



ORIGINAL ARTICLE

Interpretation of World Health Organization growth charts for assessing infant malnutrition: A randomised controlled trial

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Aims: The study aims to assess the effects of switching from National Center for Health Statistics (NCHS) growth references to World Health Organization (WHO) growth standards on health-care workers' decisions about malnutrition in infants aged <6 months.

Methods: We conducted a single blind randomised crossover trial involving 78 health-care workers (doctors, clinical officers, health service assistants) in Southern Malawi. Participants were offered hypothetical clinical scenarios with the same infant plotted on NCHS-based weight-for-age charts and again on WHO-based charts. Additional scenarios compared growth charts with a single final weight against charts with the same final weight plus a preceding growth trend. Reported (i) level of concern, (ii) referral suggestions and (iii) feeding advice were elicited with a questionnaire.

Results: Even after adjusting for health-care worker type and experience, using WHO rather than NCHS charts increased: (i) concern: aOR 4.4 (95% CI 2.4–8.1); (ii) odds of referral: aOR 5.1 (95% CI 2.4–10.8); and (iii) odds of feeding advice which would interrupt exclusive breastfeeding (aOR 2.4, 95% CI 1.2–4.9). A preceding steady growth trend line did not affect concern, referral or feeding advice.

Conclusions: Health-care workers take insufficient account of linear growth trend, clinical and feeding status when interpreting a low weight-for-age plot. Because more infants <6 months fall below low centile lines on WHO growth charts, their use may increase inappropriate referrals and risks undermining already low rates of exclusive breastfeeding. To avoid their being misinterpreted in this way, WHO charts need accompanying guidelines and training materials that recognise and address this possible adverse effect.

Key words: breastfeeding; growth chart; international child health; nutrition infant; randomised controlled trial.

What is already known on this topic?

- 1 WHO growth standards are based on a breastfed population and are technically superior to NCHS growth references.
- 2 However, more infants aged <6 months fall below anthropometric thresholds for malnutrition.
- 3 Implications for exclusive breastfeeding have been debated but lack an evidence base.

What this paper adds?

- 1 Health-care workers take insufficient account of linear growth trend, clinical and feeding status when interpreting low weight-for-age growth chart plots.
- 2 They are hence more concerned about small infants when assessed using World Health Organization-based rather than the National Center for Health Statistics-based growth charts: this risks interrupting exclusive breastfeeding.
- 3 To prevent inappropriate management, guidelines and training should emphasise the importance of growth trend, breastfeeding adequacy and clinical status.

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Under-nutrition is prevalent in low- and middle-income countries, underlying 35% of total disease burden in children aged under 5 years.¹ Treatment and prevention are global priorities.² Infants aged under 6 months (henceforth infants <6 months) are among those affected.³ Correctly differentiating those who need urgent attention from those who do not is a critical first step of effective patient management.

Until recently, many countries used charts and tables based on the 1978 National Center for Health Statistics (NCHS) references to assess and monitor growth.^{4,5} These had several limitations including the NCHS reference infants not following optimal breastfeeding practices and having a different growth pattern

