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ORIGINAL ARTICLE

Cost analysis of the treatment of severe acute malnutrition in West Africa

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Abstract

We present an updated cost analysis to provide new estimates of the cost of providing community-based treatment for severe acute malnutrition, including expenditure shares for major cost categories. We calculated total and per child costs from a provider perspective. We categorized costs into three main activities (outpatient treatment, inpatient treatment, and management/administration) and four cost categories within each activity (personnel; therapeutic food; medical supplies; and infrastructure and logistical support). For each category, total costs were calculated by multiplying input quantities expended in the Médecins Sans Frontières nutrition program in Niger during a 12-month study period by 2015 input prices. All children received outpatient treatment, with 43% also receiving inpatient treatment. In this large, well-established program, the average cost per child treated was €148.86, with outpatient and inpatient treatment costs of €75.50 and €134.57 per child, respectively. Therapeutic food (44%, €32.98 per child) and personnel (35%, €26.70 per child) dominated outpatient costs, while personnel (56%, €75.47 per child) dominated in the cost of inpatient care. Sensitivity analyses suggested lowering prices of medical treatments, and therapeutic food had limited effect on total costs per child, while increasing program size and decreasing use of expatriate staff support reduced total costs per child substantially. Updated estimates of severe acute malnutrition treatment cost are substantially lower than previously published values, and important cost savings may be possible with increases in coverage/program size and integration into national health programs. These updated estimates can be used to suggest approaches to improve efficiency and inform national-level resource allocation.

KEYWORDS
community-based management, cost, ingredients approach, Niger, severe acute malnutrition

1 | INTRODUCTION

Undernutrition remains a significant contributor to both child mortality and morbidity: it is associated with 45% of all deaths among children <5 years (Black et al., 2013) and increases both the risk and severity of infectious illness (Scrimshaw & SanGiovanni, 1997). The most lethal form of undernutrition in children is severe acute malnutrition (SAM). Since its inception, treatment of SAM included hospitalization for all cases. More recently, ready-to-use-therapeutic foods (RUTF) and decentralized care models have enabled community-based treatment for most children, with high recovery rates (World Health Organization, World Food Programme, United Nations System Standing Committee on Nutrition and United Nations Children's Fund, 2007). This community-based approach is recognized as one of the 13 "high-impact" nutrition interventions for its potential to save lives (Bhutta et al., 2008) and is included in the package of "key interventions" promoted by the Scaling Up Nutrition movement (Horton, Shekar, McDonald, Mahal, & Brooks, 2010). Despite potential for community-based management to provide safe, effective, and timely care, access to SAM treatment remains unacceptably low, with only 7–13% of children with SAM receiving treatment in 2012 (UNICEF et al., 2012).

A fundamental obstacle to increasing program coverage is the perceived high cost of treatment, yet there are few empirical studies on the subject. Current estimates are limited by the use of generic costing inputs and reflect costs experienced when the transition to community-based treatment was just beginning. Considerable experience has been gained about how to best implement the intervention, and the present-day cost of providing SAM may differ from earlier estimates.

We undertook this study to generate updated estimates of SAM treatment costs. We collected data from a Médecins Sans Frontières (MSF) nutrition program in Niger and estimated per patient costs for SAM treatment as well as expenditure shares for major cost categories. In addition to the empirical results, we present sensitivity analyses to explore costs that may be realized with different input prices and two hypothetical delivery scenarios.

2 | METHODS

This study was undertaken to estimate the cost of SAM treatment provided in routine inpatient and outpatient settings. This analysis used MSF program data from Madarounfa, Niger, where SAM treatment is provided in parallel with basic pediatric care (not costed) within the routine health system.

2.1 | Study setting

Niger is one of the poorest countries in the world, ranking 188 of 188 on the Human Development Index (United Nations Development Program, 2015). The nutrition program is set in the Madarounfa Health District in the Maradi region of south-central Niger. The district is largely rural and representative of the Sahel region of sub-Saharan Africa (Institut National de la Statistique, 2013). Household food production in this region is linked to rain-fed agriculture. Decreases in food quantity and quality in the months preceding the annual harvest and increases in infectious illness are associated with a seasonal increase in acute malnutrition among children <5 years of age. The Maradi region has some of the highest rates of acute malnutrition in the country, with 16.3% wasting estimated in May 2013 (Institut National De La Statistique Republique du Niger, 2013).

