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Bringing Child Health Closer to Families: Lessons From a Family MUAC Intervention in Urban and Rural South Africa

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ABSTRACT

Mid-upper-arm circumference measurement (MUAC) is a simple, cost-effective approach to identify wasting in children. The Family MUAC intervention supported community health workers (CHWs) to mentor mothers and child caregivers to measure their children's MUAC at home. Sixty-four CHWs participated in seven sites in Gauteng and KwaZulu-Natal (KZN), South Africa. A cross-sectional survey was conducted to determine caregivers' ability to measure MUAC correctly and regularly. Ten households were randomly selected from household lists provided by each CHW. Fieldworkers collected data about the household, all children aged 6 months to 5 years living there and assessed caregiver's knowledge and skills in MUAC measurement. Data were collected in 521 households (Gauteng 201; KZN 351); 560 mothers/caregivers, (Gauteng 207; KZN 353) and 703 children (Gauteng 235; KZN 468) participated. Gauteng sites were high-density urban with small families in informal houses with access to water and sanitation, compared to rural KZN with larger households and poor water and sanitation access. Low household income and household food insecurity was the norm across all sites. In KZN a higher proportion of mothers/caregivers had received Family MUAC training compared to Gauteng (256/353; 72.5% vs. 93/270; 34.4%, $p < 0001$). Most trained mothers/caregivers achieved competency (263/349; 75.3%); this was significantly higher in KZN compared to Gauteng (215/256; 83.9% vs. 48/93; 51.6%; $p < 0.001$). Mothers/caregivers of 126/703 (17.9%) children recorded MUAC for ≥ 6 months (KZN 116/468, 24.8%; Gauteng 10/235, 4.3%). When designing community-based interventions for hard-to-reach communities it is important to address context-specific challenges to achieve sustainable high coverage.

1 | Introduction

Despite the major decline in global under-five mortality since 1990, undernutrition in all its forms continues to take a devastating toll on children's growth and development, especially children under 5 years of age living in low- and middle-income countries (LMIC) (Victora et al. 2021). Children with undernutrition have reduced immunity leading to recurrent

Abbreviations: CHW, community health workers; FW, field worker; HFIAS, Household Food Insecurity Access Scale; KZN, KwaZulu-Natal; LMIC, low- and middle-income countries; MAM, moderate acute malnutrition; MUAC, mid-upper arm circumference; PHC, primary health care; RTHB, Road to Health Booklet; SAM, severe acute malnutrition; USAID, United State Agency for International Development; WFHZ, weight-for-height Z score.

Summary

- In low income areas with poor coverage of routine growth monitoring, most mothers and caregivers who had received training and mentoring from community health workers (CHWs) could correctly measure mid-upper-arm circumference (MUAC) on their children, demonstrating that household MUAC measurement is feasible.
- High levels of coverage and sustainability of household MUAC measurements were not achieved for Family MUAC in these hard-to-reach communities because of challenges experienced in urban and rural contexts, particularly in high-density urban sites.
- Context-specific challenges should be identified and addressed during implementation of community-based interventions if high levels of sustainable coverage are to be achieved. Solutions should be developed in partnership with families and communities.

illnesses, delayed physical, mental and emotional growth and higher mortality (Black et al. 2008). Undernutrition, including stunting, severe wasting and micronutrient deficiencies are an underlying cause of one-third of deaths in under five children (Black et al. 2010). In addition, childhood undernutrition has lifelong effects, so that malnourished children are unlikely to reach their full potential as adults, limiting their ability to provide for themselves and their families, and creating a cycle of poverty and malnutrition for future generations (Victora et al. 2008; von Fintel and Richter 2019). These effects are particularly devastating in low- income countries where severe acute malnutrition (SAM) remains common and few children with SAM have access to treatment (Bliss et al. 2018; Victora et al. 2021). Finding affordable solutions for prevention and early detection of malnutrition in these settings remains a crucial public health priority if global targets to end hunger and eliminate malnutrition are to be achieved. (Sachs 2012; Victora et al. 2021; World Health Organization 2018).

South Africa is an upper-middle income country, where under-five mortality has been successfully reduced from 39 deaths per 1000 live births in 2015 to 28 per 1000 live births in 2020 (Dorrington et al. 2021). Despite this progress, SAM remains a significant underlying cause of child mortality, accounting for one-third of all in-hospital child deaths (Bamford et al. 2018; Committee on Morbidity and Mortality in children under 5 years CoMMiC 2020; Ndlovu et al. 2022). Improvements to malnutrition rates in South Africa mask wide differences in socio-economic and health and nutrition indicators between different districts and provinces (Ndlovu and Padarath 2024; von Fintel and Richter 2019), with women and children in low-income communities in both rural and informal urban areas at highest risk (Nkonki et al. 2011). Children living in the poorest wealth quintiles are three times more likely to be stunted than those in the wealthiest (SA Department of Health 2016).

Therefore, it is important to explore targeted approaches for early detection and treatment of malnutrition that are accessible to mothers and children in the most vulnerable communities, where children are most at risk (Victora et al. 2021). In South Africa, growth monitoring is routinely undertaken in primary health care (PHC) facilities using anthropometric measures to determine the weight-for-height Z-score (WFHZ). However, this approach requires high-quality, well-maintained equipment and trained staff to implement effectively, and further requires mothers to bring their children to the clinic, which may be costly for low-income families. In contrast, identification of children with wasting is possible in communities and in households using a simple tape to measure the mid-upper arm circumference (MUAC)(Alé et al. 2016; Briend et al. 2016). MUAC results are interpreted using the colour coding marked on the tape (red, yellow or green).