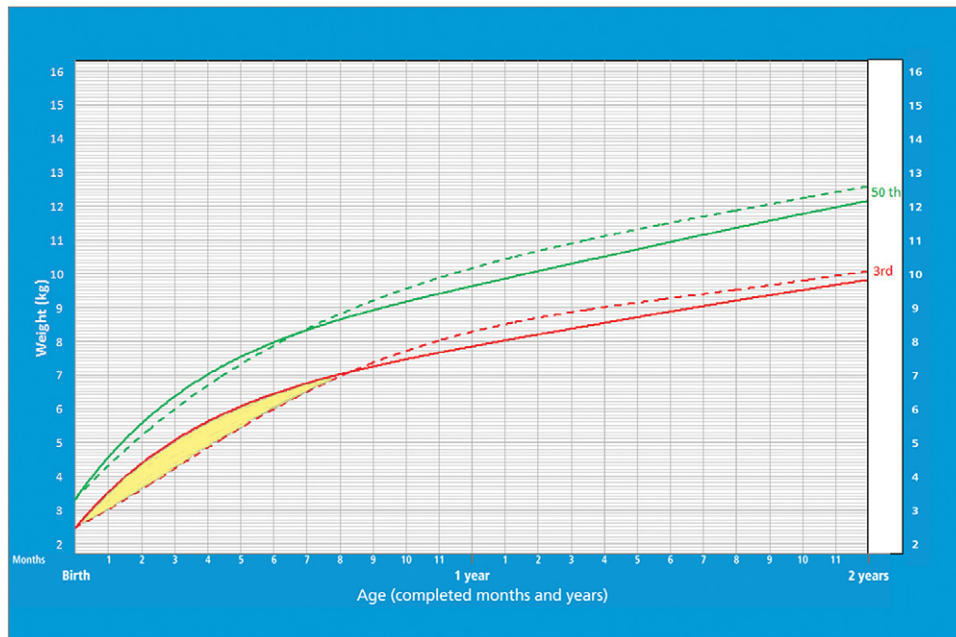


Fig. 1 WHO (solid line) and NCHS (dashed line) 50th and 3rd percentile curves for weight-for-age. Prior to 8 months more infants are below the 3rd WHO percentile (see shaded zone). NCHS, National Center for Health Statistics; WHO, World Health Organization.

from breastfed infants.⁶ Addressing this and other shortcomings, the World Health Organization (WHO) initiated a global multicentre growth reference study and in 2006 released WHO growth standards.⁷ These were based on exclusively breastfed infants living in optimal conditions for growth. Resulting growth curves are a globally applicable growth *standard* describing how all children *should grow* rather than a *reference* describing how a specific cohort of children *did grow*.⁸

Technically superior, the WHO standards have important differences from NCHS references.^{5,9,10} Used at population level, one difference is that more infants <6 months fall below anthropometric thresholds for undernutrition (e.g. weight-for-age ≤ 3 z-scores for severe underweight)^{3,11} (Fig. 1). Some authors have suggested that using WHO standards to assess individual infants <6 months therefore risks 'doing more harm than good'¹²: health-care workers or carers might inappropriately interrupt exclusive breastfeeding (EBF) due to concern that a small but clinically well infant is getting insufficient milk.¹² Arguments against this concern include the view that: '... most health professionals will consider the baby's birth-weight, growth trend, any problems with lactation, and infections that might explain the apparent growth failure'.¹³

Our study aimed to provide an evidence base to this debate about WHO-based charts used for assessment of individual infants.¹⁴ As WHO standards are being rolled out in many countries worldwide,¹⁵ anything that conflicts with their stated aim of 'supporting appropriate infant feeding practices'¹⁶ risks adverse public health consequences. Our objectives were to determine whether health-care workers using WHO-based rather than NCHS-based growth charts are more concerned about clinically well, exclusively breastfed infants aged <6 months; whether they refer such infants more often; and

whether they give advice which risks interrupting EBF. We also wanted to explore whether knowledge of the preceding growth trend modifies any concerns about nutritional status and adequacy of breastfeeding.

Materials and Methods

We conducted our study in Blantyre district, Malawi, from May to June 2010. Participants came from six of eight community health centres and from Queen Elizabeth Central Hospital, a teaching hospital which also serves as the main district hospital for Blantyre.

Study participants

We recruited 78 health-care workers whose everyday job involves assessing infants and children and making decisions about nutritional status and further management:

- 1 Clinicians included doctors and clinical officers (independent practitioners whose initial training is 3 years rather than the 5 which doctors spend in medical school). Twenty-seven of 35 eligible clinicians identified at the hospital were recruited to the study. The others were unavailable for interview (e.g. away on leave, on work elsewhere).
- 2 Health surveillance assistants (HSAs) are Malawi's primary health-care cadre. They mostly have secondary school qualifications with some months additional clinical training. They are based in the community and are responsible for delivery of front-line care of basic problems and referral of more complex cases.

