
Tirang R. Neyestani
neytr@yahoo.com; t.neyestani@sbmu.ac.ir
Full list of author information is available at the end of the article

Conclusions Our findings using SEM approach provided more concrete evidence for the effect of the household's SES on child's nutritional status. Nevertheless, we still need to monitor the studied population in the context of our surveillance program to document more conclusive causal associations.

Keywords Child malnutrition, Socioeconomic status, Structural equation modeling, Surveillance

Background

One of the important indicators of poor health is childhood malnutrition including undernutrition (wasting, stunting, underweight and micronutrient deficiencies) and overnutrition (overweight and obesity). The coexistence of overnutrition (obesity) and some forms of undernutrition (like micronutrient deficiency) can also be seen in a child especially in developing countries [1]. Malnutrition makes it difficult, if not impossible, to achieve full human potentials and sustainable development goals (SDGs) [2]. According to the reports of World Health Organization (WHO) and United Nations Children's Fund (UNICEF) in 2019, the global prevalence rates of stunting, wasting, overweight/obesity and micronutrient deficiency in under 5 year children were 149 million, 50 million, 38.2 million and 340 million, respectively [3, 4]. It is noteworthy that under-nourished children are considerably at higher risk of mortality due to common childhood illnesses including pneumonia and diarrhea [5, 6]. The prevalence of childhood undernutrition in low- and middle-income, as compared with prosperous, communities is higher mainly due to disparities in financial resources and human development index [7]. Meanwhile, child malnutrition imposes heavy costs to both governmental and private health services sectors leading to losing financial resources of the community by making such a vicious cycle [8, 9]. Socioeconomic factors of the household including income, parents' education and occupation and housing are important contributors to the nutritional status of the child [10].

Devastating effects of malnutrition are by no means confined just to childhood. A growing body of evidence indicates an association between childhood malnutrition and non-communicable diseases (NCDs) later in adulthood [11, 12]. Combating childhood malnutrition is, therefore, considered as a preventive strategy against NCDs including cardiovascular disease (CVD) and diabetes [13, 14].

According to the UNICEF global nutrition report, Iran was 14th and 53rd in prevalence rates of stunting and wasting, respectively, among nearly 130 countries in 2016 [15]. In 2020, a meta-analysis concluded that the prevalence of underweight, stunting, and wasting was 8.4%, 14.5% and 5.6% among 0–6 years old children in Iran [16].

Though cross-sectional surveys can provide a snapshot of the nutritional status of the target population, they are commonly unable to provide adequate information of the underlying causes of nutritional problems, which are inevitably needed for planning suitable interventions. This information is usually obtained from Food and Nutrition Surveillance (FNS) systems [17]. Iran FNS, has been run since 2014 by the National Nutrition and Food Technology Research Institute (NNFTRI) with collaboration of the Community Nutrition Office of the Ministry of Health (MOH) and with the support of UNICEF [18]. As a part of FNS, we assessed the nutritional status of 2–5 y children residing in food insecure provinces and examined the associations with anthropometric, demographic/socioeconomic, dietary diversity and household food security variables.

Methods

Details of the comprehensive Iran FNS protocol are extensively documented in a separate publication [19]. We performed a survey in food insecure provinces. The classification of these provinces was based on the results obtained from a comprehensive national study. In this study, provinces were classified into three main categories of secure, relatively secure, and insecure, based on three key factors: access to sufficient food, economic ability to procure healthy food, and the utilization of healthy food [20].

Study settings

We conducted the study in eight provinces including Khuzestan, Kerman, Ilam, Bushehr, Hormozgan, Kohgiluyeh va Boyerahmad, Sistan va Baluchestan and South Khorasan, that were all considered food insecure according to the national report [20].

Participants

Considering the prevalence of anemia among children reported in Second National Integrated Micronutrient Survey (NIMS-II) (9.5%) [21], absolute precision of 4% (based on CDC guide) [22], response rate of 90%, and design effect of 1.2, at least 270 children from each province had to be enrolled. Finally, we enrolled 280 children aged 24–60 months from each province, using formula suggested by CDC guide [22].

In each province, multistage cluster random sampling with probability proportional to size was employed. Sampling in towns and villages was done by simple random method using postal codes. In each province, 14 clusters were selected based on the information obtained from Statistical Center of Iran. Each cluster comprised 20 children. Sampling was started from the southwest corner of the residential blocks of each cluster and spirally approaching other houses clockwise until 20 children within each cluster were successfully selected. From each household all eligible children were selected by convenient method. Participants were invited to attend the health house/center to complete the questionnaire on the pre-appointed day. A written informed consent was signed by the child's parent. In this study, an android application comprising electronic questionnaires was employed for data collection.

