Maternal & Child Nutrition

DOI: 10.1111/mcn.12252

Original Article

Adherence to recommendations on lipid-based nutrient supplement and iron and folic acid tablet consumption among pregnant and lactating women participating in a community health programme in northwest Bangladesh

Kassandra L. Harding[*], Susana L. Matias[*], Malay K. Mridha[*,†], Md. Moniruzzaman[†], Stephen A. Vosti[*], Sohrab Hussain[‡], Kathryn G. Dewey[*] and Christine P. Stewart[*]

[*]*Program in International and Community Nutrition, University of California, Davis, California, USA,* [†]*International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh, and* [‡]*Save the Children, Dhaka, Bangladesh*

Abstract

Limited knowledge exists on sustained adherence to small-quantity lipid-based nutrient supplements for pregnant and lactating women (LNS-PL) and how this compares with that of other prenatal supplements. To address these gaps, a random subsample of women ($n = 360$) during pregnancy, early (6- to 12-week post-partum) and late (12- to 24-week post-partum) lactation, from an ongoing effectiveness trial in Bangladesh, was selected for in-home interviews about LNS-PL or iron/folic acid (IFA) use and preferences. Prevalence of high adherence (≥70% of the recommendation) based on self-reported supplement consumption was 67%, 68% and 81% among LNS-PL recipients during pregnancy, early and late lactation, and was 87% and 71% among IFA recipients during pregnancy and early lactation, respectively ($P = 0.044$). Programmatic factors (e.g. distribution and visits by programme staff) were consistently statistically significantly associated with reported high adherence. Among LNS-PL recipients, high overall supplement acceptability score [odds ratio (OR): 8.62; 95% confidence interval (CI) 3.53, 20.83] and use of reminder techniques (OR: 4.41; 95% CI 1.65, 11.76) were positively associated, and reported vomiting at enrollment was negatively associated (OR: 0.34; 95% CI 0.14, 0.80), with reported high adherence. Selected women ($n = 16$) and key informants ($n = 18$) participated in in-depth interviews about perceptions and acceptability of LNS-PL. Women perceived benefits of taking LNS-PL, but some faced barriers to consumption including aversion to odour and taste during pregnancy, forgetfulness and disruptions in supply. To achieve high adherence, results from this study suggest that maternal supplementation programmes should focus on programmatic barriers and consider incorporating reminder techniques. Organoleptic acceptability of LNS-PL, particularly during pregnancy, may also need to be addressed.

Keywords: lipid-based nutrient supplements, iron and folic acid, pregnancy, post-partum, adherence, Bangladesh.

Correspondence: Christine P. Stewart, Department of Nutrition, University of California, 1 Shields Avenue, Davis, CA 95616, USA. E-mail: cpstewart@ucdavis.edu

Introduction

Small-quantity lipid-based nutrient supplements (LNS) have been developed as a preventative approach to chronic malnutrition among pregnant and lactating women and their children in low-resource settings (Chaparro & Dewey 2010). In efficacy trials, LNS for pregnant and lactating women (LNS-PL) has been shown to increase birth size among vulnerable subgroups in Burkina Faso (Huybregts *et al.* 2009) and Ghana (Adu-Afarwuah *et al.* 2015), but not in Malawi (Ashorn *et al.* 2015), and to mitigate post-partum weight loss among human immunodeficiency virus-positive women in Malawi by ~0.6 kg (Kayira *et al.* 2012). The contribution of adherence to LNS-PL to observed variations in results is not clear.

To understand and interpret the effectiveness of LNS-PL in a 'real world' community programme setting, more information regarding sustained consumption patterns of LNS-PL is needed. All of the trials

have recommended daily consumption of LNS-PL throughout pregnancy, and adherence to this recommendation undoubtedly modifies the impact of the intervention on health and nutrition outcomes. Adherence may also differ over the course of pregnancy and lactation, because of the distinct physiologic differences during these periods, because of varying motivations for adherence or because of factors influencing long-term adherence. Yet current knowledge of adherence in this target group is limited to short duration acceptability studies (Adu-Afarwuah *et al.* 2011; Mridha *et al.* 2012) and efficacy trials (Huybregts *et al.* 2009; Kayira *et al.* 2012), where 95–100% adherence rates and 75–92% adherence rates have been reported, respectively. Further, little is known regarding adherence to LNS-PL compared with other antenatal supplements such as multiple micronutrient (MMN) or iron/folic acid (IFA) tablets as well as factors related to LNS-PL adherence, particularly in a programmatic context.

Adherence to IFA and MMN capsule recommendations has been studied previously in an array of contexts, and a number of personal, environmental and programmatic factors have been associated with adherence (Galloway & McGuire 1994; Ghanekar *et al.* 2002; Aguayo 2004; Jasti *et al.* 2005; Lutsey *et al.* 2008; Seck & Jackson 2008; Shankar *et al.* 2009; Tessema *et al.* 2009; Zeng *et al.* 2009; AM 2010; Kulkarni *et al.* 2010; Young *et al.* 2010; Lacerte *et al.* 2011; Oriji *et al.* 2011; Barbour *et al.* 2012; Zavaleta *et al.* 2012). While some factors seem context specific, some general themes have been consistently reported. For example, guaranteed access has been consistently cited as a factor influencing adherence in contexts where supplements are being supplied to women at no cost (Galloway & McGuire 1994; Galloway *et al.* 2002; Seck & Jackson 2008; Shankar *et al.* 2009; Zeng *et al.* 2009; Kulkarni *et al.* 2010). Clear understanding of the supplement recommendations (Galloway & McGuire 1994; Galloway *et al.* 2002; Ghanekar *et al.* 2002; Seck & Jackson 2008; Shankar *et al.* 2009; Kulkarni *et al.* 2010; Mridha *et al.* 2012), perceived benefits of the supplement (Ghanekar *et al.* 2002; Seck & Jackson 2008; Tessema *et al.* 2009; Oriji *et al.* 2011; Zavaleta *et al.* 2012) and remembering to take supplements (Ghanekar *et al.* 2002; Seck & Jackson 2008; Zavaleta *et al.* 2012) have also been previously identified as important.

The primary objectives of the current study are as follows: (1) to evaluate sustained adherence to LNS-PL during pregnancy and post-partum and how it compares with adherence to IFA and (2) to determine programmatic and individual factors associated with adherence within the context of a rural community health and development programme in Bangladesh.

Methods

This evaluation is nested within the Rang-Din Nutrition Study, a cluster randomized trial that evaluated the effectiveness of LNS provided to pregnant and lactating women and children at improving nutritional and health outcomes. Details of the study methods have already been published (Mridha *et al.* 2016). In brief, LAMB Integrated Rural Health and Development (previously known as Lutheran Aid to Medicine in Bangladesh), a local, Christian faith-based non-

Key messages

- Programmes providing lipid-based nutrient supplements for pregnant and lactating women (LNS-PL) or iron/folic acid to pregnant and lactating women would benefit from incorporating tools and techniques to aid women in remembering to take supplements.
- Programmes should plan for participant travel and incorporate tools that will make acquiring and traveling with supplements easier, along with developing a strong monitoring and evaluation systems to ensure that supplements are received continually and on-time by the target group.
- Adherence to prenatal LNS-PL is influenced by food aversions and nausea, which are common during pregnancy; these constraints may be addressed by providing some product choices, either with the product flavours or with the product form.

governmental organization, implemented the effectiveness trial through their Community Health and Development Program in the Rangpur and Dinajpur districts in northwest Bangladesh in September 2011. The supervision region of each community health worker (CHW) ($n = 64$) served as the unit of randomization into the four arms.

From September 2011 to August 2012, CHWs identified new pregnancies through an established active surveillance, and pregnancies were confirmed with a urine strip test. Women were eligible for enrollment if they were identified at or before 20-week gestation and had no plans to move out of the study area for 3 years.

At enrollment, data regarding socio-economic characteristics, food security, knowledge and attitudes and practices regarding maternal nutrition were collected by study staff at participants' homes, and medical history, depressive symptoms and anthropometric indices were collected at the community Safe Delivery Units (SDU). Reimbursements for travel to and from the SDU were provided.

