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Treatment of moderate acute malnutrition through community health volunteers is a cost-effective intervention: Evidence from a resource-limited setting

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Abstract

Treatment outcomes for acute malnutrition can be improved by integrating treatment into community case management (iCCM). However, little is known about the cost-effectiveness of this integrated nutrition intervention. The present study investigates the cost-effectiveness of treating moderate acute malnutrition (MAM) through community health volunteer (CHV) and integrating it with routine iCCM. A cost-effectiveness model compared the costs and effects of CHV sites plus health facility-based treatment (intervention) with the routine health facility-based treatment strategy alone (control). The costing assessments combined both provider and patient costs. The cost per DALY averted was the primary metric for the comparison, on which sensitivity analysis was performed. Additionally, the integrated strategy's relative value for money was evaluated using the most recent country-specific gross domestic product threshold metrics. The intervention dominated the health facility-based strategy alone on all computed cost-effectiveness outcomes. MAM treatment by CHVs plus health facilities was estimated to yield a cost per death and DALY averted of US$ 8743 and US$ 397, respectively, as opposed to US$ 13,846 and US$ 637 in the control group. The findings also showed that the intervention group spent less per child treated and recovered than the control group: US$ 214 versus US$ 270 and US$ 306 versus US$ 485, respectively. Compared with facility-based treatment, treating MAM by CHVs and health facilities was a cost-effective intervention. Additional gains could be achieved if more children with MAM are enrolled and treated.

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KEYWORDS
community management of acute malnutrition, cost-effectiveness, integrated community case management, Kenya, moderate acute malnutrition

1 | INTRODUCTION

Eradication of hunger is a critical international development agenda through Sustainable Development Goals—SDGs 2 (United Nations [UN], 2023). Despite this, undernutrition, which includes wasting (low weight-for-height), stunting (low height-for-age) and underweight (low weight-for-age) (WHO, 2023b), remains a significant public health problem. According to the reports of SDGs, 2.4 billion people, roughly 30% of the world's population, were moderately or severely food-insecure in 2020 (UN, 2023). Worldwide, 45 million children under 5 suffer from wasting (WHO, 2023a). Undernutrition is widely recognized as a significant cause of mortality in children (Bhutta et al., 2008; Black et al., 2013; UN, 2023). Research has also demonstrated the detrimental effects of undernutrition: limiting educational achievement in the short term and hampering economic development in the long run (Abu-Fatima et al., 2020; Bhutta et al., 2008).

There is a significant body of knowledge demonstrating the benefits of using food supplements for the treatment of acute malnutrition, defined as wasting and/or nutritional oedema, in children under the age of 5. Several studies have assessed the use of Ready-to-use Therapeutic Foods (RUTFs) and Ready-to-use Supplementary Foods (RUSFs) for the treatment of severe acute malnutrition (SAM) (López-Ejeda et al., 2019) and moderate acute malnutrition (MAM) (Cichon, Das, et al., 2023; Lazzerini et al., 2013; Lelijveld et al., 2018), respectively. Efforts over the past 10 years to scale up acute malnutrition treatment have shown mixed success, with treatment coverage remaining unacceptably low (World Health Organization, 2020). To increase treatment coverage, innovative delivery approaches, particularly treatment of acute malnutrition by trained and equipped community health volunteers (CHVs) or community health workers (CHWs), have been investigated.

A growing number of studies have examined the cost-effectiveness of community-based treatment for acute malnutrition involving CHVs. All studies reported on the cost-effectiveness of SAM treatment by CHVs (Goudet et al., 2018; López-Ejeda et al., 2019, 2020; Puett et al., 2013; Rogers et al., 2018, 2019; Wilunda et al., 2021). However, there is a dearth of information on the cost-effectiveness of the involvement of CHVs in the treatment of MAM to inform policy action. In Kenya, policymakers are currently considering the option of CHVs to treat acute malnutrition by integrating the treatment of both moderate and severe acute malnutrition into integrated community case management (iCCM). Without evidence of the value for money of this health intervention, this health policy may not be appealing to policymakers. With country-specific information on the value for money of the involvement of CHVs in treating acute malnutrition, the government and its partner agencies are well-equipped to respond effectively. This study aimed to investigate the cost-effectiveness of community-based treatment of MAM involving CHVs operated through the integration of treatment into iCCM in Kenya.

Key messages

- Treatment of MAM by CHVs and health facilities involved a lower cost compared with the health facility-based treatment approach alone.
- Treatment of MAM by CHVs and health facilities was cost-effective compared with the health facility-based treatment approach alone.
- Greater health and economic gains could be realized if more children with MAM are enrolled and treated by CHVs through the integration of acute malnutrition treatment into iCCM.

2 | METHODS

2.1 | Study setting

We implemented the intervention in Turkana County, an arid area in Northern Kenya. The county is drought-prone and has experienced frequent, successive and prolonged droughts. Therefore, undernutrition is a highly prevalent condition in the area. Severe gaps in human resources for health and nutrition further complicate the provision of high-quality services. According to the SMART survey conducted in June 2019, covering all livelihood zones in Turkana (agro-pastoral, formal employment/business/petty, trade and pastoral), the prevalence of MAM was 19.7%, with an estimated SAM rate of 5.9% (Turkana County, 2019). The existence of community units (CUs) with CHVs already trained in the basics of community health strategy modules coupled with prior iCCM practice implementation represents an excellent opportunity to implement community-led interventions to improve children's health and nutritional status.

