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Diagnostic criteria for severe acute malnutrition and fatal outcomes in children aged 6–59 months, Nigeria

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Abstract

Objective To determine factors associated with inpatient death among a cohort of children aged 6–59 months with severe acute malnutrition in north-western Nigeria.

Methods Our observational study used routine programmatic data of all children aged 6–59 months admitted to two inpatient facilities in Katsina State with severe acute malnutrition in 2022. We assessed nutritional status at admission by weight-for-height Z-score (WHZ), mid-upper-arm circumference (MUAC) and bilateral nutritional oedema using World Health Organization definitions. We used Cox-proportional hazard models to identify predictors of mortality, with and without adjustment for sex, age group, nutritional status at admission, major clinical complications and comorbidities.

Findings Of 12 771 children included in the analysis, we observed an overall inpatient mortality of 8.4%. Compared with children admitted by the MUAC criterion alone, we noted that children admitted by the WHZ criterion alone had twice the risk of death; children admitted with kwashiorkor and low WHZ had more than four times the risk. Older marasmic children had a higher risk of death than younger children (adjusted hazard ratio: 1.74; 95% confidence interval: 1.50–2.03). We did not observe any significant association between stunting and mortality. Our findings were not altered by any of the complications or comorbidities recorded.

Conclusion Children with a low WHZ at admission have a higher risk of death than those with a low MUAC, and should be subject to special considerations when associated with oedema. MUAC alone is an insufficient criterion to identify all the children at risk of death from malnutrition.

Introduction

Each year severe acute malnutrition contributes to millions of deaths among children aged 6–59 months based on weight-for-height Z-score (WHZ).¹ If children with a low mid-upper-arm circumference and nutritional oedema (kwashiorkor) are added, the prevalence estimate doubles;^{2,3} when incidence instead of prevalence is considered, the burden increases dramatically.⁴ Regardless of the exact magnitude, severe acute malnutrition is a major concern.

The World Health Organization (WHO) defines severe acute malnutrition as any combination of WHZ less than $-3Z$, mid-upper-arm circumference less than 115 mm and/or bilateral nutritional oedema.⁵ Affected children have a higher risk of death by a factor of approximately nine compared with healthy children.⁶ Children without clinical complications can be managed in the community through outpatient therapeutic programmes; however, children who fail an appetite test, have severe oedema, medical complications or clinical danger signs are categorized as having complicated severe acute malnutrition and are initially managed in inpatient facilities.⁷

In sub-Saharan Africa, 10–40% of children with severe acute malnutrition admitted for inpatient care die.⁸ WHO predicts that the mortality could be reduced to less than 5% if their guidelines are followed.⁹ However, few studies have reported on factors associated with inpatient mortality from severe acute malnutrition. A review of 19 such studies since 2000 only had 400 patients per study.¹⁰ As well as having insufficient power or using outdated guidelines and standards, the results of these studies had not been adjusted for important confounding factors including complications, comorbidities and nutritional oedema.^{3,11} Early identification of prognostic factors, referral to inpatient facilities and risk stratification at admission could reduce inpatient mortality in affected children.

Katsina State in North-Western Nigeria has 34 local government areas with an estimated population of 10.3 million.¹² The region has recently faced high levels of banditry and is the most food insecure in Nigeria; recent surveys show alarming levels of malnutrition classified under the Integrated Food Security Phase Classification for Acute Malnutrition as Phase 3 (serious) to Phase 4 (critical).^{13–15} Since 2021, *Médecins Sans Frontières* (MSF) Operational Centre Paris with the Katsina State Ministry of Health has managed acute malnutrition in the local government areas of Jibia, Katsina and Mashi, admitting the largest cohort of children with severe acute malnutrition ever treated by MSF.¹⁶ Among all patients treated in our therapeutic programmes, almost all deaths occurred in children admitted to one of our inpatient facilities. To provide insights into the mechanisms underlying inpatient

mortality, we examine the factors associated with death among children with severe acute malnutrition.

Methods

We collected clinical and anthropometric data from all patients aged 6–59 months admitted to the two inpatient MSF facilities in Katsina town from 1 January to 31 December 2022.

Treatment in these inpatient facilities followed WHO guidelines and the current national protocol.^{9,17}

Data encoders routinely entered data from patient files and registers into an Excel (Microsoft, Redmond, United States of America) line list to facilitate supervision, audit and early detection of anomalous mortality. Staff entered data at admission and completed each patient's details at or shortly after discharge. We de-identified data before compiling weekly analyses.

We excluded children that did not meet the criteria for severe acute malnutrition, or had implausible or missing weight, height, MUAC, oedema or outcome, from our analysis (Fig. 1).

Statistical analysis

Our primary outcome was all-cause in-hospital mortality. Children who defaulted (i.e. were lost to follow-up) were included in the analysis. There were no transfers to other institutions.

We defined our independent variables as age group (6–23 and 24–59 months), sex, local government area of residence (either supported or not supported by MSF), type of admission (direct admission or transfer from an outpatient therapeutic programme), weight, height, MUAC, WHZ, height-for-age Z-score (HAZ), nutritional status, nutritional grade (oedema in the feet, hands and face classified as grades 1, 2 and 3, respectively), major clinical complications and common comorbidities (including a rapid malaria test at admission). Health workers diagnosed dehydration and sepsis from clinical signs alone, respiratory infection by tachypnoea alone, and hypoglycaemia mostly by clinical signs and occasionally blood glucose. We assessed nutritional status based on current WHO definitions⁵ and, to avoid Simpson's paradox (an extreme form of confounding where the results of a comparison can be reversed, making a less important variable appear dominant),^{3,18,19} we classified children into one of the categories defined in Table 1.