MUAC can be accurately measured by minimally trained personnel such as CHWs (Blackwell et al. 2015), and several studies have shown that mothers and other family members can use a MUAC tape to correctly measure the MUAC of children at home (Blackwell et al. 2015; Bliss et al. 2018; Grant et al. 2018). This approach recognises that family members are in the best position to detect signs of wasting earlier and are motivated to do so. Using MUAC to identify undernutrition is low cost and MUAC can be checked more frequently by family members, thereby increasing early diagnosis and improving outcomes for children (Alé et al. 2016; CoMMiC 2020). In addition, MUAC has been shown to be a better predictor of mortality for children aged 6–59 months than WFHZ, particularly if used regularly (Briend et al. 2016; Chiabi et al. 2017).

In South Africa, CHW's existing scope of practice includes measuring MUAC in children at the community or household level. However, CHWs are overworked with multiple responsibilities that may limit their ability to check the MUAC frequently and regularly (Mhlongo et al. 2020; Murphy et al. 2021; Musoke et al. 2022). In this paper we describe an intervention, known as Family MUAC, which aimed to extend the practice of measuring MUAC for early detection of malnutrition to mothers, caregivers, and other family/community members involved in the child's care in the household. By shifting activities for early detection of malnutrition from health workers to mothers or caregivers, Family MUAC has the potential to save money, save valuable time for CHWs, improve outcomes for high-risk children, raise awareness about malnutrition and empower the community.

In this study we aimed to determine whether it was feasible for mothers and child caregivers to measure MUAC regularly at home and record their findings, whether they were able to measure MUAC accurately and to determine the coverage of household MUAC measurements in participating communities. We present the findings of a household survey conducted in two contrasting urban and rural settings to to evaluate whether Family MUAC could address the need to improve early detection of wasting among children in the most vulnerable communities.

2 | Methods

2.1 | Study Design

A cross-sectional household survey was conducted to determine competency of mothers/caregivers measuring MUAC and the coverage of Family MUAC activities 3 months after completion of the intervention.

2.2 | Study Setting

Family MUAC was implemented in two provinces in South Africa, namely Gauteng and KwaZulu-Natal (KZN) provinces. The intervention was implemented in seven sites in five districts (three sites in Gauteng and four sites in KZN), with each site comprising the catchment area of one PHC clinic. Sites were purposively selected in partnership with the Department of Health (DoH) in each province, based on high SAM incidence and/or high SAM case fatality rates in these communities.

Sites in Gauteng were largely urban with many informal houses and shacks. Population density in the three Gauteng sites varied between 519 and 3003 people per square kilometre, median age was between 28 and 30 years and annual average household income ranged between R29,400.00 and R57,300.00 (US$ 1535–US $ 2992). One-third of households in the Gauteng sites were female-headed (33%–38%), and approximately half the population was employed (49%–53%) (Statistics South Africa 2016). Immunisation coverage was 83% for children under 1 year, almost half of mothers (45%) were exclusively breastfeeding their infants at the 14-week immunisation visit, and SAM in-patient case fatality rate was 7.7% (Ndlovu and Padarath 2024).

The four KZN sites comprised very deep rural areas with scattered households and traditional dwellings. Population density was between 59 and 64 people per square kilometre, median age was 18–19 years, and annual average income was R14,600.00 (US $775). More than half of households in KZN sites were female-headed (54%–59%), with very low employment rates (18%) (Statistics South Africa 2016). Immunisation coverage for children under 1 year of age was 92%, most infants (56%) were exclusively breastfed at the 14-week immunisation visit, and SAM in-patient case fatality rate was 10.5% (Ndlovu and Padarath 2024).

2.3 | Participants and Sampling

The survey was conducted among mothers and caregivers of children aged 6 months to < 5 years living in households served by CHWs participating in the Family MUAC intervention. All participating CHWs provided lists of the households they served where there was a child aged 6 months up to 5 years. Household lists were updated before data collection to allow for families moving in and out of the area and for changes to children's eligibility as they got older. These updated household lists provided the sampling frame, regardless of the participation of individual households in Family MUAC. The number of eligible households on the list provided by CHWs varied widely between participating CHWs from 3 to 74 households (KZN 3–58; Gauteng 13–76; mean 31). Ten households were randomly selected to participate from the list provided by each CHW, plus an additional five households to provide alternates to replace households where the mother and child were unavailable.

2.4 | Inclusion and Exclusion Criteria

We included all mothers and caregivers of children aged 6 months up to 5 years who were living in selected households (defined as sleeping in the household at least four nights per week). Child caregivers were defined as follows

- Mother: Biological mother of an eligible child.
- Primary caregiver: The main carer of an eligible child whose mother *does not live* in the household, including the father of the child.
- Day caregiver: The carer of an eligible child whose mother lives in the household but is absent at the time of the interview.

Mothers, fathers and primary caregivers were eligible to participate fully and provided informed consent. Day caregivers provided consent only for the child to have MUAC and pedal oedema checked by field workers (FWs). When there were multiple children with different mothers or caregivers living in the household, all were included in the survey.

Mothers or primary caregivers who were aged less than 16 years or who had been living in the household for less than 2 months were excluded because they had not been exposed to the intervention.

