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The association between micronutrient powder delivery patterns and caregiver feeding behaviors in rural China

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Abstract

Background: High adherence and proper usage of micronutrient powder (MNP) influence child nutritional outcomes, yet few studies explore the role of delivery patterns. This study explores the association between MNP delivery patterns and MNP feeding behaviors among Han and minority caregivers in rural Western China.

Methods: In August 2019, a total of 1021 caregiver-child pairs were selected through a four-stage cluster sampling process. A cross-sectional survey collected information on caregiver demographics, MNP delivery patterns (channel and frequency), and MNP feeding behaviors (proper usage and adherence). Using logistic regression, we examined which delivery channels and delivery frequencies were associated with proper usage and high adherence.

Results: The results indicated that minority caregivers had lower levels of proper MNP usage than did Han caregivers (89.2%), with Tibetan caregivers' reporting the lowest rates of adherence (32.6%). Logistic regression revealed that that township-based channel was significantly correlated with proper usage among Tibetan and Yi caregivers (Odds Ratio, OR = 2.0, $p < 0.01$; and OR = 3.5, $p < 0.001$). Overall, the township-based and home-visit channels were significantly correlated with high adherence (OR = 1.7 and OR = 2.3, respectively; $p < 0.001$); delivery frequency was significantly correlated with high adherence (2 months: OR = 2.2, $p < 0.001$ and ≤ 1 month: OR = 3.5, $p < 0.001$) but not correlated with proper usage among the whole sample and individual ethnic groups.

Conclusions: In conclusion, the study finds evidence of a correlation between MNP delivery channel and both proper usage and high adherence as well as a correlation between MNP delivery frequency and high adherence.

Keywords: Micronutrient powders, Adherence, Proper usage, Feeding behavior, Delivery patterns, China, Rural

Background

Child undernutrition is a serious global health problem that causes adverse outcomes in short- and long-term development. "Undernutrition" is a deficiency in the intake of energy and/or nutrients by children, resulting in four forms: wasting (low weight-for-height), stunting

(low height-for-age), being underweight (low weight-for-age), and micronutrient deficiencies (deficiencies in vitamins and minerals) [1]. All four forms of undernutrition jeopardize the health, growth, development, and survival of children, and all can cause negative, irreversible effects [2]. Specifically, children who suffer from undernutrition can experience significant delays in their cognitive and psychomotor development as well as weakened resistance and immunity to diseases and increased rates of child morbidity and mortality [3]. Undernutrition has been shown to lead to lifelong consequences that involve adverse health outcomes, including

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worsened intellectual and reproductive abilities as well as increased risk of hypertension, diabetes, and psychiatric disorders in adults [2, 4, 5]. These adverse health outcomes may affect human capital and economic productivity, making undernutrition more than just a public health concern [6, 7].

The literature has demonstrated that undernutrition is a particularly serious problem in many low- and middle-income countries (LMICs) [8–10]. In LMICs, the prevalence of overall childhood stunting among children under the age of 5 years ranges from 21.5 to 32.4%, and the rates of similarly-aged children being underweight ranges from 27.3 to 27.6% [8]. Although less widespread than stunting and being underweight, childhood wasting affects 4.9 to 7.9% of children in LMICs [8]. The prevalence of micronutrient deficiencies in children ranges from 5 to 38.8% [11–13]. In addition, an estimated 29% of children in LMICs have vitamin A deficiencies [14], and more than 50% of children in LMICs suffer from zinc deficiencies [15].

Fortunately, programs that distribute micronutrient powder (MNP) to households with infants and young children have the potential to reduce widespread undernutrition; however, research in LMICs frequently finds evidence of inconsistent implementation among programs as well as variations in adherence to the MNP programs [16, 17]. Internationally, MNP programs have been implemented to address child undernutrition, and studies have found that such programs, when implemented fully, can lead to significant declines in undernutrition, as is the case in Asia, Africa, and the Caribbean [18–20]. Previous research also suggests that the delivery channels of MNP (how MNP is distributed to caregivers) affects MNP coverage and caregiver adherence to MNP. One study in Nepal, which compared different MNP delivery channels (e.g., distribution of MNP by community health volunteers versus at health facilities), reported that both channels led to significant but incomplete (by themselves) coverage of MNP and concluded that multiple delivery patterns were needed for successful MNP program implementation [21]. A study in Uganda reported that delivery pattern and program adherence are correlated and that a community-based delivery channel resulted in higher levels of MNP adherence than did a health facility-based delivery channel (58.3% compared to 31.4%) [22].

Similar to research in other LMICs, several studies have found high rates of child undernutrition in rural China [23, 24]. In China, a middle-income country, there is a large and substantial number of undernourished children who live in rural areas. The National Institute of Nutrition and Health reported that approximately 7 million children (under the age of 5) in rural China are

stunted (20.3%), and 2 million are underweight (8.0%) [25, 26]. As recently as 2019, the prevalence of iron-deficiency anemia (IDA) was reported to be around 50% in Western and Southern rural China, which is twice the overall prevalence of IDA across all of China's rural areas (25.1%) [27]. When looking closely at those affected by undernutrition in rural China, research finds that rates of undernutrition are higher among minority ethnic groups (such as the Tibetan and Yi areas) than China's majority ethnic group (Han) [28, 29].

