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Reducing wasting in young children with preventive supplementation: a cohort study in Niger

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Abstract

Objective—To compare the incidence of wasting, stunting and mortality among children aged 6 to 36 mo receiving preventive supplementation with either ready-to-use-supplementary-foods (RUSF) or ready-to-use-therapeutic-foods (RUTF).

Subjects and methods—Children aged 6 to 36 mo in 12 villages of Maradi, Niger ($n = 1645$) received a monthly distribution of RUSF (247 kcal / 3 spoons / day) for 6 mo or RUTF (500 kcal sachet / day) for 4 mo. We compared the incidence of wasting, stunting, and mortality among children receiving preventive supplementation with RUSF vs. RUTF.

Results—The effectiveness of RUSF supplementation depended on receipt of a previous preventive intervention. In villages where a preventive supplementation program was previously implemented, the RUSF strategy was associated with a 46% (95% CI: 6% to 69%) and 59% (95% CI: 17% to 80%) reduction in wasting and severe wasting, respectively. In contrast, in villages where the previous intervention was not implemented, we found no difference in the incidence of wasting or severe wasting by type of supplementation. Compared to the RUTF strategy, the RUSF strategy was associated with a 19% (95% CI: 0% to 34%) reduction in stunting overall.

Conclusions—We found that the relative performance of a 6-mo RUSF supplementation strategy vs. 4-mo RUTF strategy varied with receipt of a previous nutritional intervention. Contextual factors will continue to be important in determining the dose and duration of supplementation that will be most effective, acceptable, and sustainable for a given setting.

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Keywords

ready-to-supplementary-foods; ready-to-use-therapeutic-foods; prevention; wasting; child malnutrition; Niger

Introduction

In recent years, ready-to-use-therapeutic-foods (RUTF) have transformed the treatment of child malnutrition. These energy-dense micronutrient spreads often made of peanuts, oil, sugar, and milk powder have been shown effective in the treatment of severe wasting in children and have made large-scale community-based care and treatment possible (1–5). The acceptability and effectiveness of RUTF have led to the development of a variety of new, targeted ready-to-use spreads, including ready-to-use-supplementary-foods (RUSF). RUSF were developed to serve as a supplement to traditional complementary foods and were specifically designed with the prevention of malnutrition among children aged 6 to 36 mo in mind. Compared to RUTF, which provide large quantities of energy and the micronutrients needed by children with severe wasting, RUSF provide lower energy and the recommended daily allowance of micronutrients when combined with the local diet in a small daily dose of spread (Table 1). The RUSF formulation developed for use in prevention, rather than treatment, and the lower cost relative to RUTF have contributed to an increasing interest in the use of RUSF within nutritional programs.

In April 2007, Médecins sans Frontières (MSF) initiated a preventive program in which supplementation with the new RUSF formulation was offered to children aged 6 to 36 mo during the months preceding the harvest season throughout the district of Guidan Roundji, Niger (6). In order to assess the effectiveness of preventive supplementation with RUSF vs. RUTF, we used data collected in 6 villages in Guidan Roundji that received RUSF through the district-wide program and 6 villages in the district of Madarounfa that received preventive supplementation with RUTF. In this study, we present a comparison of the incidence of wasting, stunting and mortality over 12 mo of follow-up among children aged 6 to 36 mo receiving preventive supplementation with either RUSF or RUTF.

Methods

Starting in August 2006, 3533 children aged 6 to 60 mo were enrolled in a cluster randomized trial to examine the effectiveness of short-term supplementation of RUTF in the prevention of wasting. Details of the trial design have been previously published (7). Briefly, non-malnourished children with weight-for-height $\geq 80\%$ of the National Center for Health Statistics (NCHS) reference median in 6 randomly selected villages in the Maradi region of Niger (3 in the Madarounfa district and 3 in the Guidan Roundji district) received a monthly distribution of RUTF (1 sachet per day, 92 g [500 kcal]; Plumpy'nut; Nutriset, Malaunay, France) for 3 mo preceding the harvest (August to October). Children in 6 other villages (3 in the Madarounfa district and 3 in Guidan Roundji district) received no preventive supplementation. Surveillance activities, including anthropometric measurements and physical examinations, were conducted on a monthly basis by field teams in each of the 12 study villages. In April 2007, after 8 mo of follow-up, the trial was interrupted due to the observed benefit of supplementation with RUTF to reduce the incidence of wasting.