In collaboration with the Ministry of Health, MSF has been supporting pediatric care in the Madarounfa Health District since 2001. From 2008 to 2014, responsibility for project activities was transferred to a local Nigerien nongovernmental organization, Forum Santé Niger. Forum Santé Niger provided care to >30,000 children in the Madarounfa Health District annually.

2.2 | Program description

Community-based management of acute malnutrition (CMAM) addresses limitations in traditional inpatient treatment, including limited capacity, low coverage, and high costs from long inpatient stays. CMAM combines outpatient treatment for those with preserved appetite and no medical complications (80–90% of children) and inpatient treatment to stabilize those with medical complications, while emphasizing community mobilization and treatment linkages for moderate acute malnutrition (MAM). The approach, proven safe and cost-effective, was endorsed by the United Nations in 2007 (World Health Organization, World Food Programme, United Nations System Standing Comittee on Nutrition and United Nations Children's Fund, 2007) and has since been adopted in >65 countries (UNICEF, 2013).

According to international guidelines, children 6 to 59 months of age are eligible for outpatient treatment if they meet the following criteria: (a) weight for height Z score (WHZ) <−3 according to the 2006 WHO Growth Standards, mid-upper arm circumference (MUAC) <125 mm or mild/moderate bipedal edema; (b) sufficient appetite according to a test feeding of RUTF; and (c) absence of clinical complications requiring hospitalization (World Health Organization, 2013). Dedicated clinical staff monitor children at weekly outpatient clinic visits using weight and MUAC measurements until program exit (defined as WHZ >−2 at two consecutive visits, MUAC >115 mm and resolution of edema and clinical complications). Routine medical treatment is provided on admission, including antibiotic and antihelminthic treatment, measles vaccination, and antimalarial treatment. A ration of RUTF (175–200 kcal/kg/day) is provided weekly on admission and until discharge. Children are referred to the hospital for any clinical complication requiring inpatient management, weight loss >5% between two consecutive visits, or lack of weight gain after 2 weeks. In hospital, children receive necessary medical management and are provided with therapeutic milk during stabilization, followed by RUTF before returning to outpatient care.

The nutritional program in Madarounfa, Niger is a stand-alone program, uniquely providing nutritional therapy for children with SAM. Services are delivered at or in proximity to established health facilities where basic health services were provided but with dedicated personnel, physical infrastructure, and other resources. In 2013, the

Key messages

- The community-based management of severe acute malnutrition is a safe and effective approach to provide life-saving treatment, but access to care remains low.
- One obstacle to increasing program coverage is the perceived high cost of treatment. Few empirical costing studies exist, and available estimates are limited by the use of generic costing inputs and reflect costs early in the transition to community-based management.
- This study provides updated empirical estimates of severe acute malnutrition treatment costs. We found the overall cost per child treated to be €148.86, substantially lower than previously published values. Sensitivity analyses suggest important cost savings are possible in programs operating at scale and when integrated into existing health systems.

nutritional program included five health centers for outpatient treatment and one hospital for inpatient care. Table 1 presents program indicators for 2013.

2.3 | Perspective and time period

Costs were assessed from a provider perspective and included costs for all clinical services (inpatient and outpatient) comprising SAM treatment, plus related management and administration costs, over the calendar year 2013. We excluded national-level support costs, such as guideline development and advocacy. Also excluded were community screening and mobilization costs for active case-finding and treatment of MAM, and costs borne by households (transportation, food purchases, and productivity losses related to treatment).

