BMC Public Health

RESEARCH

Open Access

Prevalence and influencing factors of micronutrient powder adoption among children aged 6–24 months by parental and grandparental caregivers: an analysis from rural China

Yiran Tian[1†], Fangqun Leng[1†], Xinru Zhou[1], Yadi He[1], Linhua Li[1], Ruixue Ye[1], Andrew Rule[2], Jieyuan Feng[2], Scott Rozelle[2], Yuju Wu[1*] and Huan Zhou[1*]

Abstract

Background Micronutrient powder (MNP or Yingyangbao, a dietary supplement that contains multiple vitamins and minerals) programs can reduce the risk of anemia among children. One such program in China distributed free MNP to children aged 6–24 months in poor rural areas. However, there are indications that the generation of primary caregiver (i.e., parent or grandparent) may influence MNP feeding behavior. The purpose of this study was to investigate the prevalence and influencing factors of effective MNP feeding behavior among parents and grandparents in a rural developing setting.

Methods We conducted a cross-sectional study of 884 caregivers and children in formerly impoverished rural areas of Sichuan Province using multi-stage random sampling. Data were collected on caregivers' MNP feeding behavior, their core perceptions and health beliefs about MNP, children's responses to MNP, MNP delivery patterns, and demographic characteristics. Influencing factors of parents' and grandparents' MNP feeding behavior were analyzed using two-level logistic regression.

Results Total effective MNP feeding behavior rate among caregivers was 40.95%. Grandparents demonstrated higher MNP adoption than parents ($\chi^2 = 4.445$, $P = 0.035$). After controlling for sociodemographic characteristics, grandparents were more likely than parents to achieve effective MNP adoption ($OR = 1.360$, $P = 0.035$); child's preference for MNPs ($OR_{\text{parental subgroup}} = 1.736$, $OR_{\text{grandparental subgroup}} = 1.496$; $P < 0.050$) and caregiver's self-efficacy ($OR_{\text{parental subgroup}} = 1.157$, $OR_{\text{grandparental subgroup}} = 1.393$; $P < 0.050$) were influencing factors of feeding behavior for caregivers of both generations. Parents were also influenced by perceived barriers to feeding MNPs ($OR = 0.904$, $P = 0.040$), while grandparents were more strongly influenced by child's discomfort to MNPs ($OR = 0.240$, $P = 0.023$) and caregiver's knowledge about MNPs ($OR = 1.557$, $P = 0.014$).

[†]Yiran Tian and Fangqun Leng contributed equally to this work.

*Correspondence:
Yuju Wu
yujuwu@scu.edu.cn
Huan Zhou
Zhouhuan@scu.edu.cn
Full list of author information is available at the end of the article

Conclusion Future efforts to improve the feeding behavior of caregivers in MNP programs both in China and abroad should improve children's preference for MNP by changing its composition and taste, and increase caregivers' feeding self-efficacy through health education. Moreover, parents should be taught to cope with time and ability barriers that may limit MNP adoption, while grandparents should be emphasized the importance and potential side effects of MNP.

Keywords Micronutrient Powder, Yingyangbao, Influencing factor, Caregiver, China

Introduction

Child malnutrition is a public health issue of global concern, with anemia being one of the particularly prominent consequences. According to the World Health Organization (WHO), approximately 40% of all children aged 6 to 59 months globally are estimated to be affected by anemia [1]. A large share of them resides in low- and middle-income countries (LMICs) where anemia is especially prevalent among children [1]. In China, for example, 36.9% of children aged 6 to 24 months experience anemia and the rate reaches as high as 42.0% in rural areas [2]. Anemia has a wide range of adverse effects on the short- and long-term development of children, causing cognitive, physical, and emotional delays, as well as negatively influencing educational and health outcomes later in life [3–7]. 6 to 24 months of age is a crucial stage for children's growth and development, but also one where anemia frequent occurs [8]. Therefore, implementing effective nutritional interventions for children aged 6 to 24 months in LMICs is vital for addressing anemia and promoting healthy early childhood development.

One effective intervention to reduce anemia in LMICs is the use of micronutrient powder (MNP) to supplement children's diets [9]. In China, the MNP program has been implemented since 2012, primarily involving the provision of free MNP to children aged 6–24 months in impoverished and rural areas, with the aim of improving nutrition and reducing anemia [10, 11]. MNP, also known as Yingyangbao in China, is a powdered micronutrient blend specifically designed for children and contains a high density of multiple vitamins and minerals, including vitamin A, vitamin B, vitamin D, folate, calcium, iron, zinc, and others [11]. Children aged 6–24 months in LMICs frequently experience anemia and micronutrient deficiencies because they have difficulty obtaining sufficient micronutrients from their daily diets [12]. Therefore, MNP, as a convenient and effective dietary supplement, holds great significance in reducing the risk of anemia and improving the nutritional status of children in these regions [13–17]. In China, the coverage of the MNP program has been continuously expanding in the past decade. Starting from providing MNPs to children aged 6–24 months in 100 former nationally designated poverty-stricken counties in 2012, the program has expanded to cover all 832 former nationally designated poverty-stricken counties in 2023 [11, 18]. According to the data from the National Health Commission of the People's Republic of China, by 2023, the MNP program had benefited a total of 19.28 million children in former national impoverished areas. In the areas where the program has been continuously monitored, the anemia rate and stunting rate among children aged 6 to 24 months decreased by 71.7% and 74.3%, respectively, between 2012 and 2023 [19].

Despite the program's proven success in alleviating anemia and improving nutrition among children [11], caregivers' compliance with MNP feeding remains less than ideal in rural China [20]. Studies have shown that caregivers do not always administer MNP to children effectively [21]. For instance, Li et al. found in a survey of poor areas in Hunan Province that the effective MNP feeding rate was 48.0% [22], while Bai et al. found that the effective MNP feeding rate was only 32.1% in areas with high ethnic minority concentration in Gansu Province, and some caregivers have never used the MNP [23]. Furthermore, there are indications that the effectiveness of MNP feeding behaviors may differ along generational lines [24]. Specifically, parental caregivers and grandparental caregivers may differ in their understanding of the importance of MNP and their adherence to feeding guidelines [25]. Differences in children feeding behavior between parents and grandparents are well documented in the international literature, including in LMICs [26–28]. While this suggests that adoption of MNP may vary according to the generation of the caregiver, there is a lack of studies specifically examining this question in LMICs [29]. In rural China, the primary caregivers of children are not limited to parents only, especially in the context of rapid urbanization over the past few decades, which has led many rural parents to migrate to cities for work when their children are just six months old [30]. Consequently, grandparents in these families have increasingly taken on the important responsibility of raising their grandchildren. In 2022, 172 million people migrated for labor in China; nearly 90% of the children of this migrant worker population were mainly taken care of by grandparents [31]. Given that education rates among adults aged 60 and above in China are significantly lower than

those of adults aged between 20 and 59 [32], it is possible that grandparents and parents who raise children in rural China may have different levels of understanding of the importance of nutrition and MNP, potentially leading to differences in MNP feeding behavior between the two generations. Given the limited effectiveness of existing MNP programs and varied compliance, it is urgent and practically significant to identify the factors influencing effective MNP feeding behavior among caregivers of different generations.