2.2 | Overview of iCCM and CMAM

iCCM is a strategy for treating common childhood illnesses, especially diarrhoea, malaria and pneumonia, at the community level using trained, equipped and supervised CHVs (WHO/UNICEF, 2012). It is a cost-effective strategy that relies on trained community members to

diagnose and treat the most common causes of child death in developing countries. CMAM is a decentralized community-based approach to the treatment of acute malnutrition (WHO/UNICEF, 2007). Treatment matches the child's nutritional and clinical needs, with most children receiving treatment at home with ready-to-use food supplements. Inpatient care is only provided in complicated cases of acute malnutrition. The integration of acute malnutrition treatment into iCCM has the potential to enhance service coverage and access to malnutrition treatment services, leading to better treatment outcomes.

2.3 | Description of the programme

The Ministry of Health worked with Save the Children International, Action Against Hunger (AAH), with the support of UNICEF to integrate CMAM into iCCM in Turkana County. The effectiveness of this intervention was assessed using a two-arm noninferiority cluster randomized-controlled trial (cRCT). For the trial, community units (clusters) were randomly assigned to control or intervention groups. In the control group, 73 CHVs only screened and referred MAM and SAM cases to the nearby health facility for treatment by health workers based on the standard Ministry of Health protocol.

In contrast, in the intervention group, 61 CHVs sought and screened children with acute malnutrition in the community through house-to-house visits and enrolled those who were eligible in the study. The identified children were treated in the community using simplified tools and protocols as detailed elsewhere (Kimani-Murage et al., 2019). Children with MAM received RUSF for 14 days until the next visit. Albendazole and folic acid (appropriate for weight) were given on the spot and further dosage was explained to the caregiver. Mothers were advised on the follow-up, breastfeeding and diversification of feeding in addition to RUSF. Children with SAM (MUAC < 115 mm or presence of bilateral pitting oedema without complications) or MAM (MUAC in the range of 115–125 mm) and whose parents/caretakers provided consent at enrolment were included in the study. Children with MUAC < 90 mm or danger signs were excluded and directly referred to the health facility. While treatment in the control area was available only at health facilities, treatment in the intervention area was available at both the health facilities and CHV sites.

The trial consecutively enrolled 272 children aged 6–59 months with uncomplicated moderate and severe acute malnutrition, who were enrolled in the overall programme. To provide a more accurate picture of costs outside of trial conditions, we used programme admission (i.e., all admissions recorded by the malnutrition treatment programme within the study period) data for economic evaluation. The latter consisted of 903 children with moderate or severe acute malnutrition recruited between January and September 2019. Of these, 857 were MAM admissions: 365 were in the control area and 492 were in the intervention area. As mentioned above, in the control area, all the children were treated at the health facility. In the intervention area, 376 children were treated at health facilities and 116 children were treated at CHV sites. A flowchart outlining the participants' enrolment in the cRCT is provided in Supporting Information S1: Figure 1.

2.4 | Data collection procedures

Data collection took place between January and September 2019 and combined prospective and retrospective approaches. The prospective method was mainly used to collect data needed to measure the effectiveness of the studied interventions. The data were gathered during the intervention to determine the coverage of SAM and MAM treatments, other pertinent nutrition and iCCM variables and treatment outcomes. All the data were collected by experienced interviewers using a questionnaire. The prospective data included household sociodemographic and economic characteristics; child characteristics comprising morbidity; and the child's weight and vital status (dead or alive), height, mid-upper arm circumference (MUAC) and presence of oedema, which were all recorded weekly for SAM and biweekly for MAM cases. Recovery and nonresponse to treatment were determined through MUAC measurement. Additionally, the total number of visits (data points) depended on how quickly the child recovered, but the maximum number of visits was eight. The details of the collected data are available elsewhere (Kimani-Murage et al., 2019).

Economic data were gathered retrospectively. Data on costs included primary and secondary cost data. Primary cost data were collected through field surveys with households and CHVs using structured questionnaires. The household survey, which collected data on time (travel time to facilities and caring time), transportation and additional food purchased when visiting health facilities and at home for children with acute malnutrition, sought to determine whether making treatment available closer to communities could result in cost savings. The data were purposefully collected from 40 households (20 in each study arm) through a rapid survey. A similar technique was used to interview 40 CHVs (20 in each study arm) before and after the intervention to assess whether the integration of CMAM into iCCM changed their workload. In this regard, the time that CHVs spent on treatment-related activities was collected and the variation in time between the two groups was evaluated. Secondary cost data were gathered by reviewing the accounting data of the implementing agencies. The collected costs included staff training, supervision and monitoring (transport and lodging), treatment activities (food supplies and medications) and personnel costs (stipends and per diems). The salaries of the personnel were estimated using the salaries of staff from the government who could perform similar roles. An overview of the programme's cost centres and data sources is presented as Supporting Information S2: Table 1.

2.5 | Analysis

2.5.1 | Effectiveness measures

The analysis applied trial data to the entire study sample. The effectiveness intervention included estimating the primary and secondary outcome measures for the intervention and control groups. Both primary (recovery rate) and secondary (default rate, death rate, nonresponse rate, average length of stay and average weight gain) study outcomes were defined according to the Kenyan

National Guidelines for Integrated Management of Malnutrition. According to guidelines, a child is discharged from treatment as cured when he or she achieves a Green MUAC of 12.5 cm or more for two consecutive visits, defaulted if absent for three consecutive visits and nonresponse for MAM/SAM if the child is discharged as having not achieved the cured discharge criteria after 16 weeks on treatment. The average length of stay is the number of days from treatment initiation to exit from the study due to recovery, death, default or nonresponse among the recovered children. The average weight gain is the change in grams per kilogram per day from treatment initiation to exit from the study among recovered children. Furthermore, the analysis followed the intention-to-treat principle. The econometric model used to evaluate the effectiveness outcomes was derived from existing literature. The details of the analytical technique are available elsewhere (Donfouet et al., 2024; Kimani-Murage et al., 2019).