2.4 | Data analysis

We applied a combination of activity-based costing and an "ingredients approach" (Drummond, Sculpher, Torrance, O'Brien, & Stoddart, 2005), considering three main activities: (a) outpatient treatment for uncomplicated cases, (b) inpatient treatment to stabilize complicated cases, and (c) management and administration. Within each activity, we considered four cost categories: personnel; therapeutic food; medical supplies and materials; and infrastructure and logistical support. For each category, we created a cost inventory and quantified resources used during the 12-month evaluation period. Costs in local currency (FCFA) were converted to Euros at FCFA 656 = €1. The cost per child for inpatient care was calculated by dividing total inpatient costs by total inpatient cases and similarly for outpatient care. Outpatient costs were calculated overall and for the five individual outpatient sites. The cost per child for management was calculated by dividing total management costs by total patients enrolled. The overall cost per child was calculated by dividing the sum of total outpatient, inpatient, and management costs by total patients enrolled.

We conducted one-way sensitivity analyses for key parameters. We also considered alternative operational scenarios, created to represent (a) a vertical government-supported SAM program and (b) an integrated government-supported SAM program. The vertical program scenario assumed that (a) functions currently performed by expatriate staff would be performed by the national staff costed using the Ministry of Health salary levels; (b) nonroutine medicines would be purchased using the Ministry of Health cost schedule; and (c) program management and administration would be provided by existing personnel at health district- and national-levels (zero additional cost). In addition to these assumptions, the integrated program scenario (SAM treatment provided in combination with basic health services, including growth monitoring and vaccination using the same personnel and infrastructure) assumed that human resources, infrastructure, and management and administration costs could all be borne by existing capacity, at zero additional costs.

2.5 | Data sources and assumptions

Personnel cost data (salary, benefits, and allowances) were extracted from program administrative records and valued using the 2015 MSF salary scale for Niger. The composition of the outpatient, inpatient, and management teams is presented in Table 2. Outpatient personnel included one team per site for 8 hr, 5 days a week; inpatient personnel included one team responsible for 24-hr care, 7 days a week at the central hospital.

TABLE 1 Nutritional program characteristics, Madarounfa, Niger 2013

			Outpatient care					
	Total	Inpatient care	All outpatient	Site 1 Dan Issa	Site 2 Gabi	Site 3 MDF	Site 4 Safo	Site 5 Tofa
Number of admissions, *n*	16,084	6,903[a]	13,395	8,321	1,223	1,762	996	1,093
Patient characteristics								
Admission criteria, *n* (%)	5,742 (36)	1,275 (47)	4,467 (33)					
MUAC <115 mm	9,784 (61)	1,000 (37)	8,784 (66)					
WHZ <−3 and MUAC ≥115 mm	558 (3)	414 (15)	144 (1)					
Bipedal edema								
Program outcomes								
Recovered [b], %	92.1	91.2	96.1	94.9	96.6	99.3	98.2	97.3
Weight gain (g/kg/d) among recovered	10.7	19.3	8.0	8.1	7.7	7.7	7.8	7.7
Duration of treatment (d) among recovered	20.3	4.6	25.7	25.9	25.9	25.6	24.1	25.4
Nonresponse%	0.3	0.3	0.2	0.1	0.9	0.1	0.1	0.1
Transfer to inpatient care, %	1.8	1.7	1.0	1.0	1.4	0.2	1.5	2.1
Default, %	2.9	0.8	2.6	3.9	1.0	0.4	0.1	0.5
Death, %	2.9	5.9	0.1	0.1	0.2	0.1	0.1	0.0

[a]Includes 2,689 direct admissions to the inpatient unit and 4,214 transfers from outpatient care.

[b]Recovered children in inpatient care here includes children recovered according to program protocol (4.4%) and children transferred to outpatient care following stabilization (86.8%).