To address this health issue, China's public health system has implemented MNP programs across the country, following recommendations from the World Health Organization (WHO) [30]. In 2012, the National Health Commission, in cooperation with the All-China Women's Federation, implemented a nutrition improvement project for children in poverty-stricken areas in 21 provinces [30]. The program, titled Child Nutrition Improvement Program, provides free MNP (*yingyangbao* in Mandarin) in the form of a soy-based powder with added micronutrients, such as iron, zinc, and vitamins, to families with children aged 6 to 24 months across rural China [30, 31].

Although the implementation of China's MNP program was supposed to be carried out uniformly across the nation, there is evidence that adherence to MNP in rural Western China varies across ethnic groups. Specifically, the findings indicate that Han caregivers typically have higher adherence to MNP than do minority groups, such as the Yi and Tibetan [32–34]. In rural Western China, ethnic groups have distinct food cultures and feeding practices, in addition to different lifestyles [24, 28, 35], that may influence how caregivers access MNP and how they feed MNP to their children. To the best of our knowledge, no study has examined the association between MNP implementation success/failure and the delivery patterns and feeding behaviors of MNP across different ethnic groups in China.

Given the gap in the literature, this paper has two main objectives. First, we investigate the differences in MNP delivery patterns (delivery channels and frequencies of delivery) and caregiver feeding behaviors of MNP (proper usage and adherence) among Han, Tibetan, and Yi caregivers. Second, we explore the associations between delivery patterns (delivery channels and frequencies of delivery) and feeding behaviors (proper usage and adherence) of MNP among these three ethnic groups.

Methods

Sampling

In August 2019, the research team conducted a cross-sectional study in rural areas of Sichuan Province, located in Western China. Sichuan Province is home to many ethnic minority groups, there is the largest inhabited area

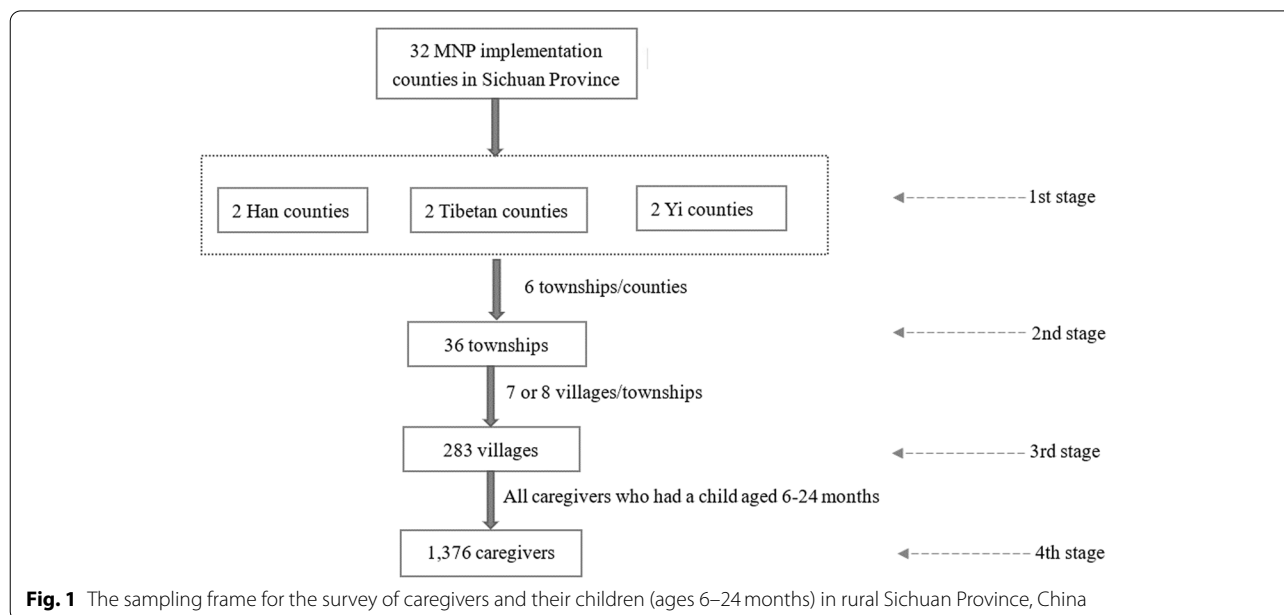
of the Yi ethnic group, the second-largest inhabited area of the Tibetan ethnic group [36]. Within the total population of Sichuan Province (83.67 million), 93.2% are ethnically Han (the majority in China), and the remaining 6.7% include non-Han ethnic minority populations, including Tibetan (1.7%) and Yi (3.1%), other minorities including Qiang, Miao, Hui, Mongolian et.al total accounting for 2% [36]. To capture the ethnic diversity of Sichuan, our sample comprised children and caregivers from Han, Tibetan, and Yi households.

We used a four-stage cluster sampling method to select the sample (Fig. 1). First, we obtained a list of 32 known MNP program implementation sites in Sichuan province (where MNP was distributed free of charge by the government) from the Sichuan Provincial Maternal and Child Health Care Hospital (*Sichuan sheng fu you bao jian yuan*). From the 32 counties, a total of six, two Han and four minority counties (which included two Tibetan counties and two Yi counties), were randomly selected. Counties were determined to be minority counties if the majority of the county population identified as one non-Han ethnic minority or two or more minority ethnicities (Tibetan or Yi) [37]. In this sample, Tibetan populations account for 92 and 72.47% of the two Tibetan counties [38, 39], while Yi populations account for 97.5 and 97.1% of the two Yi counties [40, 41]. The Han counties were determined when the majority of the county identified as Han. In the Han counties, Han populations accounted for 99.6 and 99.8% of the total of the two county populations [42, 43].