We calculated distributions of patients and deaths over each level of the specified variables. Subsequently, we performed Pearson's χ^2 tests (P -value < 0.05) to examine whether the distributions of deaths differed across levels, in relation to case fatality rates.

We then ran univariable Kaplan–Meier models comparing mean or median survival times for each variable. Variables with a P -value of less than 0.05 were retained and paired for bivariable models to test for the presence of one-way interactions. We included all significant covariates and interactions in a full multivariable analysis, both with and without adjustment for the potential confounders of sex, age group, nutritional status at admission, major clinical complications, comorbidities and their relevant interactions. Given the persistence of the interaction between age group and nutritional status groups in the full model (P -value < 0.05), we also present stratified multivariable analyses for children with marasmus (that is, non-oedematous malnutrition) and kwashiorkor, disaggregating these distinct malnutrition forms.

We report both crude and adjusted hazard ratios (HR and aHR) with 95% confidence intervals (CI). A comparison of aHR with HR shows the magnitude of association between death and covariates. We assessed the proportional hazard assumption based on Schoenfeld residuals test (both global and scaled) and log-minus-log graphs. We considered covariates with a P -value of less than 0.05 to be statistically significant predictors of death in children with severe acute malnutrition.

We conducted a sensitivity analysis to determine whether results varied when children recorded as defaulters were considered as deaths.

We analysed all data using R software, version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics

Our research fulfilled the exemption criteria set by the MSF Ethics Review Board for posteriori analyses of routinely collected clinical data, and was conducted with the permission of the Medical Director of MSF Operation Centre Paris. The Katsina State Ministry of Health additionally approved the secondary use of routinely collected programmatic data for our analysis and publication. Informed consent was not required as the data were collected for monitoring and evaluation purposes within the MSF-supported nutrition programme.

Results

Our initial analysis included 12 771 children; an anthropometric measurement (MUAC) had not been recorded for 15 children (0.1%) and a further 49 children were excluded from the Cox analysis (0.4%; Fig. 1).

We observed that the case fatality rate remained steady throughout the year at about 8.4% (1074/12 771; monthly range: 3.8–10.8), despite the seasonality in admissions (Fig. 2). A slightly higher proportion of older children were admitted during the peak. A total of 5 826/12 771 (45.6%) patients were direct admissions to the inpatient facility, mostly from local government areas not supported by MSF (9012; 70.6%), and were evenly split by age (6–23 months: 6396; 50.1%) and sex (girls: 6258; 49.0%; Table 2). Of the deaths, 792/1074 (73.7%) were from local government areas not supported by MSF. We observed that the older children had a much higher risk of death than the younger children (aged 24–59 months: 648; 60.3%), and girls accounted for 579/1074 (53.9%) of the deaths.

We noted that 11 297/12 1771 (88.5%) of the admitted patients were stunted (HAZ < −2Z) but no significant association was observed between stunting, often interpreted as chronic malnutrition, and mortality. We did not consider HAZ in any of the models explaining variations in mortality (Table 2).

We observed that many patients had very severe acute malnutrition: the majority (6973; 54.6%) had a MUAC of less than 110 mm and a WHZ of less than −4Z (7583; 59.4%), both of which corresponded to the highest case fatality rates. Such severity explains why 6995 (54.8%) of the children met the admission criteria for both MUAC and WHZ. Significantly different case fatality rates were observed by admission criterion. The lowest case fatality rate (2.9%; 14/479) was observed among children admitted by the MUAC criterion alone; those with only a low WHZ had more than double this mortality (6.4%; 98/1531), and those fulfilling both admission criteria had an even higher mortality (8.2%; 575/6995). We noted that patients with only oedema had a similar mortality (4.6%; 51/1104) to those with oedema and a low MUAC (4.5%; 13/289). Our findings reveal that oedematous children with a low WHZ had the highest mortality of all severe acute malnutrition groups (18.1%; 97/535; Table 2).

Of all clinical complications considered, we observed that a diagnosis of hypoglycaemia was associated with the highest risk of death (22.4%; 143/639). Children with dehydration had a slightly increased mortality (10.7%; 137/1279), whereas patients with fever had a lower mortality rate (6.4%; 399/6204). Among comorbidities, we noted a lower risk of

death for both chronic diarrhoea (7.1%; 209/2938) and acute diarrhoea (5.9%; 76/1289). Our results show that clinically diagnosed sepsis (13.2%; 328/2485) and rapid respiration (11.1%; 45/405) contributed significantly to mortality (Table 2).

Both the unadjusted and adjusted Cox regression models found several factors significantly associated with the probability of dying in marasmic children (Table 3). Patients diagnosed with severe acute malnutrition based only on the WHZ criterion had about double the risk of death compared to those diagnosed using only the MUAC criterion (aHR: 1.93; 95% CI: 1.10–3.39); this result was robust after adjustment of the model. Older children had a higher risk of death than younger children (aHR: 1.74; 95% CI: 1.50–2.03) and boys a lower risk than girls (aHR: 0.82; 95% CI: 0.71–0.95). Of the complications tested, only fever, hypoglycaemia and other had a significant impact upon mortality. We observed that sepsis becomes significant (aHR: 1.62; 95% CI: 1.06–2.47) after adjustment for the other variables.

We noted that dehydration, diarrhoea and acute respiratory infection did not contribute to mortality among marasmic children. The same model for oedematous children found slightly different results; sex and age did not contribute to the risk of death (Table 3). This demonstrates that the effect of these variables on overall case fatality rate was entirely the result of the marasmic children. Low MUAC did not significantly increase the risk of death in oedematous children (aHR: 0.91; 95% CI: 0.49–1.67), but low WHZ increased the hazard ratio massively (aHR: 3.31; 95% CI: 2.35–4.68). In contrast to the marasmic children, in oedematous children dehydration (aHR: 1.49; 95% CI: 1.03–2.15) and acute respiratory infection (aHR: 2.32; 95% CI: 1.23–4.38) increase the risk of death, but not chronic diarrhoea (aHR: 0.98; 95% CI: 0.63–1.53) or acute diarrhoea (aHR: 0.96; 95% CI: 0.52–1.78). As with marasmus, hypoglycaemia (aHR: 2.83; 95% CI: 2.04–3.93) and sepsis (aHR: 1.97; 95% 1.29–2.99) increase the risk of death for oedematous children.