TABLE 2 Inputs by program activity in MSF nutritional program, Madarounfa, Niger 2013

Input	Outpatient care	Inpatient care	Management and administration
Personnel			
Expatriate medical staff	0.5 nurse supervisor	1 inpatient medical referent, 1 doctor, and 1 clinical nurse supervisor	
National medical staff	0.5 doctor; per site[a]: 1 nurse supervisor, 1 nurse, and 1 nutritional assistant	7 doctors, 1 nurse supervisor, 17 nurses, and 24 nutritional assistants	
Expatriate support staff	—	—	1 head of mission, 1 medical coordinator, 1 finance/human resources coordinator, 1 pharmacy coordinator, 1 logistics coordinator at country-level coordination, and 1 project coordinator at field site
National support staff		2 laboratory technicians, 10 hygienists, 1 receptionist, 1 cook, and 1 guard	1 project administrator, 1 administrative assistant, 1 finance assistant, 1 human resources assistant, 1 project logistics coordinator, 1 logistics supervisor, 2 logistics assistant, 1 pharmacy supervisor, 1 pharmacy assistant, 7 drivers, 17 guards, 1 cook, and 2 cleaners
Incentives for Ministry of Health staff	Per site: 1 head of health center, 1 nutritional assistant or nurse, 3 receptionists, and 1 hygienist	2 district chiefs, 4 hospital chiefs, 1 nutrition unit chief, 1 nurse, 2 laboratory technicians, 1 hygienist, 3 cooks, 3 guards	—
Therapeutic food	Plumpy'nut, as per pharmacy distribution to five outpatient sites in 2013	F-75, F-100, and Plumpy'nut as per pharmacy distribution to inpatient sites in 2013	—
Medical supplies and materials			
	Routine treatment at admission (antibiotic and antihelminthic therapy, rapid malaria test, and measles vaccination as needed), other drugs, and medical supplies as per 2013 distribution to five outpatient sites; anthropometric equipment kit	Clinically indicated treatments, and medical equipment, supplies, and consumables as per 2013 distribution to inpatient facility; anthropometric equipment kit	Medical emergency preparedness kits for staff
Infrastructure and logistical support			
Vehicles	One 4 × 4 ambulance per facility, including international sea freight, parts and service for maintenance, fuel, and insurance	One 4 × 4 ambulance, including international sea freight, parts and service for maintenance, fuel, and insurance	Vehicle rental and maintenance for city transport
Nonmedical equipment and supplies	Tables, chairs, plastic mats, and water containers by local purchase	Beds and mattresses, tables, chairs, small cooking utensils, caregiver kit including plastic mat, bed nets, cover, soap, daily meals, and stove by local purchase; water containers with chlorination kit, generator, cold chain equipment, and sterilizer from MSF Logistics, including international sea freight	Office maintenance material (tools and equipment), energy, telecommunications and technology equipment, consumable supplies and stationary, furniture
Buildings	Construction, routine repair, maintenance, hygiene supplies, and utilities of semipermanent structure for outpatient consultations; local warehouse facility with guards and allocation estimated as proportion of stock volume destined for outpatient facilities	Construction, routine repair, maintenance, hygiene supplies, and utilities of structure for inpatient care; local warehouse facility with guards and allocation estimated as proportion of stock volume destined for inpatient facility	Rental, maintenance, utilities, and communications for office and warehouse
Transport and support services	Ground transportation from the capital to project office (two times per year by 10-ton truck rental) and from project office to health centers (two times per month by pick-up rental)	Ground transportation from the capital to project office (two times per year by 10-ton truck rental) and from project office to health centers (two times per month by pick-up rental).	International and domestic staff travel; local customs and clearance costs; administrative support services

[a]Nurse and nutritional assistant staffing increased with one additional staff per post in Gabi, Madarounfa, and Safo and with two additional staff per post in Dan Issa in peak season (5 months).

We extracted data from the pharmacy information system on quantities of therapeutic food, medical supplies, and related materials distributed to each health facility. Items were valued with 2015 unit prices provided by MSF's procurement department (http://www.msflogistique.org/index.php/en/). For equipment and consumables not managed in the pharmacy information system, quantities were provided by program advisors and items valued with 2015 local market or international procurement prices. Prices for therapeutic foods and medical supplies procured internationally included purchase prices and insurance, plus international sea freight from the Logistics center (France) to the capital, or exceptionally international air freight for cold chain or hazardous items utilized in inpatient care. In-country transport costs were included in logistical support.