Assessments
Provincial health staff were trained for all assessments through several workshops and webinars. NNFTRI, in cooperation with MOH, held these workshops. Due to the Covid-19 epidemic, all workshops were held online.

Anthropometric measures and demographic factors were assessed. Socioeconomic questionnaires were filled at the household level. Dietary intake was assessed.

Anthropometric measures
Anthropometric measures included weight and height of children. To measure weight, digital scale (S0141021, donated by UNICEF) with measurability up to 150 kg and accuracy of 100 g (0.1 kg) was used. Weight measurement was performed before measuring the height. The child should stand on the center of the weight scale platform with light clothing and without shoes. The examiner had to be sure that the diaper is clean and dry, if existed. The child was asked to look straight ahead and not to bend when he/she was standing on the scale. Both hands had to be placed at sides of the body. The scale was reset if the child jumped on it or he/she was too active [23, 24]. Height was measured using a stadiometer consisted of a measuring board (0–200 cm) placed on a firm, flat and horizontal surface with a moveable horizontal headboard perpendicular to the tape. After removing hat, socks, shoes and hair ornaments that interfered with the measurement, the child was asked to stand against stadiometer, neither slumped nor stretching, with heels put together, legs straight, arms at sides, shoulders relaxed, looking straight ahead, without tipping the head up or down, touching their heels the vertical board and flatting buttocks against the vertical board. The examiner had to check that the back of the head, shoulder blades, buttocks, legs and heels were in touch with the vertical board. If it was not possible that all of the mentioned points touched the vertical board due to especial body shape, it was needed to be checked that at least three points including back of the head, buttocks and heels were in touch with the vertical board. Then the examiner had to bring the perpendicular headpiece down to touch the crown of the head. The headboard was pulled down to rest firmly on top of the head and compress the hair. At this time, the reading was done to the nearest 0.1 cm [25].

Quality assurance
Four children from each cluster were selected randomly. Three observers measured children's weight and height three times. This step was supervised by a person other than primary examiners (preferably supervisors from or appointed by the provincial medical universities). Quality assurance aimed to ensure both measurement accuracy and inter-rater reliability. The data were then reviewed for discrepancies, and if significant differences were noted, measurements were retaken by a fourth observer. Inter-rater reliability was assessed using intra-class correlation coefficients (ICCs) to ensure consistency across observers (data not shown).

Anthropometric data analysis
To analyze anthropometric data, the Anthro Survey Analyzer was used [26]. The tool incorporates standard methodology as in the WHO Anthro Software Nutrition Survey module and adds more accurate calculations of confidence intervals and standard errors around the estimates taking into account complex sample designs, whenever is the case. It provides results for three of the anthropometric indices including height-for-age, weight-for-age and weight-for-height.

The analyses were based on the WHO Child Growth Standards. The Anthro software provides child malnutrition estimates for the most common cutoffs. The most common indicators in assessing child nutrition status for national surveys are as follow:

Stunting: Height for age <-2SD, Severe wasting: Weight for height <-3SD, Wasting: Weight for height <-2SD, Overweight: Weight for height>+2SD, Underweight: Weight for age <-2SD.

Implausible data according to the WHO flagging system were excluded through the Anthro software as below:

Lower SD and Upper SD, respectively: <-6 and >+5 for weight for age, <-6 and >+6 for height for age, <-5 and >+5 for weight for height.

Demographic and socioeconomic assessment
Data of demographic and socioeconomic status (SES) were collected using questionnaires. These data comprised parents' weight and height, child's birth date, birth weight, birth height, birth order, sex, ethnicity, child's caregiver, history of diseases, breastfeeding situation, age of cow milk introduction, diarrhea in the last two weeks, feeding practice during child diarrhea, smoke exposure, receiving nutrition counseling for child over the previous year and if the child is under coverage of social support

program. Moreover, information regarding the parents' educational level, the occupation of the household's head, household size, number of rooms, region of the residency (urban/rural), ownership of a range of durable assets (e.g. car, motorcycle, fridge-freezer/side by side, freezer, stove/oven, computer/laptop, telephone, microwave, vacuum cleaner, dish washer, cart that is drawn with the animal, tractor/combine, television/LCD/LED, Wi-Fi, and boat/motorboat), home ownership, and access to basic services (e.g. electricity supply, source of drinking water, kitchen, toilet, bathroom) were also collected using these questionnaires. Households were classified as poor (lowest 40%), middle (subsequent 40%) and high SES (top 20%), as originally described elsewhere [27].

Dietary assessment

Dietary diversity score

Nine-item dietary diversity score (DDS) questionnaire was completed for children according to the FAO guideline. It included the following components:

Food groups The questionnaire categorized foods into ten groups: cereals, roots and tubers, vegetables, fruits, meat, eggs, fish, legumes and nuts, dairy products, and oils and fats.