Second, six townships within each of the six selected counties were randomly selected, totaling 36 townships.

Third, from each of the 36 townships, the research team randomly selected six villages. If a village had a population of fewer than 800 people, we combined two neighboring villages (each with fewer than 800 people) and considered them as one village-level sampling unit. In total, 283 villages were selected. Last, our team obtained a list of all registered births over the previous 24 months (August 2017– February 2019) from local officials in each village. This list was used to confirm target child age range (6–24 months) during the survey period by calculating the difference between the survey date and the registered birth date.

In this study, ‘caregiver’ refers to the person in a family who is primarily responsible for taking care the child on a daily basis (the primary caregiver). Since China’s MNP program provides free MNP for children aged 6–24 months, all children in this target age range with their primary caregiver were deemed eligible to be enrolled in the survey. Finally, in the 283 villages, a total of 1376 (Fig. 1) pairs were eligible for the survey. However, 140 failed to enroll in the study due to various reasons: (A) the caregiver and the child had migrated to another city or province to live or work; (B) the caregiver was absent and would not return to the residence during the time of the survey; (C) the caregiver’s child was sick, and the caregiver was unable to be interviewed; or (D) the caregiver refused to be interviewed. Of the 1236 caregivers who enrolled in the survey, 1021 were included in the final analytical sample. A total of 215 caregivers (exclusion rate 17.39%) were not included in the final analysis due to various reasons: (a) their children died before the survey began; (b) they had never heard of



or seen MNP; (c) the caregiver left during the questionnaire administration due to personal reasons and failed to return; (d) the caregiver initially accepted the investigation but refused to complete the questionnaire due to fatigue or lack of interest; or (e) the caregiver or investigator omitted an item on the survey. After running an attrition analysis, our results mainly showed no significant differences between the 1021 caregivers who were included and the 215 caregivers who were not included in the final analytical sample (see the Appendix Table 1 in the Additional File 1). The only significant differences between included and excluded caregivers were educational background ($p=0.002$) and delivery frequency ($p=0.001$).

Data collection

Data for the study were collected by trained enumerators using a structured survey questionnaire. The questionnaire was developed by the research team after a comprehensive literature review and two rounds of Delphi expert consultation. The research team piloted the survey in two non-sample villages with 20 caregivers. The questionnaire was then revised to form the final survey.

Accompanied by a local county doctor, trained enumerators visited households and were introduced to each household's primary caregiver. To overcome the language barriers in ethnic minority communities, we recruited and trained local volunteers to help translate the Mandarin survey questionnaire into proper dialects. In total, the survey gathered three blocks of data: (a) caregiver MNP feeding behaviors with a focus on the provision of MNP to children; (b) channels of access to MNP (i.e., how the family came into possession of MNP); and (c) sample demographic characteristics (available in Appendix Table 2 in Additional File 1).

The first block of data included information on caregiver MNP feeding behaviors. First, caregivers were asked to report their usage of MNP, including how they usually fed MNP to their children, by choosing one of three answers: (a) 1=adding MNP to warm boiling water and stirring into a paste, (b) 2=mixing MNP with other supplementary food, or (c) 3=other. According to the official MNP feeding instructions from the National Health Commission [2], "proper usage" is defined as "adding MNP to warm, boiling water and stirring into a paste, or as mixing MNP with other supplementary food" (Answers 1 or 2). Any other MNP usage methods not described by the official instructions was determined "not proper usage." Second, caregivers were asked about their adherence to the frequency of provision of MNP to their children and reported the number of MNP sachets that they fed their child every week, by choosing either 1=4 sachets or more/week or 0=fewer than 4 sachets/

week. "high adherence" was defined as feeding a child at least four MNP sachets every week, and "low adherence" was defined as feeding a child fewer than four MNP sachets every week. These definitions of adherence were in accordance with the official government MNP instructions and previous studies [10, 18, 44, 45].

The second block of data collected was on MNP delivery patterns. First, we asked caregivers to choose which type of delivery channel they used to access MNP: (a) 1=village-based channel (village health office, village activity room, or village committee location); (b) 2=township-based channel (township health center); or (c) 3=home-visit delivery channel (caregiver's household by a home visit from the village doctor or village women's director). Second, we asked caregivers how often they accessed MNP: (a) 1=every three or more months (≥ 3 months); (b) 2=every two months (2 months); or (c) 3=every month or multiple times every month (≤ 1 month).

The third block of data collected was demographic characteristics of children, caregivers, and households. For child characteristics, caregivers reported their child's gender, age in months, and health status. Regarding health status, caregivers were asked to report whether their child's health was (a) 1=very poor, (b) 2=poor, (c) 3=fair, (d) 4=good, or (e) 5=very good. For caregiver characteristics, caregivers reported their gender, age in years, level of educational attainment (never attended school; did not complete elementary school; completed elementary school; completed primary school; completed high school or above), ethnicity (Han, Tibetan, or Yi); and occupation (farmers, full-time stay-at-home parents, or other). Finally, we collected demographic information on household characteristics, which included annual household income (<RMB 1.2k, ~RMB 1.2k, ~RMB 2.5k, \geq RMB 5k).