Quantities and valuation of infrastructure and logistical support were based on program budgets and financial records. Infrastructure inputs included capital items (buildings, vehicles, and nonmedical equipment) and recurrent costs (maintenance, repairs, and cleaning). Capital costs were annuitized using conventional methods and discounted at 3% (Drummond et al., 2005). A useful life of 5 years was assumed for vehicles, semipermanent buildings, and other capital items (generator, sterilizer, and cold chain equipment) and 2 years for cooking equipment and furniture. Capital items costing <€100 were treated as recurrent costs. We accounted for in-country freight, including ground transportation from the capital to project office (2 times per year by truck rental) and from project office to health centers (2 times per month by pick-up rental). Warehouse expenses (rental fees, utilities, insurance, and warehouse personnel) were allocated proportional to floor space used to stock items for distribution to the outpatient versus inpatient sites.

Management and administration costs included personnel, infrastructure, and logistical services at project- and capital-levels identified in 2013 program expenditure records, whereas expatriate support staff at the capital-level reflect minimum program requirements. Expenses were allocated to the SAM program proportional to the program's contribution to the overall budget in 2013 and to individual sites proportional to SAM patient volume in 2013.

3 | RESULTS

3.1 | Costs by activity and overall

The overall cost of SAM treatment was €148.86 per child treated. Empirical costs per child treated for outpatient care, inpatient care, and management and administration are presented in Table 3. The outpatient cost was €75.50 per child, where two costs predominated: therapeutic food (44%, €32.98 per child) and personnel (35%, €26.70 per child). Personnel costs were dominated by medical staff, where expatriate and national medical staff contributed €10.01 (13%) and €12.63 (17%) per child, respectively. Approximately €1 per child (1%) of outpatient care was attributed to routine treatment, while the cost per child was €7.14 for nonroutine medical treatment and supplies, and €7.66 for infrastructure and logistical support (each approximately 10% of outpatient costs). Heterogeneity in outpatient costs was observed between sites, with total outpatient costs per child costs ranging from €49.71 for a site with 8,321 admissions per year to €140.56 for a site with 996 admissions per year. A simple logarithmic cost curve relating outpatient volume to outpatient costs implied substantial economies of scale, with total costs increasing by 5.3% (and average costs declining by 4.3%) for every 10% increase in client volume, largely due to lower per-child personnel costs in high-volume sites (Figure 1).

The inpatient cost was €134.57 per child. Personnel accounted for the largest portion of inpatient costs (56%, €75.47 per child), followed by transport and logistical support (18%, €23.57 per child), and non-routine medical treatment and supplies (16%, €21.19). Therapeutic food contributed 11% of inpatient costs (€14.34 per child). Management and administration costs per child were €40.38, with 76% (€30.63 per child) attributed to personnel and infrastructure and 23% (€9.18 per child) to logistical support.

3.2 | Costs for alternative operational models

Figure 2 presents results for one-way sensitivity analyses and the two alternative operational scenarios. Reductions in input prices of medical treatments and therapeutic food had limited effect on total costs per child, while increases in program size/coverage and the substitution of expatriate medical staff with national staff lowered total costs per child substantially (€99.60 and €96.31, respectively vs. €148.86 in the base case). Hypothetical scenarios representing typical vertical and integrated government-supported SAM treatment programs yielded further important cost reductions (€74.23 and €42.49, respectively vs. €148.86 in the base case).

4 | DISCUSSION

This study provides updated empirical estimates of SAM treatment costs in a high-burden, low-income setting. We found the overall cost per child treated to be €148.86, with costs of outpatient treatment, inpatient treatment, and management and administration of €75.50, €134.57, and €40.38 per child, respectively. Therapeutic food and personnel dominated outpatient costs, while personnel was the most significant component of inpatient care. Substantial economies of scale were apparent in outpatient costs, with per-child personnel costs decreasing as patient volume increased.