The full Cox regression model combining both marasmic and oedematous children broadly confirmed the results from the stratified analyses for marasmus and kwashiorkor (Table 3). Those variables that were significant either in marasmic or oedematous children separately were generally also significant in the combined data set. One exception is age, which is not significant in the full model but has an interaction with nutritional status. From the analysis of the different nutritional groups (Fig. 3), marasmic children, but not oedematous children, have an age effect.

We ran the same model assuming that all defaulters (420 children; 3.3%) had died and found the outcome and conclusions to be unaffected. The Kaplan–Meier survival curves

showed that the deaths occurred regularly throughout admission to the inpatient facility and were not clustered shortly after admission (available in online supplementary).²⁰

Discussion

Our retrospective analysis was based on the line list used for close surveillance and routine weekly audits of the clinical programme. All children were treated according to a standardized protocol, with no experimental interventions, additional sampling or selective inclusion beyond fulfilling the WHO-recognized diagnostic criteria. The incidence of mortality remained approximately stable, although admissions increased tenfold indicating that the protocol was implemented consistently throughout the year.

We observed that the proportions of patients in each of our seven anthropometric groups are different from the proportions found in community surveys of this region, in which a low WHZ is more prevalent than a low mid-upper-arm circumference^{14,15,21} and few children fulfil both criteria. This difference is because the ascertainment of children at the community level was by a mid-upper-arm circumference of less than 120 mm; the children treated in the community therefore had a milder illness and a very low case fatality rate, and diagnostic proportions were closer to those found in community surveys. Overall, the combined mortality rate from severe acute malnutrition among inpatients and outpatients was 1.5% (1 130/77 244), which is well below the WHO recommended target threshold of 5%.

Our results confirm and extend the results of previous research,¹⁹ who analysed 14 935 inpatients with severe acute malnutrition from 17 African countries. They showed that mortality was higher among children meeting only the WHZ criterion than those meeting only the mid-upper-arm circumference criterion. However, this study had several limitations as the researchers included historical data collected long before the publication of the current WHO admission criteria; included data from multiple inpatient facilities and agencies that were following many different (and sometimes outdated) protocols; and did not provide any information on complications or comorbidities.¹⁹

Our results are also consistent with data from almost 10 000 children treated for severe acute malnutrition in the Democratic Republic of the Congo;¹¹ these data showed that WHZ alone is more strongly associated with hospital mortality than mid-upper-arm circumference either considered alone or with WHZ after adjustment for age, sex, nutritional oedema, infection and stunting. The presence of nutritional oedema was also found to increase the risk of death.¹¹

We observed that conditions that were expected to increase mortality did not appear to be important contributors to death. The presence of acute watery or chronic diarrhoea, dehydration or malaria did not increase the risk of death in marasmic children. We ascribe these results to affected children receiving effective treatment. Sepsis only became significant after the data were adjusted for confounding factors. The positive effect of fever probably served as a marker for children able to mount a beneficial inflammatory reaction.^{22–24} Although human immunodeficiency virus (HIV) infection is a risk factor for mortality, no data were available for this cohort. A recent meta-analysis among children hospitalized with severe acute malnutrition found HIV infection, diarrhoea, pneumonia, shock and lack of appetite were each associated with an increased risk of death.¹⁰

Among oedematous children, although diarrhoea was not associated with mortality, a diagnosis of dehydration increased mortality. By definition, oedema indicates overhydration; a patient cannot be overhydrated and dehydrated at the same time. Presumably such diagnoses indicate hypovolaemia rather than dehydration. The causes of shock include sepsis, liver failure, cardiogenic shock, toxic shock and drug interactions. Giving excess sodium to overhydrated children with high intracellular sodium concentrations and leaky cell membranes is potentially dangerous.^{25–27} If there is weight gain (fluid retention) associated with acute respiratory infection, the most likely cause of the tachypnoea is pulmonary oedema secondary to iatrogenic fluid overload leading directly to cardiac failure, not infection. This mechanism would account for the increased mortality associated with both dehydration and tachypnoea in oedematous children without vomiting, diarrhoea or evidence of excess fluid loss. In our results, sepsis is also a purely clinical diagnosis that in reality usually denotes shock or simply severe illness. Most deaths did not occur soon after admission, which could be ascribed to pre-admission factors. As shown in the Kaplan–Meier plots most deaths appeared to occur after the child had deteriorated under treatment in hospital, indicating that some aspect of the treatment may not have been optimal or appropriate.

The finding that older children have a higher risk of death from severe acute malnutrition is consistent with the multicountry pooled study of untreated community cohorts,²⁸ which showed a higher mortality for children older than 2 years diagnosed by both mid-upper-arm circumference and WHZ. Although many studies have found younger children to be at higher risk, no significant difference in risk by age and sex was described in one recent meta-analysis.¹⁰ We expect the proportion of both WHZ-only and older children to be higher in contexts where there is a high caseload of severely malnourished children, such as in severe crisis situations.²⁹

Of the children included in this analysis, two-thirds were severely stunted. Stunting refers to chronic undernutrition, which has been hypothesized to augment mortality among acutely malnourished children;^{28,30} our study does not support that conclusion.