Community health workers and village health volunteers visited participating women within their supervision region monthly to distribute supplements, provide messages regarding supplement use (standard messages found in Appendix 1 in the Supporting Information) and counsel mothers and were not involved with data collection. LNS-PL recipients were instructed to take one sachet each day throughout pregnancy and through 6-month post-partum. IFA recipients were instructed to take one tablet each day throughout pregnancy and one tablet every alternate day after childbirth through 3-month post-partum.

Adherence sub-study

Between December 2012 and April 2013, we conducted a mixed-methods sub-study on adherence, utilizing both structured surveys and semi-structured in-depth interviews (IDI). A randomly selected sub-sample ($n = 360$) stratified by cluster in the LNS-PL or IFA arms was selected from three target groups of women from the LNS-PL arm: pregnancy (28- to 40-week gestation), early lactation (6- to12-week post-partum) and late lactation (12- to 24-week post-partum), and two target groups from the IFA arms: pregnancy and early lactation. Sample size was based on detecting a consumption difference of one supplement/week between groups with $\alpha = 0.05$, 80% power and an intra-cluster correlation of 0.01.

Women were administered a questionnaire at home that asked about their supplement intake in the previous week; methods of consumption; acceptability; supplement sharing, loss, destruction, selling or exchanging; running out of supplements; distribution mechanisms; and recall of messages related to supplement use (Appendix 2 in the Supporting Information). Enumerators counted the number of remaining supplements in the woman's supply. Overall and organoleptic acceptability was assessed by asking women how much they liked or disliked the supplements using a 5-point Likert scale, ranging from '1 = dislike it a lot' to '5 = like it a lot'. Organoleptic assessments included questions about the taste, smell, consistency and colour of the supplements.

A total of 34 individuals were purposively sampled from four groups within the LNS-PL arm for the IDIs: participants with lower adherence, participants with higher adherence, influential relatives and CHWs. For the purpose of sample selection, women's adherence was based on their self-reported consumption at 36-week gestation and 42-day post-partum. Higher adherers were those who reported consuming five, six or seven sachets in a week at both interviews; otherwise, they were considered lower adherers for this purpose. Influential family members included mothers-in-law, sisters-in-law and husbands. CHWs in six unions were interviewed. Supplements were referred to by their local names in the interviews: *Jononi* for LNS-PL and *Alic* for IFA tablets.

We identified factors that have been previously reported to influence adherence to prenatal supplements and grouped them into themes using an integrated model of the Theory of Planned Behavior (Glanz *et al.* 2008). This guided the IDI guide development and the statistical analysis of factors associated with adherence. Two female interviewers conducted all IDIs, which focused on perceptions about barriers and facilitators to consuming LNS-PL, the participant's

personal experience and advice received and given (Appendix 2 in the Supporting Information). CHWs were also asked about challenges they faced while distributing supplements.

Data management and analysis

Quantitative data were double-entered into an Oracle database or Microsoft Access and converted to SAS version 9.3 (SAS Institute Inc. Cary, NC, USA) for analysis.

Adherence was determined using maternal self-report of consumption during the previous 7 days and was analysed as an ordinal variable. Variables were also created for 'non-adherence' (0% of supplements consumed), 'low adherence' (1–69%) and 'high adherence' (≥70%). As there is no established standard definition in the literature for 'high adherence' to perinatal supplements, we chose 70% as a cut-off. This corresponds to taking the supplements 5 or more days in a week, which we would expect to be beneficial while allowing leeway for some days of not taking the supplements. Further, we defined 'adherence as recommended' as reporting consuming seven supplements for all groups except IFA during lactation, for whom adherence as recommended was three to four supplements, because of the difference in recommendations for this group (alternate days). Supplement count was explored as a measure of adherence, but the programmatic data provided incomplete data for this analysis.

Gestational age was calculated based on woman's recall of last menstrual period. Household food security was assessed at baseline and dichotomously categorized using the Household Food Insecurity Access Scale (Coates *et al.* August August 2007). Supplement acceptability scores were collapsed into 'like it a lot' and do not 'like it a lot' for the purpose of analysing this variable as a factor associated with adherence.

Generalized linear mixed models were used to compare baseline characteristics and account for differences among groups, using appropriate link functions (e.g. cumulative logit or logit) for the various ordinal, binary and continuous outcome variables. All models accounted for the design effect and were adjusted for multiple comparisons using the Tukey–Kramer method. To evaluate the difference among groups in reported shared, lost or destroyed, and sold or exchanged supplements, the Rao–Scott chi-squared test was used, accounting for the design effect. We built a series of models to answer four questions regarding factors associated with high adherence to LNS-PL and IFA: (1) which factors are associated with high adherence to either LNS-PL or IFA consumption recommendations during pregnancy or lactation; (2) how do factors associated with high adherence differ between LNS-PL and IFA during pregnancy; (3) which factors are associated with adherence to LNS-PL among women, and do these relationships differ by physiological state (pregnancy, early lactation or late lactation); and (4) which factors are associated with adherence to IFA among women, and do these relationships differ by physiological state (pregnancy or early lactation). For question 1, we evaluated all potential factors associated with high adherence (Appendix 3 in the Supporting Information) in bivariate models. For the remaining questions, we first evaluated potential risk factors as effect modifiers of the relationship between supplement type or physiological status and high adherence for each of the three questions stated previously. Factors with significant ($P \leq 0.10$) interactions with supplement type or physiological status, depending on the question, and the interaction term, as well as those significant in bivariate associations ($P \leq 0.10$), were included in a backwards-stepwise regression process, and terms were removed until we achieved a parsimonious model (all $P \leq 0.05$). We repeated this process for each of the three questions. Factors with very low or high prevalence (<5% or >95%) were not included in the analysis, a criterion that did not greatly impact the other variables in the final models and prevented the inclusion of uninformative variables.

Within 72 h of each IDI, audio recordings were transcribed into Bengali by the interviewer and then transcriptions were translated to English, a subset of which was reviewed by a second translator. English transcripts were imported into NVivo v 10 (QSR International, Melbourne, Australia). Constant comparison analysis (Glaser & Strauss 1967) was used for coding the IDIs. One researcher (KLH) coded all IDIs using *a priori* codes from the participant adherence survey and a review of the literature while also adding codes that emerged during the coding process. We took several steps to achieve quality and validity in the IDI data

(Creswell & Miller 2000). The two primary IDI analysts (KLH and CPS) both have experience in Bangladesh and are familiar with the context and culture. Two additional analysts coded 25% of the interviews in replicate, and all three codes were compared. The two primary analysts independently reviewed the coded data to define the codes (Glaser & Strauss 1967), after which they discussed and resolved disagreements. Codes were then aggregated into overarching, agreed-upon themes.

Ethical approval

This sub-study was approved by the University of California, Davis Institutional Review Board, the International Center for Diarrheal Disease Research, Bangladesh (ICDDR,B) Ethics Committee and by the LAMB Research Ethics Committee. Each participant was read the consent statement in Bengali and indicated their consent prior to being interviewed. If the participant was <18 years old, her guardian provided consent on her behalf, and participants who could not write provided consent with a thumbprint.

Results

Of the 4011 total participants in the study, 405 women were invited to participate in the adherence sub-study, and 360 women completed it. Baseline characteristics of the subsample did not differ significantly from those of the overall study population, with the exception of a slightly earlier gestational age at enrollment among the subsample women. In addition, baseline characteristics generally did not differ significantly between the five subsample groups (Table 1).

Mean self-reported adherence did not differ significantly between groups, nor did the prevalence of non-adherence and low adherence (Table 2). Women given LNS-PL and IFA reportedly consumed their assigned supplement an average of 71.4% and 85.4% of the recommended times in the previous week, respectively. The prevalence of high adherence was significantly different among groups ($P = 0.044$), but after adjusting for multiple comparisons, the differences were no longer significant. For IFA, the prevalence of high adherence was higher in pregnancy (87%) than in early lactation (71%) ($P = 0.023$). During pregnancy, the prevalence of high adherence was lower for LNS-PL (67%) than for IFA (87%) ($P = 0.015$). Prevalence of sharing supplements was greater among LNS-PL recipients (18%) than IFA recipients (3%) ($P < 0.001$), and prevalence of lost and destroyed supplements was greater among IFA recipients (9%) than LNS-PL recipients (4%) ($P = 0.05$). No women reported having exchanged or sold the supplements for money or other goods. Approximately 12.6% of women had zero supplements at the time of the interview, and 15% of LNS-PL recipients and 13% of IFA recipients reported that they had run out of supplements at least once ($P = 0.61$). These data suggest deviations in the supplement distribution protocol and can be considered indicators of programme performance.