2.5.2 | Costing analysis

The ingredient-based costing approach was applied to estimate costs. The total costs incurred in treating children with acute malnutrition were estimated as those borne by the provider and beneficiary households. The total provider costs for treating acute malnutrition comprised the incurred costs for curative care, infrastructure, integration of CMAM into iCCM (only for the intervention arm), training, personnel and supervision. All of these include recurrent and capital costs. Capital costs, including the cost of items whose useful life exceeded 1 year, comprised buildings, MUAC tapes, desks, cupboards, chairs, weighing scales, CHV job aids, dosage calculators, sick child recording from booklets and key message flip charts. Consistent with existing studies, capital costs were annualized, based on each item's average life of utilization, discounted at a rate of 5%, as per recent recommendations (Haacker et al., 2020). The recurrent costs included supervision and monitoring (transport and lodging), treatment activities, personnel costs (salaries or stipends for CHVs) and the additional time spent on CHVs for community outreach.

Household costs, including transport, additional food and productivity losses, were estimated for both the intervention and control groups. All data were analysed using Excel and Stata. Personnel costs were apportioned based on the time spent on the project activities. All costs incurred before our base year were adjusted for inflation using a gross domestic product (GDP) deflator. The estimated total costs by intervention arm were further disaggregated into moderate and severe malnutrition as this paper reports solely on the cost linked to MAM. Unit costs per child treated (admitted), recovered and death averted were estimated by dividing the total costs for each intervention site by the number of children treated (admitted), recovered and total deaths averted, respectively. The number of children treated (admitted) was obtained from the implementing agencies and included all the children enrolled from January to September 2019. The total number of children who recovered from an acute malnutrition episode was obtained by multiplying the number of children with MAM and SAM enrolled in the intervention groups with the corresponding recovery rates from the cRCT data. The total number of deaths averted in each group was obtained as the product of the number of children who recovered from acute malnutrition multiplied by the expected mortality rate for children under 5 with MAM. All costs are expressed in US$ (2019), with KES 1 = US$ 0.0096.

2.5.3 | Cost-effectiveness evaluation

Cost-effectiveness combines both provider and beneficiary costs. The analysis was performed only for MAM, using an Excel-based cost-effectiveness model programmed in Excel 2010. We restricted the analysis to MAM cases because the trial enrolled only a small number of SAM cases (29/272). The model considered the cost and effectiveness measures of the comparison groups to produce various metrics, including the cost per child treated, recovered, death and DALY averted. The costs per child treated and recovered were estimated as the total economic cost divided by the number of children younger than 5 years treated and recovered in each group, respectively. The cost per death averted was estimated as the total economic cost divided by the number of deaths averted in each group, with deaths averted as the product of recovered children multiplied by the expected mortality rate. The cost per DALY averted was estimated as the total economic cost divided by the total DALYs averaged in each group. The estimation of DALYs combines morbidity (years of healthy life lost to disability, YLD) and mortality (years of life lost to premature mortality, YLL). In line with Rushby and Hanson (2001), the following two equations were used to calculate the total YLDs and YLLs averted in each study group:

$$YLDs[K,r,B] = D\left\{\frac{KCe^{ra}}{(r+B)^2}\{e^{-(r+B)(L+a)}[-(r+B)(L+a)-1] - e^{-(r+B)a}[-(r+B)a-1]\} + \frac{1-K}{r}(1-e^{-rL})\right\}$$

and,

$$YLLs[K,r,B] = \frac{KCe^{ra}}{(r+B)^2}\{e^{-(r+B)(L+a)}[-(r+B)(L+a)-1] - e^{-(r+B)a}[-(r+B)a-1]\} + \frac{1-K}{r}(1-e^{-rL}).$$

With K is the age-weighting modulation factor, C the constant, r the discount rate, a the age at onset of disability or age at death, B the parameter from the age-weighting function, L the duration of disability or standard expectation of life at age a, and D the disability weight.

2.5.4 | Cost-effectiveness model parameters

Table 1 shows the input parameters used to model the cost-effectiveness ratios. The parameters comprised effectiveness outcomes as well as economic and demographic data. Programme effectiveness

TABLE 1 DALY model input parameter values.

Parameter	Units	Base case	Sensitivity analysis 95% CI	Source
Number treated (admitted) in the intervention group	cases	492	Fixed	Programme data
Number treated (admitted) in the control group	cases	365	Fixed	
Recovery rate intervention group	cases	69.8%	60.4%–77.8%	Donfouet et al. (2024)
Recovery rate control group	cases	55.7%	46.1%–64.9%	
Degree for disability for death (YLL)	n.a.	1	Fixed	
Degree for disability for moderate wasting (YLD)	n.a.	0.051	0.031–0.079	IHME (2023)
Life expectancy females & males (YLL)	years	66.5	65.1–67.9	
Age at start of episode (YLD)	months	22.03	20.59–24.01	
Age at death (YLL)	years	2.00	1.65–2.30	
Duration of MAM episode (YLD)	months	2.00	1.85–2.15	
Age-weighting factor	n.a.	1	0–1	Rushby and Hanson (2001)
Age weight	n.a.	0.04	Fixed	
Constant	n.a.	0.1658	Fixed	
Discount rate	n.a.	0.05	0.04–0.06	Haacker et al. (2020)
Expected deaths from MAM	Deaths	3.5%	2.64%–4.68%	Goudet et al. (2018)

outcomes were mainly derived by analysing the data collected from both study groups within the cRCT. Review articles and data from international organizations were the preferred sources for input parameters when a primary data source was unavailable. When data from review papers were unavailable for a specific parameter, the data from individual articles were considered. Because the WHO's GDP per capita threshold-based approach for assessing the cost-effectiveness of health care interventions was criticized for imprecision (Marseille et al., 2015), the most recent country-specific cost-effectiveness ranges were used. For Kenya, interventions ranging between US$ 32 and $519 are deemed cost-effective (Woods et al., 2016). Based on this, the treatment of acute malnutrition by CHVs was deemed "cost-effective" if the cost per DALY averted ranged from US$ 32 to $519.