With the successful implementation of a community-based prevention program using RUTF and the development of products specifically designed for prevention in young children, MSF, in collaboration with the Ministry of Health, initiated a district-wide preventive program in Guidan Roundji using the new RUSF formulation. In the preventive program,

all children 60–85 cm tall (aged 6 to 36 mo) were eligible for participation in a monthly distribution of RUSF (3 spoons per day, 46.3 g [247 kcal]; Plumpy'doz; Nutriset, Malaunay, France) from May to October 2007 (6 mo, Figure 1). Children aged 6 to 36 mo were targeted for supplementation with RUSF as this formulation was specifically developed for children of this age according to the manufacturer. Monthly distributions of RUSF were made in 325g pots (1 pot = 1 weekly ration per child) at sites located within walking distance from each village. At the time of RUSF distribution through the preventive program, nutrition assistants also screened children in attendance for mid-upper arm circumference < 110 mm or edema and referred children to the MSF nutritional treatment program when indicated.

To allow for a comparison of the RUSF supplementation strategy being implemented in Guidan Roudji vs. RUTF, we continued monthly follow-up activities in the 12 study villages of the previous trial (6 in Guidan Roudji and 6 in Madarounfa) and continued the preventive distribution of RUTF to children aged 6 to 60 mo from July to October 2007 (4 mo) in the 6 study villages of Madarounfa. Monthly distributions of RUTF were made in individual sachets (1 sachet = 1 daily ration per child) and took place at the same location and time as monthly follow-up activities. As the preventive supplement strategy was determined at the village-level, children were eligible to receive only one type of preventive supplementation and there was no overlap between the two interventions. Supplement distributions were made directly to care givers with instructions to ensure that the target child consumed the amount prescribed by the study per day (e.g. 1 sachet of RUTF or 3 spoons of RUSF). Actual intake by the target child was not directly observed.

All children aged ≤ 60 mo in the 12 study villages were followed on a monthly basis from April 2007 to March 2008. At monthly follow-up visits, trained nutrition assistants carried out anthropometric measurements with the use of standardized methods and calibrated instruments. Child height (recumbent length if <85 cm) was measured to the nearest 0.1 cm using a wooden measurement board. Weight was measured to the nearest 0.1 kg using a hanging Salter scale. Any child found with weight-for-height Z score (WHZ) < -3 of the WHO growth standards (weight-for-height < 70% of the NCHS reference median in April 2007) or with medical complications at a follow-up visit was referred to the nutritional program or neighboring governmental health facility, respectively, for treatment provided at no cost. In 2007, there were 6 nutritional outpatient centers operated by MSF in Guidan Roudji and 2 in Madarounfa. If a child did not present for the monthly follow-up visit in the village, the head of village provided the cause of absence. If a child had died, the cause of death was provided by a family member or the head of village.

Statistical analysis

Children aged 6 to 36 mo at baseline in the 12 study villages comprise the cohort in which we compare the RUSF supplementation strategy (247 kcal / 3 spoons / day for 6 mo) to the RUTF supplementation strategy (500 kcal / sachet / day for 4 mo) with regards to the incidence of wasting, stunting and mortality over 12 mo. Our endpoints specifically included wasting (WHZ < -2), severe wasting (WHZ < -3), stunting (height-for-age Z score (HAZ) < -2), and severe stunting (HAZ < -3) according to the WHO growth standards (8), and mortality. Mortality events included all reports for which the cause for absence from surveillance visits was reported to be death by a family member or the head of village.

We examined the distribution of baseline (April 2007) characteristics by supplementation strategy using generalized estimating equations to adjust standard errors for clustering at the village-level. Next, we explored the association between supplementation strategy and the incidence of wasting, stunting and mortality among children aged 6 to 36 mo at baseline. Among children free from the outcome at baseline, we estimated hazard ratios (HR) and

95% confidence intervals (CI) using marginal Cox proportional hazards models with time from recruitment to the event (wasting, stunting, or death) as the outcome and calendar month as the time scale. All 95% CIs used robust estimates of the variance to account for clustering at the village-level. Children contributed person-time to the analysis from baseline (April 2007) until the first occurrence of the outcome or the end of study (March 2008).