CMAM is a safe and cost-effective approach in the management of SAM, but efforts to scale up treatment access in resource-constrained settings have been limited by perceived high costs. However prior to this study, evidence on the cost of the current CMAM model was sparse and inconsistent (Supplementary Table 1). Costing methods and study designs differ among available studies, but the overall cost provided here is among the lowest of previously reported estimates (€139 to €239, (Bachmann, 2009, Concern Worldwide, 2007, Gaboulaud, 2004, Puett et al., 2013, Tekeste, Wondafrash, Azene, & Deribe, 2012, Wilford, Golden, & Walker, 2012)). Our estimate reflects current costs within a context of an established nutrition program and may reflect greater efficiency attributable to operational experience, program scale, and/or more precise costing methods targeting only costs directly required for SAM treatment. Important differences in costs between contexts may arise from differences in the services offered, local transport infrastructure, and patient mix.

The most important cost driver in outpatient care was therapeutic food (RUTF), an imported ready-to-use paste comprised of milk powder, vegetable oil, peanut paste, sugar and a mineral and vitamin pre-mix. In previous studies, RUTF similarly comprised a major

TABLE 3 Financial costs by program activity in MSF nutritional program, Madarounfa, Niger 2013

	Financial cost per child, € (% of column total)							
	Outpatient care							
Activity	All outpatient	Site 1 Dan Issa	Site 2 Gabi	Site 3 Madarounfa	Site 4 Safo	Site 5 Tofa	Inpatient care	Management and administration
N	13,395	8,321	1,223	1,762	996	1,093	6,903	
Personnel	26.70 (35%)	9.49 (19%)	57.51 (49%)	44.57 (43%)	67.61 (48%)	57.14(48%)	75.47 (56%)	30.63 (76%)
Expatriate medical staff	10.01	3.22	21.93	15.22	26.93	24.54	23.31	–
National medical staff	12.63	4.96	26.69	23.18	29.76	22.65	41.88	–
Expatriate support staff	–	–	–	–	–	–	–	20.01
National support staff	1.74	0.56	3.81	2.64	4.68	4.26	7.68	10.62
Ministry incentives	2.32	0.75	5.09	3.53	6.24	5.69	2.60	–
Therapeutic food	32.98 (44%)	29.94 (60%)	33.57 (28%)	39.97 (38%)	43.75 (31%)	34.34(29%)	14.34 (11%)	–
Medical supplies and material	8.15 (11%)	7.48 (15%)	11.35 (10%)	8.67 (8%)	9.05(6%)	8.07(7%)	21.19 (16%)	0.57 (1%)
Systematic treatment	1.01	1.01	1.01	1.01	1.01	1.01	–	–
Other treatment and materials	7.14	6.47	10.34	7.66	8.04	7.06	21.19	0.57
Infrastructure and logistics	7.66 (10%)	2.79(6%)	16.08 (14%)	11.09 (11%)	20.15 (14%)	18.40(16%)	23.57 (18%)	9.18 (23%)
Vehicles	5.93	1.91	12.99	9.02	15.96	14.54	2.30	1.60
Nonmedical equipment and supplies	0.42	0.34	0.56	0.48	0.62	0.59	15.26	1.03
Buildings	1.28	0.52	2.50	1.56	3.55	3.24	5.56	3.47
Transport and logistical support	0.03	0.03	0.03	0.03	0.03	0.03	0.45	3.07
TOTAL	75.50 (100%)	49.71 (100%)	118.52 (100%)	104.30 (100%)	140.56 (100%)	117.95 (100%)	134.57 (100%)	40.38 (100%)