We included all health-care workers available at health centres on the day of our visit, and were introduced to them by the

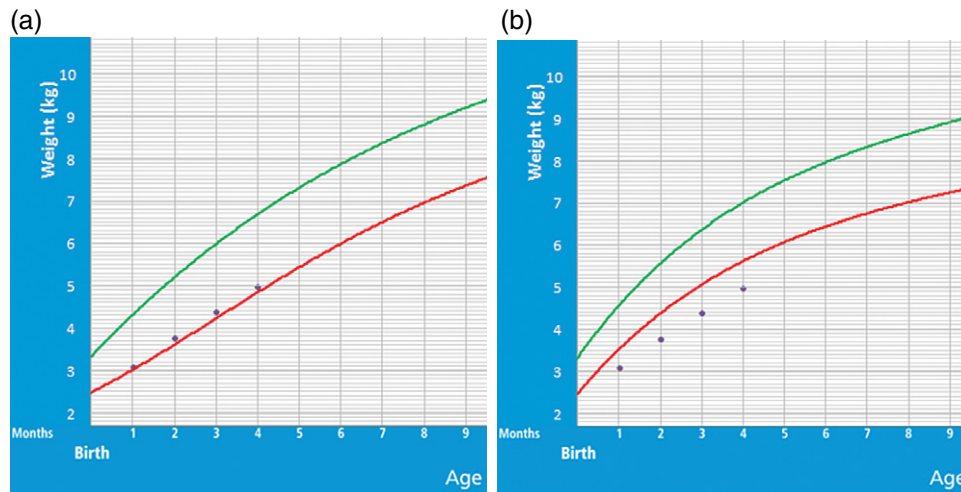


Fig. 2 The same steady growth pattern plotted on the NCHS chart (a) and WHO chart (b). The infant is described as ‘currently breastfeeding well; no recent illness; alert and active on examination’. NCHS, National Center for Health Statistics; WHO, World Health Organization.

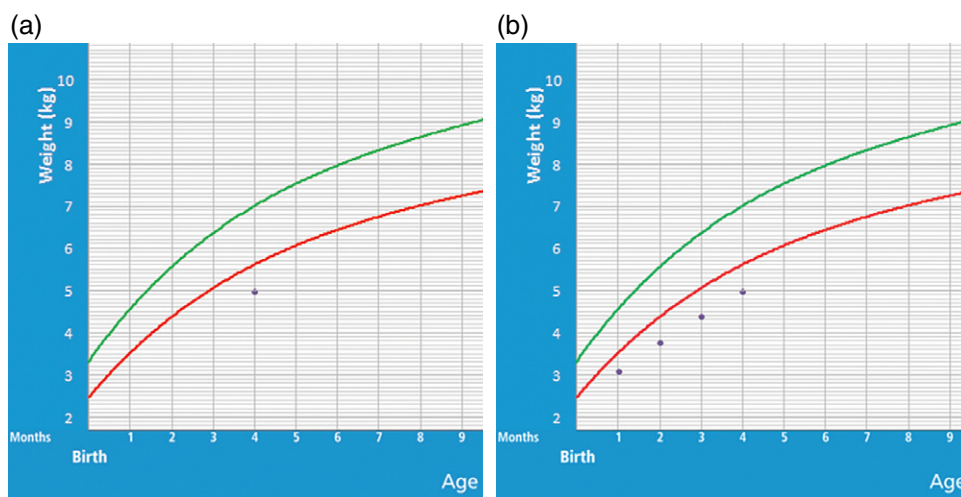


Fig. 3 The same final weight plotted on the WHO chart without (a) and with (b) the previous growth trend. Again, the infant is described as ‘currently breastfeeding well; no recent illness; alert and active on examination’. WHO, World Health Organization.

health-centre person in charge. Our only exclusion criterion was being non-English speaking (only one HSA’s English was not good enough to allow us to communicate effectively).