Propensity score adjustment was used to assess the effect of potential confounders (9–11). We estimated the propensity score in the full cohort using a logistic regression in which we estimated the probability of receiving the RUSF supplementation strategy given the baseline characteristics that were *a priori* considered to be potential confounders or were associated with the supplementation strategy in univariate analyses at $P < 0.20$ (12). This included child's age at baseline (6–11, 12–23, 24–36 mo), sex, baseline WHZ and HAZ (continuous), previous episode of malnutrition as reported by mother upon recruitment (yes/no), child's sleeping under bed net as reported by mother upon recruitment (yes/no), malaria diagnosis at previous visit (yes/no), being breastfed ≥ 6 mo (yes/no), maternal age (13–19, 20–29, ≥ 30 y), maternal education (yes/no), maternal BMI (< 18.5 , 18.5–24.9, ≥ 25), parity, more than one co-spouse in the household (yes/no), and number of children in household aged < 5 y (0–1, 2–3, ≥ 4) (c statistic = 0.71). Indicators for quartile categories of the propensity score were included as independent variables in each outcome model. When considering the potentially confounding effects of child's age, sex, and baseline WHZ and HAZ, there was no difference when using traditional multivariate or propensity score adjustment. In models for stunting, severe stunting, and mortality, we additionally adjusted for intervention status from the previous trial.

In the cohort analysis reported here, we considered that the performance of the RUSF strategy may be modified by receipt of the previous nutritional intervention (7), owing to differences in nutritional status, food security environment or use of the supplement within the household associated with the previous intervention experience. To assess the potential interaction between the previous intervention in the randomized trial and subsequent preventive strategy using RUSF or RUTF, we compared Cox models with and without a cross-product term for previous and subsequent supplementation strategies using a partial likelihood ratio test for the wasting and stunting outcomes. The interaction was not assessed for mortality due to limited power. $P \leq 0.05$ was considered statistically significant. Analyses were conducted using SAS version 9.1 (SAS Institute Inc, Cary, North Carolina).

The study protocol was approved by the Government of Niger and the Comité de Protection des Personnes, “Ile-de-France XI”, France, and the study was authorized by the Ministry of Health of Niger. Approval from all heads of villages was received prior to the start of the study, and the objectives of the study and study protocol were explained to heads of households with eligible children before inclusion. An informed consent statement was read aloud in the local dialect before being signed or fingerprinted by the head of household or child care giver.

Results

A total of 1645 children, corresponding to 1151 households, were included in the analysis. Nineteen percent of children were aged < 12 mo at baseline and 40% were aged between 12 and 23 mo. The mean age ($\pm$ SD) of children's mothers was 25.7 y (± 6.4), and educational attainment was low, with a minority of mothers (4%) ever attending school. On average, children receiving RUSF were slightly older ($P = 0.03$) and had lower WHZ scores at baseline ($P = 0.05$) (Table 2). The prevalence of stunting and presence of morbidities did not significantly differ by supplementation strategy at baseline. During the 12 mo surveillance period, children contributed a total of 19,234 mo to follow-up for the survival

endpoint, with a median of 12 visits per child (mean 11.2 ± 2.1). The number of children with anthropometric measurements in April, July, October 2007, and January 2008 was 772, 754, 754, and 725 within the RUSF strategy and 873, 868, 854, 846 within the RUTF strategy, respectively. More children in the RUSF strategy, compared to the RUTF strategy, were in villages that received the previous nutritional intervention (50.3% vs. 43.9%). On average, children had higher WHZ scores ($-0.76 Z \pm 1.07$ vs. $-0.93 Z \pm 1.10$) and HAZ scores ($-2.24 Z \pm 1.04$ vs. $-2.56 Z \pm 1.15$) at baseline in villages where the nutritional intervention was previously implemented.

We found that the previous nutritional intervention modified the association between subsequent preventive strategy and the risk of wasting (P for interaction = 0.002) and severe wasting (P for interaction = 0.05). In villages that did not receive the previous intervention, we found no difference in the incidence of wasting (adjusted HR: 1.31, 95% CI: 0.59 to 2.91) or severe wasting (adjusted HR: 1.21, 95% CI: 0.69 to 2.14) by supplementation strategy (Table 3). On the other hand, in villages that received the previous intervention, the RUSF strategy was associated with a lower risk of wasting (adjusted HR: 0.54, 95% CI: 0.31 to 0.94) and severe wasting (adjusted HR: 0.41, 95% CI: 0.20 to 0.83) when compared to the RUTF strategy.