Frequency of consumption For each food group, respondents were asked to indicate the frequency of consumption over the past 24 h.

Scoring Each food group consumed was assigned a score of 1, and the total DDS was calculated by summing the scores for all food groups, with a possible range from 0 to 10 [28, 29].

The questionnaire was developed electronically and was completed online. DDS, evaluated simply by counting the number of food groups consumed, was categorized as low (less than 4 food groups), medium (5 to 6 food groups) and high (more than 7 food groups).

Statistical analyses

Descriptive statistics was used to summarize participants' characteristics and measured variables. Numerical variable data were presented as mean and standard deviation (SD), and frequencies and percentages were used to express categorical variable data. Considering the complex sampling design, all analyses were adjusted according to the survey design and sampling weights. Chi-square test was used to compare categorical variables. Multiple logistic regression analysis was used to calculate the odds ratio (OR) for various types of malnutrition, including stunting, wasting, and underweight, in relation to the different determinants assessed.

Structural equation modeling (SEM) was performed to assess the structural relationship of malnutrition indicators (height for age [HAZ], weight for age [WAZ] and weight for height [WHZ] Z-scores) with other variables. SEM is strongly capable of hypothesizing any type of relations and interactions among the studied variables in a single causal framework. The SEM was deemed suitable for developing a model to explain relationships among the studied variables based on the variance/covariance matrix using maximum likelihood estimation. The evaluation of the model's fitness was based on four comparative fit indices: (CFI) > 0.9, the Tucker-Lewis Index (TLI) > 0.9, the root mean square error of approximation (RMSEA) < 0.06 and standardized root mean square residual (SRMR) < 0.08 [30]. Moreover, SEM is very useful when analyzing mediated effects and simultaneously testing the indirect effects of each mediator independently [31]. New pathways, as suggested by the modification index, were added to the model one by one after discussion among the researchers. While modification indices offered valuable statistical insights for model refinement, the selection of new pathways was also guided by biological and theoretical reasoning. Each suggested pathway was evaluated for its biological plausibility and consistency with existing literature on malnutrition determinants. The initial model was constructed based on a comprehensive review of prior studies and theoretical frameworks relevant to malnutrition in children. This approach ensured that the final model was both statistically sound and theoretically grounded. After the final best-fitted model was obtained, indirect relationships related to malnutrition indicators were examined. The direct and indirect effects and the *p* value were reported. A two-sided $p<0.05$ was considered statistically significant. All analyses were performed using STATA 17.0 (Stata Corporation, College Station TX, USA).

Results

Demographic characteristics

A total of 2247 children were enrolled in the study, with a mean age of 42.2 ± 0.3 months, of whom 1048 (46.6%) were female and 1438 (64%) were urban residents (Table 1). No major differences in demographic or socioeconomic characteristics were seen between boys and girls.

Prevalence of different forms of malnutrition

Based on Z score criteria, 216 (10.1%) of the studied children had less than −2SD height for age, 188 (8.1%) had lower than −2SD weight for age and 193 (8.4%) had lower than −2SD weight for height (Table 1). The prevalence rates of stunting, wasting and underweight were not significantly different between boys and girls. Nevertheless, the occurrence of stunting was significantly higher in

Table 1 Comparison of demographic and socioeconomic characteristics and different forms of malnutrition between girls and boys