Existing research into factors influencing MNP adoption behavior has mainly focused on the social demographic characteristics of caregivers and children, the degree to which children accept MNP, and the delivery providers and delivery patterns of MNP [33, 34]. A small number of previous studies have found that there are differences in compliance with MNP between grandparents and parents, but these studies have found mixed results that prompt further exploration [35, 36]. For example, Sun et al. showed that grandparents exhibited slightly better compliance with MNP than parents in rural China [35]. In contrast, a survey by Yue et al. in 2018 found that grandparents scored slightly worse than parents across a range of children feeding behaviors, including vitamin supplementation [36]. Moreover, previous research has not delved deeply into how the factors influencing effective MNP feeding behavior varied between parental and grandparental caregivers. Additionally, these previous studies have generally not used health-related behavioral theories to more carefully examine the factors that contribute to generational differences in MNP feeding behavior. In this study, we introduce the Health Belief Model (HBM) to explore the cognitive factors that influence the MNP feeding behavior among paternal and grandparental caregivers. The HBM emphasizes the influence of individuals' attitudes and beliefs on the implementation of behaviors. It proposes perceived susceptibility, perceived severity, perceived benefits, barriers to performing the behavior, and self-efficacy as the core determinants of behavior [37]. The HBM has been widely applied to explain and predict various health-related behaviors [38–40].

Therefore, given the lack of research examining generational differences in factors that influence caregivers' compliance with MNP feeding and research examining psychological determinants of MNP feeding behavior, we incorporated the Health Belief Model to explore factors influencing caregiver's MNP feeding behavior among parents and grandparents. In summary, we pursue three specific objectives in this paper. First, drawing on the HBM, we describe the characteristics and MNP feeding behavior of parents and grandparents in rural China. We then identify the differences in MNP feeding behavior between parents and grandparents, before finally exploring the factors influencing MNP feeding behaviors of parents and grandparents.

Methods

Study design and participants

In May 2019, our research team conducted a cross-sectional study in rural areas of Sichuan Province, a region in China with a diverse ethnic population, which boasts the largest concentration of the Yi ethnic group and the second largest Tibetan area in the country. This study used a four-stage random sampling method to obtain the study population. First, considering the required sample size and the potential differences in MNP feeding behaviors between ethnic groups [20, 21, 24], we randomly selected two counties primarily inhabited by Han people, two primarily inhabited by Tibetan people, and two primarily inhabited by Yi people, from all 32 counties in Sichuan where the MNP program had been implemented. Second, six townships were randomly selected from each sampled county, totaling 36 townships. Third, seven to eight villages with a population of more than 800 people were randomly selected from each sampled township, totaling 283 villages. Fourth, all caregivers with 6- to 24-month-old children in every sampled village were invited to participate in the study. The method of sample size estimation was provided in Additional file 1.

Households that met all of the following requirements were enrolled in the study: (1) The child was between 6 and 24 months of age; (2) Participants were residing in counties where the MNP program was implemented; (3) The household identified a parent or a grandparent as the child's primary caregiver, defined as the family member most responsible for feeding the child; (4) The primary caregiver had no listening and speaking impairments that prevent enumeration of the survey. Additionally, households where the child or the primary caregiver had severe health issues were excluded from the study. Ultimately, 884 pairs of caregivers and their children or grandchildren participated in our project.

MNP program

MNP is distributed by government health organizations through a three-tier system at the county, township, and village levels [11]. In Sichuan Province where the study took place, for example, MNP is distributed from county-level health organizations to township and village health centers. When village physicians or physicians in township health centers receive MNPs from the county level, they distribute MNPs door-to-door to households with children aged 6 to 24 months, or caregivers can pick them up at village clinics or township health centers. Because the WHO and the Chinese MNP program office

recommend that children aged 6 to 24 months should be fed 4 to 7 packages of MNP per week [12, 41], typically one box of MNP (containing 30 packages) is distributed to or picked up by each household every month. MNP can be consumed after being mixed with boiling water or sprinkled directly onto food, providing essential micronutrient supplements for children. Some children may experience some discomfort reactions when they first start consuming MNP, such as refusal to eat, diarrhea and dark stool [42]. Previous research has shown that these are normal occurrences, and caregivers can appropriately adjust the frequency and quantity of consumption based on the child's condition [42].

In this study, effective MNP feeding behavior was defined as the caregiver providing four or more packages of MNP to the children in the seven days prior to the survey. The effective MNP feeding rate was defined as the percentage of caregivers who provided four or more packages of MNP to children in the week prior to the survey, relative to all caregivers surveyed. The primary caregiver was defined as the individual in the household who was primarily responsible for looking after the sampled child's diet on a daily basis.

Ethical approval

Ethical approval for this study was obtained from the Medical Ethics Review Committee of Sichuan University (Approval No. K2018103). All the caregivers of the sampled children signed an informed consent form prior to participation.

Data collection

Data for this study were collected using a structured questionnaire by trained enumerators who visited the homes of the participants to conduct face-to-face surveys with the primary caregivers (parents or grandparents) of the children. Different from previous studies, this study designed corresponding questionnaire items combined with the Health Belief Model during the questionnaire design, hoping to explore the relationship between health beliefs and MNP feeding behavior. The questionnaire we used was developed after a comprehensive literature review and two rounds of expert consultation. Then we conducted a pre-survey in two non-sample villages with a total of 20 caregivers. Based on the findings from the pre-survey, the questionnaire was further refined and modified, resulting in the final version used for data collection. In the sampled communities where the majority of residents were of Tibetan or Yi ethnicity, our research team, with the aid of local doctors, used local dialects to provide information about the MNPs to the caregivers. We also used trained local volunteers to translate between Mandarin and local dialects during the survey interviews. In total, five types of data were collected from the sampled households: caregiver's MNP feeding behavior, MNP delivery patterns, caregiver's perceptions of core information about MNPs, child's response to MNP, and caregiver's and child's demographic characteristics.

Caregiver's MNP feeding behavior

First, we collected data on caregiver's MNP feeding behavior, which was the outcome of interest for this study. This was done by asking caregivers if they had fed their child four or more packages of MNP in the past seven days. If they had, the caregiver was considered to conduct effective MNP feeding behavior. If not, the caregiver was considered to conduct ineffective MNP feeding behavior.

MNP delivery patterns

Second, we collected data on MNP delivery patterns. We began by asking the caregivers how they had received their MNPs: (a) via household distribution (i.e., home visits by village doctors or doctors in township health centers); (b) via self-collection (i.e., caregivers went to the village clinics or township health centers themselves to collect the MNPs); or (c) via both delivery patterns.

Caregiver's core perceptions and health beliefs about MNPs

Third, we collected data from caregivers about their (1) core MNP perceptions and (2) health beliefs about MNPs. The section on core MNP perceptions asked the caregivers six questions on the basic attributes of the MNP (including its ingredients, health effects, and response to abnormalities after administration) and how to administer MNPs (including the serving size, feeding method, and storage conditions). If a question was answered correctly, one point was added to the caregiver's core MNP perceptions score; the higher the score, the better the caregiver's knowledge was assumed to be in this area.