Our study was limited by the possibility of confounding from unmeasured factors, as is the case any observational analysis. Nevertheless, the operational nature and the completeness of the data from real-life facilities mean that our data are representative of conditions in developing countries, as opposed to experimental studies and trials where additional staff, training and materials are usually temporally available.

Our study benefited from the fact that MSF Operational Centre Paris and the Nigerian health ministry deployed teams trained in WHO inpatient severe acute malnutrition guidelines alongside logisticians, ensuring an uninterrupted supply of therapeutic foods and medicines, clinical supervision and audit via line lists.

We conclude that mid-upper-arm circumference alone does not identify malnourished children with the highest risk of death; instead, children with a measurement of less than 115 mm had the lowest risk of death. Our inpatient data have shown that children with a low WHZ at admission had twice the risk of death, which increased further if also oedematous. These children should be subject to special considerations, forming a separate diagnostic category and considered as an exceptionally high-risk group. Moreover, accurate interpretation of signs of dehydration and rapid respiratory rate in oedematous children is particularly important for further mortality reduction. Earlier risk stratification at admission, strengthened diagnostic capacity, standardized shock management (especially for oedematous children) and timely referral systems from outpatient to inpatient care could also improve survival outcomes.

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Competing interests:

None declared.

References

1. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al.; Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*. 2013 Aug 3;382(9890):427–51. [https://doi.org/10.1016/S0140-6736\(13\)60937-X](https://doi.org/10.1016/S0140-6736(13)60937-X) PMID:23746772
2. Frison S, Checchi F, Kerac M. Omitting edema measurement: how much acute malnutrition are we missing? *Am J Clin Nutr*. 2015 Nov;102(5):1176–81. <https://doi.org/10.3945/ajcn.115.108282> PMID:26377162
3. Grellety E, Golden MH. Severely malnourished children with a low weight-for-height have similar mortality to those with a low mid-upper-arm-circumference: II. Systematic literature review and meta-analysis. *Nutr J*. 2018 Sep 15;17(1):80. <https://doi.org/10.1186/s12937-018-0383-5> PMID:30217196
4. Isanaka S, O'Neal Boundy E, Grais RF, Myatt M, Briend A. Improving estimates of numbers of children with severe acute malnutrition using cohort and survey data. *Am J Epidemiol*. 2016;184(12):861–9. <https://doi.org/10.1093/aje/kww129> PMID:27856446
5. WHO child growth standards and the identification of severe acute malnutrition in infants and children: a joint statement by the World Health Organization and the United Nations Children's Fund. Geneva & New York: World Health Organization & United Nations Children's Fund; 2009. Available from: <https://iris.who.int/handle/10665/44129> [cited 2025 Apr 24].
6. Olofin I, McDonald CM, Ezzati M, Flaxman S, Black RE, Fawzi WW, et al.; Nutrition Impact Model Study (anthropometry cohort pooling). Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: a pooled analysis of ten prospective studies. *PLoS One*. 2013 May 29;8(5):e64636. <https://doi.org/10.1371/journal.pone.0064636> PMID:23734210
7. Management of severe malnutrition: a manual for physicians and other senior health workers. Geneva: World Health Organization; 1999. Available from: <https://iris.who.int/handle/10665/41999> [cited 2025 Apr 24].
8. Tickell KD, Denno DM. Inpatient management of children with severe acute malnutrition: a review of WHO guidelines. *Bull World Health Organ*. 2016 Sep 1;94(9):642–51. <https://doi.org/10.2471/BLT.15.162867> PMID:27708469
9. Ashworth A, Khanum S, Jackson A, Schofield C. Guidelines for the inpatient treatment of severely malnourished children. Geneva: World Health Organization; 2003. Available from: <https://iris.who.int/handle/10665/205172> [cited 2025 Apr 24].
10. Karunaratne R, Sturgeon JP, Patel R, Prendergast AJ. Predictors of inpatient mortality among children hospitalized for severe acute malnutrition: a systematic review and meta-analysis. *Am J Clin Nutr*. 2020 Oct 1;112(4):1069–79. <https://doi.org/10.1093/ajcn/nqaa182> PMID:32885807
11. Ngaboyeka G, Bisimwa G, Neven A, Mwene-Batu P, Kambale R, Kingwayi PP, et al. Association between diagnostic criteria for severe acute malnutrition and hospital mortality in children aged 6-59 months in the eastern Democratic Republic of Congo: the Lwiro cohort study. *Front Nutr*. 2023 May 16;10:1075800. <https://doi.org/10.3389/fnut.2023.1075800> PMID:37293673