Statistical analysis

The statistical analysis consists of three parts. First, we use descriptive analyses (means, standard deviations or SD, and shares) to present demographic characteristics of children and their caregivers. Second, we report the prevalence of proper usage and adherence of MNP, using univariate analysis (χ^2 test) to explore the association of MNP feeding behaviors (proper usage and adherence) with MNP delivery patterns (delivery channels and frequency) among Han, Tibetan, and Yi groups. Third, we use logistic regression to examine which delivery channels and delivery frequencies are associated with proper usage and high adherence. In this study, we take the village-based delivery channel and the lowest frequency (≥ 3 months) as reference. Odds ratios for the unadjusted (without the controlled variables) and adjusted results

are reported; *p*-values below 0.05 are considered statistically significant. All analyses were carried out using Stata 14 (Stata Corp, 2015).

Ethics statement

This study has been performed in accordance with the Declaration of Helsinki and has been received ethical approval from the Sichuan University Medical Ethical Review Board (Approval No. K2018103). Before conducting interviews, trained enumerators explained the study aims, process, potential risks and benefits, privacy measures that would be taken, rights and duties of the individual, and contacts for the study to participating caregivers. Enumerators also presented each caregiver with a standardized document that contained the above information. Participating caregivers signed the consent forms for their own and their child's involvement in the program if

applicable, other participating caregivers also gave their oral consent.

Results

Demographic characteristics

The demographic characteristics of the total sample, Han subsample, Tibetan subsample, and Yi subsample are reported in Table 1. A total of 1021 pairs of caregivers and children were included in our study, including 352 Han, 307 Tibetan, and 362 Yi caregiver-child pairs. Less than half of the sample children (48.1%) were female, and the mean child age was 18.9 months (Standard Deviation, SD = 5.8 months). The mean child health status score was 4.4 (SD = 0.8), which was between 4 = good health and 5 = very good health. There were no significant differences in the characteristics of the sample children among the three ethnic groups.

Regarding caregiver characteristics, the majority of caregivers were female (89.3%), and the mean age of the

Table 1 Demographic characteristics of sample child and caregiver pairs from rural western China (*N* = 1021)

Variable	Total (<i>N</i> = 1021)		Han (<i>n</i> = 352)		Tibetan (<i>n</i> = 307)		Yi (<i>n</i> = 362)		<i>p</i> -value
	<i>N</i> / Mean	(%) / (SD)	<i>n</i> / Mean	(%) / (SD)	<i>n</i> / Mean	(%) / (SD)	<i>n</i> / Mean	(%) / (SD)	
Child characteristics									
Gender									0.941
Female	491	(48.1%)	169	(48.0%)	150	(48.9%)	172	(47.5%)	
Male	530	(51.9%)	183	(52.0%)	157	(51.1%)	190	(52.5%)	
Age (months)	18.9	(5.8)	19.36	(5.6)	18.59	(5.9)	18.72	(5.9)	0.474
Health status	4.4	(0.8)	4.18	(0.7)	4.49	(0.8)	4.54	(0.7)	0.156
Caregiver characteristics									
Gender									0.059
Female	912	(89.3%)	324	(92.0%)	265	(86.3%)	323	(89.2%)	
Male	109	(10.7%)	28	(8.0%)	42	(13.70%)	39	(10.8%)	
Age (years)	35.9	(12.9)	39.3	(13.5)	35.9	(12.9)	32.6	(11.3)	0.003
Educational background									
Never went to school	476	(46.6%)	40	(11.4%)	153	(49.8%)	283	(78.2%)	< 0.001
Did not complete elementary school	117	(11.5%)	54	(15.3%)	36	(11.7%)	27	(7.5%)	
Completed elementary school	132	(12.9%)	51	(14.5%)	46	(15.0%)	35	(9.7%)	
Completed primary school	170	(16.7%)	129	(36.7%)	31	(10.1%)	10	(2.8%)	
Completed high school or above	126	(12.3%)	78	(22.2%)	41	(13.4%)	7	(1.9%)	
Occupation									
Farmer	418	(40.9%)	45	(12.8%)	84	(27.4%)	289	(79.9%)	< 0.001
Full-time stay-at-home parent	466	(45.6%)	256	(72.7%)	157	(51.1%)	53	(14.6%)	
Other	137	(13.5%)	51	(14.5%)	66	(21.5%)	20	(5.5%)	
Annual household income (AHI)									
< RMB 1.2 k	326	(31.9%)	14	(3.9%)	48	(15.6%)	264	(72.9%)	< 0.001
~ RMB 1.2 k	305	(29.9%)	84	(23.9%)	143	(46.6%)	78	(21.6%)	
~ RMB 3.5 k	146	(14.3%)	70	(19.9%)	64	(20.9%)	12	(3.3%)	
≥ RMB 5 k	244	(23.9%)	184	(52.3%)	52	(16.9%)	8	(2.2%)	

Notes: Child age, child health status, and caregiver age are listed in mean (SD); all other variables are listed in frequency (percentage). Child health status was reported by caregivers on a scale of 1 to 5: 1 = very poor; 2 = poor; 3 = fair; 4 = good; or 5 = very good

sample caregivers was 36.9 years. There were significant differences in caregiver educational attainment and occupation among the ethnic groups ($p < 0.001$). In the case of educational attainment, 49.8% of Tibetan and 46.6% of Yi caregivers reported that they had never attended any level of school, while Han caregivers had significantly higher levels of educational attainment ($p < 0.001$). The majority of Yi caregivers were farmers (79.8%), while 14.6% were full-time stay-at-home parents, and 5.5% were other (such as individually self-employed drivers, for example). In contrast, the majority of Han and Tibetan caregivers were stay-at-home parents (72.7 and 51.1%, respectively).