2.5 | Sample Size

A sample size of 460 children was required to estimate the proportion of children identified as malnourished by the expert MUAC practitioners within ±3% with probability of 95% with a baseline estimate of 8% (South African National Department of Health 2016). The sample size was increased by 8% to account for possible missing/unusable data. The sample size was therefore 30 CHWs and 250 households in each of the two provinces (total 60 CHWs and 500 households) to determine an accurate estimate of the proportion of children with SAM or moderate acute malnutrition (MAM) in the community. However, for logistic reasons a total of 64 CHWs participated in the intervention and were included in the household survey (29 from Gauteng and 35 from KZN).

2.6 | Description of the Family MUAC Intervention

Family MUAC was a community-based intervention to train and mentor mothers and child caregivers in households to check their children for wasting and undernutrition using a MUAC tape and checking for pedal oedema, with the aim of improving early detection of undernutrition. Family MUAC was implemented using existing staff and resources. The *Family MUAC Intervention* provided one Family MUAC facilitator in each province for an 8-month intervention period, after which Family MUAC was handed over to the DoH. The Family MUAC facilitator supported the intervention in each province, facilitated Family MUAC set up in each participating area, advocated for Family MUAC at provincial, district and local level, and mentored CHW participants through the intervention period.

In each participating community a task team was established comprising local stakeholders including community leaders, traditional leaders, traditional healers, ward counsellors and health

sector representatives. The Family MUAC community task team played a strong role in supporting Family MUAC implementation by introducing Family MUAC to the community and advocating for Family MUAC in wider local leadership structures and in the community. This support strongly encouraged both mothers and CHWs to participate in Family MUAC.

CHWs are non-professional health workers selected by the local community who are deployed in most areas in Gauteng and KZN. CHWs work in small teams known as ward-based PHC outreach teams (WBPHCOTs) supervised by a nurse, and they have responsibilities for health promotion and prevention in the households they serve, including for child health and nutrition. They receive a small monthly stipend (approx. USD250) and are not formally employed by the Department of Health. While there is a 12-month curriculum for CHW training this remains fragmented, WBPHCOTs are not established in all areas, and there is limited integration into the formal health system (D'Ambruoso et al. 2023).

CHWs participating in Family MUAC received a 1-day training to update their knowledge and skills about MUAC measurement and age-appropriate nutrition counselling. CHWs were then trained to support mothers and child caregivers in households to check MUAC and pedal oedema on their children and record their findings on a simple colour-coded household recording form every 2 weeks (Supporting Information: Appendix Figure 1). This 1-day training was led by a Family MUAC facilitator employed in each province.

During the intervention period CHWs visited all their assigned households with children aged 6months to 5 years every month to train and support mothers and caregivers to initiate and establish regular household MUAC measurements. In addition, CHWs provided nutrition counselling and supported mothers and caregivers to use the child's patient held clinic record (Road to Health Book [RTHB]) to access information about age-appropriate feeding practices and danger signs of severe illness in children.

Family MUAC was delivered by CHWs supported by the Family MUAC facilitator. All CHWs received mentoring from the Family MUAC facilitator (three visits per CHW in KZN and four in Gauteng), who accompanied them on household visits to support project implementation. The duration of the intervention was 8 months (August 2021 to March 2022).

2.7 | Data Collection Procedure

Data were collected by a team of two FWs in each province. FWs were trained for 1 week in standard operating procedures and data collection processes, and received extensive instruction and supervised practice measuring MUAC to ensure they had skills to undertake the role of MUAC experts against whom the mother's performance could be assessed.

FWs approached all selected households and, if mothers were unavailable, they returned twice more, so that only if after three visits they were unable to find the mother at home did they use an alternate household. FWs asked to speak to mothers and caregivers of all the children aged between 6 months and 5 years living in the household. Potential participants were then screened for eligibility. For all eligible mothers or caregivers, the study was explained and written informed consent obtained.

Data was collected using three structured questionnaires: (1) household tool, (2) mother/primary caregiver tool which included an assessment of each mother's performance measuring MUAC on her child and (3) child tool which included the FWs (expert) MUAC measurement for each child. The FWs also reviewed the RTHBs to check the date of the last weight and height measurements done at the health facility.

All mothers or primary caregivers were shown a MUAC tape and asked if they have ever seen a MUAC tape before. Those who reported that they had seen a MUAC tape were asked questions and requested to demonstrate use of the tape to assess their skills and knowledge. Those who had never seen a MUAC tape were not assessed and were scored as zero.

2.7.1 | Data Management and Analysis

Data were collected using android tablet devices and uploaded to a central server in real time using proprietary software. Extensive data checks were conducted by office-based researchers to ensure data completeness. Data were cleaned by a team of three researchers. Data were analysed using SPSS V28 and included descriptive statistics for frequencies, means, median, inter-quartile range and standard deviation. Pearson chi-square was used to determine significance.

To evaluate knowledge and skills of mothers and primary caregivers, a score was developed based on the responses to five questions (knows what tape is used for; knows how often it should be used; knows what to do for a red/yellow/green reading) and their performance in five steps demonstrating how to measure MUAC (removes clothing, identifies mid-upper arm, arm hanging down and attaches tape, tightens tape appropriately, identifies correct colour). A score of one point was allocated to each correct response or activity with a total available score of 10. Scores of 7 and above were deemed to be competent. Mothers who reported they had never seen a MUAC tape were not asked to demonstrate and scored zero.

The USAID Household Food Insecurity Access Scale (HFIAS) was used to assess food insecurity. HFIAS comprises nine questions related to access to food and has been widely used and validated in South Africa (Masa and Sharma 2021; van den Berg and Walsh 2023). If any answers indicated that there was a lack of access to food, participants were asked how often this occurred (rarely, sometimes, often). A score was calculated based on these answers, using the validated scoring method, and categories included no food insecurity, mild/moderate food insecurity, or severe food insecurity (Coates et al. 2007).