Among those children not stunted at baseline, there were fewer stunting events associated with the RUSF strategy, compared to the RUTF strategy. After adjustment, the RUSF strategy was associated with a 19% (95% CI: 0% to 34%) reduction in the incidence of stunting. We found no difference in the incidence of severe stunting by supplementation strategy, and no interaction with the previous intervention was observed for the incidence of stunting (P for interaction = 0.36) or severe stunting (P for interaction = 0.49). We found no difference in mortality between supplementation strategies.

Discussion

This study examined differences in the incidence of wasting, stunting, and mortality among children aged 6 to 36 mo that received preventive supplementation with either RUSF or RUTF. To our knowledge, this is the first study to provide information on the relative performance of preventive supplementation strategies in young children using RUSF vs. RUTF to reduce the occurrence of malnutrition and mortality in young children. This study draws from an extensive surveillance database that included a relatively large number of children and high rates of follow-up (< 4% of follow-up visits missed). Application of propensity score methods to control for confounding by a number of measured factors allows the use of these unique data to inform the ongoing discussion on the use of RUSF within nutritional programs while randomized trial data become available.

This study, however, has several limitations. In addition to the dose, the two preventive strategies under comparison differ in important ways, including the duration of supplementation, mode and time of initiation of distributions, and age of children eligible for supplementation. The frequency of anthropometric screening also differed by strategy, with children receiving the RUSF strategy screened twice as often as those receiving the RUTF strategy owing to screening at both the RUSF distribution sites and monthly follow-up visits. As a result, our conclusions relate to the relative performance of the two preventive strategies overall, rather than the individual products. In addition, this comparison involves children from different districts. The study districts may differ with respect to baseline nutritional status, malaria endemicity, frequency of additional food aid distributions (e.g. corn-soy blend and oil), proximity to medical and nutritional care, and other unmeasured factors that influence the health and survival of children. While we are unable to ensure the comparability of children between districts owing to the non-randomized nature of the study,

we do have information on a number of potential confounders. Adjustment for baseline anthropometry and other measured factors did not substantially alter our conclusions. Finally, we do not have complete data on compliance or supplement use within the household and thus cannot know if the supplement was consumed as intended by the target child.

We found that the effectiveness of preventive supplementation varied with the village experience with a previous nutritional intervention. The mechanisms underlying this interaction are unclear, but they are more likely related to contextual factors related to the village experience with the previous intervention than to individual factors associated with intake, such as baseline nutritional status. Children in villages where the previous nutritional intervention was implemented were of better nutritional status (measured by higher WHZ scores), and it is plausible that duration of supplementation may contribute more to improvements in weight gain than dose among children of better nutritional status. However, the effect of the supplementation strategy on the incidence of wasting or severe wasting was not modified by baseline WHZ or HAZ in supplemental analyses (data not shown). The interaction by previous intervention also persisted in the subgroup of children who were not eligible for the previous intervention due to their young age, again indicating that village-, rather than individual-level, factors associated with the previous intervention may contribute to the observed interaction.

In villages with previous experience with RUTF supplementation, RUTF may have been used as a replacement (as opposed to a complement) to habitual family meals or breast milk or shared with other household members. Either scenario could have contributed to lower energy intake with RUTF in villages where the previous intervention was implemented. Increased energy intake has previously been associated with increased weight gain (13, 14), and the energy provided by RUSF is within the range (200–300 kcal/day, assuming average breast milk intake) that older infants require from complementary foods (15). Previous evaluations of RUSF supplementation have been consistent in demonstrating improved weight gain in a variety of study populations and against a range of comparator products, including micronutrient fortified flours and porridge (16–18).

We found that the 6-mo RUSF strategy was related to a reduction in the incidence of stunting relative to the 4-mo RUTF strategy. It is possible that the duration, rather than the dose, of supplementation may contribute more to the maintenance of linear growth associated with the RUSF strategy. Although the impact of previous complementary feeding interventions on linear growth has been inconsistent (19–22), our study is consistent with the limited evidence specific to RUSF. RUSF was related to greater length gain compared to micronutrient-fortified flour among children aged 6–18 mo in Malawi (17), a micronutrient-only supplement among older infants in Ghana (13), and an unfortified spread among stunted children aged 3–6 y in Algeria (23).

