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**Short malnourished children do not gain excessive fat with
food supplementation**

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Short malnourished children do not gain excessive fat with food supplementation

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24

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26 (ISRCTN42569496)
27

28 **Abbreviations:** The Alliance for International Medical Action (ALIMA); (CHW); corn-soy blend
29 (CSB); children recruited by MUAC and ≥ 67 cm (LONG); children recruited by MUAC and < 67
30 cm (SHORT); lipid-based nutrient supplements (LNS); Mid-upper arm circumference (MUAC);
31 moderate acute malnutrition (MAM); ready-to-use therapeutic food (RUTF); severe acute
32 malnutrition (SAM); weight-for-height z-score (WHZ)
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35 **Table of Contents Summary**

36 We assess if it is justified to exclude shorter children with moderate acute malnutrition from
37 treatment out of fear they will accumulate too much fat
38

39 **What's Known on This Subject**

40 It is policy for national malnutrition programs in many African countries to exclude shorter children
41 with moderate acute malnutrition (MAM) from treatment due to concerns they will accumulate too
42 much fat thereby putting them at later risk of non-communicable diseases
43

44 **What This Study Adds**

45 Our study shows that shorter children with low MUAC do not gain excessive fat during
46 supplementation and thus should be offered treatment. The WHO should integrate this evidence into
47 its recently updated Integrated Management of childhood Illness (IMCI) recommendations
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4 **Contributors' Statement Page**

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6 Dr Fabiansen conceptualized the research, conducted the research, acquired the data, performed
7 statistical analysis and wrote the first draft of the manuscript. Mr Phelan, Drs Kurpard, Wells,
8 Filteau, Briend, Christensen and Drs Cichon, Iuel-Brockdorff and Mr Yaméogo conducted the
9 research and acquired the data. Dr Ritz conceptualized the research and design and performed
10 statistical analysis and interpretation of data. Dr Shepherd conceptualized the research and
11 contributed to data interpretation. Drs Michaelsen and Friis conceptualized the research and design
12 and contributed to the interpretation of data. All authors critically revised the article for important
13 intellectual content, and approved the final manuscript as submitted and agree to be accountable for
14 all aspects of the work.
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ABSTRACT

Background: In moderate acute malnutrition (MAM) programs, it is common practice not to measure mid-upper arm circumference (MUAC) of children whose length is <67 cm. This is based on expert opinion that supplementation of shorter children with low MUAC and weight-for-height z-score (WHZ) ≥ -2 may increase risk of excessive fat accumulation. Our aim was to assess if shorter children gain more fat than taller children when treated for MAM diagnosed by low MUAC alone.

Methods: This observational study included children aged 6-23 months with MUAC between 115-125 mm and WHZ ≥ -2 . Based on length at admission, children were categorized as SHORT if <67 cm and LONG if ≥ 67 cm. Linear mixed-effects models were used to assess body composition based on deuterium dilution and skinfold-thickness.

Results: Following 12 weeks of supplementation, there was no difference in change in fat mass index (-0.038kg/m^2 , 95%CI $-0.257;0.181$, $p=0.74$) or fat-free mass index (0.061kg/m^2 , 95%CI $-0.150;0.271$; $p=0.57$) in SHORT vs LONG. In absolute terms, the SHORT children gained both less fat-free mass (-230g , 95%CI: $-355;-106$, $P<0.001$) and fat mass (-97g , 95%CI $-205;10$, $p=0.076$). There were no difference in changes in absolute subscapular and triceps skinfold-thickness and z-scores ($p>0.5$).

Conclusions: SHORT children with low MUAC do not gain excessive fat during supplementation. These data support a recommendation for policy change to include all children ≥ 6 months with low MUAC in supplementary feeding programs, regardless of length. The use of length as a criterion for measuring MUAC to determine treatment eligibility should be discontinued in policy and practice.

INTRODUCTION

Childhood malnutrition contributes to almost half the mortality in children under five years ¹.

Moderate acute malnutrition (MAM) is currently defined as weight-for-height z-score (WHZ) between -3 and -2 (i.e. moderate wasting), and/or mid-upper arm circumference (MUAC) between 115 and 125 mm ². While the prevalence of MAM is unknown, moderate wasting alone affects 33 million children at any time ³ and is associated with a three-fold increased risk of death ⁴.

Protocols for management of acute malnutrition in many African countries (including Cameroon, Central African Republic, Chad, Guinea, Ivory Coast, Mali, Mauritania, Senegal, and Togo) instruct health personnel to measure MUAC only of children with length ≥ 67 cm when assessing eligibility for MAM or severe acute malnutrition (SAM) treatment programs ⁵⁻¹³. In Ethiopia, admission by MUAC alone for SAM treatment is restricted to children with lengths >65 cm ¹⁴. These shorter children are enrolled in treatment only if they meet WHZ criterion, which is less closely linked to the risk of death and misses high-risk children who would have been identified by MUAC. Hence, current practice excludes short children who would benefit from nutritional support.