2.5.5 | Sensitivity analysis

Costing assessments are subject to inaccuracies surrounding estimates, partly because of the uncertainty associated with certain input parameters. Costing evaluators frequently conduct sensitivity analyses to consider the uncertainties surrounding the cost parameters (Husereau et al., 2013). A sensitivity analysis was performed to understand the effects of the variation in the selected model parameters and their subsequent impacts on the cost-effectiveness ratios. This sensitivity analysis focused solely on the intervention group to better judge the worthiness of the new approach. Consistent with Rushby and Hanson (2001), the discount rate and age-weighting factor were varied between their respective ranges. Univariate sensitivity analysis was also conducted to understand the variations in variables such as age at death, age at the start of the episode, disability weight, age-weighting factor, social discount rate, expected mortality from MAM, recovery rate and life expectancy at birth on the cost per DALY averted in the intervention group. This was performed by varying the central value for each estimate around its confidence interval. In addition, the intervention's overall cost was conservatively varied by ±25% to assess its influence on the cost per DALY averted. Such variations further affected all parameters, allowing the assessment of relative changes and stability of the findings. Table 1 provides more information on confidence interval sources.

2.6 | Ethical consideration

Initially, the study protocol and tools were reviewed by the African Population and Health Research Center's (APHRC) ethics review committee, internally. The African Medical and Research Foundation (AMREF) Health Africa Ethical and Scientific Review Committee (number P416/2017) approved the study protocol and tools. All the caregivers, CHVs and other study participants provided written informed consent.

3 | RESULTS

3.1 | Comparison of treatment outcomes between groups

Table 2 provides an overview of the selected treatment outcomes between children in the control and intervention groups from the

cRCT data that were applied to the numbers of children admitted according to the programme data. The findings showed that the recovery rate was higher in children with MAM treated with CHVs (intervention) than in those treated in health facilities only (control): 69.8% versus 55.7%. The defaulter rate, defined as the proportion of children recorded as absent for 3 consecutive weeks per the Kenyan national guidelines for integrated management of malnutrition, was lower in the intervention group (10.4%) than in the control group (24.5%). There was also a higher average weight gain and shorter length of stay for recovered children in the intervention group than in the control group, with a mean length of stay of 2 months, 95% CI (1.85–2.15).

3.2 | Programme costs

Table 3 shows the total cost of treating children with MAM in the control and intervention (CHVs plus) groups. The total programme costs amounted to US$ 98,520 in the control group and US$ 105,081 in the intervention group. In proportion to total programme costs, treatment appeared to be among the most critical drivers, consuming a minimum of 47% of the total costs, irrespective of the study arm. Treatment costs were much higher in the intervention group than in the control group: US$ 57,360 versus US$ 46,642. However, the control group's costs for supplementary foods were 20% higher than those of the intervention group (US$ 7588 vs. US$ 9076). The findings also show that the costs incurred by CHVs in training and managing children with acute malnutrition were higher in the control group than in the intervention group. Only the costs incurred in integrating acute malnutrition tools into the iCCM, personnel, infrastructure and supervision were higher in the intervention group than in the control group.

3.3 | Cost-effectiveness outcomes

Table 4 presents the cost-effectiveness outcomes of the control and intervention groups. The treatment of children with MAM by the CHVs and health facilities dominated the only health facility treatment strategy for all computed cost-effectiveness outcomes. Specifically, the treatment of children with MAM using the CHVs plus approach was estimated to cost US$ 8743 and US$ 397 per death and DALY averted, respectively. In comparison, the treatment of MAM in health facilities only resulted in much higher costs per death averted at US$ 13,846 and US$ 637 per DALY averted.

The findings also showed that more children in the intervention group recovered from MAM, indicating that the CHVs' plus strategy

TABLE 3 Total programme costs of the treatment of moderate acute malnutrition by intervention group (2019 US$).

Items	Intervention Cost (US$)	%	Control Cost (US$)	%
Training of CHVs	7958	7.57	9127	9.26
Training	7958	7.57	9127	9.26
Treatment	57,360	54.59	46,642	47.34
Commodities (RUSF)	7588	7.22	9076	9.21
CHVs' per diem	14,459	13.76	15,014	15.24
Capital costs	823	0.78	157	0.16
CHVs' extra time for integrating CMAM	2206	2.10	0	0.00
Personnel (health facility) costs	32,284	30.73	22,395	22.73
Integration of CMAM into ICCM	8953	8.52	0	0.00
Consultancy for the contextualization of the tools	8953	8.52	0	0.00
Infrastructure	3200	3.05	2982	3.03
Building rental cost	869	0.83	1440	1.46
Upkeep of the health centre	2331	2.22	1542	1.57
Supervision	1829	1.74	1323	1.34
Supervision	1829	1.74	1323	1.34
Household costs	25,781	24.53	38,446	39.02
Transport	5053	4.81	5606	5.69
Productivity losses	5141	4.89	8136	8.26
Additional foods	15,587	14.83	24,704	25.07
Total cost	105,081	100.00	98,520	100.00

TABLE 2 Comparative treatment outcomes between control and intervention groups.

	Control *n* = 116	Intervention *n* = 127	Significance *p* value
Recovery rate (*n*, %)	59 (55.7)	74 (69.8)	0.042
Defaulter rate (*n*, %)	26 (24.5)	11 (10.4)	0.005
Nonresponse rate (*n*, %)	21 (19.8)	21 (19.8)	0.104
Length of stay (days) (mean, SD)	70.3 (45.44)	49.0 (25.9)	0.116
Average weight gain (g/kg/day) (mean, SD)	1.72 (3.4)	2.69 (4.7)	0.578

Note: No death was recorded during the intervention in both groups.

for treating MAM is more effective than the health facility treatment alone approach. Finally, the results also indicate lower costs per child treated (admitted) and recovered in the intervention group than the control group: US$ 214 versus US$ 270 and US$ 306 versus US$ 485, respectively.