Data about caregiver's health beliefs were collected according to the Health Belief Model. As such, the section on health beliefs about MNPs had five subsections, broken down as follows: (1) perception of how susceptible the child is to anemia and malnutrition; (2) perceived severity of child anemia and malnutrition; (3) perceived benefits of using MNPs; (4) barriers to the adoption of MNPs; and (5) feeding self-efficacy, or caregivers' confidence in their own ability to use MNPs effectively. Each section's items were scored using a 5-point Likert scale, with 1 indicating "completely disagree" and 5 indicating "completely agree". A higher score on the perceived benefits section, for example, indicated a greater awareness of the benefits of MNP usage; conversely, a higher score

on the perceived barriers section indicated having more negative beliefs about MNPs.

Perceived susceptibility to child anemia and malnutrition This subsection of the survey assessed the caregiver's awareness of child susceptibility to anemia and malnutrition. Sample questions included, "Do you think that children under 2 years of age may suffer from nutritional deficiencies?" and "Do you think that children under 2 years of age may suffer from anemia?" (William and Tom, 2006).

Perceived severity of child anemia and malnutrition This subsection assessed a caregiver's awareness of the seriousness of common child nutritional diseases such as anemia. Sample questions included, "If a child is chronically deprived of nutrients, do you think there may be adverse consequences?" and "If a child is anemic for a long time, do you think there may be adverse consequences?".

Perceived benefits of using MNPs This subsection asked a caregiver about the benefits of using MNPs for children. Sample questions included, "Do you believe that using MNPs will help your child to grow taller or to reach maturity better?" and "Do you believe that consistently using MNPs will prevent your child from becoming anemic?".

Barriers to the adoption of MNPs This subsection collected information about any factors or beliefs held by caregivers that may serve as barriers to using MNPs effectively. Sample questions included, "Do you think that feeding your child MNPs will interfere with feeding them other foods?" and "Do you think it is difficult to use MNPs?".

Self-efficacy in using MNPs This subsection assessed a caregiver's confidence in their ability to use MNPs. Sample questions included, "If you encounter issues in feeding MNPs to your child (e.g., your child dislikes eating them, or people around you do not support you using them, etc.), do you believe that you will still be able to administer MNPs?" and "Do you believe that you will be able to persist in feeding MNPs to your child?".

Child's response to MNPs

Fourth, we collected data on children's response to MNPs by inquiring with their caregivers, including the level of children's preference for MNPs and whether they experienced any discomfort after consuming it. Specifically, caregivers were asked to indicate how much their child liked the MNPs on a scale of 1–5, with higher scores indicating greater child's preference for MNPs. And caregivers also reported whether their child had any adverse reactions to the MNPs (yes/no).

Caregiver's and child's characteristics

Finally, we collected basic information on the caregivers and their children. Caregivers were asked to report their gender, age, ethnicity (Han, Tibetan, or Yi), marital status (married or other), education level (never attended school, attended some primary school, or above primary school education), and occupation (farmer, full-time caregiver, or other). A five-item questionnaire was also administered to caregivers in order to assess the level of perceived social support that they enjoyed. Each item included a statement about the caregiver's feelings of being supported and was scored on a Likert 5-scale, with 1 referring to "completely disagree" and 5 referring to "completely agree". Higher total scores indicated a higher degree of perceived social support. For the children, caregivers reported their child's age (in months). Finally, we collected demographic information on each caregiver's household characteristics, including annual household income.

Statistical analysis

Data analysis consisted of three parts. First, we used descriptive analyses to present the basic sociodemographic characteristics of parental and grandparental caregivers. The classification variables were described statistically by frequency and constituent ratio, and the difference between groups was compared by Chi-square test. For quantitative variables, normal data were described by mean and standard deviation, skewness data were described by quartile, and the differences between groups were compared by T-test or Mann–Whitney test, respectively. Second, we reported the prevalence of effective MNP feeding behaviors, and conducted a logistic regression analysis with the type of caregiver as the independent variable and effective MNP feeding behavior as the dependent variable, while controlling for child and household characteristics to examine whether there were differences in MNP feeding behaviors between parental and grandparental caregivers. Then, we used univariate analyses to explore differences in the study variables between parental and grandparental caregivers. Third, logistic regression analyses were used to separately assess the relationship between parental and grandparental caregivers' effective MNP feeding behavior and the study variables. Since the data were stratified, with caregivers (level 1) nested within townships (level 2), we created two-level logistic models for analysis. To do this, we constructed a null model to verify the applicability of

our research model to the two-level logistic model. The results of that model indicated that the multilevel logistic regression model was appropriate. Then, the township-level explanatory variables were added to the null model. Last, individual-level explanatory variables were added. All analyses were performed with Stata 17.0. Differences were considered statistically significant at $P < 0.05$.

Results

Summary characteristics

Table 1 presents summary statistics for the sample. In total, 884 pairs of caregivers and their children or grandchildren were included; 604 (or 68.33%) of the caregivers were parental caregivers, and 280 (or 31.67%) were grandparental caregivers; and the sample composition was similar to what previous research found in rural China [43–45]. There were slightly more children in the 13- to 18-month-old age group (36.76%) than the 6- to 12-month-old group (27.15%) and the 19- to 24-month-old group (36.09%). The majority of caregivers were female (91.63%), with a median age of 33 years. A slight majority of caregivers were of Han ethnicity (39.93%). The vast majority of caregivers were married (95.59%). About 43% of the caregivers had never attended school,

Table 1 Basic information about caregivers and children ($N = 884$)

Variable	Total n(%)/p50(p25, p75)	Parental caregivers n(%)/p50(p25, p75)	Grandparental caregivers n(%)/p50(p25, p75)	χ^2/z	*P*
Child's characteristic					
Child's age (in months)				23.499	< 0.001***
6–12	240 (27.15)	193 (31.95)	47 (16.79)		
13–18	325 (36.76)	214 (35.43)	111 (39.64)		
19–24	319 (36.09)	197 (32.62)	122 (43.57)		
Caregiver's characteristics					
Gender				14.449	< 0.001***
Female	810 (91.63)	568 (94.04)	242 (86.43)		
Male	74 (8.37)	36 (5.96)	38 (13.57)		
Age (in years)				−23.494	< 0.001***
	33 (27, 48)	29(25, 33)	53 (48, 56)		
Ethnicity				95.085	< 0.001***
Han	353 (39.93)	214 (35.43)	139 (49.64)		
Tibetan	265 (29.98)	147 (24.34)	118 (42.14)		
Yi	266 (30.09)	243 (40.23)	23 (8.21)		
Marital status				26.591	< 0.001***
Married	845 (95.59)	592 (98.01)	253 (90.36)		
Other	39 (4.41)	12 (1.99)	27 (9.64)		
Education				67.914	< 0.001***
Never attended school	381 (43.10)	237 (39.24)	144 (51.43)		
Some primary school	240 (27.15)	136 (22.52)	104 (37.14)		
Above primary school	263 (29.75)	231 (38.25)	32 (11.43)		
Occupation				59.687	< 0.001***
Farmer	261 (29.52)	220 (36.42)	41 (14.64)		
Full-time caregiver	469 (53.05)	269 (44.54)	200 (71.43)		
Others	154 (17.42)	115 (19.04)	39 (13.93)		
Social support	19 (16, 21)	19 (16, 21)	20 (18, 22)	−5.131	< 0.001***
Annual household income				15.976	< 0.001***
< RMB 35 k	466 (52.71)	346 (57.28)	120 (42.86)		
RMB 35 k-70 k	290 (32.81)	179 (29.64)	111 (39.64)		
> RMB 70 k	128 (14.48)	79 (13.08)	49 (17.50)		