Owing to the interruption of the earlier trial, this study compared the performance of two preventive strategies in the context of whether or not a nutritional intervention was implemented in the previous year. The finding that previous intervention can modify the effectiveness of a nutritional program underscores that contextual factors should be considered early in program development, as the most effective dose and duration of supplementation may depend on the particular context of the program setting. Our findings suggest that there may be some settings in which there is no appreciable difference in the prevention of wasting between strategies that provide lower energy for longer duration and those that provide higher energy for shorter periods. However, the non-significant trend towards an increased risk of both wasting and severe wasting among children receiving the

RUSF strategy in villages without the previous intervention is of concern. This should be confirmed in other studies.

Randomized trials that allow for direct estimation of the preventive effect of RUSF on the anthropometric and micronutrient status of young children are warranted. As age and nutritional status continue to be important predictors of nutritional outcomes, studies designed to compare the effectiveness of RUSF by age and nutritional status are also needed to identify groups in which supplementation is most effective and could be targeted. Finally, cost-effectiveness studies are required to help guide the choice of the strategy according to the context. While preventive strategies using RUSF for longer durations may be appropriate in some settings owing to its lower costs (\$ 0.19/dose/day for RUSF vs. \$ 0.37/dose/day for RUTF, written communication Stéphane Doyon, MSF, Paris, France, February 2009), the extended duration of such strategies will have additional indirect costs and programmatic implications.

Conclusion

We found that the relative performance of a 6-mo RUSF supplementation strategy vs. 4-mo RUTF strategy varied with receipt of a previous nutritional intervention. Contextual factors will continue to be important in determining the dose and duration of supplementation that will be most effective, acceptable, and sustainable for a given setting. As we continue to better understand the implications of supplementation with ready-to-use foods, their targeted use in community-based preventive programs could contribute to important improvements in child nutrition.

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Abbreviations

RUSF	ready-to-use-supplementary-foods
RUTF	ready-to-use-therapeutic-foods
MSF	Médecins sans Frontières
NCHS	National Center for Health Statistics
WHZ	weight-for-height Z score
HAZ	height-for-age Z score
WHO	World Health Organization
BMI	body mass index

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Figure 1.

As part of the parent trial, RUTF (500 kcal/sachet/day) were distributed in 6 villages (3 villages in Madarounfa and Guidan Roudji) for 3 mo from August to October 2006 to children aged 6 to 60 mo with weight-for-height $\geq 80\%$ of the NCHS reference median. During this time, no supplements were distributed in 6 other study villages (3 villages in Madarounfa and Guidan Roudji). Subsequently, RUSF (247 kcal/3 spoons/day) were distributed in the 6 study villages of Guidan Roudji for 6 mo from May to October 2007 to all children aged 6 to 36 mo as part of district-wide preventive program. RUTF (500 kcal/sachet/day) were distributed in the 6 study villages of Madarounfa for 4 mo from July to October 2007 to all non-malnourished children aged 6 to 60 mo. As the preventive supplementation strategies were determined at the village-level, children were eligible to receive only one type of preventive supplementation and there was no overlap between the RUSF and RUTF strategies. In villages where RUTF were distributed as part of the previous trial, 79.4% of children in the RUSF group and 77.5% of children in the RUTF group would have been eligible by the age criterion to receive the previous nutrition intervention for at least 1 mo between August and October 2006.

Monthly follow-up was conducted in all 12 study villages by nutritional assistants and research nurses from August 2006 to March 2008, with follow-up from April 2007 to March 2008 included in this cohort analysis. During monthly follow-up visits from April 2007 to March 2008, all children aged 0 to 60 mo received a physical examination and anthropometric assessment and were referred to treatment if WHZ < -3 (weight-for-height $< 70\%$ of the NCHS reference median in April 2007) or edema. In addition, at the site of RUSF distributions, children in attendance were screened for mid-upper arm circumference < 110 mm or edema by nutritional assistants and referred children to the MSF nutritional treatment program when indicated.