Variables	Girls	Boys	*P*-value	Total
Age (month)	42.03 ± 0.45	42.3 ± 0.43	0.651	42.16 ± 0.30
Urban/rural	664 (63.0)	774 (66.0)	0.333	1438 (64.5)
Urban, n(%)	384 (37.0)	425 (34.0)		809 (35.5)
Rural, n(%)				
Family size	181 (14.5)	226 (14.0)	0.732	407 (14.2)
1–3, n(%)	648 (58.9)	725 (61.3)		1373 (60.2)
4–5, n(%)	219 (26.6)	242 (24.7)		461 (25.6)
6 and more, n(%)				
Father education	89 (10.9)	89 (8.4)	0.555	178 (9.6)
Illiterate, n(%)	258 (32.9)	292 (33.2)		550 (33.1)
Basic, n(%)	199 (16.7)	186 (14.1)		385 (15.3)
High school, n(%)	265 (23.0)	321 (26.2)		586 (24.7)
Diploma, n(%)	195 (13.5)	264 (14.7)		459 (14.1)
Undergraduate, n(%)	46 (3.0)	49 (3.4)		95 (3.2)
Postgraduate, n(%)				
Mother's education	83 (9.4)	108 (11.7)	0.465	191 (10.6)
Illiterate, n(%)	285 (34.9)	298 (33.7)		583 (34.3)
Basic, n(%)	161 (12.5)	180 (13.7)		341 (13.1)
High school, n(%)	284 (22.3)	337 (22.6)		621 (22.5)
Diploma, n(%)	221 (19.4)	250 (15.8)		471 (17.5)
Undergraduate, n(%)	18 (1.5)	28 (2.5)		46 (2.0)
Postgraduate, n(%)				
Father's job	7 (0.4)	7 (0.2)	0.367	14 (0.3)
Retired, n(%)	104 (12.7)	111 (10.0)		215 (11.3)
Unemployed, n(%)	394 (34.5)	457 (36.5)		851 (36.0)
Freelance, n(%)	54 (6.4)	50 (5.8)		104 (6.1)
Fisher/Farmer/Rancher, n(%)	176 (14.1)	242 (18.0)		418 (16.1)
Employed, n(%)	317 (30.9)	334 (29.7)		651 (30.3)
Worker, n(%)				
Mother's job	936 (88.9)	1085 (91.7)	0.06	2021 (90.4)
Housewife, n(%)	28 (2.7)	18 (0.7)		46 (1.7)
Freelance, n(%)	69 (7.1)	84 (6.4)		153 (6.7)
Employed, n(%)	19 (1.2)	14 (1.2)		33 (1.2)
Worker, n(%)				
Sources of drinking water	917 (78.8)	1083 (82.4)	0.177	1974 (78.1)
Tap/bottle, n(%)	135 (21.2)	118 (17.6)		279 (21.8)
Other, n(%)				
Dietary diversity score	358 (39.2)	409 (41.4)	0.120	767 (40.3)
1 to 4, n(%)	476 (42.6)	558 (45.3)		1034 (44.1)
5 to 6, n(%)	199 (18.1)	207 (13.2)		406 (15.6)
7 to 9, n(%)				
Passive smoking	238 (26.1)	273 (24.3)	0.518	511 (25.2)
Yes, n(%)	814 (73.9)	928 (75.7)		1742 (74.8)
No, n(%)				
Socioeconomic status	330 (46.7)	392 (49.9)	0.619	722 (48.4)
Low, n(%)	561 (45.1)	596 (42.7)		1157 (43.9)
Medium, n(%)	161 (8.1)	213 (7.3)		374 (7.7)
High, n(%)				
Stunting	101 (10.2)	115 (9.8)	0.851	216 (10.1)
Yes, n(%)	942 (87.8)	1080 (90.1)		2022 (89.9)
No, n(%)				
Wasting	88 (7.5)	105 (9.2)	0.299	193 (8.4)
Yes, n(%)	964 (92.5)	1096 (90.8)		2060 (91.6)
No, n(%)				
Underweight	101 (8.9)	85 (7.3)	0.324	188 (8.1)
Yes, n(%)	944 (91.1)	1113 (92.7)		2055 (91.9)
No, n(%)				

children residing in rural than in urban areas ($p=0.025$). Stunting and underweight were more prevalent in those children from families with low SES ($p<0.001$ and $p=0.019$, respectively). The prevalence of stunting and wasting was not different among three DDS categories but underweight was more prevalent among the children with the lowest DDS ($p=0.017$, Table 2).

Associations of different forms of child malnutrition with other variables

Multivariate logistic regression model was employed to analyze the relationship between stunting, wasting, underweight status and other variables (Table 3). Following adjustment for sex and age, logistic regression revealed father's employment status, especially being a worker[1] (OR=4.95), was positively associated with increased the odds of stunting in the studied children. Meanwhile, living in an urban area (OR=0.64), higher education of father and mother (OR=0.37; OR=0.29, respectively), not being a passive smoker (OR=0.57) as well as middle and high SES (OR=0.4; OR=0.09, respectively) decreased the odds of stunting. No statistically significant association was seen for wasting in the logistic regression model. Nonetheless, odds of underweight was negatively associated with the mother's education (OR=0.48), mother's job (OR=0.41), not being a passive smoker (OR=0.59), middle and high SES (OR=53; OR=23, respectively) and medium DDS (OR=0.51). Medium household size (OR=2.66) and father's employment, especially workers (OR=3.5), increased the odds of underweight in children.

Structural equation modeling (SEM)

Figure 1 illustrates the SEM diagram with significant standardized estimates. A priori, we predicted 32 paths to directly and/or indirectly affect outcomes, originating from eight variables labeled (Table 4). The goodness-of-fit indices of the final model indicated an acceptable fit (RMSEA=0.0, GFI=0.673, CFI=1.0, TLI=1.002, SRMR=0.004). Coefficient of determination for final model was 0.425. Standardized path coefficients are provided in parentheses. Higher SES had a positive relationship with HAZ (0.089), WAZ (0.163) and WHZ (0.109). The effect of SES was greatest on WAZ, indicated by the highest absolute value of a path coefficient. Living in an urban area had a slightly greater effect on HAZ (0.050) compared with WAZ (0.045).