Factors associated with adherence during pregnancy

High adherence was positively associated with food security [odds ratio (OR): 2.51; 95% confidence interval (CI) 1.06, 5.95], high overall acceptability scores (OR: 5.38; 95%CI 2.16, 13.33) and use of reminder techniques (OR: 3.01; 95%CI 1.09, 8.33) and negatively associated with having a supplement count of zero at the time of the interview (OR: 0.04; 95%CI 0.01, 0.22) in bivariate models. Women provided with IFA had greater odds of high adherence than women provided with LNS-PL (OR: 3.28; 95%CI 1.26, 8.53).

Reported vomiting (at enrollment) was negatively associated with high adherence to LNS-PL, and high overall acceptability was positively associated with high adherence to LNS-PL, while being visited by a CHW in the past month was positively associated with high adherence to IFA (Table 3). After combining all significant terms into a mutually adjusted model, high acceptability and supplement count of zero remained in the model. After stratifying the final model by supplement group, high acceptability (OR: 14.93; 95%CI 3.34, 66.67) and supplement count of zero (OR: 0.02; 95%CI 0.001, 0.32) remained significantly associated with adherence to LNS-PL during pregnancy, and supplement count of zero was marginally significantly associated with adherence to IFA during pregnancy (OR: 0.05; 95%CI 0.002, 1.05), but high acceptability was not (OR: 0.91; 95%CI 0.10, 7.94).

Table 1. Comparison of baseline characteristics between the sub-sample study groups and between the sub-sample and overall study population

	LNS-PL			IFA		Sub-sample	Total sample	*P* value (a)[¶]	*P* value (b)**
	Pregnancy	Early lactation	Late lactation	Pregnancy	Early lactation				
N	73	72	72	71	72	360	4011		
Characteristic	Mean ± SD*								
GA at enrollment (weeks)	12.6 ± 3.0	13.2 ± 3.3	12.3 ± 3.1	12.2 ± 2.8	12.8 ± 3.2	12.6 ± 3.1	13.1 ± 3.4	0.27	0.021
GA or post-partum age at time of adherence interview (weeks)	34.7 ± 2.6	9.6 ± 1.9	19.9 ± 3.2	34.3 ± 2.8	9.4 ± 1.9				
Age (years)	20.8 ± 5.2	22.2 ± 4.7	21.3 ± 4.7	21.8 ± 5.2	21.8 ± 4.2	21.6 ± 4.8	22.0 ± 5.0	0.52	0.17
Primiparous[†] (%)	47[A]	24[A]	44[A]	40[A]	29[A]	37	35	0.025	0.63
Previous stillbirth[†] (%)	0	7	6	7	6	5	6	--[‡]	0.55
Tobacco use[†] (%)	2	6	3	9	3	4	5	--[‡]	--[‡]
Early pregnancy BMI[†] (kg m^{-2})	19.8 ± 2.7	20.4 ± 2.3	20.6 ± 2.5	19.8 ± 3.0	20.0 ± 2.5	20.1 ± 2.6	20.1 ± 2.8	0.29	0.88
Underweight (BMI <18.5 kg m^{-2})[†] (%)	30[A,B]	19[A,B]	18[B]	39[A]	33[A,B]	28	28	0.02	--[‡]
Height[†] (cm)	149.9 ± 4.9	150.4 ± 5.6	151.5 ± 5.7	151.1 ± 5.4	150.8 ± 5.6	150.7 ± 5.4	150.5 ± 5.4	0.49	0.48
Short stature (<145 cm)[†] (%)	15	24	14	7	13	15	16	0.10	0.47
MUAC[†] (cm)	24.5 ± 2.5	25.0 ± 2.3	25.6 ± 2.3	24.8 ± 2.8	24.8 ± 2.3	24.9 ± 2.5	24.9 ± 2.7	0.085	0.61
Highest grade in school completed[§] (years)	6.8 ± 3.3	6.5 ± 3.1	6.4 ± 2.6	6.0 ± 3.2	6.0 ± 3.4	6.3 ± 3.1	6.2 ± 3.3	0.56	0.92
Did not attend any school (%)	7	6	6	3	10	6	8	0.57	0.32
Highest grade in school household head completed[§] (years)	4.0 ± 4.1	4.4 ± 4.0	3.2 ± 3.7	3.6 ± 4.2	4.0 ± 4.1	3.9 ± 4.0	4.1 ± 4.1	0.50	0.18
Household head did not attend any school (%)	27	25	38	34	25	30	30	0.38	0.83
Husband's occupation (%)								0.47	0.84
Farmer	21	18	19	11	11	16	16		
Business owner	18	13	19	13	22	17	19		
Transport worker	16	13	17	13	13	14	15		
Day labour	36	38	33	44	31	36	33		
Other	10	19	11	20	24	17	18		
Religion (%)								0.17	0.39
Islam	73	74	83	76	85	78	80		
Hindu	23	25	17	24	15	21	19		
Christian	4	1	0	0	0	1	1		
Buddhism						0	<1		

LNS-PL, lipid-based nutrient supplement for pregnant and lactating women; IFA, iron and folic acid; BMI, body mass index; MUAC, mid-upper arm circumference; GA, gestational age; SD, standard deviation. *Mean ± SD except where noted. [†]Missing seven participants from LNS-PL-pregnancy, one from IFA-pregnancy, two from each LNS-PL-early lactation and IFA-early lactation, four from LNS-PL-late lactation, 16 sub-study participants and 159 overall participants. [‡]Model could not converge because of insufficient sample size in some cells. [§]Includes those who never attended school as 0 grades completed. [¶]*P*(a) – tests the difference among the five sub-sample groups using *t*-tests and chi-squared test accounting for clusters. Among characteristics found to be significantly different at $P < 0.05$, we tested for group-wise differences, adjusting for multiple comparisons using the Tukey–Kramer method for multiple comparisons. Significant between-group differences at $P < 0.05$ are indicated with different superscript letters. **P(b) – tests the difference between the sub-sample and the overall study population.

Table 2. Adherence comparisons by supplementation group and pregnancy or post-partum stage

Adherence definition	LNS-PL			IFA		*P**
	Pregnancy	Early lactation	Late lactation	Pregnancy	Early lactation	
N	73	72	72	71	72	
Self-reported adherence[†] [mean ± SD; median (IQR)]	4.8 ± 3.0 6 (3–7)	4.9 ± 3.1 6 (3–7)	5.2 ± 2.6 7 (5–7)	5.9 ± 1.8 7 (5–7)	3.0 ± 1.8 3 (2–4)	0.12[¶¶]
Percent of supplements consumed[‡] (Mean)	68.7	70.2	74.4	84.9	85.9	
Adherence as recommended[§] (%)	45	42	53	56	58	0.30
Non-adherence[¶,**] (%)	22	21	17	6	19	0.19
Low-adherence[††] (%)	11	11	3	7	10	0.39
High-adherence[‡‡,§§] (%)	67[A]	68[A]	81[A]	87[A]	71[A]	0.044

LNS-PL, lipid-based nutrient supplement for pregnant and lactating women; IFA, iron/folic acid tablet; IQR, interquartile range; SD, standard deviation. **P* value calculated using mixed binary logistic regression or mixed multinomial logistic regression models, accounting for design effect and adjusted for multiple comparisons. [†]Reported number of times supplement was consumed in the past week. [‡]Percent out of 7 or 3.5 (IFA in lactation) reportedly consumed in the previous week. [§]Prevalence of reported consumption of 7 or 3-4 (IFA in lactation) supplements in the previous week. [¶]Prevalence of women who reported consuming zero supplements in the previous week. **In individual comparisons, there were significant differences between IFA pregnancy vs. early lactation ($P = 0.026$) and LNS-PL vs. IFA in pregnancy ($P = 0.039$). [††]Prevalence of reported consumption <70% and >0% of recommended supplements/week. [‡‡]Prevalence of reported consumption ≥70% of recommended supplements/week. [§§]In pairwise comparisons, there were significant differences between IFA pregnancy vs. early lactation ($P = 0.023$) and LNS-PL vs. IFA in pregnancy ($P = 0.015$). [¶¶]Adherence is treated as a multinomial variable.