2.8 | Ethics Statement

Ethical approval was obtained from the Biomedical Research Ethics Committee at the University of KwaZulu-Natal (BREC/00003893/2022), the KwaZulu-Natal Department of Health (KZ_202203_30)

and Gauteng Department of Health (GP_202203_057). Individual approval was obtained from ethics committees in the three districts in Gauteng and letters of support were obtained from the two districts in KZN. All participating mothers and primary caregivers provided written informed consent to participate. Day caregivers provided limited written consent for malnutrition screening only. Any child identified with a low MUAC or pedal oedema during data collection was referred to the CHW who ensured that the child attended the health facility. Special ethical approval was obtained to allow mothers from 16 years of age to provide their own consent to participate in the study without the need for additional parental consent (BREC/00004363/2022).

3 | Results

The household survey was conducted between June and October 2022. Data were collected from 521 households (201 households in Gauteng and 351 households in KZN). In KZN, FWs successfully recruited child carers in all ten selected households for 33/35 participating CHWs, and for two CHWs five alternate households were visited (total 10 alternate households visited). However, in Gauteng recruitment was challenging and alternate households were used to achieve the required sample size for 10/29 CHWs, in several cases requiring selection of additional alternates (total 95 alternate households visited). All eligible children living in selected households who were present at the time of data collection were included. Eight hundred and twenty-two children participated in the study comprising 703 children who lived with a mother or primary caregiver, and 117 children where there was a day caregiver present. Child participants with a day caregiver were only included in the analysis to determine the prevalence of undernutrition. We enrolled 560 child carers, comprising 442 mothers and 118 primary caregivers, which included nine males, who were either fathers or other male relatives (Figure 1).

3.1 | Characteristics of Participants and Households

Household characteristics in the two provinces demonstrated the contrast between the two settings (Table 1). Families in Gauteng were more likely to live in nuclear families than those in KZN, where there were extended families with more residents per household and single parent families were common. In both communities there was a high proportion of female headed households. Households in rural KZN were more likely to use a pit latrine and collect water from rivers or dams, compared to urban Gauteng where most households used a flush toilet and piped water. Household income was very low in all sites in both provinces and household food insecurity was the norm in all communities.

Sociodemographic characteristics of mothers and primary caregivers in the two provinces were similar, but one notable difference was that mothers and primary caregivers in Gauteng were more likely to be unmarried and living with their partner than in KZN (Gauteng 72/207, 34.8% vs. KZN 26/353, 7.4%), whereas in rural KZN it was more common for unmarried women who were in a relationship to be living apart from their partner (KZN 162/353, 45.9% vs. Gauteng 39/207, 18.8%) (Supporting Information: Appendix Table 1). Among 703 participating children, those in Gauteng were more likely to be living with their mother compared to children in KZN (Gauteng 219/235, 70.6% vs. KZN 291/468, 57.1%) and children in KZN were more likely to be living with a grandparent as the primary caregiver (Gauteng 4/235 (1.3%) vs. KZN 122/468 (23.9%).

3.2 | Performance of Mothers and Primary Caregivers in Measuring MUAC

A higher proportion of mothers and primary caregivers in KZN reported having seen a MUAC tape compared to Gauteng (KZN 306/353; 86.7% vs. Gauteng 129/207; 62.3%, $p < 0.001$). Similarly, a higher proportion of mothers and primary caregivers in KZN reported having received training about Family MUAC (256/353; 72.5% vs. 93/270; 34.4%, $p < 0001$). Table 2 shows the scores among all mothers/primary caregivers.

Table 3 shows the overall scores achieved by mothers and primary caregivers based on the scoring system shown in Table 2 for (1) all mothers and caregivers in participating households regardless of whether they had participated in Family MUAC, (2) mothers and caregivers who had seen a MUAC tape and (3) mothers and caregivers who had received Family MUAC training. Scores in KZN were higher for all groups compared with those in Gauteng. Among mothers and caregivers who had received training a substantial proportion of mothers achieved competency (263/349; 75.3%) but this was significantly higher for KZN compared with Gauteng (215/256; 83.9% vs. 48/93; 51.6%; $p < 0.001$).

3.3 | Programme Coverage of the Family MUAC Intervention

We reviewed the uptake of the regular household MUAC measurements in participating households using two different data sources. First, mothers and primary caregivers were asked about their participation in Family MUAC activities, and secondly the household recording form was reviewed and the number of entries observed. Findings are shown in Table 4.

3.4 | Coverage of Facility-Based Well Child Services

The RTHB was reviewed for all participating children to determine the coverage of routine facility-based growth monitoring in the two provinces. For children aged 6- < 12 months where growth monitoring is recommended monthly more than one-third of children had not have their weight checked in the past 8 weeks. For children aged 12months to < 24months where the recommendation is 2-monthly growth monitoring around 60% of children had not had their weight checked in the previous 8 weeks (Table 5).