12. Contact National Bureau of Statistics [internet]. Abuja: National Bureau of Statistics; 2025. Available from: <https://www.nigerianstat.gov.ng/contact> [cited 2025 May 2].
13. Essential needs analysis: Northwest and Northcentral Nigeria (Sokoto, Zamfara, Katsina, Benue, Niger, Kaduna). Key findings from the October 2021 & February 2022 assessment reports. Rome: World Food Programme; 2022. Available from: https://fscluster.org/sites/default/files/documents/essential_needs_analysis_-_northwest_and_northcentral_nigeria.pdf [cited 2025 Apr 24].
14. Northeast and northwest Nigeria: IPC acute malnutrition analysis report May 2022 – April 2023. Rome: Integrated Food Security Phase Classification; 2022. Available from: https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/IPC_Nigeria_Acute_Malnutrition_May22_April23_Report.pdf [cited 2025 Apr 11].
15. Nutrition survey using SMART methodology in the LGAs of Jibia, Katsina and Mashi, Katsina State, Nigeria. Geneva: Médecins Sans Frontières; 2022. Available from: <https://remit.msf.org/studies/1471> [cited 2025 Apr 24].
16. Lacharité MO. Resale of therapeutic food: who benefits from demonising mothers? Geneva: Médecins Sans Frontières; 2022. Available from: <https://msf-crash.org/en/blog/humanitarian-actors-and-practices/resale-therapeutic-food-who-benefits-demonising-mothers> [cited 2025 Apr 24].
17. National guidelines for inpatient management of severe acute malnutrition in infants and young children in Nigeria. Abuja and New York: Federal Ministry of Health and United Nations Children's Fund; 2016. Available from: <https://reliefweb.int/report/nigeria/national-guidelines-inpatient-management-severe-acute-malnutrition-infants-and-young> [cited 2025 Apr 24].
18. Tu YK, Gunnell D, Gilthorpe MS. Simpson's paradox, Lord's paradox, and suppression effects are the same phenomenon—the reversal paradox. *Emerg Themes Epidemiol*. 2008 Jan 22;5(1):2. <https://doi.org/10.1186/1742-7622-5-2> PMID:18211676
19. Grellety E, Golden MH. Severely malnourished children with a low weight-for-height have a higher mortality than those with a low mid-upper-arm-circumference: I. Empirical data demonstrates Simpson's paradox. *Nutr J*. 2018 Sep 15;17(1):79. <https://doi.org/10.1186/s12937-018-0384-4> PMID:30217205
20. Grellety E, Simons E, Mousset M, Roederer T, Amakade-Woyengba A-P, Malwal S, et al. Severe acute malnutrition diagnostic criteria and risk factors for inpatient mortality among children aged 6–59 months in North-Western Nigeria: an observational cohort study. Supplementary material [online repository]. London: figshare; 2025. <https://doi.org/10.6084/m9.figshare.29050550.v1>
21. Grellety E, Golden MH. Weight-for-height and mid-upper-arm circumference should be used independently to diagnose acute malnutrition: policy implications. *BMC Nutr*. 2016;2(10):1–17. <https://doi.org/10.1186/s40795-016-0049-7>
22. Rytter MJH, Babirekere-Iriso E, Namusoke H, Christensen VB, Michaelsen KF, Ritz C, et al. Risk factors for death in children during inpatient treatment of

- severe acute malnutrition: a prospective cohort study. *Am J Clin Nutr*. 2017 Feb;105(2):494–502. <https://doi.org/10.3945/ajcn.116.140822> PMID:28031190
23. Irena AH, Mwambazi M, Mulenga V. Diarrhea is a major killer of children with severe acute malnutrition admitted to inpatient set-up in Lusaka, Zambia. *Nutr J*. 2011 Oct 11;10(1):110. <https://doi.org/10.1186/1475-2891-10-110> PMID:21989455
24. Nabukeera-Barungi N, Grenov B, Lanyero B, Namusoke H, Mupere E, Christensen VB, et al. Predictors of mortality among hospitalized children with severe acute malnutrition: a prospective study from Uganda. *Pediatr Res*. 2018 Jul;84(1):92–8. <https://doi.org/10.1038/s41390-018-0016-x> PMID:29795207
25. Patrick J, Golden M. Leukocyte electrolytes and sodium transport in protein energy malnutrition. *Am J Clin Nutr*. 1977 Sep;30(9):1478–81. <https://doi.org/10.1093/ajcn/30.9.1478> PMID:409272
26. Patrick J. Death during recovery from severe malnutrition and its possible relationship to sodium pump activity in the leucocyte. *BMJ*. 1977 Apr 23;1(6068):1051–4. <https://doi.org/10.1136/bmj.1.6068.1051> PMID:870140
27. Forrester T, Golden M, Brand S, Swales J. Reduction in vitro of red cell glutathione reproduces defects of cellular sodium transport seen in oedematous malnutrition. *Eur J Clin Nutr*. 1990 May;44(5):363–9. PMID:2167221
28. Schwinger C, Golden MH, Grellety E, Roberfroid D, Guesdon B. Severe acute malnutrition and mortality in children in the community: comparison of indicators in a multi-country pooled analysis. *PLoS One*. 2019 Aug 6;14(8):e0219745. <https://doi.org/10.1371/journal.pone.0219745> PMID:31386678
29. Bilukha O, Leidman E. Concordance between the estimates of wasting measured by weight-for-height and by mid-upper arm circumference for classification of severity of nutrition crisis: analysis of population-representative surveys from humanitarian settings. *BMC Nutr*. 2018;4(1):24. <https://doi.org/10.1186/s40795-018-0232-0> PMID:31911840
30. McDonald CM, Olofin I, Flaxman S, Fawzi WW, Spiegelman D, Caulfield LE, et al.; Nutrition Impact Model Study. The effect of multiple anthropometric deficits on child mortality: meta-analysis of individual data in 10 prospective studies from developing countries. *Am J Clin Nutr*. 2013 Apr;97(4):896–901. <https://doi.org/10.3945/ajcn.112.047639> PMID:23426036

Table 1. Classification of nutritional status of children aged 6–59 months with severe acute malnutrition admitted to two inpatient facilities in Katsina, Nigeria, 2022

Nutritional status	Oedema	MUAC (mm)	WHZ (mm)
MUAC only	No	< 115	$\geq -3Z$
WHZ only	No	≥ 115	< $-3Z$
WHZ and MUAC	No	< 115	< $-3Z$
Oedema only	Yes	≥ 115	$\geq -3Z$
Oedema and MUAC	Yes	< 115	$\geq -3Z$
Oedema and WHZ	Yes	≥ 115	< $-3Z$
Oedema, WHZ and MUAC	Yes	< 115	< $-3Z$

MUAC: mid-upper-arm circumference; WHZ: weight-for-height z-score.