Study design

We employed a single blind, randomised crossover design. Participants were interviewed individually at their workplace. We showed a series of hypothetical clinical scenarios, each with an accompanying growth chart (Figs 2,3). All participants saw the same set of scenarios. Unbeknown to them, each scenario was repeated twice: the same child’s weight was plotted once on a WHO chart (Fig. 2b) and again on an NCHS chart (Fig. 2a). This paired design aimed to detect any shift in individual responses. The layout of the growth charts was based on WHO weight-for-

age percentile charts.¹⁷ Weight-for-age is widely used internationally, including in Malawi, and staff there are familiar with it. To be consistent with existing local growth charts, only the 3rd and 50th percentile lines were displayed.¹⁸ These charts are typical of those in many other countries worldwide.

All scenarios described a patient who was 4 months old, breastfeeding well, with no recent illness, and alert and active on clinical examination. A normal ‘wash-in’ scenario was followed by a pre-generated block randomised sequence ensuring that no two successive scenarios were the same.

With the first comparison pair (Fig. 2), we assessed the overall effect of using WHO standards; the same steady growth pattern plotted on NCHS curves (control) and WHO curves (intervention). The second pair (Fig. 3) assessed whether information about growth trend affected interpretation: a single

measurement below the (WHO-based) growth curve (control) was compared with the same measurement set in context of a preceding steady growth trend (intervention, again plotted on a WHO-based chart).

Outcomes

For each scenario, we asked participants three questions reflecting their interpretation:

- 1 Level of Concern ('How would you rate this child's well-being?') – using a 5-point Likert scale ranging from 'Not Worried at all' to 'Very Worried'
- 2 Recommended Management ('How would you manage this child?') – 'Discharge', 'Arrange a Follow up at the same setting', 'Refer to a different setting' or 'Admit to Hospital'
- 3 Feeding Advice ('With regards to feeding, what would you advise?') – 'Exclusive Breastfeeding', 'Complementary Feeding', 'Top up feeding using Infant Formula milk' or 'Inpatient feeding using Therapeutic Milk'.

Questions were asked by study investigator UNA, who also recorded participants' verbal responses on a study proforma.

Blinding and sequence generation

Participants were blinded to the objectives of the study. The interviewer (UNA) was aware of the study objectives but blind to the allocation sequences which were generated independently. The interviews and instructions followed a standard protocol.

Sample size

The study was designed to detect a difference of 1 in median on a 5-point Likert scale in the main outcome measure (level of concern) with 90% power at 5% significance, based on a Wilcoxon test. A sample size of 20 clinicians (doctors and clinical officers) and 20 HSAs was obtained.

Statistical analysis

We aggregated the four responses for 'Recommended Management' into the binary outcome 'Managed Locally' (i.e. 'Discharge' or 'Arrange to follow up') versus 'Refer or Admit' ('Refer' or 'Admit'). Similarly, we aggregated responses for 'Feeding Advice' into 'Maintain Exclusive Breastfeeding' ('Continue Exclusive Breastfeeding') versus 'Interrupt Exclusive Breastfeeding' ('Initiate complementary Feeding', 'Top up feeding using Infant Formula milk' or 'Inpatient feeding using Therapeutic Milk').

We used Wilcoxon's signed rank test for differences in levels of concern; McNemar's test for differences in binary outcomes; and logistic regression and ordinal logistic regression to explore confounding by type of health-care worker and years of experience.

Ethics

All participants were given a study information sheet and asked for written consent. The study was approved by Malawi's College of Medicine Research and Ethics Committee, ref P03/10/911.

Results

Seventy-eight health-care workers were approached and all consented to enrolment. All completed the study and responded to all the scenarios: there were no missing responses. We recruited 51 (65%) HSAs, 9 (12%) clinical officers and 18 (23%) doctors. Thirty-two (41%) had 0–3 years of experience, 15 (19%) had 4–6 years and 31 (40%) had 7+ years experience.