[a] Categorical variables were described by the number and proportion of samples for each category, and the group differences were analyzed by the chi-square test. Quantitative data for a skewed distribution (e. g. caregiver age) were described by median and quartiles, and differences between groups were compared with the Mann–Whitney test

[b] *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

and about 53% of the caregivers were full-time caregivers. The median score for social support perceived by caregivers was 19. In terms of household characteristic, about half of the caregivers reported an annual household income of less than RMB 35,000 ($5,074); only 14.48% of the caregivers reported an annual household income of more than RMB 70,000 ($10,147). We observed significant differences between the ages of children raised by parents and those raised by grandparents. Between parental and grandparental caregivers, we found differences in gender, age, ethnicity, marital status, education level, occupation, social support and annual household income (all $P<0.05$).

MNP feeding behavior

Table 2 presents the effective MNP feeding rate of the parental and grandparental caregivers. According to the results, grandparental caregivers demonstrated significantly better MNP feeding behavior than parental caregivers ($\chi^2=4.445$, $P=0.035$). Out of the 604 parental caregivers, 233 (38.58%) of them demonstrated effective MNP feeding behavior, while 129 of the 280 grandparental caregivers (46.07%) demonstrated effective MNP feeding behavior.

The results in Table 3 show that the type of caregivers was significantly associated with effective MNP feeding behavior after controlling for child and household characteristics variables. Compared to parental caregivers, grandparental caregivers were more likely to achieve effective MNP feeding behavior (*OR* = 1.360, 95% *CI*: 1.021 ~ 1.812, $P=0.035$).

According to our univariate analysis (Table 2), in addition to differences in sociodemographic characteristics, parental and grandparental caregivers differed significantly in terms of the score of child's preference for MNP ($P=0.014$), the MNP delivery pattern ($P<0.001$), their MNP knowledge score ($P=0.013$), their awareness of child's susceptibility to anemia and malnutrition ($P=0.008$), and their perceived barriers to effective MNP feeding ($P=0.001$). The results of an additional analysis comparing only the parents and grandparents who engaged in effective MNP feeding behavior are presented in Appendix Table 1 [see Additional file 2].

Factors influencing MNP feeding behavior by caregiver type.

Table 4 displays the factors influencing the MNP feeding behavior of parental and grandparental caregivers. The results of the logistic regression without controlling for demographic characteristics are shown in Appendix Table 2 [see Additional file 3]. For the parental caregivers, after controlling for demographic characteristics, child's preference for MNPs (*OR* = 1.736, 95% *CI*: 1.457 ~ 2.067, $P<0.001$), caregiver's perceived barriers to feeding MNPs (*OR* = 0.904, 95% *CI*: 0.820 ~ 0.995, $P=0.040$) and

Table 2 Children's response to MNP, caregivers' MNP feeding behavior, information and health belief model scores

Variable	Total n(%)/ p50(p25,p75)	Parental caregivers n(%)/p50(p25,p75)	Grandparental caregivers n(%)/p50(p25,p75)	χ^2/z	*P*
Effective MNP feeding behavior				4.445	0.035*
No	522 (59.05)	371 (61.42)	151 (53.93)		
Yes	362 (40.95)	233 (38.58)	129 (46.07)		
Child's uncomfortable reaction after eating MNP				0.732	0.392
No	821 (92.87)	564 (93.38)	257 (91.79)		
Yes	63 (7.13)	40 (6.62)	23 (8.21)		
Score of child's preference for MNP	4 (2, 5)	4 (2, 5)	4 (3, 5)	−2.456	0.014*
MNP delivery pattern				25.134	< 0.001***
Home visit-based	67 (7.58)	41 (6.79)	26 (9.29)		
Township or village-based	642 (72.62)	416 (68.87)	226 (80.71)		
Both	175 (19.80)	147 (24.34)	28 (10.00)		
Knowledge score	4 (4,5)	4 (4, 5)	4 (4, 5)	2.486	0.013*
Perceived susceptibility	1 (0, 2)	1 (0, 2)	1 (0, 2)	2.654	0.008**
Perceive severity	1 (1, 2)	1 (1, 2)	1 (1, 2)	1.664	0.096
Perceived barriers	8 (7, 9)	8.5 (7, 9)	8 (7, 9)	3.258	0.001**
Perceived benefits	8 (6, 9)	8 (6, 9)	8 (7, 9)	−0.930	0.352
Self-efficacy	8 (6, 9)	8 (6, 9)	8 (6, 9)	1.383	0.167

[a] Categorical variables were described by the number and proportion of samples for each category, and the group differences were analyzed by the chi-square test. Quantitative data for a skewed distribution were described by median and quartiles, and differences between groups were compared with the Mann–Whitney test

[b] *$p<0.05$, **$p<0.01$, ***$p<0.001$

Table 3 Logistic regression result for the relationship between the type of the caregiver and effective MNP feeding behavior

Variable	OR	*P*	95%*CI*
Type of the caregiver			
Parental caregiver	1.000		
Grandparental caregiver	1.360	0.035*	(1.021, 1.812)
Child's age (in months)			
6–12	1.000		
13–18	0.910	0.622	(0.624, 1.326)
19–24	0.771	0.183	(0.526, 1.130)
Caregiver's gender			
Female	1.000		
Male	1.673	0.079	(0.942, 2.971)
Caregiver's age (in years)	1.004	0.739	(0.980, 1.029)
Caregiver's ethnicity			
Han	1.000		
Tibetan	0.539	0.005**	(0.351, 0.828)
Yi	0.579	0.093	(0.307, 1.095)
Caregiver's marital status			
Married	1.000		
Other	2.336	0.032*	(1.074, 5.078)
Caregiver's education			
Never attended school	1.000		
Some primary school	0.927	0.724	(0.608, 1.414)
Above primary school	1.199	0.488	(0.717, 2.005)
Caregiver's occupation			
Farmer	1.000		
Full-time caregiver	0.781	0.319	(0.480, 1.270)
Others	1.046	0.878	(0.588, 1.861)
Caregiver's social support	1.059	0.006**	(1.016, 1.104)
Annual household income			
< RMB 35 k	1.000		
RMB 35 k-70 k	0.893	0.565	(0.608, 1.312)
> RMB 70 k	0.679	0.139	(0.406, 1.134)

* $p<0.05$

** $p<0.01$

*** $p<0.001$

MNP feeding behavior self-efficacy (*OR* = 1.157, 95% *CI*: 1.024 ~ 1.308, *P* = 0.019) were significantly associated with MNP feeding behavior. Among parental caregivers, child's preference for MNPs and caregiver's feeding self-efficacy were the factors most strongly associated with effective MNP feeding behavior, while caregiver's perception of barriers to MNPs feeding was the factor most strongly associated with ineffective feeding behavior. For the grandparental caregivers, after controlling for demographic characteristics, child's uncomfortable reaction to MNPs (*OR* = 0.240, 95% *CI*: 0.070 ~ 0.822, *P* = 0.023) and preference for MNPs (*OR* = 1.496, 95% *CI*: 1.134 ~ 1.974, *P* = 0.004), caregiver's own knowledge of feeding MNPs (*OR* = 1.557, 95% *CI*: 1.092 ~ 2.218, *P* = 0.014) and MNP feeding self-efficacy (*OR* = 1.393, 95% *CI*: 1.117 ~ 1.737, *P* = 0.003) all significantly influenced MNP feeding behavior. Among grandparental caregivers, child's preference for MNPs, caregiver's knowledge about MNPs and self-efficacy were the factors most strongly associated with effective MNP feeding behavior, while the child's uncomfortable response to MNPs was the factor most strongly associated with ineffective feeding behavior. During the course of the data analysis, we conducted multicollinearity analysis, and the results indicated that there was no significant multicollinearity among the variables [see Additional File 4], making it feasible to use logistic regression for analysis.