According to the data on household characteristics, 31.9% of caregivers had annual household incomes (AHI) in the lowest income bracket (<RMB 1.2k) and 23.9%, in the highest bracket (\geq RMB 5k). When comparing AHI among different ethnic groups, we find that Han households reported significantly higher AHI than did Tibetan and Yi households ($p < 0.001$). Specifically, more than half of Han households (52.3%) reported AHI in the highest income category and only 3.9% of households, in the lowest income level. For the average AHI of Tibetan households, 15.6% were in the lowest AHI level, and 16.9% were in the highest level. Finally, the majority of Yi households (72.9%) reported incomes in the lowest AHI level,

while only 2.2% of Yi households reported incomes in the highest AHI level.

Distribution of delivery patterns and feeding behaviors across ethnic groups

Table 2 shows the results on MNP delivery patterns and MNP feeding behaviors among the caregivers in the full sample and in the ethnic subsamples. Across the full sample, the most common delivery pattern was the township-based channel (53.1%), followed by village-based (28.5%) and home visit-based (18.4%). The most prevalent delivery frequency was every month or multiple times per month (49.9%), followed by every 3 or more months (39.1%). Overall, 74.0% of all caregivers reported proper usage, and 75.1% reported high adherence to MNP feeding guidelines.

Table 2 also shows significant differences in MNP delivery patterns and MNP feeding behaviors between Han, Tibetan, and Yi caregivers. There were significant differences in the most common delivery channel among the ethnic groups. Whereas most Han and Tibetan caregivers accessed MNP through the township-based channel (82.1 and 59.9%, respectively), most Yi caregivers accessed MNP through the village-based channel (51.4%) ($p < 0.001$). There also were significant differences in MNP access frequency among the families in

Table 2 Differences in MNP delivery patterns and MNP feeding behaviors between ethnic groups

Item	Total (N)	(%)	Han (n)	(%)	Tibetan (n)	(%)	Yi (n)	(%)	p-value
Delivery pattern									
Channel ^a									< 0.001
Village-based	291	(28.5%)	45	(12.8%)	60	(19.5%)	186	(51.4%)	
Township-based	542	(53.1%)	289	(82.1%)	184	(59.9%)	69	(19.1%)	
Home visit-based	188	(18.4%)	18	(5.1%)	63	(20.5%)	107	(29.6%)	
Frequency									< 0.001
≥ 3 months	399	(39.1%)	127	(36.1%)	95	(30.9%)	177	(48.9%)	
2 months	113	(11.1%)	54	(15.3%)	28	(9.1%)	31	(8.6%)	
≤ 1 month	509	(49.9%)	171	(48.6%)	184	(59.9%)	154	(42.5%)	
Feeding behavior									
Proper usage ^b									
Yes	755	(74.0%)	314	(89.2%)	224	(73.0%)	217	(59.9%)	
No	266	(26.1%)	38	(10.8%)	83	(27.0%)	145	(40.1%)	< 0.001
Adherence ^c									
Low	254	(24.9%)	77	(21.9%)	100	(32.6%)	77	(21.3%)	
High	767	(75.1%)	275	(78.1%)	207	(67.4%)	285	(78.7%)	0.001
Total	1021	(100.0%)	352	(34.5%)	307	(30.1%)	362	(35.5%)	

Notes: MNP refers to micronutrient powder

^a Village-based delivery channel: MNP was distributed at the village health office, village activity room, or village committee location; township-based: MNP was distributed at the township health center; home visit-based: MNP was distributed to the household in a home visit

^b Proper usage (Yes) refers to following the MNP feeding instructions: Adding MNP to warm boiling water and stirring into paste; or mixing MNP with other supplementary food. Proper usage (No) refers to other usage

^c High adherence: ≥ 4 MNP sachets were consumed every week, low adherence: < 4 MNP sachets were consumed every week

the different ethnic groups. Han and Tibetan caregivers accessed MNP at a significantly higher frequency (48.6 and 59.9% accessed MNP ≤ 1 month, respectively) than did Yi caregivers (48.9% accessed MNP ≥ 3 months; $p < 0.001$).

The results also show that there were significant differences in MNP feeding behaviors among Han, Tibetan, and Yi caregivers. Han caregivers had significantly higher rates of proper usage (89.2%) than did Tibetan (73.0%) and Yi (59.9%) caregivers ($p < 0.001$). In addition, Tibetan caregivers had significantly higher rates of adherence to MNP (32.6%) than did Han (21.9%) and Yi (21.3%) caregivers ($p = 0.001$).

Associations between MNP delivery patterns and feeding behaviors across ethnic groups

Table 3 presents the results of the multivariate analysis of MNP delivery patterns (channel and frequency) and MNP feeding behaviors (proper usage and adherence to MNP guidelines by caregivers) among the sample’s ethnic groups. The univariate analysis results (unadjusted logistic regressions) and overall results of the multivariate analysis (when the regression analysis controlled for demographic characteristics) are displayed in Appendix Table 3 and Appendix Table 4, respectively, in Additional File 1.