The practice of restricting treatment admission by MUAC alone to children of length ≥ 67 cm is not supported by data and has never been formally endorsed by the World Health Organization (WHO). Two reasons can be identified to explain this exclusion. First, the inclusion of a length restriction for MUAC is likely a holdover from older versions of emergency nutrition guidelines that used length as a proxy for age (<6 months) because it can sometimes be difficult to ascertain age in a fast moving emergency. The WHO, for example, used length of 60 cm as a proxy for age of 6 months in publications from 1995 and 2000 ^{15,16} while length of 65 cm was used in older versions of guidelines from non-governmental humanitarian organizations like Médecins Sans Frontières (MSF) in 1995 and Valid International in 2006 ^{17,18}. It is important to identify children <6 months

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4 of age as they should be exclusively breastfed, and treated as in-patients if in need of treatment.
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6 However, length is a poor proxy for age, and most often a caretaker can recall the month of birth for
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8 an infant.
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11 Second, WHO now recommends against routine food supplementation of children with MAM due
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13 to a concern it may promote obesity and increase the risk of non-communicable diseases later in life
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15 ¹⁹. Some experts worry that shorter children above 6 months of age who only meet the low-MUAC
16
17 criteria for MAM are at most at risk of excessive fat accumulation during treatment ². Although
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19 only based on expert opinion, this seems to be the reason why many national malnutrition protocols
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21 exclude shorter children from having their MUAC measured, thereby making children ineligible for
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23 treatment, unless they meet WHZ criteria. This concern led WHO to call for research to identify
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25 appropriate MUAC admission and discharge criteria for children <67 cm and ≥ 6 months to
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27 supplementary feeding programs ².
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31 We have previously shown, that when supplemented, ponderal growth rates are similar in short and
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33 long children ≥ 6 months with a low MUAC ²⁰. Niger dropped this length restriction in 2016, and its
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35 revised protocols now call for measuring MUAC in all children ≥ 6 months, regardless of length ²¹.
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39 To what extent there is a difference in fat accumulation during treatment has not been assessed. The
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41 objective of this paper is to assess if short children (<67 cm) gain more fat than long children (≥ 67
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43 cm) when treated for MAM diagnosed by low MUAC (115-125 mm).
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48 49 **SUBJECTS AND METHODS**

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51 As previously reported ²⁰, a prospective cohort study was nested in a randomized nutrition trial
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53 (Treatfood) ²² investigating the effectiveness of 500 kcal/day supplement either as corn-soy blend
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4 (CSB) porridge or ready-to-use lipid-based nutrient supplements (LNS). The LNS supplements
5 provided almost three times more energy as fat than the CSB supplements (~57% vs ~21%).
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8 Assignment to one of the 12 supplements (6 CSB and 6 LNS) followed randomisation stratified by
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10 site.
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12 13 **Participants**

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16 Data were collected in the Province du Passoré in the Northern region of Burkina Faso at 5 research
17 sites located at different governmental health centers and staffed by the non-governmental
18 organization Alliance for International Medical Action (ALIMA, Dakar, Senegal).
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21 Children were screened in villages either by community health workers using MUAC tapes or by
22 designated screening teams with the use of both MUAC and WHZ. Moreover, children could be
23 referred from a health centre or could present at site on caretaker's initiative. At the sites, the final
24 assessment of eligibility for inclusion was performed.
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32 For the main Treatfood trial, children aged 6–23 months with MAM (defined as MUAC between
33 115-124 and/or a WHZ between –3 and –2), resident in the catchment area and whose caretaker
34 consented to participate, were included. Children were not included if treated for severe acute
35 malnutrition (SAM) or hospitalized within the past two months, if already in a nutritional program
36 or if they presented medical complications requiring hospitalization. Likewise, children with a
37 severe disability limiting the possibility of investigations and children with suspected allergy to
38 milk, peanuts, corn or soy were not included.
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50 Of the 1609 children included in the trial 468 had MUAC between 115-125mm and WHZ \geq -2, and
51 were included in the current study. In many settings these children are excluded from treatment if
52 they are also short (i.e. <65 or 67 cm). Accordingly, children in this study were categorized, based
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4 on baseline length, as SHORT (<67 cm) or LONG (\geq 67 cm) to assess if SHORT children gain more
5 fat than LONG children when treated for MAM diagnosed by low MUAC.
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11 **Procedures and study visits**