Discussion

Clarifying how children feeding behaviors vary by generation and the factors contributing to this variation is important for implementing effective, sustainable nutrition programs. In this study, we examined the current status of MNP feeding behaviors of parents and grandparents in rural China. We found that the effective MNP feeding rate among caregivers of children aged 6–24 months was relatively low, with parents engaging in even less effective feeding behavior on average than grandparents. Additionally, the factors influencing the MNP feeding behavior of parental caregivers differed from those influencing grandparental caregivers, indicating that different strategies will be needed to promote effective feeding behavior among the two groups. Below, we discuss each of these findings in more detail and consider their implications for future nutrition interventions.

Our findings showed that the overall rate of effective MNP feeding rate of caregivers of children aged 6–24 months was relatively low. Only 40.95% of the sampled caregivers engaged in effective feeding behavior, defined as providing four or more packages of MNP to children in the week before the survey. This rate is lower than the estimated MNP adoption rate in other areas of China where official MNP programs have been implemented, including poverty counties in Hunan Province (48.0%) [22], Qinghai Province (49.4%) [46]and Gansu Province (57.9%) [20]. Moreover, it is significantly lower than the target effective MNP consumption rate of 70% announced by the government [47]. These findings emphasize the need for future iterations of the MNP program to specifically target factors in Sichuan Province that prevent caregivers from effectively adopting MNP.

While the overall rate of effective MNP feeding behavior was low, our univariate and multivariate analyses also showed that parental caregivers were even less likely than grandparental caregivers to engage in effective MNP feeding behavior. This finding is consistent with the

Table 4 Logistic regression results of effective MNP feeding behavior of parental and grandparental caregivers

Variable	Parental caregivers ($n=604$)			Grandparental caregivers ($n=280$)		
	OR	*P*	95%*CI*	OR	*P*	95%*CI*
Child's age (in months)						
6–12	1.000			1.000		
13–18	0.892	0.633	(0.559, 1.425)	0.600	0.237	(0.257, 1.400)
19–24	0.694	0.137	(0.428, 1.123)	0.631	0.276	(0.276, 1.444)
Caregiver's gender						
Female	1.000			1.000		
Male	1.520	0.325	(0.660, 3.500)	1.520	0.323	(0.662, 3.487)
Caregiver's age (in years)	0.980	0.225	(0.948, 1.013)	0.982	0.268	(0.950, 1.014)
Caregiver's ethnicity						
Han	1.000			1.000		
Tibetan	0.367	0.003**	(0.190, 0.709)	0.469	0.019*	(0.249, 0.884)
Yi	0.276	0.024*	(0.091, 0.842)	0.546	0.186	(0.223, 1.339)
Caregiver's marital status						
Married	1.000			1.000		
Other	3.817	0.081	(0.850, 17.149)	1.585	0.353	(0.599, 4.196)
Caregiver's education						
Never attended school	1.000			1.000		
Some primary school	0.857	0.621	(0.464, 1.580)	0.789	0.514	(0.388, 1.606)
Above primary school	0.955	0.905	(0.453, 2.015)	1.288	0.618	(0.477, 3.479)
Caregiver's occupation						
Farmer	1.000			1.000		
Full-time caregiver	0.722	0.353	(0.363, 1.436)	1.318	0.540	(0.545, 3.186)
Others	1.087	0.835	(0.494, 2.390)	2.971	0.067	(0.927, 9.522)
Caregiver's social support	1.073	0.013*	(1.015, 1.134)	0.941	0.225	(0.854, 1.038)
Annual household income						
< RMB 35 k	1.000			1.000		
RMB 35 k-70 k	1.239	0.420	(0.736, 2.086)	0.696	0.302	(0.350, 1.384)
> RMB 70 k	1.052	0.884	(0.533, 2.076)	0.408	0.060	(0.160, 1.038)
Child's uncomfortable reaction after eating MNP						
No	1.000			1.000		
Yes	1.173	0.688	(0.538, 2.555)	0.240	0.023*	(0.070, 0.822)
Score of child's preference for MNP	1.736	< 0.001***	(1.457, 2.067)	1.496	0.004**	(1.134, 1.974)
MNP Delivery pattern						
Home visit-based	1.000			1.000		
Township or village-based	1.248	0.589	(0.559, 2.784)	0.331	0.058	(0.105, 1.039)
Both	1.710	0.196	(0.759, 3.855)	0.502	0.375	(0.109, 2.303)
Knowledge score	1.212	0.096	(0.966, 1.521)	1.557	0.014*	(1.092, 2.218)
Perceived susceptibility	1.127	0.377	(0.864, 1.470)	0.871	0.465	(0.601, 1.262)
Perceive severity	1.065	0.724	(0.753, 1.506)	1.440	0.230	(0.794, 2.611)
Perceived barriers	0.904	0.040*	(0.820, 0.995)	0.948	0.540	(0.801, 1.124)
Perceived benefits	1.132	0.059	(0.996, 1.286)	0.998	0.982	(0.816, 1.220)
Self-efficacy	1.157	0.019*	(1.024, 1.308)	1.393	0.003**	(1.117, 1.737)

* $p<0.05$

** $p<0.01$

*** $p<0.001$

conclusions of Sun et al. [35], which found that grandparents had higher average adherence to MNP than parents [35]. That earlier study found that parents had a relatively lower effective MNP feeding rate, mainly because parents were more concerned about the effectiveness of MNP and thought that free service may be bad. It is also possible that parents may be less able to maintain effective MNP feeding behavior than grandparents because of interruptions caused by their work schedules or migration for labor.

We found that the high level of child's preference for MNP and the high self-efficacy of caregivers were two primary factors promoting effective MNP feeding behavior among all caregivers. The importance of child's preference in promoting MNP adoption has been widely found in prior studies in both China and internationally [48–50]. The taste of MNP can influence whether children are willing to take MNP, which in turn can influence how likely caregivers are to persist in effectively feeding MNP to the children. Our results also showed that feeding self-efficacy, or the caregiver's subjective evaluation of whether they could effectively engage in MNP feeding, was strongly correlated with effective MNP feeding behavior. Regardless of generation, the more confident caregivers were that they could adhere to feeding their children MNP, the more likely they were to feed MNP effectively. This is consistent with the finding in Aregash et al. (2021) that the more confident caregivers were, the higher their adherence to MNP adoption [50]. Furthermore, ethnicity was also one of the factors influencing the effective MNP feeding behavior both among parental and grandparental caregivers. The finding is consistent with findings from studies by Li et al. [21] and Zhou et al. [24], which also suggested that primary caregivers who were part of ethnic minorities were less likely to engage in effective MNP feeding practices [21, 24]. This may be related to factors such as the living environment, cultural background, educational level, and dietary habits [24]. Therefore, future efforts to enhance compliance with the MNP program should consider ethnic differences and provide cultural- and context-specific feeding guidance to local caregivers.