3.5 | MUAC Measures Among Participating Children

All children, including those with a day carer, had their MUAC measured and were checked for pedal oedema by a

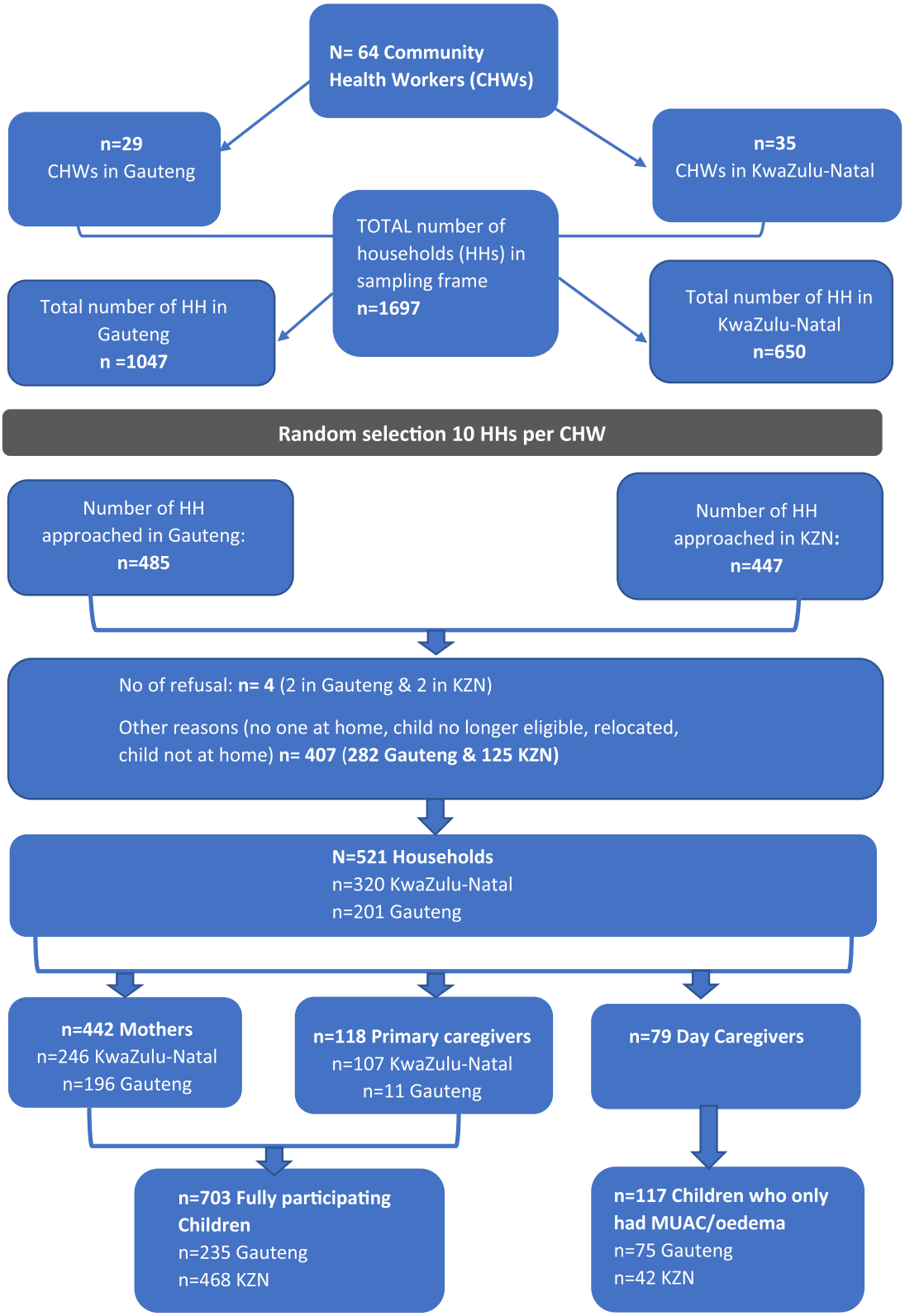

FIGURE 1 | Participant diagram.

trained FW. Rates of SAM and MAM were very low in our population with only one child with MAM and two children with SAM being identified. Characteristics of participating children are shown in Supporting Information: Appendix Table 2.

4 | Discussion

Our findings demonstrate the potential benefits and challenges of a household-based approach to identification of undernutrition, with mothers and child caregivers undertaking

TABLE 1 | Characteristics of participating households in each province.

Number of households (HHs)	Gauteng $n = 201$ (%)	KZN $n = 320$ (%)	All $n = 521$ (%)
Household size			
No of people living in the household including children	Mean 4.91	Mean 7.78	Mean 6.67
	SD 1.961	SD 3.482	SD 3.299
Family structure within the households			
Single parent family	44 (21.9)	132 (41.3)	176 (33.8)
Nuclear family	107 (53.2)	95 (29.7)	208 (38.8)
Extended family	32 (15.9)	71 (22.2)	103 (19.8)
Mixed family and nonfamily members	6 (3.0)	21 (6.6)	27 (5.2)
Other	12 (6.0)	1 (0.3)	13 (2.5)
Proportion of female-headed HHs	72 (35.8)	170 (53.1)	242 (46.4)
Dominant type of dwelling			
Constructed formal brick/block house	123 (61.2)	313 (97.8)	436 (83.7)
Traditional mud with thatch dwelling	0	7 (2.2)	7 (1.3)
Informal shack	78 (38.8)	0	78 (15.0)
Sources of drinking water			
Piped water inside the house	19 (9.5)	3 (0.9)	22 (4.2)
Piped water in the yard	47 (23.4)	85 (26.6)	132 (25.3)
Piped water at a public tap	43 (21.4)	47 (14.7)	90 (17.3)
River water/dam/lake/pond	0	92 (28.7)	92 (17.7)
Rain water tank	5 (2.5)	26 (8.1)	31 (6.0)
Borehole	0	56 (17.5)	56 (10.7)
Spring surface water	0	6 (1.9)	6 (1.2)
Tanker truck	69 (34.3)	1 (0.3)	70 (13.4)
Buying water	18 (9.0)	4 (1.3)	22 (4.2)
Toilet used by family			
Inside flush toilet	58 (28.9)	2 (0.6)	60 (11.5)
Outside flush toilet	72 (35.8)	0	72 (13.8)
Ventilated pit toilet	45 (22.4)	128 (40.0)	173 (33.2)
Pit toilet	24 (11.9)	139 (43.4)	163 (31.3)
No toilet/bush/veld	2 (1.0)	51 (15.9)	53 (10.2)
HH is connected to electricity	138 (68.7)	317 (99.1)	455 (87.3)
Fuel use for cooking food			
Electricity	115 (57.2)	235 (73.4)	350 (67.2)
Gas	41 (20.4)	14 (4.4)	55 (10.6)
Wood	1 (0.5)	61 (19.1)	62 (11.9)
Paraffin	44 (21.9)	0	44 (8.4)
Coal or cow dung	0	10 (3.1)	10 (1.9)
Overall household income			
Less than R3000.00	97 (48.3)	186 (58.1)	283 (54.3)
Between R3000.00 and R6000.00	65 (32.3)	120 (37.5)	185 (35.5)
More than R6000.00	21 (10.4)	14 (4.4)	35 (6.7)
Chooses not to answer	18 (9.0)	0	18 (3.5)
Sources of household income (multiple)			