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14 We previously described clinic visits, standard anthropometric measurements and age determination
15 ²⁰. In the present paper we additionally report on indices of body composition and skinfolds
16 assessed at baseline and at end-intervention at 12 weeks. Total body water (TBW) was assessed
17 using the deuterium dilution technique (D2O) to enable calculation of fat-free mass (FFM) and fat
18 mass (FM). The method involved giving an oral dose of 5 g deuterium oxide (D2O) (99.8%,
19 Cambridge Isotope Laboratories Inc., Andover, USA). The isotope was diluted in 5 g of bottled
20 water (LAFI, Burkina Faso), with the dosing bottle weighed with 0.01 g precision (Adam
21 equipment: model CQT 202, United Kingdom) before and after administration of the dose. Pre-dose
22 saliva samples were obtained to assess background isotope levels in body fluids, and post-dose
23 saliva samples were collected after a three-hour equilibration period as established during the pilot
24 study ²³. For each assessment, D2O enrichment was measured in duplicate in the pre- and post-dose
25 saliva samples and in a diluted sample of the dose, using Fourier Transform Infrared Spectrometry
26 (FTIR; Agilent Technologies, CA, USA) ²⁴ at St. John's Research Centre, Bangalore, India.
27 Saliva samples required at least 60 μ l saliva for analysis. Deuterium dilution space was calculated
28 as described previously ²⁵, and converted to total body water (TBW) using a factor of 1.044 to
29 adjust for proton exchange ²⁶. FFM was calculated as TBW/hydration, using age- and sex-specific
30 hydration coefficients ²⁷. FM was calculated as weight minus FFM. Data were cleaned for
31 typographical errors and implausible TBW values, based on the association of TBW with length
32 and a cut-off for FM of <0.1 and >2.4 kg.
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4 Skinfold thickness was measured in duplicate by a Harpenden caliper. The mean of the duplicate
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6 measurements were taken for analysis. Weight was measured in duplicate to the nearest 100 g using
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8 electronic scales (Seca model 881 1021659) with double weighing function. Length was measured
9
10 in duplicate with a wooden length board to the nearest 1 mm. WHZ was determined at sites using
11
12 WHO field tables, and this value was used for recruitment. MUAC was measured in duplicate to the
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14 nearest 1 mm, at the midpoint between the olecranon and the acromion process using a standard
15
16 measuring tape. Anthropometric measurements were undertaken by trained staff, after
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18 standardization sessions.
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22 In later analyses, WHZ, length-for-age z-score (LAZ) and weight-for-age z-score were calculated
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24 using the package “zscore06” in STATA 12 (College Station, Texas, USA). Skinfold-for-age z-
25
26 scores were calculated using WHO's Anthro Plus software (version 3.2.2, 2011, World Health
27
28 Organization, Geneva, Switzerland). All z-scores were calculated using the 2006 WHO child
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30 growth standards.
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32 33 **Outcomes**

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36 Changes were evaluated in FM, FFM, weight, length, and skinfold thickness (both raw values and
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38 skinfold thickness-for-age z-scores). By dividing FFM and FM by length squared the indices are
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40 expressed as (kg/m^2) independent of length, i.e. FFM index (FFMI) and FM index (FMI). In
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42 addition, fat was calculated as a percentage of total body weight.
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46 47 **Statistical analysis**

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50 Data were double entered in Epidata 3.1 (Epidata Association, Odense, Denmark) and double entry
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52 checks were performed on a daily basis. All statistical analyses were carried out using the statistical
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54 software package Stata version 12 (StataCorp, College station, Texas, USA). Baseline and endline
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4 characteristics of children were summarized as mean (SD) or percentages, and categories were
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6 compared at baseline using two-sample t-tests for continuous variables and chi-square tests for
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8 categorical variables.
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11 To evaluate differences in outcomes between groups during the 12-week supplementation
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13 intervention, a linear mixed analysis of covariance model was considered as the main analysis,
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15 resulting in an estimated mean difference at the end of the study adjusted for differences at baseline.
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17 Specifically, the analyses included adjustment for food intervention as well as a number of baseline
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19 characteristics: baseline measure of the outcome, age, sex, and month of admission (as fixed
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21 effects). Random intercepts were included in the model to adjust for variation between sites. In the
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23 adjusted analysis, weight was derived by adding FFM and FM. Additionally, for direct outcomes of
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25 fat (FM and FMI) we evaluated the two-way interaction between length group and product group
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27 (CSB compared with LNS) in order to assess effect modification by type of product. Moreover,
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29 possible effect modification was also evaluated for stunting at admission in a) two categories: above
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31 and below LAZ of <-2 , or b) or three categories: severe stunting (LAZ <-3), moderate stunting
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33 (LAZ ≥-3 to <-2) or absence of stunting (LAZ ≥-2). The same adjustments were applied in these
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35 additional analyses as in the main analysis. Model checking was based on residuals and normal
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37 probability plots. A significance level of 0.05 was applied.
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46 **RESULTS**

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49 A total of 1609 children, of which 55% were girls, were randomized to 12 weeks of supplementary
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51 feeding in the Treatfood trial²². Of these, 50% (804) were included by both WHZ and MUAC, 21%
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53 (337) by WHZ alone and 29% (468) by MUAC alone. Among the 468 children recruited by MUAC
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4 only, on whom this this paper is based, 230 (49%) were <67 cm (SHORT) and 238 (51%) ≥67 cm
5 (LONG)²⁰. During the intervention, 3 SHORT and 11 LONG children dropped out prior to
6 completion of supplementation at week 12. Body composition based on D2O dilution both at
7 baseline and after 12 weeks were successfully determined in 195 (85%) of SHORT children and
8 195 (82 %) of LONG children (**Figure 1**). At baseline, there were substantial differences in age and
9 sex distributions, as well as in standard anthropometry between SHORT and LONG, whereas there
10 were no differences in allocation to the different experimental diets and season of inclusion (**Table**
11 **1**). Mean values of body composition variables determined at baseline and after supplementation are
12 presented in **Table 2**. At baseline, the weight of SHORT children was 1.474 (95%CI: 1.355; 1.593)
13 kg less than that of LONG children, which reflected a 0.120 (0.047; 0.193) kg lower FM and a
14 1.354 (1.219; 1.489) kg lower FFM. Adjusted for length squared this corresponded to a 0.325
15 (0.163; 0.487) kg/m² higher FMI in SHORT compared to LONG children, but no difference (-0.056
16 kg/m², -0.230; 0.118) in FFMI. Body fat was 1.9 (0.8; 3.0) percentage points higher in SHORT
17 compared to LONG children.