The analysis showed that as the age of a child increased, there was a slight but consistent negative impact on both HAZ (-0.049) and WAZ (-0.05). Boys had a higher HAZ compared to girls, as indicated by the positive effect of

[1] 'Worker' refers to an individual engaged in manual labor or low-skilled jobs, typically characterized by lower income and job security.

Table 2 Prevalence of stunting, wasting and overweight according to residence area, socio-economic status and dietary diversity score in the studied children

Form of Malnutrition	Residence Area				Socio-Economic Status				Dietary Diversity Score			
	Urban	Rural	*P* value	Total	Low	Middle	High	*P* value	1 to 4	5 o 6	7 to 9	*P* value
Stunting,	114 (8.6)	102 (12.6)	0.025	216 (9.7)	106 (14.7)	92 (6.5)	18 (1.6)	< 0.001	74 (42.5)	94 (45.5)	37 (12)	0.541
Yes, n (%)	1314 (91.4)	703 (87.4)		2017 (90.3)	606 (85.3)	1061 (93.5)	356 (98.4)		691 (40.3)	928 (43.5)	368 (16.1)	
No, n (%)												
Wasting,	131 (7.6)	62 (9.6)	0.242	193 (8.6)	72 (8.9)	105 (8.6)	16 (3.8)	0.198	73 (48.5)	81 (41.1)	32 (10.4)	0.156
Yes, n (%)	1308 (92.4)	747 (90.4)		2055 (91.4)	640 (91.1)	1046 (90.3)	349 (95.8)		690 (39.6)	942 (44.1)	373 (16.2)	
No, n(%)												
Underweight,	110 (7.1)	78 (9.9)	0.108	188 (8.4)	79 (10.0)	92 (6.9)	17 (3.0)	0.019	79 (54.7)	67 (32.4)	32 (12.9)	0.017
Yes, n (%)	1323 (92.9)	727 (90.1)		2050 (91.6)	639 (90.0)	1060 (93.1)	357 (97.0)		687 (39.2)	960 (44.8)	373 (15.9)	
No, n (%)												

Table 3 Logistic regression analysis of risk factors of stunting, wasting, and underweight

	Stunting			wasting			underweight		
	Odds Ratio	**95% Confidence interval**	***P* value**	**Odds Ratio**	**95% Confidence interval**	***P* value**	**Odds Ratio**	**95% Confidence interval**	***P* value**
Living place	-	-	0.026	-	-	-	-	-	-
Rural	0.64	0.44, 0.94		0.75	0.48, 1.18	0.224	0.7	0.45, 1.10	0.131
Urban									
Members of family	-	-	-	-	-	-	-	-	-
≤ 3	1.70	0.85, 3.42	0.133	1.46	0.81, 2.65	0.205	2.66	1.29, 5.48	0.008
4–5	1.69	0.79, 3.6	0.169	0.78	0.36, 1.68	0.537	1.81	0.81, 4.03	0.144
≥ 6									
Father's education	-	-	-	-	-	-	-	-	-
Under diploma	0.37	0.24, 0.57	< 0.001	1.05	0.67, 1.63	0.823	0.66	0.42, 1.05	0.084
Diploma and above									
Mother's education	-	-	-	-	-	-	-	-	-
Under diploma	0.29	0.18, 0.45	< 0.001	1.37	0.89, 2.10	0.149	0.48	0.29, 0.77	0.002
Diploma and above									
Father's job	-	-	-	-	-	-	-	-	-
Employed	3.31	1.44, 7.6	0.005	0.92	0.37, 2.3	0.865	2.95	1.22, 7.13	0.016
Unemployed	2.35	1.13, 4.88	0.022	0.90	0.46, 1.74	0.756	1.57	0.74, 3.32	0.231
Freelance	4.95	2.5, 9.8	< 0.001	1.21	0.65, 2.26	0.541	3.5	1.76, 6.96	< 0.001
Worker									
Mother's job	-	-	-	-	-	-	-	-	-
Housewife	0.52	0.22, 1.22	0.135	0.46	0.21, 1.0	0.050	0.41	0.18, 0.95	0.039
Other									
Passive smoking	-	-	-	-	-	-	-	-	-
Yes	0.57	0.37, 0.87	0.011	0.93	0.57, 1.50	0.773	0.59	0.36, 0.94	0.028
No									
Socioeconomic status	-	-	-	-	-	-	-	-	-
category	0.40	0.25,0.62	< 0.001	0.93	0.60, 1.44	0.757	0.53	0.33, 0.84	0.007
Low	0.09	0.04,0.19	< 0.001	0.40	0.11, 1.42	0.161	0.23	0.08, 0.68	0.008
Middle									
High									

The models were adjusted for sex and age

child's sex (0.042). Mother's education had a negligible positive effect on HAZ (0.014).