3.4 | Sensitivity analysis

Supporting Information S3: Table 2 and Figure 1 show the findings of the univariate sensitivity analysis performed on the model input parameters for the intervention group. The results showed that the estimated cost-effectiveness ratios were most sensitive to variations in expected mortality, intervention cost, discount rate and recovery rate (Supporting Information S3: Table 2).

The larger the range, the more imprecise the estimated cost per DALY averted by the intervention, with a larger effect being observed for the expected mortality rate. Nevertheless, except for the upper value for the expected mortality, the estimated costs per DALY averted by the intervention, varying between US$ 297 and US$ 528, remain cost-effective considering the country-level cost-effectiveness threshold of US$ 32–US$ 519 (Woods et al., 2016).

TABLE 4 Programme cost-effectiveness outcomes (2019 US$).

	Intervention	Control
Total cost	105,081	98,520
Number of children treated (admitted)	492	365
Number of children recovered	343	203
Deaths averted	12	7
Total DALYs averted	265	155
Cost per child treated (admitted)	214	270
Cost per child recovered	306	485
Cost per death averted	8743	13,846
Cost per DALY averted	397	637

4 | DISCUSSION

This study investigated the cost-effectiveness of community-based management of MAM in children under 5 years of age in Turkana, Kenya. Although there is a growing literature on the cost-effectiveness of the treatment of MAM by CHVs, country-specific evidence of the value for money in the use of CHVs for the treatment of acute malnutrition remains to be documented in several countries, including Kenya. This study provides additional insights that add to the emerging literature on the involvement of community members in the fight against this form of acute malnutrition. The study highlights some findings that are worthy of discussion.

The total cost of MAM treatment was 7% higher for community-based treatment than for facility-based treatment: US $ 105,081 versus US$ 98,520. Numerous studies that investigated the costs of community management of acute malnutrition using CHVs also reported higher total costs of the management of acute malnutrition using CHVs. This was the case in cost-effectiveness evaluations of community-based management of acute malnutrition by CHVs in various countries, including Bangladesh (Puett et al., 2013), India (Goudet et al., 2018), Mali (Rogers et al., 2018) and Pakistan (Rogers et al., 2019), although the focus was on SAM. The higher costs observed for the intervention group in our study appear to be primarily driven by the combination of personnel and consultancy costs for integrating CMAM into iCCM, as well as infrastructure and supervisory costs. For example, in addition to the 10 nutritionists (5 per study arm) supporting all examined facilities

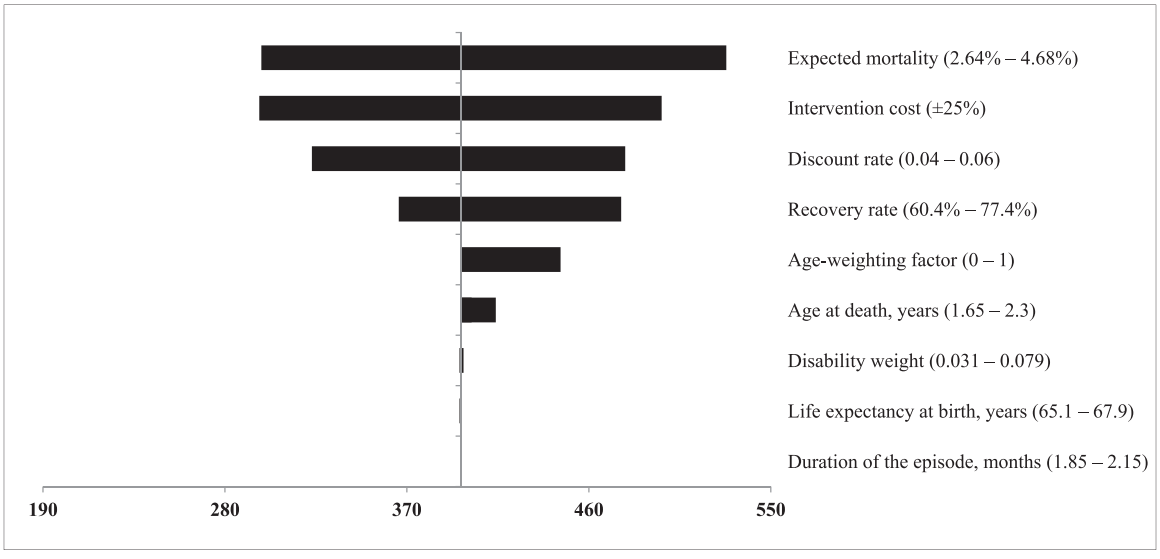

FIGURE 1 Tornado diagram of univariate sensitivity analysis of cost per DALY averted for the intervention group.

during programme implementation, a project supervisor (a maternal-infant young child nutrition—MIYCN specialist) was recruited to support solely the intervention arm. This adds to the costs of building rental and upkeep of the health centres before launching the intervention. Furthermore, costs of food commodities were higher in the control group than in the intervention group. The control group's higher RUSF costs could be explained by the group's significantly longer duration of stay (70.30 vs. 49.00 days). This study also reported higher health personnel costs for the intervention group and higher training costs for CHVs in the control group. The allocation of a project supervisor (MIYCN specialist) to exclusively support the intervention supervisory activities may account for the higher health personnel costs for the intervention group. Besides, the control group's increased CMAM and iCCM refresher training, with more CHVs attending training sessions (73 CHVs were active in the control arm as opposed to 61 CHVs in the intervention arm), may help to explain the variation in training expenses between the two groups.