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35 Adjusted differences from baseline to endline are presented in **Table 3**. Following the 12 weeks of
36 supplementation, there was no difference of change in FMI (-0.038 kg/m², 95%CI -0.257; 0.181,
37 p=0.74) or FFMI (0.061 kg/m², 95%CI -0.150; 0.271; p=0.57) in SHORT vs LONG children. The
38 SHORT children actually gained both less FFM (-230 g, 95%CI: -355; -106, p<0.001) as well as
39 FM (-97 g, 95%CI -205; 10) although the latter was not significant (p=0.076). The differences in
40 FM and FFM summed up to a 328 g (95%CI: 199; 456, p <0.001) lower weight gain in SHORT
41 compared to LONG children. There were no differences in subscapular and triceps skinfold
42 thickness and z-scores (all p>0.5).

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53 For FM and FMI there was no effect modification of product type, (CSB or LNS) (p>0.30).

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55 Likewise, there was no effect modification by stunting at admission (present or non-present)

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4 (p>0.50) or stunting at admission stratified by severity (severe stunting, moderate stunting or non-
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6 present) (p>0.45).
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DISCUSSION

In response to WHO's call for research to identify appropriate MUAC admission and discharge criteria for children <67 cm and ≥ 6 months to supplementary foods², we show here that short children with MUAC 115-125 mm but WHZ >-2 do not gain excessive fat during supplementation. Our results therefore challenge current policy and practice in several African countries of measuring MUAC only in children more than 6 months of age above a certain length threshold, thus excluding shorter children with only low MUAC from eligibility for MAM or SAM treatment programs⁵⁻¹⁴.

The exclusion of short children is based solely on expert opinion, and reflects a concern that these children are just stunted rather than wasted, have slow catch-up growth, and may accumulate excessive fat mass following supplementation, thereby putting them at risk of non-communicable diseases later in life. We previously reported that ponderal growth rates were similar in short and long children who received supplementation for MAM determined only by low MUAC²⁰, and a similar finding was reported in children with SAM²⁸.

The current study is the first to report direct evidence on fat accumulation following treatment for such children, and our data show there is no excessive fat gain in the SHORT children compared to LONG children. In fact, weight gain in both groups overwhelmingly came in the form of FFM. These findings were independent of children having received LNS or CSB supplement. Because LNS contains a high level of fat, some experts were concerned that this food could lead to higher fat deposition in the malnourished child. Earlier we showed that LNS did not lead to high fat accumulation in treatment of children for MAM²². We now show that this concern is unwarranted even in shorter children enrolled in treatment solely by MUAC and, furthermore, is not modified by stunting at admission.