However, not all factors influenced the feeding behavior of parents and grandparents in the same way. For example, caregivers' perceived barriers to effective feeding strongly influenced the MNP feeding behavior of parental caregivers, but not of grandparental caregivers. These barriers included perceived difficulties in feeding MNP to children, such as children refusing to eat, caregivers not having enough time and energy to administer MNP on schedule, etc. The negative influence of such perceived barriers on MNP adoption has also been previously found in Aregash et al. (2021) [50]. One possible reason that parents may be relatively susceptible to these perceived barriers is that grandparents generally have more experience raising children and may be less alarmed or dissuaded from proper feeding behavior by perceived difficulties. Parents with less feeding experience, on the other hand, may be less accustomed to barriers to feeding their babies, possibly increasing the influence of these barriers on their own feeding behavior.

Likewise, we identified several factors that strongly influenced the feeding behavior of grandparents but not parents. In addition to children's preference for MNP and caregivers' self-efficacy, grandparents' feeding behavior was positively influenced by their level of knowledge about MNP. We found that there was a difference in the scores of parents' and grandparents' MNP-related knowledge, with grandparents exhibiting slightly lower MNP-related knowledge. This finding echoes the results of Yue et al. [36], which also found lower levels of nutritional knowledge among grandparents than parents, consistent with the lower average educational level of grandparents than parents [36]. An earlier study in Nepal also found that the likelihood of effective MNP feeding behavior was improved when correct MNP feeding was demonstrated to older caregivers who were less knowledgeable about MNP skills [51]. Taken together, these findings suggest that increasing education and outreach about MNPs among grandparents may be an important measure to promote MNP adoption by grandparents in future interventions.

Another factor that influenced grandparents' feeding behavior more strongly than that of parents was the perception of child's discomfort after MNPs were administered. Common discomfort reactions of children after taking MNP include refusal to eat, nausea, vomiting, loose stool, black stool [42]. In the total sample of this study, 7.13% of the caregivers reported that children exhibited discomfort after taking MNP. In the subsample of grandparents, this proportion was higher, with 8.21% of the grandparents reporting that their babies had some kind of discomfort reaction after taking MNP. Past studies including Dusingizimana et al. [52] have also found that discomfort reactions of children after taking MNP, such as vomiting and black stool, are one of the major obstacles to effective MNP feeding behavior [52]. One possible explanation for the relatively high influence of these reactions on the feeding behavior of grandparents is that grandparents may pay more attention to or be more likely to observe child's discomfort reactions than parents. Additionally, the apparent tendency of grandparents to reduce MNP feeding behaviors when they perceive child's discomfort may indirectly reflect their relative lack of knowledge about MNP. At the same time, this finding also suggests that before distributing MNP,

program representatives should fully explain to caregivers some common discomfort reactions that may exist after the child take MNP, so as to reduce their panic and distrust of MNP when they encounter the child's discomfort.

This study has several strengths and limitation that merit mention. One major strength of this study is that our study fills in some of the main gaps in previous studies and provide substantial evidence that can be used to improve the efficiency of MNP implementation in China and other similar countries. Additionally, our analysis is based on the Health Belief Model, which has rarely been used in past studies of feeding behavior and adherence in MNP programs. This model provides specific behavior-related insights that can be used to guide future efforts to improve health-related behavior. In terms of the limitation, our study relies on caregivers' self-reports of MNP consumption, which may introduce reporting bias and recall bias into our data. In anticipation of this, we implemented several quality control measures to minimize the potential biases associated with self-reported data. These include ensuring the scientific validity and feasibility of the survey protocol and questionnaire through literature review, expert consultation, and pilot surveys. During survey administration, we employed dual verification through both field and data platform checks to ensure the authenticity and completeness of the data. Future research in this field should consider adopting more objective data collection methods to further enhance data credibility, such as conducting direct observations of caregivers' MNP feeding practices through home visits spanning a continuous week.

Conclusion

In summary, our study found that the MNP feeding status of parents and grandparents in rural China is far from ideal, with parents showing relatively poorer MNP feeding practices. Child's preference for MNPs and caregiver's self-efficacy influence the effective administration of MNP by both parental and grandparental caregivers. Perceived barriers strongly influence the MNP feeding behavior of parental caregivers, while limited knowledge about MNP and the perception of child's discomfort after taking MNP influence grandparents' MNP feeding behavior. These preliminary findings provide important information for subsequent development of effective intervention strategies to improve the MNP feeding status of caregivers and the nutritional status of children in rural areas. Our findings suggest that future efforts to improve the feeding behavior of caregivers in MNP programs need to focus on children's preference for MNP and caregivers' self-efficacy. For instance, improving the composition and taste of MNP [53] can make children prefer to eat MNP, while doctors regularly conducting health education sessions for caregivers and encouraging their participation in psychological support groups can be effective strategies to enhance caregivers' self-efficacy. Generation-specific measures are also needed. For example, more methods for overcoming MNP feeding barriers should be imparted to parental caregivers through regular health education conducted by experts. Additionally, grandparental caregivers should meet with experts to increase their understanding of MNP and learn how to cope with children's uncomfortable reactions to MNP. These findings can increase the design and implementation of MNP programs both in rural China and in other LMICs, helping to ensure adequate nutrition and healthy development for children worldwide.

Abbreviations

MNP	Micronutrient powder
LMICs	Low- and middle-income countries
WHO	World Health Organization
HBM	Health belief model
OR	Odds ratio
CI	Confidence interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22006-w.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Acknowledgements

The authors of this study would like to appreciate the collaboration of the local officials and all participants for supporting the survey.

Authors' contributions

HZ, YJW and SR designed the study and supervised it. YRT, FQL, XRZ, YDH, LHL and RXY collected data. YRT and FQL analyzed data, interpreted results and wrote the report. YRT, AR and JYF revised the report from preliminary draft to submission. All authors have read and approved the manuscript.

Funding

National Natural Science Foundation of China, Grant/Award Number: 71874114 and 72274130.

Data availability

The datasets are not publicly available due to institutional policy. However, the data can be available through the corresponding author under reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Medical Ethics Review Committee of Sichuan University (Approval No. K2018103). All the caregivers of the sampled children signed an informed consent form prior to participation. And informed consent was obtained from the legal guardians of all children involved in the project. All of the participants were voluntary and their

information was kept completely confidential. The methods used in this study were conducted according to the relevant regulations and standards.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Health Behavior and Social Medicine, West China School of Public Health and West China Fourth Hospital, Sichuan University, No.16 South Renmin Road 3 Section, Chengdu 610041, China. [2]Stanford Center on China's Economy and Institutions, Freeman Spogli Institute for International Studies, Stanford University, Stanford, CA 94305, USA.