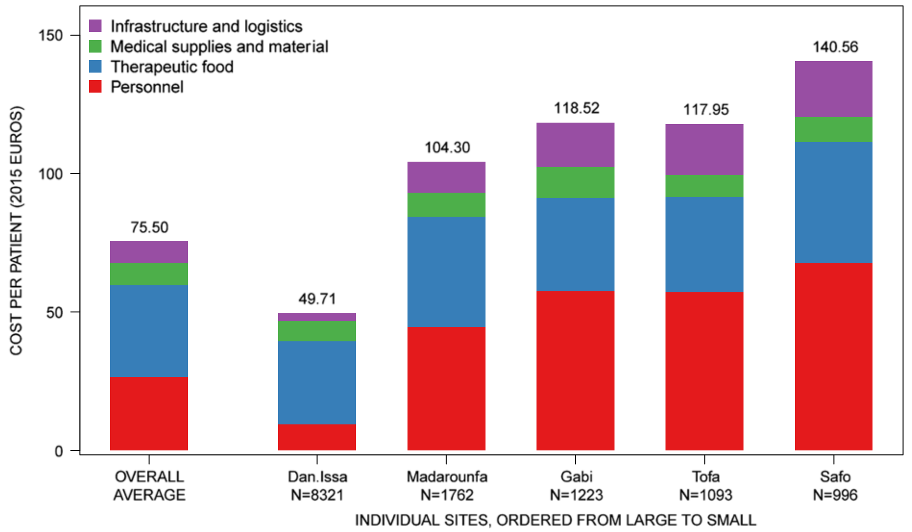

FIGURE 1 Cost per child for outpatient services realized by individual sites, ordered by service delivery volume

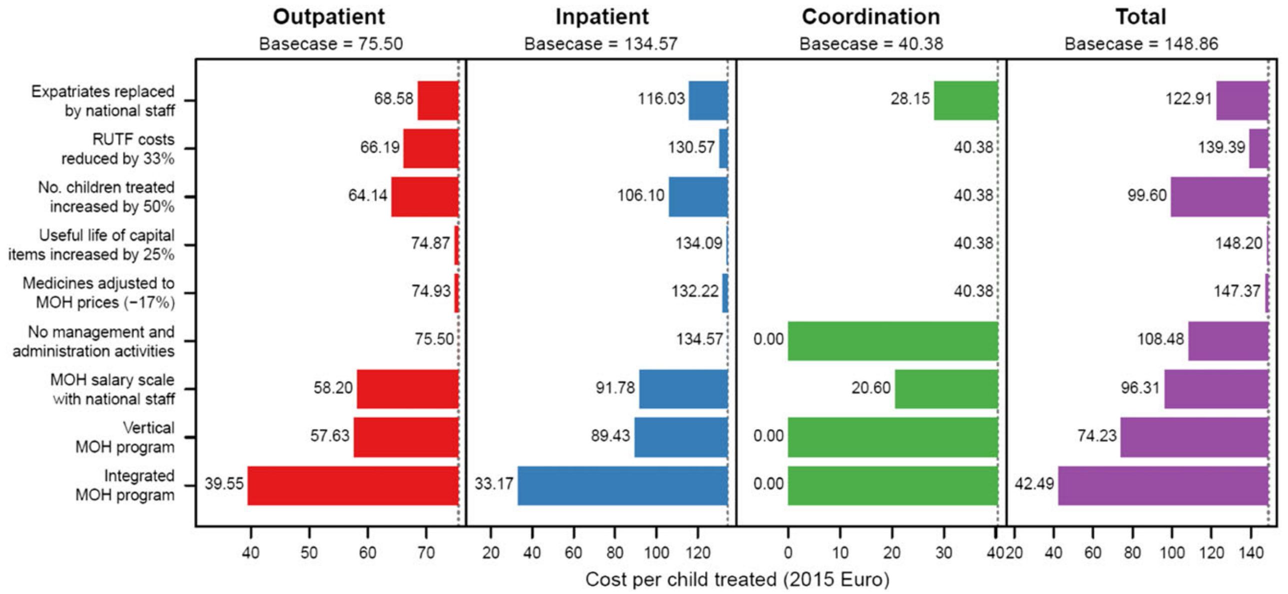

FIGURE 2 Estimated cost per child for outpatient care, inpatient care, management and administration, and total program costs under various scenarios

component of total costs (24% to 40% of total costs, (Bachmann, 2009, Puett et al., 2013, Tekeste et al., 2012, Wilford et al., 2012, Concern Worldwide, 2007)). As RUTF is a high-cost input, development of cheaper formulations through local production and/or use of indigenous food sources has been considered. The cost of locally-produced RUTF would be context- and even producer-specific, as final costs depend on the cost of ingredients, production volume, supplier agreements, demand, and packaging. While there are many potential benefits of local production (readily accessible stock in case of emergency; lower transport costs; and local economic benefits), recent experience has not suggested substantial cost savings with local production Ingredient costs can remain high given import and local taxes, and potential cost savings through automating certain production elements or customizing production machinery may be limited by lower production volumes. Ongoing operational research to understand the cost-effectiveness of a reduced RUTF dose in outpatient SAM treatment may provide evidence for an alternative model to reduce overall program costs by reducing the requirements for high-cost RUTF inputs (ISRCTN Identifier ISRCTN50039021).