(Continues)

TABLE 1 | (Continued)

Number of households (HHs)	Gauteng $n = 201$ (%)	KZN $n = 320$ (%)	All $n = 521$ (%)
Salaries or wages from employer	83 (41.3)	33 (10.3)	116 (22.3)
Informal work or trading	25 (12.4)	30 (9.4)	55 (10.6)
Child support grant	133 (66.2)	300 (93.8)	433 (83.1)
Disability grant	4 (2.0)	8 (2.5)	12 (2.3)
Old age pension	11 (5.5)	134 (41.9)	145 (27.8)
Support from partner/maintenance	60 (29.9)	118 (36.9)	178 (34.2)
Support from family members	18 (9.0)	128 (40.0)	146 (28.0)
Other	3 (1.5)	17 (5.3)	20 (3.8)
Household food insecurity score			
Food secure	44 (21.9)	42 (13.1)	86 (16.5)
Mild food insecurity	35 (17.4)	61 (19.1)	96 (18.4)
Moderate food insecurity	62 (30.8)	102 (31.9)	164 (31.5)
Severe food insecurity	60 (29.9)	115 (35.9)	175 (33.6)

Abbreviations: KZN, KwaZulu-Natal; SD, standard deviation.

TABLE 2 | Mothers and primary caregivers (ALL) scoring for knowledge and practice in measuring MUAC by province.

	Gauteng $n = 207$[a]	KwaZulu-Natal $n = 353$[b]	Total $n = 560$
Scoring of knowledge/practice for MUAC by ALL mothers and primary caregivers			
Knows what tape is used for	77 (37.2)	262 (74.2)	339 (60.5)
Knows how often MUAC should be done	44 (21.3)	228 (64.6)	272 (48.6)
Knows what to do for a red reading	65 (31.4)	228 (64.6)	293 (52.3)
Knows what to do for a yellow reading	30 (14.5)	177 (50.1)	207 (37.0)
Knows what to do for a green reading	75 (36.2)	233 (66,0)	308 (55.0)
Demonstration:			
Removes clothes	73 (35.3)	230 (65.2)	303 (54.1)
Identifies mid upper arm	43 (20.8)	218 (61.8)	261 (46.6)
Arm hanging down attaches tape	52 (25.1)	216 (61.2)	268 (47.9)
Tightens tape appropriately	57 (27.5)	203 (57.5)	260 (46.4)
Identifies correct colour on MUAC tape	80 (38.6)	239 (67.7)	319 (57.0)

Abbreviation: MUAC, mid-upper-arm circumference.
[a]Includes 78 child caregivers who had never seen tape and scored zero.
[b]Includes 47 child caregivers who had never seen a tape and scored zero.

MUAC measurements on their own children. Family MUAC was implemented in two contrasting low-income settings, selected based on high SAM incidence and/or high SAM case fatality rates in these areas and, as a result, we were able to demonstrate the importance of considering context in the design and implementation of a community-based intervention. Although mothers and caregivers who had received training were able to measure the MUAC accurately, poor coverage and lack of sustainability threatened the success of the approach. In addition, coverage of routine facility-based well child services was poor in both settings, demonstrating the vulnerability of children in high-risk areas, and highlighting the need to find a solution to ensure that essential services reach these children.

Mothers and other caregivers play the most important role in caring for the health and well-being of their children, and are in the best position to detect any signs of ill health or undernutrition (Alé et al. 2016). Supporting mothers and caregivers in households to take a lead in assessing nutrition and caring for the health of their children has the potential to reduce child morbidity and mortality. Our findings demonstrate that mothers trained on MUAC and supported by CHWs were able to perform MUAC correctly, were competent in interpreting MUAC results and knew what action to take for a low MUAC. These findings are consistent with a number of other studies (Alé et al. 2016; Blackwell et al. 2015; Bliss et al. 2018). Thus, mothers have the potential to take a leading role in identification of wasting in their children, thereby improving the frequency of MUAC measurement and allowing earlier detection of malnutrition (Alé et al. 2016). Further, these activities have the wider benefit of empowering mothers to take a lead in caring for the health of themselves and their children (Seidu et al. 2022). Blackwell and colleagues noted

TABLE 3 | Mothers and primary caregivers scoring for knowledge and practice.