Interpreting clinical scenarios plotted on NCHS versus WHO growth charts

The median level of concern about the same infant rose from 2/5 plotted on the NCHS chart (Fig. 2a) to 4/5 plotted on the WHO chart (Fig. 2b) ($P < 0.01$), and 46 respondents (59%) were more concerned with the WHO chart (Fig. 4). Use of the WHO chart was associated with greater concern (adjusted odds ratio 4.4, 95% CI 2.4 to 8.1) (Table 1, 'Use of WHO chart'). Only adjusted figures are shown: unadjusted values were very similar.

Patient management was also significantly influenced by growth chart used: 50 (64%) of health-care workers recommended referral or admission when using WHO charts, as against 24 (30%) when using NCHS charts (adjusted odds ratio 5.1, 95% CI 2.4 to 10.8). Doctors and more experienced health-care workers were however both less likely to suggest referral or admission.

Feeding advice was also influenced by chart type: 44 (56%) of participants recommended interrupting EBF when using the WHO chart compared with 29 (37%) using the NCHS chart (adjusted odds ratio 2.4, 95% CI 1.2 to 4.9). There were no significant differences between types of health-care worker, though more experienced individuals were less likely to interrupt breastfeeding.

Interpreting scenarios with and without a preceding growth (upward sloping weight-for-age) trend line

The median level of concern when a single low weight was plotted (Fig. 3a) was 5 ('very concerned'). When a favourable preceding growth trend was also shown (Fig. 3b), the level of concern was significantly lower at 4 ($P = 0.02$) though still high. Figure 5 shows that 31 (40%) of respondents were equally concerned with or without the growth trend and 14 (18%) were less concerned with the single weight without the preceding trend. The only factor that significantly influenced level of concern was experience, with more experienced health-care workers being less concerned, and very experienced respondents significantly less so (Table 1, 'Absence of Growth Trend').

Patient management was uninfluenced by the growth trend, with 50 (64%) of respondents opting to refer or admit the infant with the growth trend present, as against 54 (69%) when only the single weight was shown (adjusted odds ratio 1.3, 95% CI 0.6 to 2.6). Again, more experienced health-care workers were significantly less likely to refer or admit the infant.

Feeding advice was also uninfluenced by the growth trend: 44 (56%) of respondents opted to interrupt EBF when the growth trend was present compared with 51 (65%) when only the single weight was shown (adjusted odds ratio 1.5, 95% CI 0.8 to 3.1).