Sensitivity analyses suggest that the total cost of SAM treatment could decrease with less dependence on costly external personnel and with increasing program scale. Personnel represented an important proportion of outpatient costs. As outpatient services are provided by clinical teams of fixed size, once a clinical team is in place, admissions can increase until teams reach capacity with little additional expense beyond the extra costs of RUTF and medical supplies. As a consequence, higher volume service outlets will likely experience lower average costs per child. Development of national capacity, including training of nurses and community health workers, may reduce program costs associated with external support. Strategies that increase scale and patient volume, for example, by reducing the frequency of visits of the same child from weekly to biweekly or monthly follow-up or by increasing coverage through enhanced community case finding, may be additional modifications that allow for important reductions in per child personnel costs and the overall cost of treatment. Site-specific results from this analysis suggest that treating additional children (up to a clinical team's capacity) can substantially reduce the unit cost, without a discernible impact on program indicators. Delivery models that integrate treatment for SAM and MAM may allow for similar efficiencies through greater patient volume. In this setting, 43% of children ever required inpatient care, suggesting a high burden of complicated cases. As we found outpatient care to be substantially less expensive per child than inpatient care, models that support early identification of children before the development of clinical complications in SAM, for example, through the integration of SAM and MAM treatment or improved community case finding, also present an opportunity to reduce overall program costs through reduced requirements for high-cost hospital care.

We anticipated that the study program, though highly effective and based on >10 years of operational experience, may be atypical in terms of resource inputs and that alternative operational models may allow cost savings. To examine this, we generated cost estimates for two alternative operational scenarios representing typical government-supported programs. These analyses of hypothetical vertical and integrated program scenarios suggest that SAM treatment costs could decrease substantially with less dependence on costly external expertise and with integration of SAM treatment into existing health services. The effectiveness of such models, however, has not been evaluated and additional costs for increased supervision and support may be necessary to maintain adequate levels of effectiveness in government-supported programs. As national governments continue to build human resource capacity, logistical infrastructure, and operational experience to play a greater and more independent role in the delivery of effective SAM treatment, future planning may consider these costs estimates for initial resource allocation and budgeting. Cost-effectiveness of such experiences should continue to be assessed.

This study has several limitations. First, the provider perspective does not incorporate the economic impact on households. Household costs are relevant for sustainability and equity, but could not be adequately quantified in this study. Second, large-scale outpatient programs are enabled by well-functioning health systems, appropriate human resources, timely referral systems, and institutional infrastructure. In this analysis, we assumed that the nutritional program was implemented without the need for large additional infrastructure or human resource inputs. Therefore, our principal results are applicable to established programs where sufficient health infrastructure and trained personnel resources are available. In countries that have a weaker health system treatment costs, particularly in the first years of implementation, may be more than those estimated here. Finally, the MSF nutrition program under study did not include community mobilization and screening activities; program and cost data were therefore not available for this activity.

In conclusion, we present updated empirical estimates of SAM treatment costs that are substantially lower than published values. Sensitivity analyses suggest costs can be driven down further in programs operating at scale and when integrated into existing health systems. Additional evidence on SAM treatment costs would be valuable, considering possible avenues of further cost reduction and variability in costs across contexts and delivery models.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

SI contributed to the conception and design of the study, collection, analysis and interpretation of data, and drafted the manuscript. NAM contributed to the analysis and interpretation of data, and helped draft the manuscript. JS and MA contributed to the data collection. SD and RFG contributed to the conception of the study and interpretation of data. All authors critically reviewed the manuscript for important intellectual content and approved the final manuscript.

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