Table 2. **General characteristics and case-fatality ratios of children aged 6–59 months with severe acute malnutrition admitted to two inpatient facilities in Katsina, Nigeria, 2022**

Characteristic	No. children (%)		Case fatality rate (%)	P ^a
	With severe acute malnutrition (n = 12 771)	Mortality (n = 1 074)		
Type of admission				0.7
Direct	5 826 (45.6)	496 (46.2)	8.5	
Transfer	6 945 (54.4)	578 (53.8)	8.3	
Local government area				0.017
Not supported by MSF	9 012 (70.6)	792 (73.7)	8.8	
Supported by MSF	3 759 (29.4)	282 (26.3)	7.5	
Sex				< 0.001
Female	6 258 (49.0)	579 (53.9)	9.3	
Male	6 513 (51.0)	495 (46.1)	7.6	
Age, months				< 0.001
6–23	6 396 (50.1)	426 (39.7)	6.7	
24–59	6 375 (49.9)	648 (60.3)	10.2	
HAZ at admission				0.32
≥ –2Z (not stunted)	1 474 (11.5)	134 (12.5)	9.1	
< –2Z (stunted)	11 297 (88.5)	940 (87.5)	8.3	
MUAC at admission (mm)^b				0.003
< 110	6 973 (54.6)	642 (59.8)	9.2	
110 to < 115	2 628 (20.6)	186 (17.3)	7.1	
115 to < 125	2 368 (18.5)	186 (17.3)	7.9	
≥ 125	787 (6.2)	59 (5.5)	7.5	
Missing	15 (0.1)	1 (0.1)	6.7	
WHZ at admission				< 0.001
< –4Z	7 583 (59.4)	812 (75.6)	10.7	
–4 to < –3Z	3 316 (26.0)	184 (17.1)	5.5	
–3 to < –2Z	1 030 (8.1)	45 (4.2)	4.4	
≥ –2Z	842 (6.6)	33 (3.1)	3.9	
Oedema grades at admission				< 0.001
Grade 1 or 2	1 660 (13.0)	182 (16.9)	11.0	
Grade 3	2 100 (16.4)	203 (18.9)	9.7	
Missing	6 (0.0)	2 (0.2)	33.3	
Nutritional status at admission^c				< 0.001
MUAC only	479 (3.8)	14 (1.3)	2.9	
WHZ only	1 531 (12.0)	98 (9.1)	6.4	
WHZ and MUAC	6 995 (54.8)	575 (53.5)	8.2	
Oedema	1 104 (8.6)	51 (4.7)	4.6	
Oedema and MUAC	289 (2.3)	13 (1.2)	4.5	
Oedema and WHZ	535 (4.2)	97 (9.0)	18.1	
Oedema, WHZ and MUAC	1 838 (14.4)	226 (21.0)	12.3	
Major clinical complications				< 0.001
None (failed appetite test)	3 866 (30.3)	314 (29.2)	8.1	
Moderate or severe dehydration	1 279 (10.0)	137 (12.8)	10.7	
Fever (temperature > 38.5 °C)	6 204 (48.6)	399 (37.2)	6.4	
Hypoglycaemia	639 (5.0)	143 (13.3)	22.4	
Other	783 (6.1)	81 (7.5)	10.3	
Major comorbidities				< 0.001
None (failed appetite test)	669 (5.2)	53 (4.9)	7.9	
Anaemia	339 (2.7)	27 (2.5)	8.0	
Acute respiratory infection	405 (3.2)	45 (4.2)	11.1	
Chronic diarrhoea	2 938 (23.0)	209 (19.5)	7.1	
Acute watery diarrhoea	1 289 (10.1)	76 (7.1)	5.9	
Malaria	2 761 (21.6)	167 (15.5)	6.0	
Measles	606 (4.7)	57 (5.3)	9.4	
Sepsis	2 485 (19.5)	328 (30.5)	13.2	
Other	1 279 (10.0)	112 (10.4)	8.8	

MSF: *Médecins Sans Frontières*; HAZ: height-for-age Z-score; MUAC: mid-upper-arm circumference; WHZ: weight-for-height z-score.

^a We calculated *P*-values using Pearson χ^2 -test.

^b A MUAC measurement at admission was not recorded for 15 children (0.1%).

^c See Table 1 for definitions of the different categories of nutritional status.

Table 3. Cox regression analysis for predictors of mortality in children aged 6–59 months with marasmus, kwashiorkor and severe acute malnutrition admitted to two inpatient facilities in Katsina, Nigeria, 2022