ALL mothers and caregivers	Gauteng $N = 270$ n (%)	KwaZulu-Natal $N = 353$ n (%)	Total $N = 560$ n (%)
Scores (maximum 10)	Median 0	Median 9	Median 6
	IQR 0–6	IQR 0–10	IQR 0–9
High score 9–10 (excellent)	20 (9.7)	182 (51.6)	202 (36.1)
Medium 7–8 (competent)	29 (14.0)	36 (10.2)	65 (11.6
Low 6 and below (inadequate)	158 (76.3)	135 (38.2)	293 (52.3)
Mothers who reported having SEEN a MUAC tape	**$N = 129$ n (%)**	**$N = 306$ n (%)**	**$N = 435$ n (%)**
Scores (maximum 10)	Median 5	Median 9	Median 8
	IQR 0–8	IQR 5–10	IQR 0–10
High score 9–10 (excellent)	20 (15.5)	182 (59.5)	202 (46.4)
Medium 7–8 (competent)	29 (22.5	36 (11.8)	65 (14.9)
Low 6 and below (inadequate)	80 (62.0)	88 (28.8	168 (38.6)
Mothers who had SEEN a MUAC tape and was TRAINED	**$N = 93$ n (%)**	**$N = 256$ n (%)**	**$N = 349$ n (%)**
Scores (maximum 10)	Median 7	Median 9	Median 9
	IQR 4–8	IQR 8–10	IQR 7–10
High score 9–10 (excellent)	20 (21.5)	179 (69.9)	199 (57.0)
Medium 7–8 (competent)	28 (30.1)	36 (14.1)	64 (18.3)
Low 6 and below (inadequate)	45 (48.4)	41 (16.0)	86 (24.6)

Abbreviations: IQR, interquartile range; MUAC, mid-upper-arm circumference.

TABLE 4 | Coverage of family MUAC.

Family MUAC coverage reported by mothers and primary caregivers (one per household)	Gauteng $n = 207$ (%)	KwaZulu-Natal $n = 353$ (%)	Total $n = 560$ (%)
Mother/carer reports having been shown how to use the MUAC tape	93 (44.9)	256 (72.5)	349 (62.3)
Mother/carer reports having used the tape to measure MUAC at home	71 (34.3)	178 (50.4)	249 (44.5)
MUAC tape is present in the HH	57 (27.5)	275 (77.9)	332 (59.3)
Family MUAC Coverage from observation of the household recording forms (one per child)	**Gauteng $n = 235$**	**KZN ($n = 468$)**	**Total ($N = 703$)**
The MUAC recording form is available for this child (observed)	54 (23.0)	278 (59.4)	332 (47.2)
MUAC form has been used to record MUAC (observed)	49 (20.9)	270 (57.7)	319 (45.4)
MUAC form was used for 6 months or longer	10 (4.3)	116 (24.8)	126 (17.9)
Mean number of entries	1.3 Minimum 0 Maximum 22	6.1 Minimum 0 Maximum 40	4.5 Minimum 0 Maximum 40

Abbreviations: HH, household; MUAC, mid-upper-arm circumference.

in their study of community MUAC that mothers and family members had seen MUAC measured previously but it had never been explained to them, and they appreciated the opportunity to understand and participate in their children's care, and helped each other learn (Blackwell et al. 2015). In addition, working together can improve working relationship between CHWs and mothers, build community resilience and social capital, and improve adherence to malnutrition or other treatments when required (Laurenzi et al. 2021).

However, this study highlighted problems with coverage and sustainability of the Family MUAC approach. Three months after completion of external support for family MUAC, coverage of Family MUAC training was low among mothers and caregivers, despite sampling from household lists provided by the CHWs themselves. In particular, coverage was substantially lower in Gauteng compared to KZN. In Gauteng, the sites comprised urban, informal households with small nuclear families with a high density and highly mobile

TABLE 5 | Existing coverage of growth monitoring.

Children living with mother, father/primary caregiver	Gauteng $n = 235$ (%)	KZN $n = 468$ (%)	All $n = 703$ (%)
RTHB is available today	208 (88.5)	411 (87.8)	619 (88.1)
Time since last weight check (all children)[a]			
0–4weeks	13 (5.5)	75 (16.0)	88 (12.5)
4–8 weeks	12 (5.1)	41 (8.8)	53 (7.5)
9–12 weeks	8 (3.4)	29 (6.2)	37 (5.3)
> 12 weeks	138 (58.7)	254 (54.3)	392 (55.8)
No weight recorded	36 (15.3)	7 (1.5)	43 (6.1)
No RTHB	27 (11.5)	57 (12.2)	84 (11.9)
Children aged 6-months to < 12 months	**$n = 14$ (%)**	**$n = 42$ (%)**	**$n = 56$ (%)**
Time since last weight check children aged 6 months to < 12 months[b]			
0–4weeks	5 (35.7)	21 (50.0)	26 (46.4)
4–8 weeks	3 (21.4)	6 (14.3)	9 (16.1)
9–12 weeks	1 (7.1)	5 11.9)	6 (10.7)
> 12 weeks	2 (14.3)	6 (14.3)	8 (14.3)
No weight recorded	0	1 (2.4)	1 (1.8)
No RTHB	3 (21.4)	0	3 (5.4)
Children aged 12–23 months	**$n = 59$ (%)**	**$n = 102$ (%)**	**$n = 161$ (%)**
Time since last weight check among children aged 12–23 months[c]			
0–4weeks	5 (8.5)	23 (22.5)	28 (17.4)
4–8 weeks	4 (6.8)	16 (15.1)	20 (12.4)
9–12 weeks	4 (6.8)	11 (10.8)	15 (9.3)
> 12 weeks	26 (44.1)	40 (39.2)	66 (41.0)
No weight recorded	12 (20.3)	2 (2.0)	14 (8.7)
No RTHB	7 (11.9)	10 (9.8)	17 (10.6)