Received: 18 February 2024 Accepted: 19 February 2025
Published online: 07 March 2025

References

1. WHO. Anaemia. 2023. https://www.who.int/zh/news-room/fact-sheets/detail/anaemia. Accessed 10 Oct 2024.
2. National Disease Control and Prevention Administration. Report on Nutrition and Chronic Diseases Status of Chinese Residents (2020) (in Chinese). Beijing: People's Medical Publishing House; 2021.
3. Sundararajan S, Rabe H. Prevention of iron deficiency anemia in infants and toddlers. Pediatr Res. 2021;89(1):63–73. https://doi.org/10.1038/s41390-020-0907-5. PMID: 32330927.
4. Gou BN, Zhang Q, Zheng HJ, et al. Analysis of the current status and influencing factors of nutritional anemia among infants aged 6 to 36 months in Xi'an (in Chinese). South China J Prev Med. 2024;50(07):618–621625.
5. Luo R, Shi Y, Zhou H, et al. Micronutrient deficiencies and developmental delays among infants: evidence from a cross-sectional survey in rural China. BMJ Open. 2015;5(10):e008400. https://doi.org/10.1136/bmjopen-2015-008400. PMID: 26438137; PMCID: PMC4611485.
6. Li L, Huang L, Shi Y, et al. Anemia and student's educational performance in rural Central China: prevalence, correlates and impacts. China Economic Review. 2018;51:283–93. https://doi.org/10.1016/j.chieco.2017.07.006. WOS:000449039100020.
7. Luo R, Yue A, Zhou H, et al. The effect of a micronutrient powder home fortification program on anemia and cognitive outcomes among young children in rural China: a cluster randomized trial. BMC Public Health. 2017;17(1):738. https://doi.org/10.1186/s12889-017-4755-0. PMID: 28946866; PMCID: PMC5613507.
8. Nilupar Abudoureheman. Study on growth, development, nutritional status, and influencing factors of infants and toddlers aged 6 to 24 months in two regions of Xinjiang (in Chinese). Xinjiang Medical University. 2023. https://doi.org/10.27433/d.cnki.gxyku.2023.000070.
9. Zhou H, Sun S, Luo RF, et al. Impact of text message reminders on caregivers' adherence to a home fortification program against child anemia in rural Western China: a cluster-randomized controlled trial. Am J Public Health. 2016;106(7):1256–62.
10. Xu J, Huo JS, Sun J, et al. Nutrition status of infants aged 6 to 24 months in poor areas at home and abroad study (in Chinese). Chin J Food Hyg. 2017;29(4):427–33.
11. Huo JS, Ying Yang Bao. from scientific research to nutrition intervention for infants and young children in impoverished areas (in Chinese). J Hyg Res. 2021;50(03):357–359. https://doi.org/10.19813/j.cnki.weishengyanjiu.2021.03.001.
12. WHO. Guideline: use of multiple micronutrient powders for home fortification of foods consumed by infants and children 6–23 months of age. Geneva: World Health Organization; 2011.
13. Li Z, Li X, Sudfeld CR, et al. The effect of the Yingyangbao complementary food supplement on the nutritional status of infants and children: a systematic review and meta-analysis. Nutrients. 2019;11(10):2404.
14. Huang YL, Zhang WM, Fang L. Evaluation of nutrition intervention effect of infants aged 6 to 24 months in poor areas of Anhui province (in Chinese). Chin Public Health. 2020;36(11):1582–5.
15. De-Regil LM, Suchdev PS, Vist GE, et al. Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age (review). Evid-Based Child Health. 2013;8:112–201.
16. Heidkamp RA. Evidence for the effects of complementary feeding interventions on the growth of infants and young children in low- and middle-income countries. Nestle Nutr Inst Workshop Ser. 2017;87:89–102.
17. Suchdev PS, Ruth LJ, Woodruff BA, et al. Selling sprinkles micronutrient powder reduces anemia, iron deficiency, and vitamin a deficiency in young children in Western Kenya: a cluster-randomized controlled trial. Am J Clin Nutr. 2012;95:1223–30.
18. China Development Research Foundation. Nutrition improvement program for children in impoverished areas. Available from: https://www.cdrf.org.cn/pkdqetqfzxm/index.htm. Cited 10 Dec 2024.
19. Xinhua News Agency. Nearly 20 Million Infants and Young Children Benefit: China's "Little Yingyangbao" Bring "Great Health". Xinhuanet. 2024. Available from: http://www.news.cn/politics/20241112/fe25dd06bf2d48f89dd4ba9136bcfb57/c.html. Cited 11 Dec 2024.
20. Li FY, Fang X, Liu XD, et al. Analysis of factors influencing the consumption of Yingyangbao in the child nutrition improvement project in poor areas of Gansu Province (in Chinese). Matern Child Health Care China. 2019;34(21):4851–5 CNKI:SUN:ZFYB.0.2019-21-005.
21. Li XQ, Jiang T, Liu Y, et al. Consumption and influencing factors of Yingyangbao for infants in poor areas of Ningxia (in Chinese). Chin J Child Health Care. 2019;27(3):320–2. https://doi.org/10.11852/zgetbjzz2018-0085.
22. Li HX, Yuan S, Zheng JF, et al. The relationship between Yingyangbao intervention and infants' nutrition and health status in poor areas of Hunan Province (in Chinese). Chinese Public Health. 2022;12:1560–5.
23. Bai J, Lai XC, Huang KK, et al. Analysis of anemia prevalence and influencing factors among children aged 6 to 24 months in ethnic minority areas of Gansu Province (in Chinese). Matern Child Health Care China. 2024;39(05):884–7. https://doi.org/10.19829/j.zgfybj.issn.1001-4411.2024.05.029.
24. Zhou X, Fang JQ, Luo JY, et al. Factors related to effective consumption of Yingyangbao among infants aged 6 to 24 months in impoverished rural areas of Hunan Province (in Chinese). Chin J Hyg Res. 2017;46(02):256–61. https://doi.org/10.19813/j.cnki.weishengyanjiu.2017.02.016.
25. Yao XC, Sun C, Ye RX, et al. Effect of Yingyangbao information dissemination on Yingyangbao feeding behavior of infant caregivers in different generations in rural areas (in Chinese). J Sichuan Univ (Medical Edition). 2022;06:1061–7.
26. Aubel J. The role and influence of grandmothers on child nutrition: culturally designated advisors and caregivers. Matern Child Nutr. 2012;8(1):19–35. https://doi.org/10.1111/j.1740-8709.2011.00333.x.
27. Schneiders ML, Phou M, Tum V, et al. Grandparent caregiving in Cambodian skip-generation households: roles and impact on child nutrition. Matern Child Nutr. 2021;17(S1):e13169. https://doi.org/10.1111/mcn.13169.
28. Yue A, Zhang N, Liu X, et al. Do infant feeding practices differ between grandmothers and mothers in rural China? Evidence from rural Shaanxi Province. Fam Community Health. 2018;41(4):233. https://doi.org/10.1097/FCH.0000000000000198.
29. Martin SL, McCann JK, Gascoigne E, et al. Engaging family members in maternal, infant and young child nutrition activities in low- and middle-income countries: a systematic scoping review. Matern Child Nutr. 2021;17(S1):e13158. https://doi.org/10.1111/mcn.13158.
30. The National Health Commission, PRC. National Health Commission on December 22,2018: China's Floating Population Development Report 2018 (in Chinese). (2018–12–22). http://www.nhc.gov.cn/wjw/xwdt/201812/a32a43b225a740c4bff8f2168b0e9688.shtml.
31. National Bureau of Statistics. The national monitoring and survey report on migrant workers in 2022 (in Chinese). Architecture. 2023;05:92–5.
32. China Census Yearbook (2020) (in Chinese). http://www.stats.gov.cn/tjsj/pcsj/rkpc/7rp/zk/indexch.html.
33. Roschnik N, Diarra H, Dicko Y, et al. Adherence and acceptability of community-based distribution of micronutrient powders in Southern Mali. Matern Child Nutr. 2019;15(S5):e12831[2021-11-02].https://onlinelibrary.wiley.com/doi/epdf/10.1111/mcn.12831. https://doi.org/10.1111/mcn.12831. 2021–11–02.
34. Angdembe MR, Choudhury N, Haque MR, et al. Adherence to multiple micronutrient powder among young children in rural Bangladesh: a