The cost per child treated (admitted) in the intervention group amounted to US$214.00. This estimate was higher than that of a recent study that found a cost per child treated (admitted) for MAM of US$ 165.2, equivalent to US$ 155.75 in 2019 in Niger (Cichon, Lopez Ejeda, et al., 2023). However, this cost per child treated (admitted) falls within the range of numerous previous studies. In Tanzania, the cost per child treated for SAM was estimated at 146.50 US$ in 2019 (Wilunda et al., 2021). The estimated cost of treating a child with SAM in Bangladesh was estimated at US$ 165.00, equivalent to US$ 238.69 in 2019 (Puett et al., 2013), in rural Mali, it was US$ 244.00, equivalent to US$ 242.77 in 2019 (Rogers et al., 2018), and in Pakistan, it was US$ 291, equivalent to US$ 245.76 in 2019 (Rogers et al., 2019). However, these estimates were specific to the treatment of SAM, whether by CHVs alone or by a combination of CHVs with additional patient-treatment modalities such as patient therapeutic centres, and so forth, and which treatment is different due to high dosages of RUTF and more frequent visits. Moreover, the intervention also resulted in lower costs per child recovered and death averted compared with the treatment of children with acute malnutrition in health facilities. Lower costs and higher recovery rates in the intervention group seem to correlate with much lower defaulting, which could be associated with the treatment being available closer to the communities.

The findings also showed that the community-based management of MAM involving CHVs dominated the facility-based treatment approach. Furthermore, the intervention, which yielded a cost per DALY averted of US$397, was cost-effective according to recent country-specific cost-effectiveness thresholds for Kenya, estimated to range from US$ 32 to US$ 519 (Woods et al., 2016). The cost per DALY averted in our study was almost similar in magnitude to that of a study that found a cost per DALY averted of US$ 347 in 2015, equivalent to US$ 342.02 in 2019 in Mali (Isanaka et al., 2019). However, our estimate was higher than the estimated US$ 26.00, equivalent to US$ 37.61 in 2019 per DALY averted in Bangladesh (Puett et al., 2013), and US$ 23.00, equivalent to US$ 24.09, in 2019 per DALY averted in India (Goudet et al., 2018), although these studies focused on SAM. Higher mortality rates in untreated SAM compared with MAM may help to explain why the treatment of MAM resulted in a higher cost per DALY averted. In addition, the particularly high number of children enroled in India (12,326 SAM cases) (Goudet et al., 2018) and Bangladesh's higher recovery rate of 91.9% (Puett et al., 2013) compared with our study's 69.8% for the intervention group implies that the programme in Kenya would have been increasingly effective as enrolment and recovery rates increase. Besides, the Puett et al. (2013) study was carried out in an urban setting, where a high population density may have led to a higher efficiency of treatment delivery. Furthermore, only 24% of the children in the intervention group received care from CHVs; the remainder continued to receive care from medical facilities. This means that as people become more accustomed to this method, the intervention's cost-effectiveness can increase.

Finally, the sensitivity analysis revealed that the cost per DALY averted was relatively sensitive to variations in the expected mortality among children aged 6–59 years, the total cost of the intervention, the discount rate and the recovery rate. These four parameters showed larger effects on the cost per DALY averted. However, the CHV treatment of MAM remained generally cost-effective under the confidence interval limits of these four variables. Even with the sensitivity analysis considered, the integrated community-based management of MAM by CHVs plus health facilities still dominated the facility-based approach, demonstrating the robustness of the estimates.

This study is not without limitations. Without a country-specific mortality rate attributable to MAM, an estimate has been used in various studies to model the number of deaths averted. Specifically, the mortality rate may have increased the benefits, that is, the number of deaths averted or lives saved. This, in turn, may have distorted our study findings. In addition, the intervention covered a period of 9 months (January–September 2019). Applying an annual mortality rate to the total number of children recruited over the 9 months in both the intervention and control arms to model deaths averted may also have introduced additional biases to the findings. The execution of the programme over 12 months would have led to the recruitment of other children into both study arms. This, in turn, would have affected the total costs and resulted in more deaths and DALYs being averted. Consequently, the cost-effectiveness ratios, that is, cost per DALY averted, would have been different. The intervention would have yielded a more beneficial cost per DALY averted since cost inflation would have been concentrated around treatment commodities and per diems to CHVs. Conversely, the increased number of children recruited for the programme would have resulted in more averted deaths. Therefore, more DALYs would have been prevented in both the study arms. Although data on SAM were also gathered, the analysis was restricted to MAM. Inaccurate estimations would have resulted from the small number of participants with SAM in the intervention and control arms. Therefore, it was impossible to formulate targeted recommendations for each group. In addition, the findings revealed that the recovery

rate was low in the control group. However, this is likely owing to the observed higher defaulting rate, which may be associated with the treatment being less easily accessible and less supervision in this group. Finally, applying the recovery rates from the RCT to programme data could also have distorted the findings because a significant number of children (376 out of 492) were treated in health facilities, and yet, the trial recovery data in the intervention group were collected only at CHV sites. Programme data indicated that the recovery rate at the health facility in the intervention group could have been as high as 77.4% (estimates not from an impact evaluation in a cRCT). If programme effectiveness is higher, as we believe it to be, then the intervention is likely to be more cost-effective, and our estimates are likely to be conservative.

Notwithstanding these limitations, this study boasts several strengths. It represents a pioneering effort to examine the cost-effectiveness of community-based treatment of MAM by CHVs in Kenya. Therefore, its findings may inform policy and strategy to address acute malnutrition and its consequences. Moreover, the findings of this study complement those of most published studies that focused only on analysing the cost-effectiveness of community-based treatment of SAM by CHVs.

5 | CONCLUSION

Compared with facility-based treatment alone, the integrated community management of MAM by CHVs plus facility-based care is a cost-effective intervention. The findings support the use of trained, equipped and supervised CHVs to deliver this cost-effective life-saving strategy for the management of MAM. The findings also suggest that more gains could be achieved from economic and health perspectives if more children with acute malnutrition were enroled and treated. Emphasis on identifying and enrolling all children needing treatment should be embedded in large-scale acute malnutrition programmes, particularly in drylands.