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4 By using the state-of-the-art deuterium dilution technique seconded by skinfold thickness
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6 measurements, we present comprehensive data on body fat following supplementation in MAM.
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8 Since the gold standard for body composition is cadaver dissection, all *in vivo* techniques are
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10 necessarily imperfect. Here, we used two different techniques in which their error is uncorrelated,
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12 but their results are similar, making our findings more robust.
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15 At baseline, the SHORT compared to the LONG children were younger, contained more girls, had
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17 lower MUAC, and had higher prevalence of stunting and underweight, but were less wasted²⁰.
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19 More than 90% of the 1.5 kg higher weight in LONG children at baseline was FFM, while SHORT
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21 children had higher baseline FMI and fat%, and this was supported by higher baseline skinfold
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23 thicknesses.
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27 One possible explanation for this baseline difference is that, in the process of growing poorly,
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29 SHORT children invested relatively more in fat reserves than LONG children, at a cost to their
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31 functional fat-free tissue. However, a simpler alternative explanation is that even in children with
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33 optimal growth conditions, such as those used to establish WHO 2006 growth standards, both
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35 triceps and subscapular skinfold thicknesses tend to decrease in thickness between 6 months and 2
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37 years, and more so in boys than girls. Hence, the fact that the SHORT children were also ~6 months
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39 younger at baseline might explain the higher FMI at baseline. Supporting this, baseline skinfold
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41 thicknesses were thicker in SHORT children, but when expressed as z-scores relative to WHO
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43 reference data, SHORT children actually had lower triceps values than LONG children, while their
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45 subscapular skinfold thickness was only 0.2 z-score greater than in LONG children.
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49 At the end of the intervention, the average skinfolds thickness in this study were below -1 z-score in
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51 both groups suggesting no excessive fat gain in either group.
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4 At the end of the supplementation relative measures of FMI, FFMI and percentage fat were similar
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6 between the two groups and likewise there was no difference between groups in skinfold thickness
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8 changes, whether expressed in absolute terms or as z-scores. The SHORT children gained less
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10 weight and FFM and also showed a trend towards less FM gain.
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13 A recent study found that children with MAM diagnosed solely on low MUAC experienced high
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15 rates of deterioration to SAM if left untreated²⁹. We are not aware of data on mortality data
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17 specifically for short children with MAM based only on low MUAC. However, the low MUAC
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19 SHORT children in our cohort exhibited high prevalence of additional anthropometric deficits. Half
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21 of the SHORT children were stunted and SHORT children were more underweight compared to
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23 LONG children. Stunted and underweight children have a higher mortality risk and may therefore
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25 benefit most from nutritional interventions³⁰. MUAC is a simple way to target them for treatment.
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29 The WHO recently updated its Integrated Management of Childhood Illness (IMCI), and now
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31 recommends against routinely supplementing children with MAM due to a concern for obesity. We
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33 previously showed that there was no excess fat accumulation in children with MAM supplemented
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35 with LNS or CSB²². Our findings here show that even the shorter children with MAM determined
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37 solely by MUAC, who were considered by some experts to be at the greatest risk for obesity from
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39 food supplementation, do not become obese. Such children should no longer be excluded from
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41 treatment eligibility.
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45 We are not aware of any data on fat accumulation following treatment in short children with SAM
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47 by MUAC alone. Indeed, currently only data on skinfolds could be generated in large field studies
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49 in children with SAM, as current techniques available for body composition assessment are not
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51 suitable for use in SAM. However, we see no rationale in maintaining a length restriction for
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53 MUAC assessment in SAM.
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4 In conclusion, SHORT children with low MUAC do not gain excessive fat during supplementation.
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6 Admission by the same MUAC criteria (i.e. <115 mm for SAM and 115-125 mm for MAM) should
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8 apply to any child 6-59 months of age, regardless of their length, and irrespective of their WHZ.
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10 The use of length as criterion for measuring MUAC should be discontinued in policy and practice
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12 wherever such restrictions exist. It will also be important for the WHO to integrate this evidence
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14 showing that children with MAM are not put at risk for obesity following food supplementation into
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16 its recently updated IMCI recommendations.
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DECLARATIONS**Ethics approval and consent to participate**

The trial was approved by the Ethics Committee for Health Research in Burkina Faso (2012-8-059) and consultative approval was obtained from the Danish National Committee on Biomedical Research Ethics (1208204). Consent was obtained from caregivers, prior to inclusion, verbally and in writing (signature or fingerprints). All children were treated free of charge at the study sites, irrespective of study participation. The trial is registered at www.controlled-trials.com (ISRCTN42569496).

Consent for publication

Not applicable

Availability of data and material

The dataset used during the current study is available from the corresponding author on reasonable request.

Acknowledgements

Not applicable

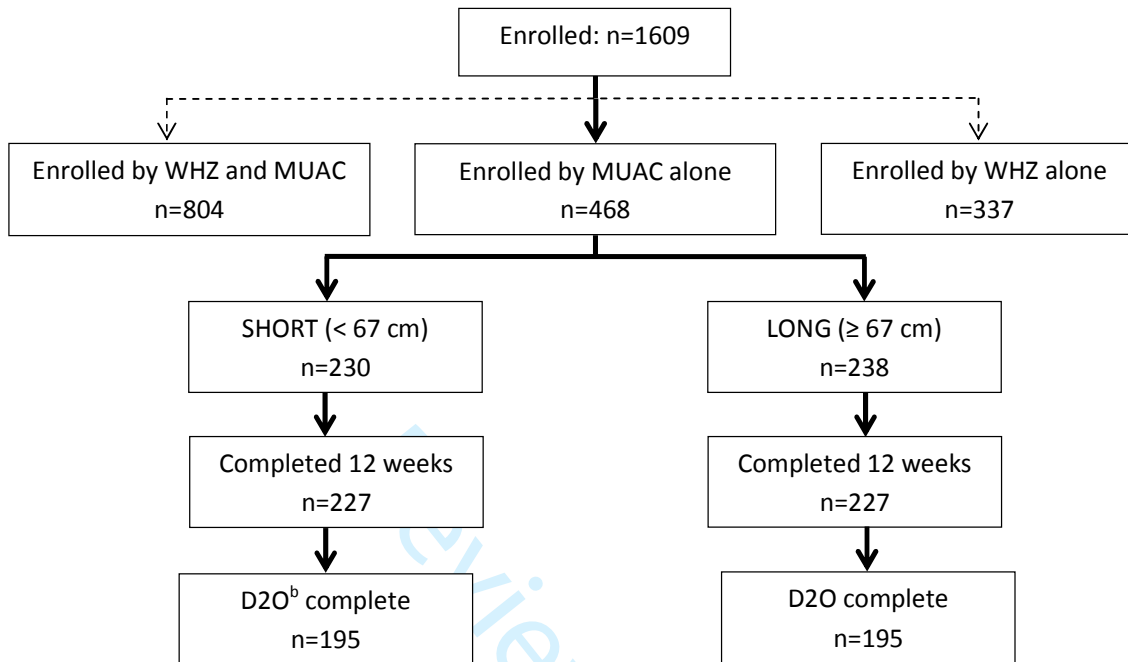
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Figure 1 participant flow chart^a