The effect of DDS on WHZ (0.048) was positive and significant. Father's education (0.15), mother's education (0.14) and living in urban area (0.08) had positive effects on SES status. The results showed that the several mediating effects had statistical significance. There were specific indirect effects of father's education on HAZ (0.032, $p=0.001$), WHZ (0.045, <0.001) and WAZ (0.061, <0.001) through effect on SES and DDS.

SES had a direct effect on DDS (0.202). Mother's education (0.062), living place (0.011) and family size (-0.016) had significant indirect effect on DDS. SES could affect DDS directly (0.202). Mother's education and family size had just an indirect effect on WHZ and WAZ.

Discussion

Prevalence of child malnutrition

We found the prevalence rates of all forms of undernutrition among 2–5 y children living in food insecure provinces in Iran from 8.1% for underweight to 10.1% for stunting. A recent study on estimation the prevalence rates of different forms of child malnutrition in low and middle-income countries during 2006–2018, the overall prevalence rates for stunting, wasting and underweight were reported 29.1%, 6.3% and 13.7%, respectively [7]. Along the same line, the pooled prevalence rate of child stunting, reflecting chronic undernutrition, in the Middle East-North Africa (MENA) countries has been reported from 13.1 to 30.1%, depending upon the human development index of the countries [32]. Though the prevalence rates of malnutrition in our studied children are lower than those reported by both these studies, they are still alarming.

Based on the available data, the prevalence of malnutrition in Iranian children under 5 years had a significant decrease from 1995 to 2004 due to development of healthcare centers and improving access to health services as well as implementation of Nationwide Primary Health Care Network [33, 34]. In 2008, a national survey on 34,200 children under 6 years old reported the low prevalence of stunting, underweight, and wasting, i.e. 4.7%, 5.2%, and 3.7%, respectively [35]. A recent study that analyzed the data from three cross-sectional

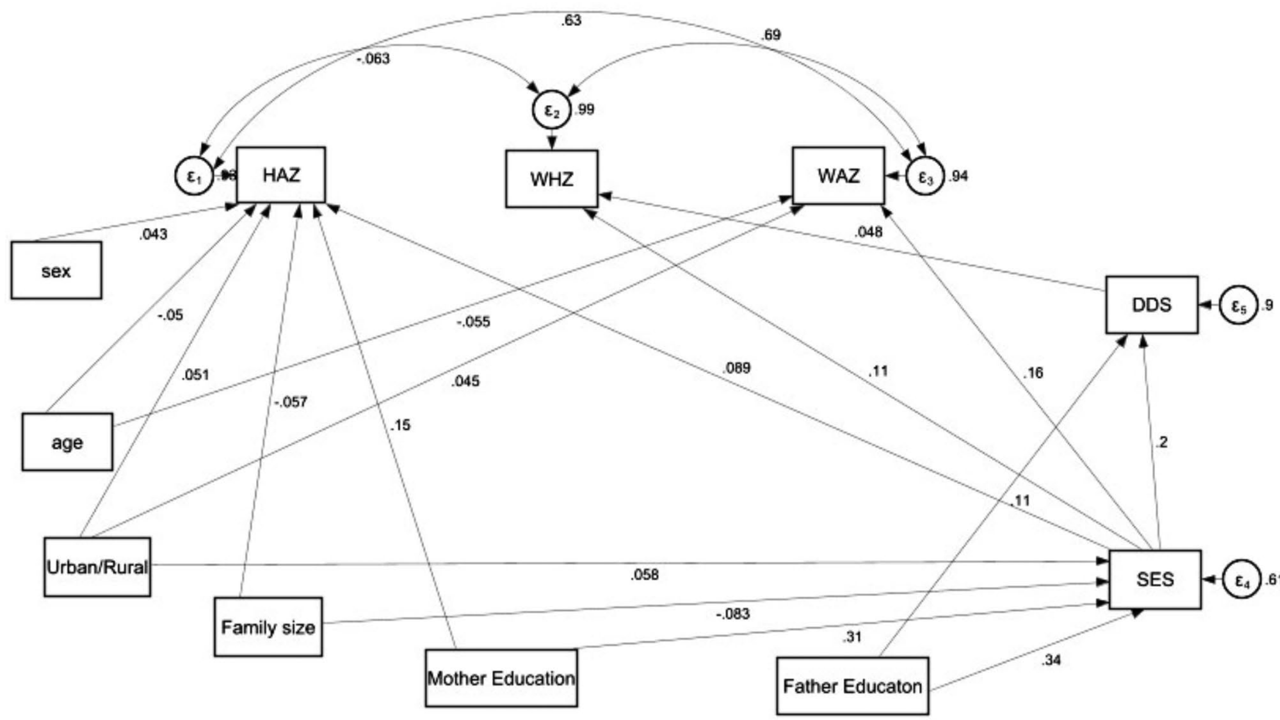

Fig. 1 Final model of factors in the pathway to malnutrition indicators (z-score of height to age, z-score of weight to height and z-score of weight to age) among 2–5 year-old children, national food and nutrition surveillance. Abbreviations: DDS: dietary diversity score; HAZ: height for age Z-score; SES: socioeconomic status; WAZ: weight for age Z-score; WHZ: weight for height Z-score