Comparison of prenatal to post-natal adherence

Similarly to what was reported previously, high adherence during the post-partum period was positively associated with high overall acceptability scores (OR: 4.72; 95%CI 2.38, 9.35) and negatively associated with having a supplement count of zero at the time of the interview (OR: 0.11; 95%CI 0.05, 0.26) and with report of ever running out of supplements (OR: 0.31; 95%CI 0.14, 0.69) in unadjusted analyses. Additionally, women who had been visited by a CHW in the previous month (OR: 5.63; 95%CI 2.71, 11.67) or visited by a village health volunteer in the previous month (OR: 2.19; 95%CI 1.12, 4.28) were more likely, while those who reported previous stillbirth (OR: 0.17; 95%CI 0.05, 0.59) were less likely to report high adherence.

Among LNS-PL recipients, reported vertigo at enrollment was positively associated with high adherence in the late lactation period, but not in the other two periods, while reported vomiting at enrollment was negatively associated with high adherence in the pregnancy and late lactation periods, but not in early lactation (Table 4). Among the programmatic factors, visits by a CHW in the previous month were positively associated with high adherence in the early and late lactation periods, but not in pregnancy. None of these interactions remained significant in the final model. While a number of factors were associated with high adherence to LNS-PL in bivariate models, only reported vomiting at enrollment, high acceptability, use of reminder techniques and having zero supplements at the time of the interview remained significantly associated with high adherence in the final model determined by stepwise variable selection.

Among IFA recipients, two interactions with physiological status were identified, neither of which remained significant in the final model (Table 5). Among all IFA recipients, only being visited by a CHW in the past month and having zero supplements at the time of the interview remained significantly associated with high adherence in the stepwise determined model.

Overall, the most common participant-specific reasons given for consumption behaviour by high adherers were the beliefs that the supplements were good for the baby (84%) or themselves (80%) and made them feel healthy (50%) and strong (30%) (Appendix 4 in the Supporting Information). Bad odour of the supplement (26%) and feelings of nausea/vomiting (19%) were reported more frequently as reasons for non-adherence among

Table 3. Multivariate analysis of high adherence during pregnancy among different risk factors categories, stratified by supplement type if the interaction between risk factor and supplement type was significant

Risk factor	Yes	No	Crude models*			Adjusted model†			Interaction	
	n (%)	*n* (%)	OR	95%CI	*P*	OR	95%CI	*P*	*P**	*P*‡
Reported vomiting at enrollment									0.052	
Lipid-based nutrient supplements	21 (60.0)	26 (83.9)	0.29	0.09, 0.97	0.045					
Iron/folic acid	32 (91.4)	29 (82.9)	2.20	0.42, 11.49	0.330					
High overall acceptability									0.031	0.032
Lipid-based nutrient supplements	38 (86.4)	11 (37.9)	10.64	3.17, 35.71	<0.001	14.93	3.34, 66.67	<0.001		
Iron/folic acid	48 (87.3)	14 (87.5)	1.08	0.16, 7.30	0.940	0.91	0.10, 7.94	0.930		
Visited by CHW in the past month									0.085	
Lipid-based nutrient supplements	42 (66.7)	7 (70.0)	0.87	0.19, 3.99	0.860					
Iron/folic acid	55 (91.7)	7 (63.6)	6.03	1.02, 35.50	0.047					
Reported no appetite at enrollment	69 (75.0)	39 (88.6)	0.39	0.13, 1.15	0.088					
Food secure	66 (83.5)	45 (69.2)	2.51	1.06, 5.95	0.037					
Use of reminder techniques	45 (88.2)	66 (71.0)	3.01	1.09, 8.33	0.034					
Visited by VHV in the past month	77 (81.9)	33 (67.4)	2.06	0.88, 4.83	0.094					
Supplement count = 0 at time of interview	2 (16.7)	109 (82.6)	0.04	0.01, 0.22	<0.001	0.03	0.00, 0.21	<0.001		

CHW, community health worker; VHV, village health volunteer; OR, odds ratio; CI, confidence interval. *Each row represents the results from a separate generalized linear model of high adherence, accounting for the design effect. Where the interaction between physiological status and risk factor is significant at $P < 0.10$, data are presented stratified by supplement type. †Each row represents a factor or factor stratified by supplement type that remained significantly associated ($P < 0.05$) in the model after backwards stepwise elimination of non-significant factors. ‡*P* value for interactions that remained significant in the final adjusted model.

LNS-PL recipients than among IFA recipients. Among the programmatic factors, running out of supplements (34%) and not being at home (18%) were two of the most frequently reported reasons among non-adherers.

Results from in-depth interviews of LNS-PL adherence

Seven of the 16 women who participated in the IDI were considered lower adherers, and the rest were higher adherers. In addition, five sisters-in-law, three mothers-in-law, two husbands and eight CHWs were interviewed. The eight CHWs interviewed had worked for LAMB an average of 6.0 ± 4.1 years at the time of the interview.

Eight themes were defined based on the coded data from IDIs: acceptability, benefits, side effects, habit, control, community, pregnancy vs. post-partum and implementation challenges. Themes reported among lower and higher adherers were similar, and thus, the overall themes are reported rather than reported by interviewee group. There was 88% and 90% agreement between the main coder and the two additional coders individually and 82% agreeability among all three coders.

Organoleptic acceptability

When discussing supplement acceptability (e.g. whether and why they liked the supplements), most participants discussed their preferences regarding the organoleptic

Table 4. Multivariate analysis of high adherence to lipid-based nutrient supplements among different risk factors categories, stratified by pregnancy, early lactation and late lactation if the interaction between risk factor and physiological status was significant

Risk factor	Yes	No	Crude models*			Adjusted model†			Interaction
	n (%)	*n* (%)	OR	95%CI	*P*	OR	95%CI	*P*	*P**
Reported vomiting at enrollment						0.34	0.14, 0.80	0.014	0.037
Pregnancy	21 (60.0)	26 (3.9)	0.29	0.09, 0.97	0.045				
Early lactation	24 (75.0)	24 (63.2)	1.75	0.61, 5.05	0.295				
Late lactation	19 (67.9)	37 (92.5)	0.17	0.04, 0.78	0.023				
Reported vertigo at enrollment									0.068
Pregnancy	37 (69.8)	10 (76.9)	0.72	0.16, 3.21	0.664				
Early lactation	33 (67.4)	15 (71.4)	0.83	0.26, 2.59	0.738				
Late lactation	45 (90.0)	11 (61.1)	6.13	1.41, 26.32	0.017				
Visited by CHW in the past month									0.056
Pregnancy	42 (66.7)	7 (70.0)	0.87	0.19, 3.99	0.857				
Early lactation	46 (78.0)	3 (23.1)	11.80	2.74, 50.85	0.001				
Late lactation	49 (86.0)	9 (60.0)	4.00	1.00, 16.05	0.051				
Use of reminder techniques	75 (81.5)	81 (64.8)	0.12	0.03, 0.52	0.005	4.41	1.65, 11.76	0.014	
High overall acceptability	112 (88.2)	44 (48.9)	7.52	3.76, 14.93	<0.001	8.62	3.53, 20.83	<0.001	
High smell acceptability	62 (89.9)	94 (63.5)	4.69	1.97, 11.24	<0.001				
High taste acceptability	89 (84.8)	67 (59.8)	3.40	1.73, 6.67	0.019				
High colour acceptability	114 (79.7)	42 (56.8)	2.99	1.56, 5.71	0.001				
High consistency acceptability	109 (79.1)	54 (61.4)	2.13	1.13, 4.00	0.019				
Visited by VHV in the past month	96 (78.1)	59 (63.4)	1.98	1.02, 3.82	0.043				
Hold belief that eating more can prevent malnutrition	75 (78.1)	76 (66.7)	1.79	0.96, 3.32	0.067				
Supplement count = 0 at time of interview	8 (24.2)	148 (80.4)	0.08	0.03, 0.21	<0.001	0.04	0.01, 0.13	<0.001	