^a Treatfood participants included in the cohort study²². ^b D2O = Body composition assessment by deuterium dilution technique

Table 1. Baseline characteristics of children with moderate acute malnutrition included by MUAC only with complete D2O data (n=390), by length category^a

	^b SHORT (n=195)	^c LONG (n=195)	P-value
Girls, % (n)	84% (163)	72% (140)	0.005
Age, months	7.7 (1.6)	14.0 (4.3)	<0.001
Weight, kg	6.012 (0.4)	7.487 (0.7)	<0.001
Length, cm	63.9 (2.1)	72.0 (3.9)	<0.001
Mid upper arm circumference, mm	121.0 (2.6)	122.2 (1.9)	<0.001
Weight for height z-score	-1.5 (0.4)	-1.7 (0.3)	<0.001
Weight for age z	-2.4 (0.6)	-2.1 (0.6)	<0.001
Length for age z	-2.0 (1.0)	-1.7 (1.0)	0.002
Length for age z, <-2 % (n)	49% (95)	35% (68)	0.006
Season at time of inclusion, % (n)			0.17
Dry season	61% (118)	67% (131)	
Rainy season	40% (77)	33% (64)	
Food supplement, % (n)			0.84
CSB	48% (94)	47% (92)	
LNS	52% (101)	53% (103)	
Site, % (n)			0.009
0	12% (24)	27% (52)	
1	15% (30)	11% (21)	
2	21% (41)	18% (35)	
3	31% (60)	26% (50)	
4	21% (40)	19% (37)	
Breastfeeding, % (n)	100% (194)	91% (178)	<0.001

^aData are mean (±SD) unless otherwise indicated. ^bSHORT <67 cm, ^cLONG ≥67 cm.

Table 2. Body composition among short and long children with moderate acute malnutrition at baseline and endline, without adjustments^a

	Baseline			Endline		
	^b SHORT (n=195)	^c LONG (n=195)	^d P Δ	SHORT (n=195)	LONG (n=195)	^e P Δ
Fat mass, kg	1.098 (0.4)	1.218 (0.4)	0.001	1.123 (0.4)	1.246 (0.4)	0.003
Fat-free mass, kg	4.914 (0.5)	6.268 (0.8)	<0.001	5.673 (0.5)	7.096 (0.9)	<0.001
%Fat, (Fat-mass/weight*100)	18.3 (5.8)	16.4 (5.3)	<0.001	16.3 (5.7)	15.0 (4.9)	0.015
Fat mass index, kg/m ²	2.689 (0.9)	2.364 (0.8)	<0.001	2.499 (0.9)	2.259 (0.8)	0.006
Fat-free mass index, kg/m ²	12.000 (0.9)	12.056 (0.9)	0.53	12.640 (0.8)	12.723 (0.9)	0.36
Triceps skinfold, mm	6.6 (1.1)	6.3 (1.0)	0.001	6.8 (1.1)	6.8 (1.2)	0.85
Triceps skinfold-for-age z	-1.5 (0.8)	-1.3 (0.8)	0.04	-1.1 (0.8)	- 0.8 (0.9)	0.007
Subscapular skinfold, mm	5.6 (0.9)	5.1 (0.8)	<0.001	5.8 (1.0)	5.4 (0.8)	<0.001
Subscapular skinfold-for-age z	-1.3 (0.9)	-1.5 (0.9)	0.03	-0.9 (1.0)	-0.9 (0.9)	0.96

^aData are mean (±SD) unless otherwise indicated. ^bSHORT <67 cm, ^cLONG ≥67 cm. ^dP value for difference at baseline between SHORT and LONG children. ^eP value for difference at endline between SHORT and LONG children.

Table 3. Changes in outcomes during supplementation^a

	^b SHORT (n=195)	^c LONG (n=195)	^d Difference in change	^e P Δ
Fat mass, kg	-0.022 (-0.088; 0.043)	0.075 (0.010; 0.140)	-0.097 (-0.205; 0.010)	0.076
Fat-free mass, kg	0.678 (0.604; 0.752)	0.908 (0.834; 0.982)	-0.230 (-0.355; -0.106)	<0.001
%Fat (Fat-mass/weight*100)	-1.8 (-2.6; -1.0)	-1.5 (-2.3; -0.7)	-0.3 (-1.6; 1.1)	0.70
Fat mass index, kg /m ²	-0.166 (-0.309; -0.234)	-0.128 (-0.271; 0.015)	-0.038 (-0.257; 0.181)	0.74
Fat-free mass index, kg/m ²	0.684 (0.556; 0.813)	0.624 (0.495; 0.752)	0.061 (-0.150; 0.271)	0.57
Triceps skinfold, mm	0.39 (0.04; 0.73)	0.35 (-0.002; 0.70)	0.04 (-0.24; 0.32)	0.77
Triceps skinfold-for-age z	0.48 (0.25; 0.71)	0.50 (0.26; 0.73)	-0.02 (-0.22; 1.85)	0.88
Subscapular skinfold, mm	0.32 (0.17; 0.47)	0.24 (0.09; 0.40)	0.08 (-0.15; 0.30)	0.52
Subscapular skinfold-for-age z	0.52 (0.36; 0.67)	0.49 (0.34; 0.65)	0.02 (-0.21; 0.26)	0.84