national surveys on children's nutritional status conducted between 1998 and 2017 also confirmed a downward trend in the prevalence of stunting, underweight, and wasting, from 15.4 to 4.8%, 10.9 to 4.3%, and 4.9 to 4.3%, respectively [36]. Nevertheless, our prevalence rates are reckoned medium according to the WHO's criteria for public health significance and still needs emergent action [37].

Wasting, the acute under-nutrition, is a consequence of severe acute weight loss due to insufficient food intake and/or a high incidence of infectious diseases, especially diarrhea. It has been estimated that 10% of deaths among under five year children globally is attributed to acute wasting [38]. The increase in the number of wasted children in the deprived provinces reflecting food insecurity should, therefore, be considered as a warning of the increase in malnutrition across the country. Recent unbridled inflation and the epidemic of the coronavirus infection in the country and hence changes in dietary pattern of the Iranian households may partially justify the current situation [39–41].

According to the reports of a nationwide survey, the coronavirus epidemic has significantly affected households' dietary intake including consumption of cereals, animal proteins [39], dairy products [40] and fruits [41]. It stands to reason that low-income families and those living in deprived provinces are more affected by these changes. Social and economic support for families with children suffering from or at risk of malnutrition as well as poverty alleviation programs can reduce the burden of child malnutrition [42].

Demographic factors affecting child's growth

Higher prevalence of stunting in children from rural areas and from households with lower SES in this study well indicates disparities and inequities in accessibility of health and social resources in the country. Living in rural areas, in more crowded households, with lower parental educational level and hence less stable father's job position and income resulting in more stressful condition, father's smoking and poor dietary diversity all increase the risk of child undernutrition. Along the same line of evidence, our SEM analysis revealed the significant contribution of SES of child's household to all indicators of child growth including HAZ, WAZ and WHR. The SES itself was influenced by the education level of both parents and living in urban areas. The axial role of poverty and low education in child malnutrition has been already documented [43].

Reports of gender difference in the prevalence of malnutrition have been contradictory. While some studies observed a higher occurrence of malnutrition in boys, some other surveys reported that due to cultural beliefs and families' attention to boys, malnutrition was more

Table 4 Direct, indirect, and total effect among malnutrition indicators and other variables in the structural equation modelling

Endogenous variables		Direct effect		Indirect effect		Total effect	
		Estimate	*P* value	Estimate	*P* value	Estimate	*P* value
Height for age Z-score	SES	0.089	0.001	0.002	0.548	0.091	0.001
	DDS	0.013	0.547	-	-	0.013	0.547
	Sex	0.042	0.038	-	-	0.042	0.038
	Father education	-0.001	0.959	0.032	0.001	0.031	0.237
	Mother education	0.14	< 0.001	0.028	0.001	0.174	< 0.001
	Living place	0.050	0.017	0.005	0.016	0.056	0.009
	Family size	-0.057	0.008	-0.008	0.004	-0.065	0.002
	age	-0.049	0.017	-	-	-0.049	0.017
Weight for height Z-score	SES	0.109	< 0.001	0.009	0.038	0.119	< 0.001
	DDS	0.048	0.031	-	-	0.048	0.031
	Sex	-0.005	0.795	-	-	-0.005	0.795
	Father education	-0.005	0.851	0.045	< 0.001	0.040	0.138
	Mother education	-0.006	0.131	0.038	< 0.001	-0.024	0.386
	Living place	0.015	0.480	0.006	0.008	0.022	0.308
	Family size	0.021	0.331	-0.011	0.001	0.01	0.646
	age	-0.011	0.599	-	-	-0.011	0.599
Weight for age Z-score	SES	0.163	< 0.001	0.006	0.148	0.169	< 0.001
	DDS	0.032	0.141	-	-	0.032	0.141
	Sex	0.035	0.086	-	-	0.035	0.086
	Father education	-0.003	0.907	0.061	< 0.001	0.058	0.030
	Mother education	0.055	0.053	0.053	< 0.001	0.108	< 0.001
	Living place	0.045	0.036	0.009	0.003	0.055	0.011
	Family size	-0.020	0.356	-0.015	< 0.001	-0.035	0.107
	age	-0.055	0.008	-	-	-0.055	0.008
SES	Father education	0.340	< 0.001	-	-	0.340	< 0.001
	Mother education	0.309	< 0.001	-	-	0.309	< 0.001
	Living place	0.057	0.001	-	-	0.057	0.001
	Family size	-0.083	< 0.001	-	-	-0.083	< 0.001
DDS	SES	0.202	< 0.001	-	-	0.202	< 0.001
	Father education	0.110	< 0.001	0.068	< 0.001	0.179	< 0.001
	Mother education	0.036	0.192	0.062	< 0.001	0.098	< 0.001
	Living place	-	-	0.011	0.002	0.011	0.002
	Family size	-0.032	0.129	-0.016	< 0.001	-0.049	0.022