Predictor	With marasmus ^a		With kwashiorkor ^b		With severe acute malnutrition (both marasmus and kwashiorkor)	
	Crude HR (95% CI)	aHR (95% CI) ^c	Crude HR (95% CI)	aHR (95% CI) ^c	Crude HR (95% CI)	aHR (95% CI) ^c
Type of admission						
Direct	Reference	–	Reference	–	Reference	–
Transfer	0.97 (0.84–1.13)	–	0.82 (0.67–1.01)	–	0.93 (0.82–1.05)	–
Local government area						
Not supported by MSF	Reference	–	Reference	–	Reference	–
Supported by MSF	0.93 (0.79–1.09)	–	1 (0.78–1.27)	–	0.93 (0.82–1.07)	–
Sex						
Female	Reference	Reference	Reference	Reference	Reference	Reference
Male	0.81 (0.70–0.94)	0.82 (0.71–0.95)	0.88 (0.72–1.08)	0.95 (0.78–1.17)	0.84 (0.74–0.95)	0.87 (0.77–0.98)
Age, months						
6–23	Reference	Reference	Reference	Reference	Reference	Reference
24–59	1.9 (1.63–2.20)	1.74 (1.50–2.03)	0.83 (0.66–1.04)	0.92 (0.73–1.16)	1.52 (1.35–1.72)	1.89 (0.65–5.44)
Nutritional status at admission^d						
MUAC only	Reference	Reference	NA	NA	Reference	Reference
WHZ only	2.14 (1.23–3.75)	1.93 (1.10–3.39)	NA	NA	2.13 (1.22–3.73)	1.94 (0.91–4.15)
WHZ and MUAC	2.34 (1.38–3.98)	2.07 (1.22–3.53)	NA	NA	2.32 (1.36–3.94)	2.13 (1.06–4.31)
Oedema	NA	NA	Reference	Reference	1.23 (0.68–2.23)	1.82 (0.70–4.72)
Oedema and MUAC	NA	NA	0.98 (0.53–1.80)	0.91 (0.49–1.67)	1.21 (0.57–2.56)	2.26 (0.60–8.53)
Oedema and WHZ	NA	NA	3.64 (2.58–5.12)	3.31 (2.35–4.68)	4.5 (2.57–7.89)	5.71 (2.59–12.6)
Oedema, WHZ and MUAC	NA	NA	2.45 (1.81–3.33)	2.07 (1.52–2.83)	3.04 (1.77–5.21)	3.37 (1.61–7.05)
Major clinical complications						
None (failed appetite test)	Reference	Reference	Reference	Reference	Reference	Reference
Moderate or severe dehydration	1.17 (0.92–1.49)	1.18 (0.92–1.52)	1.5 (1.05–2.15)	1.49 (1.03–2.15)	1.26 (1.03–1.53)	1.28 (1.04–1.57)
Fever (temperature > 38.5 °C)	0.65 (0.54–0.78)	0.73 (0.60–0.88)	1.02 (0.80–1.32)	1.08 (0.82–1.41)	0.76 (0.65–0.88)	0.83 (0.71–0.98)
Hypoglycaemia	2.57 (1.99–3.32)	2.55 (1.96–3.32)	2.62 (1.91–3.60)	2.83 (2.04–3.93)	2.57 (2.11–3.13)	2.61 (2.13–3.20)
Other	1.35 (0.99–1.84)	1.38 (1.00–1.90)	1.19 (0.79–1.78)	1.19 (0.78–1.81)	1.27 (1.00–1.62)	1.28 (0.99–1.65)
Major comorbidities						
None (failed appetite test)	Reference	Reference	Reference	Reference	Reference	Reference
Anaemia	0.85 (0.45–1.62)	1.12 (0.59–2.15)	1.39 (0.71–2.73)	1.45 (0.73–2.87)	1.08 (0.68–1.72)	1.32 (0.83–2.11)
Acute respiratory infection	1.12 (0.66–1.90)	1.34 (0.78–2.31)	2.14 (1.14–4.00)	2.32 (1.23–4.38)	1.44 (0.97–2.14)	1.7 (1.13–2.55)
Chronic diarrhoea	0.77 (0.50–1.18)	0.99 (0.65–1.53)	1.04 (0.67–1.61)	0.98 (0.63–1.53)	0.9 (0.67–1.22)	1.05 (0.77–1.42)
Acute watery diarrhoea	0.68 (0.42–1.08)	0.99 (0.61–1.59)	0.99 (0.54–1.81)	0.96 (0.52–1.78)	0.79 (0.56–1.13)	1.04 (0.73–1.50)
Malaria	0.72 (0.47–1.11)	0.96 (0.61–1.49)	1.05 (0.66–1.67)	1.16 (0.72–1.86)	0.86 (0.63–1.17)	1.07 (0.78–1.48)
Measles	1.17 (0.73–1.90)	1.40 (0.86–2.29)	2.29 (1.00–5.24)	2.27 (0.98–5.24)	1.41 (0.97–2.05)	1.66 (1.13–2.45)

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Sepsis	1.27 (0.84–1.93)	1.62 (1.06–2.47)	2.06 (1.37–3.11)	1.97 (1.29–2.99)	1.59 (1.19–2.13)	1.84 (1.36–2.47)
Other	0.86 (0.54–1.36)	1.12 (0.70–1.80)	1.35 (0.85–2.14)	1.34 (0.83–2.15)	1.08 (0.78–1.50)	1.27 (0.91–1.77)

aHR: adjusted hazard ratio; CI: confidence interval; HR: hazard ratio; MSF: *Médecins Sans Frontières*; MUAC: mid-upper-arm circumference; WHZ: weight-for-height z-score.

^a Marasmus is characterized by non-oedematous malnutrition.

^b Kwashiorkor is a form of severe malnutrition causing oedema.

^c Hazard ratio adjusted for sex, age group, nutritional status at admission, major clinical complications and comorbidities.

^d See Table 1 for definitions of the different categories of nutritional status.

Fig. 1. Flowchart of children aged 6–59 months with severe acute malnutrition admitted to inpatient facilities and children included in analyses, Katsina, Nigeria 2022.