Table 1Nutritional composition of RUTF and RUSF per unit energy and study dose¹

Component	RUTF	RUSF	RUTF	RUSF
	Per 1000 kcal		Per study dose	
Quantity, g	-	-	92	46.3
Energy, kcal	1000	1000	500	247
Protein, g	25	24	12.5	5.9
Protein, %kcal	9.5	9.5	9.5	9.5
Lipid, g	65.6	64.8	32.8	16
Lipid, %kcal	58.2	58.2	58.2	58.2
Potassium, mg	2044	1255	1022	310
Magnesium, mg	170	243	85	60
Phosphorus, mg	550	1113	275	275
Zinc, mg	20	16	10	4
Calcium, mg	590	1567	295	387
Selenium, µg	55.2	68.8	27.6	17
Iron, mg	21.2	36.4	10.6	9
Iodine, µg	184	364	92	90
Copper, mg	3.3	1.2	1.65	0.3
Manganese, mg	-	0.7	-	0.17
Thiamine, mg	1.2	2.0	0.6	0.5
Riboflavin, mg	3.4	2.0	1.7	0.5
Niacin, mg	10	24	5	6
Pantothenic acid, mg	5.6	8.1	2.8	2
Pyridoxine, mg	1.2	2.0	0.6	0.5
Folic acid, µg	386	648	193	160
Vitamin B12, µg	3.4	3.6	1.7	0.9
Vitamin C, mg	96	121	48	30
Vitamin A, µg	1680	1619	840	400
Vitamin E, mg	36.8	24.3	18.4	6
Linoleic acid, g	9.1	8	4.8	2
α-linolenic acid, g	0.9	1.2	0.5	0.3

Abbreviations: RUTF, ready-to-use-therapeutic-food, RUSF, ready-to-use-supplementary-food

¹The study dose was 1 sachet / day of RUTF and 3 spoons / day of RUSF.

Table 2

Participant characteristics in April 2007 by supplementation strategy

	RUTF	RUSF	<i>P</i> value ¹
No of villages	6	6	
No of children	873	772	
Person time (mo)	10,268	8,966	
Child Characteristics	N² (%)	N² (%)	
Child age (mo)			0.01
6–11 mo	187 (21.4)	128 (16.6)	
12–23 mo	347 (39.8)	315 (40.8)	
24–36 mo	339 (38.8)	329 (42.6)	
Sex			0.25
Male	432 (49.5)	405 (52.5)	
Female	441 (50.5)	367 (47.5)	
Wasting			
Weight-for-height Z (WHZ) score ³	−0.7 (1.1)	−1.0 (1.1)	0.01
Wasting (WHZ < −2)	99 (11.8)	122 (16.4)	0.05
Severe wasting (WHZ < −3)	27 (3.2)	27 (3.7)	0.61
Stunting			
Height-for-age Z (HAZ) score ³	−2.4 (1.1)	−2.4 (1.1)	0.97
Stunting (HAZ < −2)	543 (64.6)	483 (65.8)	0.89
Severe stunting (HAZ < −3)	268 (31.9)	197 (26.8)	0.37
Any previous malnutrition episode at entry	151 (17.7)	143 (18.8)	0.81
Breastfed ≥ 6 mo	625 (72.8)	386 (50.9)	<0.0001
Child sleeps under bed net	501 (57.7)	360 (47.1)	0.38
Health status in April 2007			
Hospitalized during last month	0 (0.0)	0 (0.0)	----
Malaria diagnosis ⁴	13 (1.6)	0 (0.0)	----
Diarrhoea diagnosis	3 (0.3)	4 (0.5)	0.51
Respiratory infection diagnosis	4 (0.5)	3 (0.4)	0.61
Maternal Characteristics			
Maternal Age			0.58
13–19 y	131 (15.6)	92 (13.1)	
20–29 y	489 (58.3)	426 (60.8)	
≥ 30 y	219 (26.1)	183 (26.1)	
Ever attended school	16 (1.9)	41 (5.5)	0.01
Number of co-wives			0.52
0	0 (0.0)	3 (0.4)	
1	367 (42.7)	297 (39.4)	
≥ 2	493 (57.3)	453 (60.2)	
Maternal Body Mass Index (kg/m ²)	21.9 ± 7.9	21.2 ± 4.4	0.01

	RUTF	RUSF	<i>P</i> value ¹
Household Characteristics			
Number of children < 5 y at home			0.06
1	98 (11.4)	114 (15.2)	
2	227 (26.5)	251 (33.5)	
3	222 (25.9)	187 (25.0)	
≥ 4	311 (36.3)	197 (26.3)	

¹ *P* values from generalized estimating equations to adjust standard errors for clustering at the village-level.