Compared to the village-based channel, the township-based channel was significantly correlated with proper usage of MNP among the full sample (Odds Ratio,

OR = 2.6, $p < 0.001$). An examination of the results within individual ethnic groups shows that the township-based channel was significantly correlated with proper usage of MNP among Tibetan and Yi caregivers (OR = 2.0, $p < 0.01$, OR = 3.5, respectively; $p < 0.001$). Delivery frequency was not significantly correlated with proper usage of MNP for the whole sample or among the ethnic subsamples.

Regarding adherence to MNP, overall, the township-based and home-visit channels were significantly correlated with high adherence (OR = 1.7 and OR = 2.3, respectively; $p < 0.001$). Among Han caregivers, the township-based channel was significantly correlated with high adherence (OR = 2.1, $p = 0.9$). The township-based and home-visit channels were significantly correlated with high adherence for Yi caregivers (OR = 2.6 and OR = 4.8, respectively; $p < 0.001$). Further, higher delivery frequency was significantly correlated with high adherence across the whole sample (2 months: OR = 2.2, $p < 0.001$; ≤ 1 month: OR = 3.5, $p < 0.001$). The results also show that, among each ethnic group, accessing MNP each month or multiple times per month was significantly correlated with high adherence (OR = 5.8, OR = 4.3, and OR = 3.1, respectively; $p < 0.001$), while accessing MNP every 2 months was significantly correlated with high adherence for Han and Yi caregivers (OR = 2.6 and OR = 3.9, respectively; $p < 0.001$).

Table 3 Multivariate analysis of proper usage and adherence to MNP among different ethnic groups using adjusted logistic regression (after control variables)

Variable	Proper usage ^b (OR)				Adherence ^c (OR)			
	Total	Han	Tibetan	Yi	Total	Han	Tibetan	Yi
Channel ^a (Village-based as reference)								
Township-based	2.6*** (0.5)	2.1 (0.9)	2.0** (0.6)	3.5*** (1.2)	1.7*** (0.3)	2.2** (0.8)	1.4 (0.5)	2.6*** (0.9)
Home visit-based	1.1 (0.2)	0.9 (0.7)	0.9 (0.3)	1.8 (0.8)	2.3*** (0.6)	N/A (0.5)	1.5 (0.5)	4.8*** (2.4)
Frequency (≥ 3 months as reference)								
2 months	0.8 (0.2)	1.1 (0.5)	0.5 (0.2)	1.8 (0.9)	2.2*** (0.6)	2.6** (1.1)	1.2 (0.6)	3.9*** (1.9)
≤ 1 month	0.9 (0.2)	1.6 (0.6)	0.8 (0.2)	1.0 (0.3)	3.5*** (0.6)	3.1*** (0.9)	4.3*** (1.5)	5.8*** (1.8)

Notes: MNP refers to micronutrient powder; odds ratios were reported; standard errors in parentheses. The results of control variables are not reported here. Adjusted logistic regression (after control variables) used the following for reference: High adherence = 1, Low adherence = 0. Proper usage = 1, Improper usage = 0

^a Village-based delivery channel: MNP was distributed at the village health office, village activity room, or village committee location; township-based: MNP was distributed at the township health center; home visit-based: MNP was distributed to the household in a home visit

^b Proper usage (Yes) refers to following the MNP feeding instructions: Adding MNP to warm boiling water and stirring into paste; or mixing MNP with other supplementary food. Proper usage (No) refers to other usage

^c High adherence: ≥ 4 MNP sachets were consumed every week, low adherence: < 4 MNP sachets were consumed every week

* $p < .05$. ** $p < .01$. *** $p < .001$

Discussion

This is the first study to explore the associations between MNP delivery patterns (delivery channel and frequency) and caregiver MNP feeding behaviors in the context of an MNP implementation program in rural China. Our results indicate that, across three ethnic groups, each group accesses MNP through different channels and at different frequencies. The data show that Han caregivers have the highest levels of proper MNP usage, whereas Yi and Han caregivers have the highest rates of adherence to the prescribed MNP program. Finally, our results show that delivery patterns influence proper MNP usage and high adherence to MNP. Specifically, we find that a township-based delivery channel leads to proper usage of MNP among Tibetan and Yi caregivers, whereas accessing MNP at a higher frequency correlates to higher adherence among Han, Tibetan, and Yi caregivers.

Generally, the attrition analysis combined with the estimated proportion of samples excluded to total samples were served as the most effective measurements [46]. Previous study found higher education level usually correlates to higher non-response rate [47, 48]. But as for this study, our samples have relatively low education level since it focused in rural China, which may impact the differences of educational level and also delivery frequency. Despite identifying such differences, the exclusion rate (17.39%) is considered acceptable given the fact that the excluded participants did not meet our study objectives or were missing crucial variables for inclusion [49]. In summation, we feel confident in our included samples representation regarding the most other variables included in this study shows no difference. Another point worth mentioning is that most Han and Tibetan primary caregivers are full-time stay-at-home parents, which is in line with households throughout rural China. In our sample, the majority of primary caregivers are female (most likely mothers or grandmothers), which is another similarity to other samples in rural China. Previous studies in rural China have demonstrated high quantities of left-behind children and female caregivers, who are financially supported by caregivers who migrate away from home to find work outside the household [50–52]. Thus, many female primary caregivers in rural China are solely responsible for looking after children and managing household affairs [53], while other household members work outside the home to financially support the family [54, 55].