^aData are mean and 95% CI calculated using linear mixed models adjusted for food intervention, baseline measure of the outcome, age, sex, month of admission and site (random effects). ^bSHORT <67 cm, ^cLONG ≥67 cm. ^dDifference in change of SHORT vs LONG. ^eP value for difference in change from baseline to endline for SHORT and LONG children.

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List word counts below (do not paste the text here). Please see the Decision Letter Attachment for allowances as they pertain to your manuscript type.

of words in Abstract: **247** (250 words allowed)

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2016-XXXX.RX – Short malnourished children do not gain excessive fat with food supplementation -- by Fabiansen et al.

EDITOR/REVIEWER COMMENTS <i>Paste each of the editor and reviewer queries here.</i>	AUTHOR'S RESPONSE <i>Paste your answer to the editor and reviewer queries here. If you alter your manuscript to address this query, you MUST paste the relevant altered text here – verbatim as it appears in the manuscript.</i>	REFERENCE PAGE <i>State where* the change now appears in your newly revised manuscript.</i>	CHANGE APPROVED ? FOR EDITORIAL USE ONLY
Editors Comments	<p>We thank you for provisionally accepting our manuscript.</p> <p>Our current title is: Short malnourished children with a low MUAC do not gain excessive fat with food supplementation</p> <p>You suggest we change it into: Short malnourished children and fat accumulation with food supplementation</p> <p>We fully acknowledge that our original title was rather long. However, we would like the title to give an idea of the main message of the paper, and your suggestion may indicate fat accumulation. We therefore kindly ask to change the title into:</p> <p>“Short malnourished children do not gain excessive fat with food supplementation”</p> <p>Likewise, we hope it is acceptable that your suggested short title Short malnourished children and fat accumulation</p>		

<p>1 2 3 4 5 6</p>	<p>Is changed into: "Short malnourished children do not gain excessive fat"</p>		
<p>7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37</p> <p>Reviewer 1's comment</p> <ol style="list-style-type: none"> 1. If possible avoid the use of an abbreviation in the title. 2. Could you please clarify the criteria for sample size calculation? 3. Please adjust superscript 2 in Figure 1. 4. In Table 1 and 2 homogenize the use of MAM (moderate acute malnutrition). 	<p>We thank reviewer 1 for the very positive review.</p> <ol style="list-style-type: none"> 1. Yes thanks, this is now avoided in the new title. 2. Thanks for pointing this out. Sample size calculation was made for the main trial. We now made it clearer which children were included in current study. The text now reads: "Of the 1609 children included in the trial 468 had MUAC between 115-125mm and WHZ \geq-2, and were included in the current study. In many settings these children are excluded from treatment if they are also short (i.e. <65 or 67 cm). Accordingly, children in this study were categorized, based on baseline length, as SHORT (<67 cm) or LONG (\geq67 cm) to assess if SHORT children gain more fat than LONG children when treated for MAM diagnosed by low MUAC ." 3. Thanks for pointing this out. The problem is that "²²" is a reference in "Pediatrics" format. To improve readability we now changed table superscripts to letters. 4. Thanks. MAM is now written as moderate acute malnutrition. 	<ol style="list-style-type: none"> 1. Title 2. In <i>statistical analysis</i> 3. In <i>Participants</i> 4. Tab 1 +2 	
<p>39 40 41</p> <p>Reviewer 2' comment</p>	<p>We thank reviewer 2 for the kind comments on our study and for us testing BOGSAT opinion</p>		
<p>43</p> <p>Reviewer 3's comment</p>	<p>We thank reviewer 3 for the very positive review</p>	<p>1 In <i>statistical</i></p>	