CHW, community health worker; VHV, village health volunteer; OR, odds ratio; CI, confidence interval. *Each row represents the results from a separate generalized linear model of high adherence, accounting for the design effect. Where the interaction between physiological status and risk factor is significant at $P < 0.10$, data are presented stratified by physiological status. †Each row represents a factor or factor stratified by physiological status that remained significantly associated ($P < 0.05$) in the model after backwards stepwise elimination of non-significant factors.

properties of the supplement. Most spontaneous comments regarding the taste and smell of LNS-PL were negative, and some participants and CHWs suggested that changing the taste would make it more acceptable. One CHW (CHW09) explained: 'Jononi is not sweet… I think it would be better to add sweet, sour and hot taste in it. The mothers would get a good taste and would be more interested in it'. The taste and smell of LNS-PL were sometimes associated with side effects and not being able to eat LNS-PL during pregnancy, as explained by one of the low adherers (participant04) interviewed: 'I think the pregnant women get a taste in their mouth in eating Jononi. All the pregnant women vomit during their pregnancy period. They cannot eat it [Jononi]… It would be good if it were made sweet'. Despite the negative comments, there were also participants who found the taste of LNS-PL acceptable, such as one high adherer (participant10) who stated: 'I felt good to take, so it was easy for me… It tastes good to take'. Comments regarding high acceptability and ease of taking the supplement were frequently cited together.

Perceived benefits

Women, CHWs and relatives reported that LNS-PL improves the health and nutrition of women and their children and increases child intelligence, the quantity of breast milk and the woman's strength. One of the high adherers (participant08) described why other women take LNS-PL during pregnancy: 'The body becomes sick during pregnancy period. If it [Jononi] is eaten, the body will be well. The baby will get nutrition. Their own health will also be well. So, they eat it… Another thing is that the intelligence of the baby will be

Table 5. Multivariate analysis of high adherence to iron/folic acid among different risk factors categories, stratified by pregnancy and early lactation if the interaction between risk factor and physiological status was significant

Risk factor	Yes	No	Crude models*			Adjusted model†			Interaction
	n (%)	*n* (%)	OR	95%CI	*P*	OR	95%CI	*P*	*P**
Food secure									0.034
Pregnancy	38 (95.0)	24 (77.4)	5.75	0.90, 37.04	0.063				
Early lactation	20 (64.5)	31 (75.6)	0.57	0.17, 1.87	0.340				
Primiparous									0.093
Pregnancy	29 (90.6)	32 (84.2)	2.02	0.37, 11.11	0.400				
Early lactation	14 (58.3)	35 (76.1)	0.37	0.11, 1.27	0.110				
Reported no appetite at enrollment	66 (73.3)	44 (88.0)	0.39	0.14, 1.14	0.084				
Visited by CHW in the past month	97 (86.6)	16 (51.6)	5.38	1.97, 14.71	0.001	3.88	1.31, 11.49	0.015	
Visited by VHV in the past month	76 (85.4)	37 (68.5)	2.23	0.88, 5.60	0.089				
Reported ever running out of supplements	10 (52.6)	102 (82.9)	0.30	0.09, 0.97	0.044				
Supplement count = 0 at time of interview	4 (33.3)	109 (83.2)	0.09	0.02, 0.42	0.003	0.14	0.03, 0.74	0.021	

CHW, community health worker; VHV, village health volunteer; OR, odds ratio; CI, confidence interval. *Each row represents the results from a separate generalized linear model of high adherence, accounting for the design effect. Where the interaction between physiological status and risk factor is significant at $P < 0.10$, data are presented stratified by physiological status. †Each row represents a factor or factor stratified by physiological status that remained significantly associated ($P < 0.05$) in the model after backwards stepwise elimination of non-significant factors.

good'. Similarly, one of the low-adherers (participant15) reflected on her experience with LNS-PL: 'Many things happen in our health… No illness will come; my health will remain good, for these… Many kinds of illness… cough, fever, pain, cold, coughs all… It was physical weakness which got better by taking Jononi…' Despite there not being any messaging in the LAMB trainings about LNS-PL increasing the quantity of breast milk, this idea was reported commonly among interviewees. This was explained in detail by one sisters-in-law (relative04): 'Children do not get enough milk if a woman does not take it. I mean, if a woman stops taking Jononi for 1 day, she produces less milk. And if the woman takes it she can produce more milk… The child cries when the mother does not take Jononi. The child does not get milk… The child gets adequate breast milk if the mother takes Jononi'.

Many stated that LNS-PL made women stronger and healthier, and there were also reports that being too weak made it challenging to consume LNS-PL. One woman reported that some women's bodies cannot tolerate so much nutrition, which makes taking LNS-PL challenging.

Perceived side effects

Most women stated that they experienced nothing bad from the supplements. However, some of the same women commented on feeling unwell, with the primary symptom being vomiting. The relationship between feeling unwell and LNS-PL was inconsistent: some women perceived feeling unwell or vomiting because of LNS-PL, and others reported that they could not take LNS-PL because they were unwell or experienced vomiting. For example, one woman (participant02) explained, 'Now I would have eaten everyday if my vomiting had stopped. I am still vomiting. For this fear, I don't eat'. In contrast, one CHW (CHW09) stated, 'Still they found it foul-smelling and it causes vomiting. Its smell causes vomiting if they take it in hand'.

Concerns about needing a Caesarean-section delivery were also reported. Many of the CHWs explained that it was an initial concern that dissipated over time. Two participants reported this fear along with two family members. This fear seemed to be perpetuated in the beginning by members of the community, then alleviated over time and after observation of other women giving birth to healthy babies after taking LNS-PL.

Habit

Women commonly reported that once taking LNS-PL became a habit, it was easy to take it regularly. However, it was not clear how women were able to establish the habit. Many women described setting routines to help to remember to take LNS-PL, such as always taking during certain times of day, before or after a specific meal or keeping the supplements out. Some women also reported that members of their family, such as their children, husband or mother-in-law, would remind them to consume the supplement. This was reflected in a quote from one mother-in-law (relatives07), who stated: 'If she forgets to take, I remind her, "Take, why don't you take?" I get angry. If she forgets, I remind her, "You must take 1 daily. It also has nutrition. It is good. Taking it is good. The child will get milk. Your health will also remain good." '

Forgetting to take LNS-PL was a barrier to adherence. Reasons for forgetting included busyness, taking care of a crying baby or travel. Motivation also seemed to be a factor related to habit formation. When asked why some women take the supplements and some do not, one CHW (CHW07) explained: 'They are habituated, plus they are getting its benefit. So they are taking it. Some do not take it for idleness…lazy. They think it is a burden'.

Control

Although not a widespread theme among participants, perceptions of less control over taking LNS-PL or challenges associated with taking it were barriers to consumption. For example, one low adherer (participant04) reported, 'I could not eat because of vomiting. So, he [my husband] forbade and I did not take it anymore'. However, it was uncommon for women to report that they were forbidden from consuming the supplements.

Community and social support

Programme and study staff provided advice to women about how and why to take LNS-PL, and in general, their advice was valued, and women felt good when others were telling them to take LNS-PL. As explained by one high adherer (participant12), 'The advice was good… I take it to be good advice because it keeps my health good, keeps the child well and gives nutrition too'. Quotes from CHWs often indicated that they thought their support to women was highly important, whereas women and relatives considered the family the more important providers of support for women. As an example, one high adherer (participant01) stated, 'I have my son. He sometimes cuts the packet and put it on my plate… He is 6 or 7 years old… He cuts it and asks me to eat it. … I feel good that my son is giving it to me'.