² Sums may not add up to totals due to missing values.

³ Values are means ± SD.

⁴ Determined by rapid finger stick assay.

⁵ Not estimable due to low frequency of events.

Table 3Effect of supplementation strategy on wasting, stunting¹ and mortality

	RUTF strategy	RUSF strategy
Wasting		
Village without previous nutritional intervention ²		
N ³	427	320
No events / child-year	85 / 359	83 / 247
Incidence rate / child-year	0.24	0.34
Unadjusted HR (95% CI)	1.00	1.34 (0.67, 2.67)
Adjusted HR ⁴ (95% CI)	1.00	1.31 (0.59, 2.91)
Village with previous nutritional intervention ²		
N ³	347	330
No events / child-year	70 / 290	36 / 282
Incidence rate / child-year	0.24	0.13
Unadjusted HR (95% CI)	1.00	0.52 (0.32, 0.84)
Adjusted HR ⁴ (95% CI)	1.00	0.54 (0.31, 0.94)
Severe wasting		
Village without previous nutritional intervention ²		
N ³	476	366
No events / child-year	33 / 436	34 / 317
Incidence rate / child-year	0.08	0.11
Unadjusted HR (95% CI)	1.00	1.35 (0.84, 2.16)
Adjusted HR ⁴ (95% CI)	1.00	1.21 (0.69, 2.14)
Village with previous nutritional intervention ²		
N ³	370	379
No events / child-year	14 / 345	8 / 340
Incidence rate / child-year	0.04	0.02
Unadjusted HR (95% CI)	1.00	0.57 (0.29, 1.11)
Adjusted HR ⁴ (95% CI)	1.00	0.41 (0.20, 0.83)
Stunting		
N ³	330	289
No events / child-year	165 / 216	127 / 183
Incidence rate / child-year	0.76	0.69
Unadjusted HR (95% CI)	1.00	0.89 (0.72, 1.11)
Adjusted HR ⁴ (95% CI)	1.00	0.81 (0.66, 1.00)
Severe stunting		
N ³	605	575
No events / child-year	144 / 495	130 / 454
Incidence rate / child-year	0.29	0.29
Unadjusted HR (95% CI)	1.00	0.95 (0.69, 1.32)

	RUTF strategy	RUSF strategy
Adjusted HR ⁴ (95% CI)	1.00	0.99 (0.76, 1.30)
Mortality		
N ³	873	772
No events / child-year	25 / 856	10 / 747
Incidence rate / child-year	0.03	0.01
Unadjusted HR (95% CI)	1.00	0.46 (0.31, 0.68)
Adjusted HR ⁴ (95% CI)	1.00	0.49 (0.23, 1.01)

¹Wasting and severe wasting are defined as WHZ < -2 and WHZ < -3, respectively. WHZ was not calculated for children with oedematous malnutrition (n = 4). These observations were therefore not included in analyses of the incidence of wasting or severe wasting. Stunting and severe stunting are defined as HAZ < -2 and HAZ < -3, respectively.

²Previous nutritional intervention consisted of a monthly distribution of RUTF (500 kcal/sachet/ day) from August to October 2006 to children aged 6 to 60 mo with weight-for-height ≥80% of the NCHS reference median.

³Number of children contributing to unadjusted analysis.

⁴From marginal Cox proportional hazards models, where the outcome variable is time until first event and time metamer is calendar month. Predictors in the adjusted model included supplementation strategy and indicators for quartiles of the estimated propensity score. The propensity score was estimated using logistic regression where the probability of receiving the RUSF supplementation strategy was predicted given child's age at baseline (6–11, 12–23, 24–36 mo), sex, baseline WHZ and HAZ (continuous), previous episode of malnutrition as reported by mother upon recruitment (yes/no), child's sleeping under bed net as reported by mother upon recruitment (yes/no), malaria diagnosis at previous visit (yes/no), being breastfed ≥6 mo (yes/no), maternal age (13–19y, 20–29y, ≥30y), maternal education (yes/no), maternal BMI (<18.5, 18.5–24.9, ≥25), parity, more than one co-spouse in the household (yes/no), and number of children in household aged < 5 y (0–1, 2–3, ≥4). Models for stunting, severe stunting, and mortality were additionally adjusted for previous intervention status. Only children who did not have the outcome at baseline were included in the analyses.