cross-sectional study. BMC Public Health. 2015;15:440[2021–11–02]. https://bmcpublichealth.biomedcentral.com/track/pdf/10.1186/s12889-015-1752-z.pdf. https://doi.org/10.1186/s12889-015-1752-z.
35. Sun C, Ye R, Akhtar M, et al. Adherence to micronutrient powder for home fortification of foods among infants and toddlers in rural China: a structural equation modeling approach. BMC Public Health. 2022;22(1):2250. https://doi.org/10.1186/s12889-022-14731-3. PMID: 36461056; PMCID: PMC9719183.
36. Yue A, Zhang N, Liu X, et al. Do infant feeding practices differ between grandmothers and mothers in rural China? Evidence from rural Shaanxi Province. Fam Community Health. 2018;41(4):233–43. https://doi.org/10.1097/FCH.0000000000000198. PMID: 30134338.
37. Rosenstock IM, Strecher VJ, Becker MH. Social learning theory and the health belief model. Health Educ Q. 1988;15(2):175–83. https://doi.org/10.1177/109019818801500203. PMID: 3378902.
38. Jorvand R, Ghofranipour F, HaeriMehrizi A, et al. Evaluating the impact of HBM-based education on exercise among health care workers: the usage of mobile applications in Iran. BMC Public Health. 2020;20(1):546. https://doi.org/10.1186/s12889-020-08668-8. PMID: 32321484; PMCID: PMC7178600.
39. Alagili DE, Bamashmous M. The Health Belief Model as an explanatory framework for COVID-19 prevention practices. J Infect Public Health. 2021;14(10):1398–403. https://doi.org/10.1016/j.jiph.2021.08.024. Epub 2021 Aug 25. PMID: 34462221; PMCID: PMC8386094.
40. Mohammadkhah F, Ramezankhani A, Atashpoosh A, et al. Effect of training based on health belief model and behavioral intention on improving dental and oral self-care behavior in 9–12-year-old Iranian female students. BMC Oral Health. 2022;22(1):515. https://doi.org/10.1186/s12903-022-02552-0. PMID: 36402972; PMCID: PMC9675157.
41. Chinese MNP program office. Notice on printing and distributing the program of children nutrition improvement project in poor areas in 2014. 2014. Available from: http://www.nhc.gov.cn/fys/s3585/201411/254523446f9241a3a3553e19dec77421.shtml. Cited 10 Oct 2024.
42. Mirkovic KR, Perrine CG, Subedi GR, et al. Predictors of micronutrient powder intake adherence in a pilot programme in Nepal. Public Health Nutr. 2016;19(10):1768–76. https://doi.org/10.1017/S1368980015003572. Epub 2015 Dec 28. PMID: 26708454; PMCID: PMC10270855.
43. Fang L. Investigation on feeding and nutritional status of children aged 6 to 23 months in poor areas of Anhui Province (in Chinese). Anhui Medical University. 2019. https://doi.org/10.26921/d.cnki.ganyu.2019.000091.
44. Li FY, Guo JX, Wang C, et al. Anemia status and its influencing factors among children aged 6 to 24 months in poor areas of Gansu Province (in Chinese). Chin J Dis Control Prev. 2019;23(10):1219–23. https://doi.org/10.16462/j.cnki.zhjbkz.2019.10.012.
45. Chen CY, Ashish KC, Huang Y, et al. The prevalence of anemia and its relationship with dietary diversity among children aged 6 to 23 months in some rural areas of China (in Chinese). Chin J Reprod Health. 2020;31(03):201–6.
46. Wu Q, Zhang Y, Chang S, et al. Monitoring and evaluating the adherence to a complementary food supplement (Ying Yang Bao) among young children in rural Qinghai, China: a mixed methods evaluation study. J Glob Health. 2017;7(1):011101.
47. The National Health Commission. Notice on Improving the Basic Public Health Service Project in 2019 (in Chinese). https://www.gov.cn/zhengce/zhengceku/2019-11/15/5452431/files/ec64f143a5964641a864ad799cc5c8b0.docx
48. Wang QZ, Wu YJ, Ye RX, et al. Exploring the influencing factors of feeding compliance behavior of infants' caregivers in poor rural areas of southern Shaanxi based on PRECEDE theory (in Chinese). Health Res. 2018;47(04):599–604.
49. Niu H, Wang Y, Tang H, et al. Food compliance and influencing factors in poor rural children in Guizhou, Yunnan and Shanxi Province (in Chinese). Health research. 2017;46(02):262–5+271. https://doi.org/10.19813/j.cnki.weishengyanjiu.2017.02.017.
50. Samuel A, Brouwer ID, Pamungkas NP, et al. Determinants of adherence to micronutrient powder use among young children in Ethiopia. Matern Child Nutr. 2021;17(2):e13111. https://doi.org/10.1111/mcn.13111. Epub 2020 Nov 9. PMID: 33169528; PMCID: PMC7988858.
51. Locks LM, Dahal P, Pokharel R, et al. Predictors of micronutrient powder (MNP) knowledge, coverage, and consumption during the scale-up of an integrated infant and young child feeding (IYCF-MNP) programme in Nepal. Matern Child Nutr. 2019;15(S5):e12712. https://doi.org/10.1111/mcn.12712. PMID: 31622040; PMCID: PMC6856851.
52. Dusingizimana T, Weber JL, Ramilan T, et al. A mixed-methods study of factors influencing access to and use of micronutrient powders in Rwanda. Glob Health Sci Pract. 2021;9(2):274–85. https://doi.org/10.9745/GHSP-D-20-00422. PMID: 34048359; PMCID: PMC8324192.
53. Ford ND, Ruth LJ, Ngalombi S, et al. Predictors of micronutrient powder sachet coverage and recent intake among children 12–23 months in Eastern Uganda. Matern Child Nutr. 2019;15(S5):e12792. https://doi.org/10.1111/mcn.12792. PMID: 31622041; PMCID: PMC7199021.

Publisher's Note