<p>1 1. Methodology: Were the mixed 2 models “random intercept” or 3 “random intercept” and “random 4 slope” models? 5 6 2. Results: How were the results 7 (mean difference, 95% CI and P- 8 value) for weight gain obtained? For 9 me is not clear: why as the weight 10 difference between end of 11 intervention and baseline not used? 12 13 3. Discussion: Are there potential 14 bias that could limit the 15 generalization of the results? 16 17 4. Are other studies needed to 18 validate the results from this study? 19 20 5. Is it possible that these 21 supplemented children develop 22 obesity later in childhood or 23 adolescence? 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42</p>	<p>1. We’ve now clarified that the linear mixed models only included random intercepts corresponding to the sites. The text now reads:</p> <p>“To evaluate differences in outcomes between groups during the 12-week supplementation intervention, a linear mixed analysis of covariance model was considered as the main analysis, resulting in an estimated mean difference at the end of the study adjusted for differences at baseline. Specifically, the analyses included adjustment for food intervention as well as a number of baseline characteristics: baseline measure of the outcome, age, sex, and month of admission (as fixed effects). Random intercepts were included in the model to adjust for variation between sites. In the adjusted analysis, weight was derived by adding FFM and FM. Additionally, for direct outcomes of fat (FM and FMI) we evaluated the two-way interaction between length group and product group (CSB compared with LNS) in order to assess effect modification by type of product. Moreover, possible effect modification was also evaluated for stunting at admission in a) two categories: above and below LAZ of <-2, or b) or three categories: severe stunting (LAZ <-3), moderate stunting (LAZ ≥-3 to <-2) or absence of stunting (LAZ ≥-2). The same adjustments were applied in these additional analyses as in the main analysis. Model checking was based on residuals and normal probability plots. A significance level of 0.05 was applied.”</p> <p>2. Thanks for the question. Weight gain was estimated using the weight measurements at the end of the study but adjusted for baseline weight (analysis of covariance). We’ve now spelled out that we used an analysis of covariance type of linear mixed model. In this way, confidence intervals and p-values were obtained directly from the model fits (This is included in text in the paper as seen in the answer to your first question)</p> <p>3. We don’t consider bias to be a problem in this study. First, selection bias is unlikely, since we included a large proportion of</p>	<p><i>analysis</i></p>	
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1 those with MAM, based on MUAC, in the study, and the follow-up
 2 rate was very high, and not different between the two groups
 3 being compared. Hence, it is unlikely that selection could have led
 4 to a bias because of, say, lower probability of inclusion/higher
 5 attrition of children more prone to accumulate fat in the short
 6 compared to the long children. Second, information bias is unlikely
 7 since the outcome was assessed in the lab by staff who were
 8 unaware of the exposure of interest. Theoretically, a source of
 9 information bias could be that short children were more or less
 10 likely to spit when given the deuterium. For example, if short
 11 (younger) children were more likely to spit, then the concentration
 12 of deuterium would be underestimated, and the total body water
 13 overestimated, and therefore, the fat mass would be
 14 underestimated. However, since this would then happen base at
 15 baseline and endline, it is not likely to affect the change in fat
 16 mass, which is our outcome of interest. In general, generalizability
 17 is likely to be lower in nutrition compared to other intervention
 18 trials, since the effect of an intervention depends on the
 19 background nutritional intake and status. However, in this
 20 substudy, we are not testing the effect of a nutrition intervention,
 21 but if short stature affects changes in body composition. Certainly,
 22 since we used strict inclusion criteria we think that our findings
 23 can be generalized to other West African populations of young
 24 children with MAM, diagnosed using MUAC, at least. Yet, we
 25 cannot exclude the possibility that different fetal and early life
 26 trajectories in growth and body composition, as well as differences
 27 in background diets, may modify the difference in change in body
 28 composition during supplementation.
 29 This paper specifically asks for a policy change in the remaining
 30 African countries where length restriction is applied to MUAC
 31 measurements, these countries are located in West and Central
 32 Africa where morbidity/mortality and malnutrition patterns (very
 33 high incidence of acute malnutrition accompanied by high levels of
 34 stunting) are similar to that seen in Burkina. We would welcome
 35 further studies. It is probably worthwhile to repeat such body

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composition studies in other malnutrition contexts such as high prevalence of kwashiorkor in DRC/East Africa and in South Asia. However, we feel that policy must be changed now as no evidence support fat accumulation in this group of children. Given the fact that we are already at the full word limit we hope it is acceptable that we make no further changes in the manuscript text.

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4. This is a very good question. Malnutrition in itself might dispose to later non-communicable diseases (NCD) including increased susceptibility to fat accumulation, but firm evidence is lacking. However, if children with MAM are not treated, they are at a 3 times higher risk of dying here and now. The fact that they do not accumulate excess fat directly following 12 weeks treatment indicates, we believe, that the risk of later obesity following modern supplementation is, if at all present, low. The longer term implications of nutritional supplementation on NCD risk would be more likely to emerge in studies of young children supplemented over longer periods, e.g. the 9-18 month. However, the only way to find out would be doing long-term follow-up and compare our present cohort with another cohort who received different or no supplementation. Also, while getting fat later increases NCD risk, so does losing lean mass early, ie the thrifty phenotype. So, it makes sense to try to address the lean deficit when it is still amenable to nutritional therapy (early critical window). Given the fact that we are already at the full word limit we hope it is acceptable that we make no further changes in the manuscript text.

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Instructions:

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Please use this table format to answer the questions posed by the editors and reviewers of your paper. Copy and paste the editor/reviewer's question in the "Comments" column and your answer to that question in the corresponding "Response" column. Be sure to ALSO paste the corrected text along with your response. For minor copyediting changes such as spelling and grammar corrections, you may simply state that the error was corrected, without pasting the altered text.

* Use the page/line numbers from your revised .doc, .rtf, or .txt file; do *not* use the page/line numbers from the submission system's auto-generated PDF.

For clarity, use one row per question. Make sure to list the page and line reference where your change can be found. If no change was made, please make sure to note that in your response in addition to your reasoning. You may delete the sample row and insert rows to this table as needed.

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