Pregnancy vs. post-partum comparison

Some women reported that their intake of LNS-PL differed, and some women reported that their intake was the same during these two times. Among women who reported that it was different, some said that they consumed less during pregnancy and some reported that they consumed more. Women who reported taking less during pregnancy said they did so because they disliked the taste and smell or because of side effects, while other participants reported taking less LNS-PL post-partum because they perceived that LNS-PL does not provide the same benefits to their child after birth or because they were too busy and forgot to consume it.

Implementation challenges

This theme encompasses a wide variety of programme implementation challenges, including supplement distribution protocols or messaging about LNS-PL, which may directly or indirectly influence women's adherence to taking LNS-PL. The CHWs shared their difficulties with the initial LNS-PL distribution, most of which were reduced or eliminated over time. In the beginning, many women were sceptical of LNS-PL and concerned that it was being provided from a Christian faith-based organization. CHWs explained that once they counselled women, they started taking LNS-PL. Similarly, the novelty of LNS-PL was an initial challenge for CHWs because they had to explain to women and the community what LNS-PL was and why it was being distributed. As described by one CHW (CHW01), 'They [the women] have never taken food like this. It was not a food of Bangladesh, on the packet it is written. So it was hard to make them understand. Now they

understand. Now there is no problem'. Additionally, LNS-PL being a foreign product and part of research study were mostly considered positive attributes, although there was some initial scepticism of LNS-PL being foreign.

There were some reports of LNS-PL being shared or destroyed. Most reports of LNS-PL being shared were related to other's curiosity. CHWs reported that a small number of women destroyed their supplements in the beginning because they did not want to consume them.

Ongoing difficulties included women not being at home when the CHW came to deliver supplements, general supplement distribution challenges and the monotony of taking LNS-PL. Supplement distribution was an initial challenge for the CHWs, and for some, it remained a challenge throughout the study.

Overall, women seemed knowledgeable about the recommendations related to LNS-PL and said that they took it as recommended. Several interviewees perceived LNS-PL as a product for poor people who could not afford other nutritious foods, because LNS-PL is very nutritious and was provided free of cost. This was typically considered a positive attribute of LNS-PL.

Discussion

In this setting, we found that self-reported adherence to supplementation recommendations was approximately 71% for LNS-PL and 85% for IFA. High adherence was strongly associated with programmatic factors, such as having a consistent supply of supplements, visits and support from CHWs and the organoleptic properties of the supplements. Women who reported high adherence (for either LNS-PL or IFA) listed numerous perceived benefits to themselves and their infants. In contrast, low adherers attributed their consumption behaviour to running out of supplements, not being at home, aversion to the smell of the supplement or nausea and vomiting.

The LNS-PL adherence rates in this study were slightly lower than reported for other prenatal supplements in similar contexts, as determined via pill count or self-report, which have been 79–95% (Aguayo 2004; Seck & Jackson 2008; Shankar *et al.* 2009; Kulkarni *et al.* 2010; Zavaleta *et al.* 2012). We did not find a difference in reported LNS-PL adherence rates between pregnancy, early lactation and late lactation periods. However, different reasons were provided for not taking LNS-PL during pregnancy compared with post-partum. For example, the smell and taste of LNS-PL and nausea and vomiting were reasons for not taking LNS-PL during pregnancy, while being too busy after the baby was born and not perceiving any benefits were reasons for lower adherence post-partum.

We found little evidence that personal and family characteristics were associated with adherence to either LNS-PL or IFA, with the exception of household food security. Food security was positively associated with high adherence to IFA during pregnancy only, but not associated with adherence to LNS-PL at any time. Taking IFA without food could have contributed to feelings of stomach upset, a common side effect of IFA supplements during pregnancy (Galloway & McGuire 1994; Hyder *et al.* 2002), which could have caused more food insecure women to consume less IFA. Another explanation could be that IFA increased appetite, as previously reported among adolescent Indian girls (Kanani & Poojara 2000) and Kenyan school children (Lawless *et al.* 1994). Thus, food insecure women could have been less adherent to IFA because they were not able to satisfy their increased appetite. This is a phenomenon that has been observed with decreased adherence to antiretroviral therapy among food insecure women in Uganda (Weiser *et al.* 2010).

Forgetfulness was reported among 12% of low adherers and non-adherers in both the LNS-PL and IFA groups, a theme reiterated in IDIs. In the IDIs, some participants articulated specific reminder techniques that they used to help them remember to consume LNS-PL every day, but it was not clear how some women were able to effectively establish the habit. Other studies have identified forgetfulness as a barrier to high adherence (Seck & Jackson 2008; Barbour *et al.* 2012; Zavaleta *et al.* 2012) and reminder techniques as a facilitator (Galloway & McGuire 1994; Lacerte *et al.* 2011). The use of reminder techniques, such as devising a habit-promoting environment or development of reminder tools, such as mobile phone text reminders, emotive cue-response health education

messages along with guidance on implementation intentions or behaviour-change campaigns focusing on emotional drivers, may be an effective means of developing the supplement consumption habit (Wood *et al.* 2005; Gollwitzer & Sheeran 2006; Biran *et al.* 2014; Kannisto *et al.* 2014).

The supplement's organoleptic properties were consistently associated with adherence to LNS-PL. Taste and smell are important considerations for nutritional products targeted to pregnant women, a period in which nausea, vomiting and food aversions are common. These factors were consistently reported in surveys as well as the IDIs to be associated with adherence to LNS-PL, yet they were of less concern to the IFA group. In comparison, in an acceptability evaluation of IFA and MMN tablets in Malawi, women reported that the odours of the two supplements were not acceptable (Aguayo 2004), which could be a barrier to adherence. Variability in the acceptability of organoleptic properties of perinatal supplements in Mexico has also been reported (Young *et al.* 2010). While it may be possible to improve adherence by modifying the smell and taste of LNS-PL, another concern that emerged from the IDIs was the monotony of consuming the same product every day for approximately one year, although the impact on adherence was unclear. Thus, perhaps providing a selection of different flavours or products to choose from would have a greater positive impact on adherence than simply altering the smell and flavour of a single product. Providing some choices, although not too many choices, can increase satisfaction (Iyengar & Lepper 2000), allows a greater sense of autonomy and thereby improve behaviour (Ryan & Deci 2000).

Our acceptability findings differ from the high acceptability found in a preliminary 14-day trial conducted in this region prior to the start of the programme (Mridha *et al.* 2012), a finding that was also reported in similar short-term trials in Ghana and Malawi (Adu-Afarwuah *et al.* 2011; Phuka *et al.* 2011). The differences could be due to the extended period of time that women were expected to consume LNS-PL. The acceptability trial only provided a 14-day supply of the supplements, which may not be long enough to assess sustained acceptability. In addition, the acceptability trial recruited women in their second or third trimester of pregnancy, whereas the women in the larger trial began supplementation at an average gestational age of 13.1 weeks, a period when nausea is more common. Women may have developed an aversion to LNS-PL if first exposed during early pregnancy, which may have had a lasting influence on adherence to LNS-PL.

Programmatic factors such as visiting the participants at least once a month and ensuring that the participant's supplement supply remains uninterrupted were significantly associated with high adherence. It is well documented that programme factors, such as guaranteeing access to supplements, can be important drivers of or barriers to prenatal supplement adherence (Galloway & McGuire 1994; Galloway *et al.* 2002; Lutsey *et al.* 2008; Shankar *et al.* 2009; Lacerte *et al.* 2011). Running out of supplements, although reported by only 12.6% of the survey sample, was the most common reason reported by LNS-PL non-adherers for consuming zero supplements in the previous week, a factor also evident in the IDIs. Women's travel also presented a particular challenge for CHWs and was a barrier to high adherence. Adherence could be improved by ensuring regular visits by health workers and health worker's adherence to supplement distribution protocol. Mobile Health approaches targeting health workers have been used successfully to improve health worker adherence to programme protocols (Zurovac *et al.* 2011; Kallander *et al.* 2013).