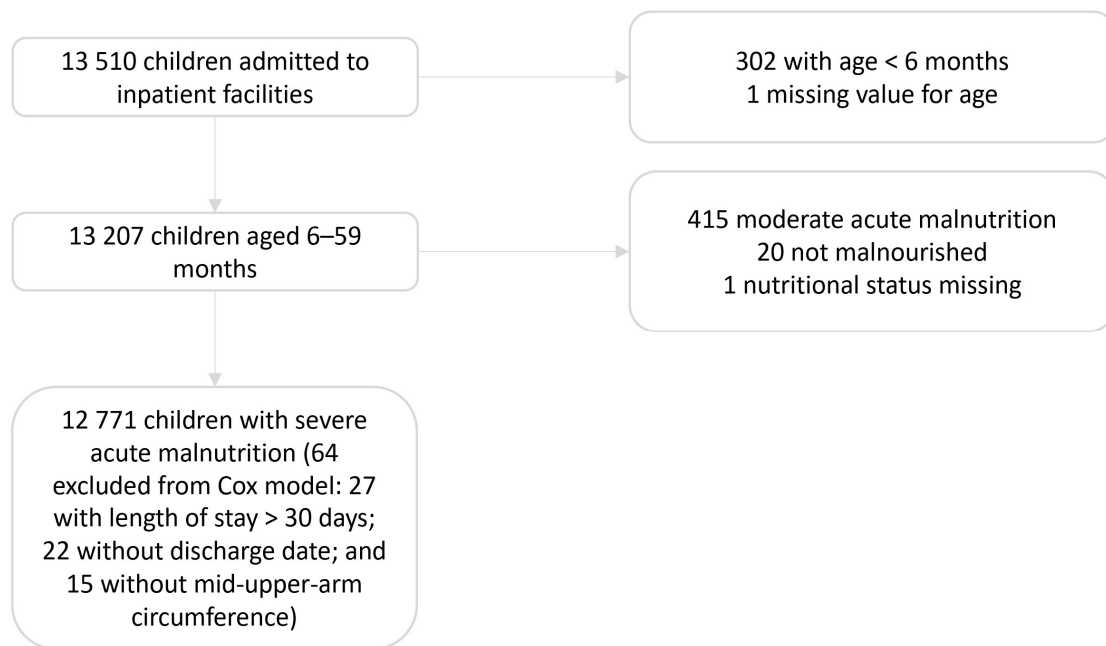


Fig. 2. Number of children aged 6–59 months with severe acute malnutrition admitted to, and weekly case fatality rate within, inpatient facilities in Katsina, Nigeria, 2022

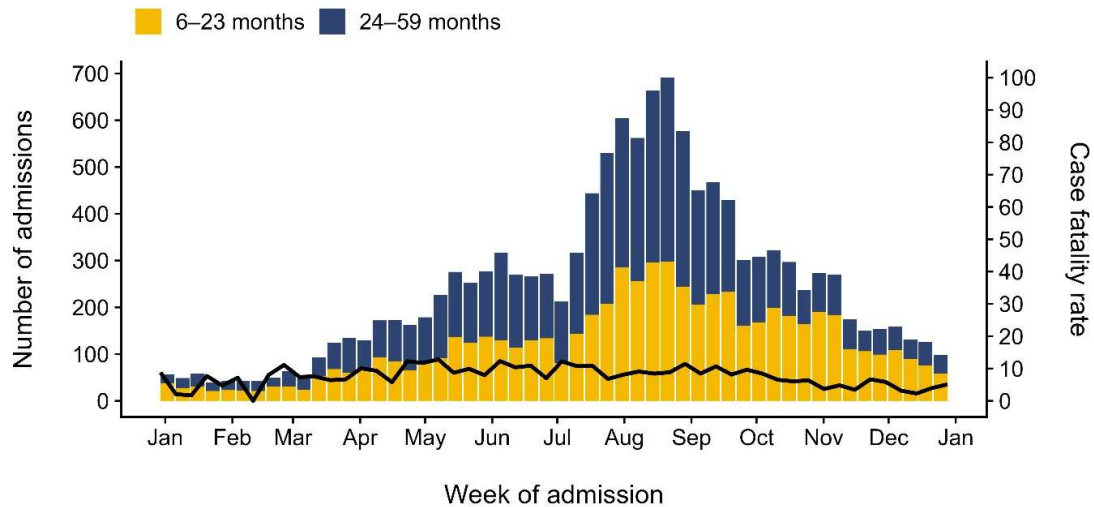
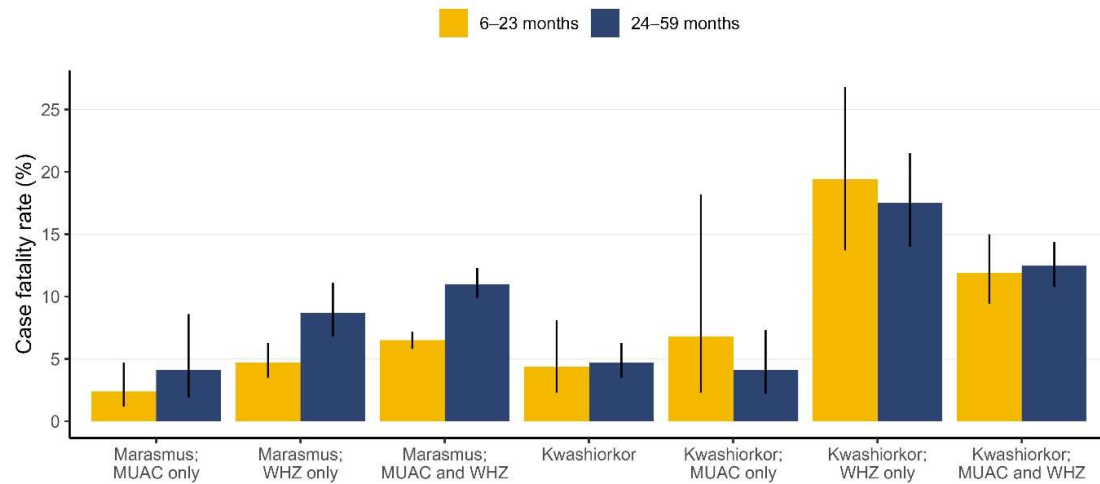


Fig. 3. Case fatality rates of children aged 6–59 months with severe acute malnutrition by diagnostic criteria and age group admitted to inpatient facilities in Katsina, Nigeria, 2022



CI: confidence interval; MUAC: mid-upper-arm circumference; WHZ: weight-for-height z-score.

Notes: Marasmus is characterized by non-oedematous malnutrition. Kwashiorkor is a form of severe malnutrition causing oedema.