AUTHOR CONTRIBUTIONS

The authors' responsibilities were as follows—Hermann Pythagore Pierre Donfouet, Elizabeth Mwaniki, Bonventure Mwangi, Daniel Tewoldeberhan, James Njiru, Lydia Karimurio, Olivia Agutu, Peter Okoth and Elizabeth Kimani-Murage designed the study. Hermann Pythagore Pierre Donfouet, Calistus Wilunda, Elizabeth Mwaniki, Bonventure Mwangi, and Elizabeth Kimani-Murage supervised implementation of the study. Patrick G. Ilboudo, Hermann Pythagore Pierre Donfouet, Calistus Wilunda, Bonventure Mwangi, Bernardette Cichon and Elizabeth Kimani-Murage cleaned and analysed the data. Patrick G. Ilboudo, Hermann Pythagore Pierre Donfouet, Calistus Wilunda and Elizabeth Kimani-Murage wrote the first draft of the manuscript. All authors interpreted the findings, reviewed the manuscript for important intellectual content and approved the final version of the manuscript. Patrick G. Ilboudo, Calistus Wilunda, Bernardette Cichon and Elizabeth Kimani-Murage had primary responsibility for the manuscript's final content.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data described in the manuscript, code book and analytic code will be made available upon request to the African Population and Health Research Center through the Microdata portal (https://aphrc.org/microdata-portal/).

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REFERENCES

Abu-Fatima, O., Abbas, A., Racalbuto, V., Smith, L., & Pizzol, D. (2020). Child undernutrition in Sudan: The social and economic impact and future perspectives. *The American Journal of Tropical Medicine and Hygiene*, *104*(3), 1149–1152. https://doi.org/10.4269/ajtmh.20-1251

Bhutta, Z. A., Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., Haider, B. A., Kirkwood, B., Morris, S. S., Sachdev, H., & Shekar, M., Maternal and Child Undernutrition Study Group. (2008). What works? Interventions for maternal and child undernutrition and survival. *The Lancet*, *371*(9610), 417–440. https://doi.org/10.1016/S0140-6736(07)61693-6

Black, R. E., Alderman, H., Bhutta, Z. A., Gillespie, S., Haddad, L., Horton, S., Lartey, A., Mannar, V., Ruel, M., Victora, C. G., Walker, S. P., & Webb, P. (2013). Maternal and child nutrition: Building momentum for impact. *The Lancet*, *382*(9890), 372–375. https://doi.org/10.1016/S0140-6736(13)60988-5

Cichon, B., Das, J. K., Salam, R. A., Padhani, Z. A., Stobaugh, H. C., Mughal, M., Pajak, P., Rutishauser-Perera, A., Bhutta, Z. A., & Black, R. E. (2023). Effectiveness of dietary management for moderate wasting among children >6 months of age—A systematic review and meta-analysis exploring different types, quantities, and durations. *Nutrients*, *15*(5), 1076.

Cichon, B., Lopez Ejeda, N., Charle Cuellar, P., Hamissou, I. A., Karim, A., Aton, C., Sanoussi, A., Ousmane, N., Lazoumar, R. H., Gado, A., Harouna, Z. Y., & Oteyza, S. G. (2023). Cost of acute malnutrition treatment using a simplified or standard protocol in Diffa, Niger. *Nutrients*, *15*(17), 3833. https://doi.org/10.3390/nu15173833

Donfouet, H. P. P., Tewoldeberhan, D., Wilunda, C., Mwaniki, E., Njiru, J., Keane, E., Schofield, L., Maina, L., Kutondo, E., Agutu, O., Okoth, P., Raburu, J., Samburu, B., Mwangi, B., Zerfu, T. A., Khamadi, W. J., Cuellar, P. C., Kavoo, D., Karimurio, L., … Kimani-Murage, E. (2024). The impacts of task shifting on the management and treatment of malnourished children in Northern Kenya: A cluster-randomized controlled trial in Northern Kenya. Health Policy and Planning, czae036. https://doi.org/10.1093/heapol/czae036

Goudet, S., Jayaraman, A., Chanani, S., Osrin, D., Devleesschauwer, B., Bogin, B., Madise, N., & Griffiths, P. (2018). Cost effectiveness of a community based prevention and treatment of acute malnutrition programme in Mumbai slums, India. *PLoS One*, *13*(11), e0205688. https://doi.org/10.1371/journal.pone.0205688

Haacker, M., Hallett, T. B., & Atun, R. (2020). On discount rates for economic evaluations in global health. *Health Policy and Planning*, *35*(1), 107–114. https://doi.org/10.1093/heapol/czz127

Husereau, D., Drummond, M., Petrou, S., Carswell, C., Moher, D., Greenberg, D., Augustovski, F., Briggs, A. H., Mauskopf, J., & Loder, E. (2013). Consolidated health economic evaluation reporting standards (CHEERS)—explanation and elaboration: A report of the ISPOR health economic evaluation publication guidelines good reporting practices task force. *Value in Health*, *16*(2), 231–250. https://doi.org/10.1016/j.jval.2013.02.002

Isanaka, S., Barnhart, D. A., McDonald, C. M., Ackatia-Armah, R. S., Kupka, R., Doumbia, S., Brown, K. H., & Menzies, N. A. (2019). Cost-effectiveness of community-based screening and treatment of moderate acute malnutrition in Mali. *BMJ Global Health*, *4*(2), e001227. https://doi.org/10.1136/bmjgh-2018-001227