The IDIs provided insight into the initial programme challenges. The concerns related to the Christian faith of LAMB were surprising given that LAMB has been well established with good rapport in the community. While LAMB has been providing services to this community for approximately 40 years, it is possible that scepticisms arose because this was a novel food-based intervention, as opposed to LAMB's traditional health information or medical services. In Bangladesh, in addition to religious food regulations (Muslim and Hindu), there are also strongly held beliefs related to appropriate food during pregnancy and illness. With these strongly held beliefs that influence attitudes and behaviours, families could have been concerned that the organization was not sensitive enough to religious dietary restrictions. CHWs, participants and family members reported that these initial challenges were eventually

overcome and most women took the supplements. Overcoming the initial challenges required community sensitization, as well as work from the CHWs to counsel individuals, families and community members.

There are a number of important limitations in this study. Firstly, we rely primarily on self-reported data. Self-reported adherence has been found to be biased and thought to be an overestimate of true adherence. Self-reported adherence in contexts other than prenatal supplementation has been compared with medication event monitoring systems, considered to be a gold standard measure of adherence and found to have moderate correlation 0.45 (95% CI: 0.34–0.56; $P = 0.001$) (Shi *et al.* 2010). Adherence estimates based on supplement count are typically considered a more reliable measure of adherence and less biased compared with self-report, although both have limitations. One study found that medication event monitoring systems data were poorly correlated with self-report data (0.35) within the context of MMN supplementation during pregnancy (Jasti *et al.* 2005). Secondly, because data collection for this sub-study was not longitudinal, we are unable to examine how individual women adjust consumption over time, and instead rely on comparisons across different women at different stages of pregnancy and post-partum. Thirdly, we were not able to distinguish between adherence during early and late pregnancy, which would have been informative in understanding whether barriers to adherence differed across this time period. Additionally, because the recommended frequency of consumption of the IFA tablets differed during the early lactation period (compared with during pregnancy or to the LNS-PL recommendations), it is difficult to determine whether differences in adherence during this period were due to the supplement type, physiological state or recommendation regimen. Lastly, although few women were screened out of the study based on the eligibility criteria ($n = 399$ out of 4410 screened), the generalizability of these results is limited to women who do not have plans to move far distances within 3 years after becoming pregnant and begin supplementation at or before 20-week gestation. However, because the selection criteria were applied equally across all intervention groups, this should not have introduced bias into the group comparisons.

Despite these limitations, these findings provide some of the first comprehensive information regarding sustained LNS-PL usage over pregnancy and lactation. This is the first study to explore adherence to LNS-PL among pregnant and lactating women in the context of an effectiveness trial and to consider personal, physiological and programmatic factors associated with adherence. Furthermore, the mixed-methods approach allowed us to triangulate the findings from the quantitative and qualitative assessments for a more comprehensive understanding of adherence to LNS-PL in this context.

Recommendations

As others consider provision of LNS-PL to pregnant and lactating women in similar contexts, the lessons learned from this study can be used to guide the development of other such programmes. These include the following:

1. Consider the differences in barriers to adherence in the pregnancy and post-partum periods such as food aversions and nausea/vomiting during pregnancy and lack of time during post-partum and that women may be motivated differently during these life stage periods based on their needs and those of their fetus or infant.
2. In populations where women often travel during pregnancy or shortly after birth, plan for ways to maintain adequate supplement supplies, such as provision of travel bags for the supplements to women, or establish a mobile-based system for women to easily inform their health worker of travel plans and supplement needs.
3. Recognize that habit formation is an important component of high adherence and consider approaches to improve habit formation, such as involvement of family members, use of mobile phone text reminders or calendars or creation of targeted behaviour-change campaigns.
4. Explore ways of enhancing the acceptability of LNS-PL during pregnancy, especially when food aversions and nausea are common. Monotony of the supplement regimen may be a barrier to adherence over a long period of time. Both issues could possibly be addressed if women are provided with

choices, either with the product flavours or product form. Alternatively, a less frequent dosing regimen may increase overall adherence (Haynes *et al.* 2008).

Where dietary adequacy is not reliably achieved through locally available foods alone, LNS-PL offers the potential to improve the nutritional quality of maternal diets. Our data suggest that while adherence to LNS-PL is comparable with that of IFA in this context, there is the potential to improve adherence through programmatic and product enhancements, although these enhancements may increase costs. As the impact evaluation has provided evidence that distributing LNS-PL to women decreased newborn stunting and small head circumference (Mridha *et al.* 2016), the results from this sub-study can be used to develop and improve the quality and cost effectiveness of the LNS-PL distribution and communication strategies within community health and nutrition programmes.

Acknowledgements

The authors acknowledge Janet Peerson from UC Davis for her statistical advice; Lia Fernald from UC Berkeley, Joseph Cummins from UC Riverside, Louise Day from LAMB and Zeina Maalouf-Manasseh from FANTA for their technical inputs and feedback on the manuscript; the Rang-Din Nutrition Study Process Evaluation Team and LAMB for their dedication to implement the study; and the participants for their support and participation.

Sources of funding

This study was carried out with funding from the Office of Health, Infectious Diseases, and Nutrition, Bureau for Global Health, U.S. Agency for International Development (USAID) under terms of cooperative agreement no. AID-OAA-A-12-00005, through the Food and Nutrition Technical Assistance III Project (FANTA), managed by FHI 360, and from NIH Research Training grant no. R25 TW009343 funded by the Fogarty International Center, Office of Behavioral and Social Sciences Research, Office of Research on Women's Health, Office of AIDS Research, National Institute of Mental Health, National Institute on Drug Abuse and the University of California Global Health Institute. The contents of this article are the responsibility of the authors and do not necessarily reflect the views of USAID, NIH or the US Government.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

All authors were involved in the design or implementation of the study and reviewed and approved the final manuscript. KLH and CPS led the analysis and interpretation with substantive inputs from KGD and SLM. MKM and SAV provided contributions to the study design and interpretation. KLH, MM, MKM and SH were involved in the data collection. KLH wrote the first draft of the manuscript with substantive inputs from CPS and KGD.

Trial registration

ClinicalTrials.gov identifier: NCT01715038

References

Adu-Afarwuah S., Lartey A., Okronipa H., Ashorn P., Zeilani Z., Peerson J. *et al.* (2015) Lipid-based nutrient supplement increases the birth size of infants of primiparous women in Ghana. *The American Journal of Clinical Nutrition* **101**, 835–46.

Adu-Afarwuah S., Lartey A., Zeilani M. & Dewey K.G. (2011) Acceptability of lipid-based nutrient supplements (LNS) among Ghanaian infants and pregnant or lactating women. *Maternal & Child Nutrition* **7**, 344–356.

Aguayo V.M. (2004) Acceptability of multiple micronutrient supplements by pregnant and lactating women in Mali. *Public Health Nutrition* **8**, 33–37

Am W.H. (2010) Compliance to intake of prenatal supplements among rural pregnant women – observational study in two sub-districts in rural Bangladesh. *Malaysian Journal of Nutrition* **16**, 323–325.

Ashorn P., Alho L., Ashorn U., Cheung Y.B., Dewey K.G., Harjunmaa U. *et al.* (2015) The impact of lipid-based

nutrient supplement provision to pregnant women on newborn size in rural Malawi: a randomized controlled trial. *The American Journal of Clinical Nutrition* **101**, 387–397.

Barbour R.S., Macleod M., Mires G. & Anderson A.S. (2012) Uptake of folic acid supplements before and during pregnancy: focus group analysis of women's views and experiences. *Journal of Human Nutrition and Dietetics* **25**, 140–147.

Biran A., Schmidt W.P., Varadharajan K.S., Rajaraman D., Kumar R., Greenland K. *et al.* (2014) Effect of a behaviour-change intervention on handwashing with soap in India (SuperAmma): a cluster-randomised trial. *Lancet Glob Health* **2**, e145–e154.

Chaparro C.M. & Dewey K.G. (2010) Use of lipid-based nutrient supplements (LNS) to improve the nutrient adequacy of general food distribution rations for vulnerable sub-groups in emergency settings. *Maternal & Child Nutrition* **6** (Suppl 1), 1–69.

Coates J., Swindale A. & Bilinsky P. (August 2007) *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide V.3*. Food and Nutrition Technical Assistance Project, Academy for Educational Development: Washington, D.C..