Abbreviations: KZN, KwaZulu-Natal; RTHB, Road to Health Booklet.
[a]5 missing.
[b]3 missing.
[c]1 missing.

population, where CHWs served large numbers of households packed closely together. In KZN, the population was more stable with large scattered households, extended families with several mothers and children, and CHWs served fewer households but travelled over longer distances. Differences in family structure and child care shown in the demographic data reflect these urban/rural differences. Families in rural areas are more traditional, co-habitation of unmarried parents is unacceptable and many children are left with their grandmothers when their mother leaves to seek work. However, communities and households in both settings were similarly vulnerable with very low incomes, high rates of unemployment, dependency on social grants, and high rates of food insecurity. Possible reasons for poor coverage in Gauteng were the large numbers of households each CHWs was required to visit, the high levels of mobility, with many mothers out of the house during the day. Changing of locations within informal settings is common, making it difficult for CHWs to access mothers and conduct follow up. In addition, sustainability was a challenge in both provinces, with most households no longer measuring MUAC 3 months after completion of the Family MUAC intervention. Reasons for this could include lack of ongoing support from CHWs, mothers' lack of self-efficacy and motivation, loss of the MUAC tape, or fear of an abnormal finding.

Our findings underscore the importance of context and demonstrated a variety of challenges CHWs face when providing care to children in very low-income settings, given their heavy workload and varied responsibilities. However, we used standardised implementation strategies without exploring possible adaptation of the intervention to address the challenges identified in each context. Involving key participants, mothers and caregivers and CHWs in planning, designing and adapting the intervention would assist in identifying context-specific gaps and implementing strategies to improve coverage and sustainability of community-based interventions like Family MUAC. In this project we successfully established Community Task

teams comprising community leaders and other stakeholders to support the project, these forums were a resource that could have been harnessed to address these challenges. More research could explore the reasons why mothers and caregivers did not continue to measure MUAC and CHWs did not continue to encourage participation. Innovative context-specific approaches to provide ongoing support for mothers should be developed in partnership with women, families and communities. In addition, it is critical for sustainability that CHWs are adequately resourced, supervised and supported.

One strategy that could address the challenges identified would be for CHWs to train and support women in groups, which would improve coverage and be cost and time-effective compared with visiting individual households. Convening mother's groups would be a good approach for both rural and urban areas, mothers could arrange to attend even if they are working or have moved their residence, and using this approach mothers could support and motivate each other, building social capital and resilience which would in turn improve sustainability. There is good evidence that women's peer support groups can improve coverage of community-based interventions, create secure spaces where women can share their opinions and experiences with their peers, thereby promoting women's empowerment, behavioural change, social capital, collective action, peer support and resilience (Gram et al. 2019). SMS reminders or WhatsApp groups would be another way for CHWs to stay in touch with mothers and remind them to measure the MUAC on their children and to provide information to mothers without having to meet. Tickell and colleagues demonstrated the effectiveness of using SMS through a randomised controlled trial where household MUAC supported by SMS was associated with 37% reduction in wasting among young children (Tickell et al. 2023).

4.1 | Strengths and Limitations

This study employed a strong methodology to determine accuracy, coverage and sustainability of household MUAC measurement in households, recruiting all mothers and children living in each participating household. The household lists were provided by the CHWs and they could have omitted households they did not visit leading to bias. However, the cross-sectional methodology means we are not able to draw conclusions about trends or the reasons for our findings. We had a smaller sample in Gauteng because of the difficulties in finding mothers at the addresses provided by the CHWs, which may have affected the results. In addition, we showed a very low prevalence of low MUAC despite working in low-income areas with reported high prevalence of malnutrition. This was because the sample size was based on an overestimate of the prevalence of malnutrition in these communities, so that the study was unable to provide a precise estimate of SAM and MAM prevalence.

5 | Conclusion

Family MUAC has the potential to address the need to improve identification of malnutrition in high-risk communities. Empowering mothers to take responsibility for the health of their children will have ongoing benefits for the child, the family and the community. Given that mothers were able to measure MUAC accurately when adequately supported, Family MUAC remains a feasible solution, but more context specific and innovative solutions are required to support and sustain implementation of community-based child health interventions in hard-to-reach populations. Solutions should be context-specific, flexible, community based, and aimed at the poorest and most vulnerable communities, focusing on giving responsibility to mothers and family members. A possible approach would be to use women's groups conducted by CHWs as a vehicle for Family MUAC. Further research should explore the barriers to sustainability and coverage for Family MUAC and evaluate possible solutions.

Author Contributions

All authors were involved in the design of the intervention. Christiane Horwood, Sphindile Mapumulo, Silondile Luthuli and Lyn Haskins conceptualized the study. Lyn Haskins, Sphindile Mapumulo, Silondile Luthuli supervised the field work. Christiane Horwood, Sphindile Mapumulo and Lyn Haskins analysed the data. Christiane Horwood wrote the first draft of the manuscript. Sphindile Mapumulo, Silondile Luthuli and Lyn Haskins contributed to writing the manuscript. All authors commented on versions of the manuscript and approved the final manuscript before submission.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data sets used and analysed during the current study are available from the corresponding author on reasonable request and motivation.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.