Kimani-Murage, E. W., Pythagore, H., Mwaniki, E., Daniel, T., Samburu, B., Cuellar, P. C., Mbochi, R., Njiru, J., Wangare, L., Karimurio, L., Agutu, O., Maina, L. G., Okoth, P., Raburu, J., Wanjohi, M., Macharia, T., & Zerfu, T. A. (2019). Integrated and simplified approaches to community management of acute malnutrition in rural Kenya: A cluster randomized trial protocol. *BMC Public Health*, *19*(1), 1253. https://doi.org/10.1186/s12889-019-7497-3

Lazzerini, M., Rubert, L., & Pani, P. (2013). Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries. *The Cochrane Database of Systematic Reviews*, (6), CD009584. https://doi.org/10.1002/14651858.CD009584.pub2

Lelijveld, N., Bailey, J., Mayberry, A., Trenouth, L., N'Diaye, D. S., Haghparast-Bidgoli, H., & Puett, C. (2018). The "ComPAS Trial" combined treatment model for acute malnutrition: Study protocol for the economic evaluation. *Trials*, *19*(1), 252. https://doi.org/10.1186/s13063-018-2594-7

López-Ejeda, N., Charle Cuellar, P., Vargas, A., & Guerrero, S. (2019). Can community health workers manage uncomplicated severe acute malnutrition? A review of operational experiences in delivering severe acute malnutrition treatment through community health platforms. *Maternal & Child Nutrition*, *15*(2), e12719. https://doi.org/10.1111/mcn.12719

López-Ejeda, N., Charle-Cuellar, P., G. B. Alé, F., Álvarez, J. L., Vargas, A., & Guerrero, S. (2020). Bringing severe acute malnutrition treatment close to households through community health workers can lead to early admissions and improved discharge outcomes. *PLoS One*, *15*(2), e0227939.

López-Ejeda, N., Charle Cuellar, P., Vargas, A., & Guerrero, S. (2019). Can community health workers manage uncomplicated severe acute malnutrition? A review of operational experiences in delivering severe acute malnutrition treatment through community health platforms. *Maternal & Child Nutrition*, *15*(2), e12719.

Marseille, E., Larson, B., Kazi, D. S., Kahn, J. G., & Rosen, S. (2015). Thresholds for the cost-effectiveness of interventions: Alternative approaches. *Bulletin of the World Health Organization*, *93*(2), 118–124. https://doi.org/10.2471/blt.14.138206

Puett, C., Sadler, K., Alderman, H., Coates, J., Fiedler, J. L., & Myatt, M. (2013). Cost-effectiveness of the community-based management of severe acute malnutrition by community health workers in southern Bangladesh. *Health Policy and Planning*, *28*(4), 386–399. https://doi.org/10.1093/heapol/czs070

Rogers, E., Guerrero, S., Kumar, D., Soofi, S., Fazal, S., Martínez, K., Morán, J. L. A., & Puett, C. (2019). Evaluation of the cost-effectiveness of the treatment of uncomplicated severe acute malnutrition by lady health workers as compared to an outpatient therapeutic feeding programme in Sindh Province, Pakistan. *BMC Public Health*, *19*(1), 84. https://doi.org/10.1186/s12889-018-6382-9

Rogers, E., Martínez, K., Morán, J. L. A., Alé, F. G. B., Charle, P., Guerrero, S., & Puett, C. (2018). Cost-effectiveness of the treatment of uncomplicated severe acute malnutrition by community health workers compared to treatment provided at an outpatient facility in rural Mali. *Human Resources for Health*, *16*(1), 12. https://doi.org/10.1186/s12960-018-0273-0

Rushby, J. F., & Hanson, K. (2001). Calculating and presenting disability adjusted life years (DALYs) in cost-effectiveness analysis. *Health Policy and Planning*, *16*(3), 326–331. https://doi.org/10.1093/heapol/16.3.326

Turkana County. (2019). *Turkana County Smart Nutrition Survey*. http://www.nutritionhealth.or.ke/wp-content/uploads/SMART%20Survey%20Reports/Turkana%20County%20SMART%20Survey%20Report%20-%20June%202019.pdf

United Nations (UN). (2023). *The Sustainable Development Goals Report 2022*. https://unstats.un.org/sdgs/report/2022/

WHO. (2023a). *Malnutrition: Key facts*. Retrieved May 23, 2023, from https://www.who.int/news-room/fact-sheets/detail/malnutrition

WHO. (2023b). *WHO guideline on the prevention and management of wasting and nutritional oedema (acute malnutrition) in infants and children under 5 years*. https://www.who.int/publications/i/item/9789240082830

WHO/UNICEF. (2007). *Community-based management of severe acute malnutrition*. https://www.unicef.org/media/96981/file/Statement-WHO-WFP-SCN-and-UNICEF-on-Community-Based-Management-of-SAM

WHO/UNICEF. (2012). *WHO/UNICEF joint statement: Integrated community case management (iCCM)*. UNICEF. https://resourcecentre.savethechildren.net/document/who-unicef-joint-statement-integrated/

Wilunda, C., Mumba, F. G., Putoto, G., Maya, G., Musa, E., Lorusso, V., Magige, C., Leyna, G., Manenti, F., Dalla Riva, D., Ntoga, B. A., & Segafredo, G. (2021). Effectiveness of screening and treatment of children with severe acute malnutrition by community health workers in Simiyu region, Tanzania: A quasi-experimental pilot study. *Scientific Reports*, *11*(1), 2342. https://doi.org/10.1038/s41598-021-81811-6

Woods, B., Revill, P., Sculpher, M., & Claxton, K. (2016). Country-level cost-effectiveness thresholds: Initial estimates and the need for further research. *Value in Health*, *19*(8), 929–935. https://doi.org/10.1016/j.jval.2016.02.017

World Health Organization. (2020). *Global action plan on child wasting: A framework for action to accelerate progress in preventing and managing child wasting and the achievement of the Sustainable Development Goals*. WHO, Nutrition and Food Safety.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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