Creswell J.W. & Miller D.L. (2000) Determining validity in qualitative inquiry. *Theory into Practice* **39**, 124–130.

Galloway R., Dusch E., Elder L., Achadi E., Grajeda R., Hurtado E. *et al.* (2002) Women's perceptions of iron deficiency and anemia prevention and control in eight developing countries. *Social Science and Medicine* **55**, 529–544.

Galloway R. & McGuire J. (1994) Determinants of compliance with iron supplementation: supplies, side effects, or psychology? *Social Science and Medicine* **39**, 381–390.

Ghanekar J., Kanani S. & Patel S. (2002) Toward better compliance with iron-folic acid supplements: understanding the behavior of poor urban pregnant women through ethnographic decision models in Vadodara, India. *Food and Nutrition Bulletin* **23**, 65–72.

Glanz K., Rimer B.K. & Viswanath K.V. (2008) *Health Behavior and Health Education: Theory, Research, and Practice*. Wiley: John & Sons, Incorporated.

Glaser B.G. & Strauss A.L. (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine: Chicago.

Gollwitzer P.M. & Sheeran P. (2006) Implementation intentions and goal achievement: a meta-analysis of effects and processes. *Advances in Experimental Social Psychology* 69–119.

Haynes R.B., Ackloo E., Sahota N., McDonald H.P. & Yao X. (2008) Interventions for enhancing medication adherence. *Cochrane Database of Systematic Reviews*, 2: CD000011.

Huybregts L., Roberfroid D., Lanou H., Menten J., Meda N., Van Camp J. *et al.* (2009) Prenatal food supplementation fortified with multiple micronutrients increases birth length: a randomized controlled trial in rural Burkina Faso. *American Journal of Clinical Nutrition* **90**, 1593–1600.

Hyder S.M., Persson L.A., Chowdhury A.M. & Ekstrom E.C. (2002) Do side-effects reduce compliance to iron supplementation? A study of daily- and weekly-dose regimens in pregnancy. *Journal of Health, Population and Nutrition* **20**, 175–179.

Iyengar S.S. & Lepper M.R. (2000) When choice is demotivating: can one desire too much of a good thing? *Journal of Personal and Social Psychology* **79**, 995–1006.

Jasti S., Siega-Riz A.M., Cogswell M.E., Hartzema A.G. & Bentley M.E. (2005) Pill count adherence to prenatal multivitamin/mineral supplement use among low-income women. *The Journal of Nutrition* **135**, 1093–1101.

Kallander K., Tibenderana J.K., Akpogheneta O.J., Strachan D.L., Hill Z., ten Asbroek A.H. *et al.* (2013) Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low- and middle-income countries: a review. *Journal of Medical Internet Research* **15**, e17.

Kanani S.J. & Poojara R.H. (2000) Supplementation with iron and folic acid enhances growth in adolescent Indian girls. *The Journal of Nutrition* **130**, 452S–455S.

Kannisto K.A., Koivunen M.H. & Valimaki M.A. (2014) Use of mobile phone text message reminders in health care services: a narrative literature review. *Journal of Medical Internet Research* **16**, e222.

Kayira D., Bentley M.E., Wiener J., Mkhomawanthu C., King C.C., Chitsulo P. *et al.* (2012) A lipid-based nutrient supplement mitigates weight loss among HIV-infected women in a factorial randomized trial to prevent mother-to-child transmission during exclusive breastfeeding. *The American Journal of Clinical Nutrition* **95**, 759–765.

Kulkarni B., Christian P., LeClerq S.C. & Khatry S.K. (2010) Determinants of compliance to antenatal micronutrient supplementation and women's perceptions of supplement use in rural Nepal. *Public Health Nutrition* **13**, 82–90.

Lacerte P., Pradipasen M., Temcharoen P., Imamee N. & Vorapongsathorn T. (2011) Determinants of adherence to iron/folate supplementation during pregnancy in two provinces in Cambodia. *Asia-Pacific Journal of Public Health* **23**, 315–323.

Lawless J.W., Latham M.C., Stephenson L.S., Kinoti S.N. & Pertet A.M. (1994) Iron supplementation improves appetite and growth in anemic Kenyan primary school children. *The Journal of Nutrition* **124**, 645–654.

Lutsey P.L., Dawe D., Villate E., Valencia S. & Lopez O. (2008) Iron supplementation compliance among pregnant women in Bicol, Philippines. *Public Health Nutrition* **11**, 76–82.

Mridha M., Matias S., Chaparro C., Paul R., Hussain S., Vosti S. *et al.* (2016) Lipid-based nutrient supplements (LNS) for pregnant women reduce newborn stunting in a cluster-randomized controlled effectiveness trial in Bangladesh. *The American Journal of Clinical Nutrition* **103**, 1–14.

Mridha M.K., Chaparro C.M., Matias S.L., Hussain S., Munira S., Saha S. *et al.* (2012) *Acceptability of Lipid-based Nutrient Supplements and Micronutrient Powders among Pregnant and Lactating Women and Infants and Young Children in Bangladesh and Their Perceptions about Malnutrition and Nutrient Supplements*. FHI 360/ FANTA-2 Bridge: Washington, DC.

Oriji V.K., Enyindah C.E. & Nyeche S. (2011) Factors determining compliance to routine iron supplementation in pregnancy at the University of Portharcout Teaching Hospital. *Nigerian Journal of Medicine* **20**, 131–134.

Phuka J., Ashorn U., Ashorn P., Zeilani M., Cheung Y.B., Dewey K.G. *et al.* (2011) Acceptability of three novel lipid-based nutrient supplements among Malawian infants and their caregivers. *Maternal & Child Nutrition* **7**, 368–377.

Ryan R.M. & Deci E.L. (2000) Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist* **55**, 68–78.

Seck B.C. & Jackson R.T. (2008) Determinants of compliance with iron supplementation among pregnant women in Senegal. *Public Health Nutrition* **11**, 596–605.

Shankar A.V., Asrilla Z., Kadha J.K., Sebayang S., Apriatni M., Sulastri A. *et al.* (2009) Programmatic effects of a large-scale multiple-micronutrient supplementation trial in Indonesia: using community facilitators as intermediaries for behavior change. *Food and Nutrition Bulletin* **30**, S207–S214.

Shi L., Liu J., Fonseca V., Walker P., Kalsekar A. & Pawaskar M. (2010) Correlation between adherence rates measured by MEMS and self-reported questionnaires: a meta-analysis. *Health and Quality of Life Outcomes* **8**, 99.

Tessema J., Jefferds M.E., Cogswell M. & Carlton E. (2009) Motivators and barriers to prenatal supplement use among minority women in the United States. *Journal of the American Dietetic Association* **109**, 102–108.

Weiser S.D., Tuller D.M., Frongillo E.A., Senkungu J., Mukiibi N. & Bangsberg D.R. (2010) Food insecurity as a barrier to sustained antiretroviral therapy adherence in Uganda. *PLoS One* **5**, e10340.

Wood W., Witt M.G. & Tam L. (2005) Changing circumstances, disrupting habits. *Journal of Personal and Social Psychology* **88**, 918–933.

Young S.L., Blanco I., Hernandez-Cordero S., Pelto G.H. & Neufeld L.M. (2010) Organoleptic properties, ease of use, and perceived health effects are determinants of acceptability of micronutrient supplements among poor Mexican women. *The Journal of Nutrition* **140**, 605–611.

Zavaleta N., Caulfield L.E., Figueroa A. & Chen P. (2012) Patterns of compliance with prenatal iron supplementation among Peruvian women. *Maternal & Child Nutrition* **10**, 198–205.

Zeng L., Yan H., Cheng Y., Dang S. & Dibley M.J. (2009) Adherence and costs of micronutrient supplementation in pregnancy in a double-blind, randomized, controlled trial in rural western China. *Food and Nutrition Bulletin* **30**, S480–S487.

Zurovac D., Sudoi R.K., Akhwale W.S., Ndiritu M., Hamer D. H., Rowe A.K. *et al.* (2011) The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. *Lancet* **378**, 795–803.

Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site.