Abbreviations: DDS: dietary diversity score; SES: socio-economic status

prevalent in girls [44–46]. However, most of these studies were conducted in restricted areas with a small sample size. In the current study, we found no difference in prevalence of malnutrition between boys and girls. This finding is in accord with previous national studies [35, 47], and several recent meta-analyses [34, 45, 46].

Dietary diversity and child's growth

We found dietary diversity could directly affect child's weight for height. A recent study from India reported that 6–23 month children with lower dietary diversity were more likely to be affected by all forms of undernutrition including underweight, wasting and stunting [48]. Nevertheless, a meta-analysis showed the association of lower dietary diversity and stunting in under five year children but failed to document similar associations with underweight and wasting [49]. Addressing dietary diversity at the policy-making level could be challenging. While nutrition education of care givers may positively improve dietary diversity of the household including the children and hence affect their growth [50], it may not be effective where poverty dominates food choices. Using fortified infant foods and home fortification could be a parallel strategy alongside women empowerment and food assistance to the needy families to improve growth of the children living in the households with low SES [51, 52].

Strengths and limitations

This study provided evidence for contributors to childhood malnutrition in underprivileged provinces of Iran using SEM methodology for the first time. These data obtained from a large sample size can be used for further policy-making and proper interventions. Nevertheless, some limitations must be acknowledged. The survey coincided with COVID-19 epidemic affecting many aspects of people's lives including dietary habits. Considering the multifaceted nature of malnutrition, prospective studies are still needed to document local determinants of childhood malnutrition and to examine different strategies to overcome it, as well.

Conclusions

In this study, we evaluated the prevalence rates of different forms of undernutrition in 2–5 y children living in the food insecure provinces in Iran. We applied SEM methodology to examine the contribution of different factors to the undernutrition of the child for the first time. Using this approach provided more concrete evidence for the effect of the household's SES on nutritional status of the child. Although SEM approach examines linear causal relationships among different variables [53], we still need to monitor the studied population in the context of our FNS program to document more conclusive causal associations.

Abbreviations

CDC	Center for disease control
CFI	Comparative fit indices
Covid-19	Coronavirus disease of 2019
CVD	Cardiovascular disease
DDS	Dietary diversity score
FNS	Food and nutrition surveillance
HAZ	Z-score of height to age
ICCs	Intra-class correlation coefficients
MENA	Middle East-North Africa
MOH	Ministry of health
NCDs	Non-communicable diseases
NIMS-II	Second national integrated micronutrient survey
NNFTRI	National nutrition and food technology research institute
OR	Odds ratio
RMSEA	Root mean square error of approximation
SD	Standard deviation
SDGs	Sustainable development goals
SEM	Structural equation modeling
SES	Socioeconomic status
SRMR	Standardized root mean square residual
TLI	Tucker-Lewis index
UNICEF	United nations children's fund
WAZ	Z-score of weight to age
WHO	World health organization
WHZ	Z-score of weight to height

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Author contributions

The main supervisors of FNS are TN and BN. The study was designed by TN and BN with intellectual aids of SR, MA, HR, DG, ZY and MM. ZA and MM helped in data gathering through vice-chancellors in health affairs and the Community Nutrition Offices of the medical universities of the studied provinces. They have been supporting the whole FNS program intellectually since its beginning. BN performed all statistical analyses. SR and SE prepared the preliminary manuscript that was then critically revised by MA, DG, HR and ZY. The manuscript was finalized by TN. All authors have read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during this study are not publicly available because of the use of data for further publications but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and informed consent to participate

All participant children's parents signed a written informed consent. The ethical issues of this study were approved by the Ethics Committee of NNFTRI (code: ir.sbmu.nnftri.rec.1396.170). All methods were carried out in accordance with relevant guidelines and regulations or Declaration of Helsinki.

Consent for publication

All participant children's parents were informed that the results of this study would be published as reports and papers while keeping the confidentiality.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Nutrition Research, National Nutrition and Food Technology Research Institute, Faculty of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Community Nutrition Office, Deputy of Health, Iran Ministry of Health and Medical Education, Tehran, Iran

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