The results show that caregivers of different ethnicities access MNP through different delivery patterns. Although few studies have compared differences in MNP delivery channels between Chinese ethnic groups, our finding is consistent with studies that find that delivery patterns differ among different groups in different

settings [21, 56, 57]. In Vietnam, Nguyen et al. (2016) found that caregivers from ethnic minorities need a complementary delivery model, beyond a health services delivery channel, to properly use MNP, due to their being geographically marginalized, with limited access to the health system [57]. As for our sample, the most common way that Tibetan and Han caregivers access MNP is through a township-based channel, and they access MNP at the highest frequency: every month or multiple times each month. Through the township-based channel, MNP is distributed to caregivers at local township health centers. Regular gatherings at township markets, called “Ganchang” in Mandarin, are a cultural tradition for many residents of rural China [58]. In addition to attending markets for trading, socializing, and viewing entertainment, rural residents can more frequently visit their local township health centers to obtain MNP. Notably, very few Yi caregivers in our sample access MNP through the township-based channel. Instead, Yi caregivers use the village-based channel and access MNP every three or more months (the lowest measured frequency). Another possible influence on delivery pattern differences is the local topography where ethnic groups live. In this study, the terrain of the sample area in the Tibetan community is dominated by plateaus, while the Han and Yi areas are mountainous regions. Local topographical features, coupled with the human resources available to MNP health programs, may dictate how MNP distributors adopt specific distribution channels and frequencies to reach certain populations and groups [36].

In addition to differences in MNP delivery patterns among ethnic groups, there are distinct differences in caregiver MNP feeding behaviors. In China, different ethnic groups have different feeding and food cultures, which may influence how they feed MNP to children [35]. For example, Han caregivers, on average, report a higher prevalence of proper MNP usage than do caregivers of children in the minority samples, which may be due to their feeding cultures and acceptance of nationwide health programs, such as this MNP implementation program. Another possible reason for differences among MNP feeding behaviors may be an issue of informational access. Among our sample, there is a high proportion of Yi and Tibetan caregivers who never attended school, which makes them more likely to be unable to read MNP written instructions and, thus, less likely to display correct feeding behaviors. Conversely, Han caregivers in our sample reported higher levels of education (and were nearly all able to read Chinese characters), which may have influenced their ability to understand the written MNP feeding instructions and other public information regarding MNP [44, 59]. Beyond educational attainment, language barriers may prohibit ethnic minority caregivers

from correctly interpreting MNP usage instructions. Distinct from Mandarin, Tibetan and Yi languages have their own characters and spellings, which makes MNP instructions written in Mandarin largely indecipherable [60]. To address these language barriers, a wider range of public information, such as pamphlets, brochures, and nutrition packaging and instructions, in more dialects and languages is needed to more effectively distribute MNP. Further, MNP distributors should disseminate information about the usage of MNP to mothers and other caregivers in person, as well as through local village broadcasts that can be projected over loudspeakers in village centers. One study conducted in Vietnam found that training MNP distributors on how to better communicate with caregivers led to better program implementation [57]. Another study, in Peru, found that MNP distributors could influence caregivers' feeding behaviors (acceptance and usage of MNP) by how they presented MNP to caregivers [61]. These findings are in line with studies in Nigeria, Kenya, Ethiopia and Ghana, which confirm that better communication and support from distributors positively influence MNP adherence [56, 62–65].

We also find differences in levels of adherence to MNP between ethnic groups. Yi and Han caregivers report the highest rates of adherence to MNP. Tibetan caregivers in our sample are the only group who falls below the recommended adherence rate by the National Health Commission (70.0%) [45]. Although this is a public health concern, when comparing these results from a recent meta-analysis on MNP adherence in LMICs, we find that the average adherence rate of our sample is slightly higher than a pooled adherence rate of 63.28% [44] and is similar to the rates reported in other studies in LMICs (65–81%) [66–70]. Moreover, our samples' adherence rates were higher than those in Cambodia (56%) [71] and Mali (65%) [66] but slightly lower than the adherence rates in Mongolia and India (88 and 84%, respectively) [72].

Previous research has neglected to evaluate the factors of proper MNP usage [10]. Our results, however, provide preliminary evidence that the type of delivery channel, not the frequency of the delivery, influences proper usage. Our results show that the township-based channel leads to proper MNP usage for caregivers, overall, as well as for Yi and Tibetan caregivers, individually. This finding indicates that township doctors may be playing an important role in distributing MNP to minority caregivers. Previous studies have identified townships doctors as an integral health communication channel for providing MNP-related information to caregivers in rural China, which was critical to caregivers knowledge of MNP and then led to better feeding behavior [73]. Specifically, township doctors provide key MNP information that is critical to educating caregivers on better MNP feeding

behaviors [74]. For these reasons, township doctors could be promoted as more important actors in future policy or interventions that aim to improve MNP usage among minority populations.

Regarding adherence, we found that the township-based and home-visit channels are significantly correlated with high adherence to MNP, regardless of ethnicity. Our findings are in line with those of studies from LMICs (Nepal, Uganda, and Vietnam) that demonstrate that delivery patterns are related to MNP adherence [21, 22, 57]. The study conducted in Nepal concluded that multiple delivery patterns may be necessary for successful MNP program implementation [21], while the study in Vietnam found that delivery through local community health centers was a key factor to high MNP adherence [57]. Other international evidence suggests that community-based distribution channels not only result in higher coverage but also influence caregivers' MNP adherence rates [67, 72]. These studies confirm that delivery patterns matter for MNP program implementation and that specific delivery patterns should be adopted based on local settings. Further, our findings indicate that the home-visit delivery channel correlates most strongly to high adherence among Yi caregivers, while the township-based channel influences high adherence among Han caregivers.

Despite delivery frequency's showing no significant association with proper usage, higher frequency does indicate higher adherence to the proposed usage patterns of MNP across all three ethnic groups. When MNP is accessed more frequently, there is a greater probability that caregivers will adhere to usage instructions more regularly, which would thus increase adherence rates. This finding also has been observed in rural Nigeria, where higher frequency leads to increased adherence, which also may be due to increased frequency of communication between caregivers and distributors [42]. More frequent access to MNP implies a more regular supply and more contact with healthcare workers, which may act as an external motivation for caregivers to increase their adherence to MNP [56, 75]. Moreover, regular distribution is recommended by the National Institute of Nutrition and Health in China [74].

In summary, several practical recommendations can be drawn from the findings and conclusions of this study. First, a wider range of public information, such as pamphlets, brochures, and nutrition packaging and instructions, in more dialects and languages is needed to distribute MNP more effectively to caregivers in rural China. Second, townships doctors could be called upon to act as important actors in policy and interventions that aim to improve MNP proper usage among minority

populations. Third, regular monthly MNP distribution is highly recommended for achieving high levels of MNP adherence, and may be an important focus for future research and/or policy initiatives.

Strengths and limitations

This study has several strengths. First, this study explores the association between delivery patterns and the MNP feeding behaviors of caregivers and provides critical information on the role of delivery patterns in MNP usage. In this way, this study addresses a major gap in prior research. Second, our study sample includes caregivers from multiple ethnic minority groups that are often underrepresented in research. To this end, this study provides data that can be directly used by local health officers and administrators to improve the efficiency of MNP programs in China and other low-income countries.

This study also has several limitations. First, because our study presents the first observational findings on the associations between MNP delivery patterns and MNP feeding behaviors in rural China, the findings cannot be interpreted as indicating causality. Second, our study focuses on data solely from the perspective of caregivers, which provides evidence from only the demand side of MNP distribution. To better understand the differences between ethnicities and how access and use MNP and improve child health outcome, future research could include data from the supply side (through MNP distribution employees and programmers) to develop the most appropriate and effective delivery patterns for both the demand and supply sides.

Conclusion

In conclusion, this study finds that caregivers from ethnic minority groups report lower levels of proper MNP usage than do Han caregivers, and Tibetan caregivers report the lowest rates of adherence to MNP. In addition, this study finds evidence of correlation between MNP delivery channel and both proper usage and high adherence as well as a correlation between MNP delivery frequency and high adherence. These preliminary data warrant more detailed and multi-ethnic investigations into the distribution of MNP in rural areas for future research and policy initiatives. The findings also can be used to inform policymakers about the access of minority groups to MNP as well as their levels of usage. Ultimately, we hope that the findings are able to motivate policymakers to explore the nature of MNP distribution as a way of addressing the Child Nutrition Improvement Implementation Programs in MNP distribution. Previous research indicates that children in

rural areas of China continue to suffer from undernutrition, especially in ethnic minority areas. Despite free access to MNP, there remain barriers to proper usage and high adherence to MNP programs.

Abbreviations

MNP: Micronutrient powder; OR: Odds Ratio; LMICs: Low- and middle-income countries; IDA: Iron-deficiency anemia; WHO: World Health Organization; SD: Standard deviation; AHI: Annual household incomes.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-022-13726-4>.

Additional File 1: Appendix Table 1. The attrition analysis of households included and excluded in the final analytical sample. An attrition analysis of the 1021 caregivers who were included in the final analytical sample and the 215 caregivers who were not included in the final analytical sample. **Appendix Table 2.** Variables' Description. Descriptions of the survey questions asked to survey participants. **Appendix Table 3.** Associations between MNP delivery patterns and feeding behaviors (unadjusted logistic regressions). Univariate analysis results of unadjusted logistic regressions to supplement **Table 3.** **Appendix Table 4.** Associations between MNP delivery patterns and MNP feeding behaviors. Overall results of the multivariate analysis (when the regression analysis controlled for demographic characteristics).

Acknowledgements

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

Authors' contributions

HZ and SR designed the study. RL, RY, and QW collected data. RL and RY analyzed data. RL and RY checked the data and results. RL interpreted data and wrote the report. RL, LP, SRD, HZ and SR revised the report from preliminary draft to submission. LP modified the language. HZ and SR supervised the study. All authors have read and approved the manuscript.

Funding

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

Availability of data and materials

The datasets generated during and/or analyzed during the current study are not publicly available due to institutional policy but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study received ethical approval from the Sichuan University Medical Ethical Review Board (Approval No. K2018103). Before conducting interviews, trained enumerators would provide the standardized printed informed consent document including the study aims, process, potential risks and benefits, privacy measures that would be taken, rights and duties of the individual, and contacts for the study to all participating caregivers. Also, the form including consent that caregivers could choose not to participate in this study or withdraw at any time. Enumerators also explained all the above information if participants have any doubts. Participating caregivers signed the consent forms for their own and their child's involvement in the program. Participation in the study was voluntary and anonymous, and participants' information was kept completely confidential. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors have no conflicts of interest relevant to this article to disclose.

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Received: 11 February 2022 Accepted: 17 June 2022

Published online: 16 July 2022

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