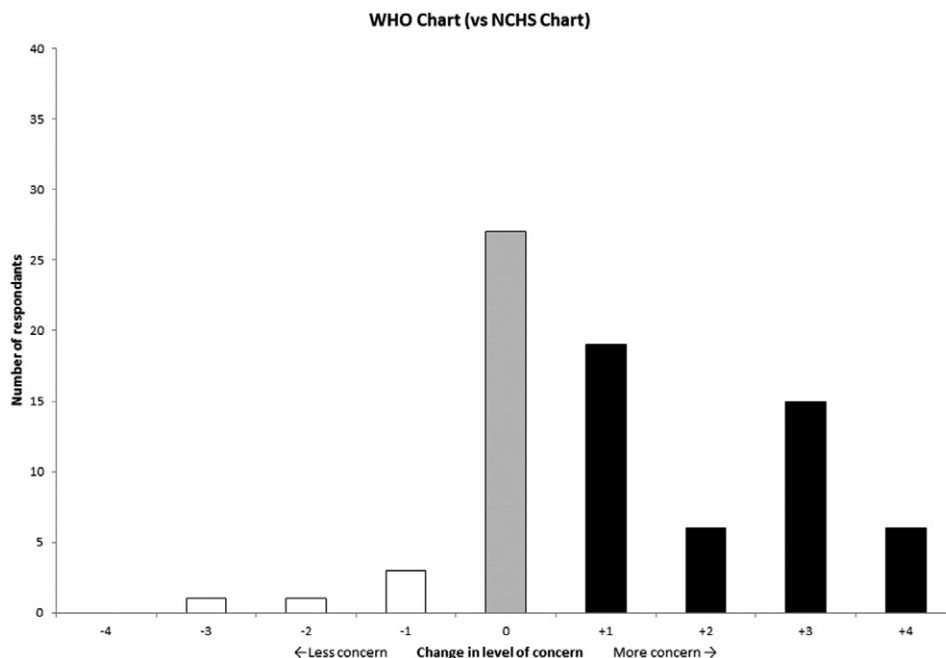


Fig. 4 Difference in level of concern (expressed on a 1–5 Likert scale) when the same infant is plotted on the WHO chart compared with the NCHS chart. 0 = no difference in concern; ≤ -1 = less concern with WHO chart; $\geq +1$ greater concern with WHO chart. NCHS, National Center for Health Statistics; WHO, World Health Organization.

Very experienced health-care workers were less likely to suggest interrupting EBF (adjusted odds ratio 0.3, 95% CI 0.1 to 0.5)

Discussion

Our findings support the concern that poorly interpreted WHO-based growth charts risk doing ‘more harm than good’ when used to assess exclusively breastfed infants aged <6 months.¹² Any chart of course may be inappropriately interpreted – but the issue is particularly relevant to WHO-based charts as more infants fall below undernutrition thresholds than with other charts. In our scenarios describing small but clinically well, exclusively breastfed infants, using WHO rather than NCHS-based growth charts increased concern, referrals and led to advice risking undermining EBF. We saw little evidence for the counter-argument that a favourable preceding growth trend modulates inappropriate concerns.¹³ Health-care worker type and experience did however affect these outcomes. Experience was particularly important, with more experienced health workers less likely to refer, admit or interrupt EBF.

With suboptimal breastfeeding responsible for some 1.4 million child deaths worldwide, 77% of which are due to non-EBF,¹ these results have serious implications for global public health. Even if a health-care worker does not explicitly advise an interruption of EBF, any insinuation about an infant being ‘malnourished’ could cause carer concern and carer-initiated interruption of EBF. Action is needed to ensure that roll-out of WHO standards supports rather than undermines EBF in this population: it is estimated that greater coverage of EBF promotion would cause a 10% reduction in infant mortality.¹⁶

Our findings also have implications for health systems. Infants who cause greater concern are more likely to be referred or admitted, stretching the capacity of existing programmes and health-care systems. The risk-benefit balance of a diagnosis of under-nutrition must be carefully considered. All current national guidelines for infants suggest inpatient-based care with exposure to the risk of hospital-acquired infection in exchange for an uncertain long-term benefit.¹⁹ Admission also represents a major opportunity cost to caregivers who may be unable to attend to the needs of other dependants.

Strengths and limitations

Though we are the first, to our knowledge, to conduct a randomized controlled trial on this issue,¹⁴ we recognise limitations of our study. Firstly, it is based on hypothetical scenarios. What our respondents said that they would do may be different to what they actually do in practice. Although basic clinical information was provided, the full nuances of clinical assessment cannot be replicated in a questionnaire-based study. This may have led to overreliance on the growth chart in making clinical decisions. Perhaps because they took our clinical description of ‘currently breastfeeding well; no recent illness; alert and active on examination’ as a general indication that the infant was otherwise well, participants did not, for example, ask questions about other measures of nutritional status (e.g. weight-for-length; length-for-age; mid-upper arm circumference (MUAC)), nor did they comment on clinical appearance (thin looking or not) as might have happened during a real consultation.

Table 1 Interpretation of clinical scenarios

| | Use of WHO chart (Fig. 2a vs. 2b) | | Absence of growth trend (Fig. 3a vs. 3b) | |
|---|-----------------------------------|---------|--|---------|
| | aOR (95% CI)† | P-value | aOR (95% CI)† | P-value |
| Factors associated with greater concern | | | | |
| Overall | 4.4 (2.4 to 8.1) | <0.01 | 1.6 (0.9 to 3.0) | 0.1 |
| Health surveillance assistant | 1 (ref) | | 1 (ref) | |
| Clinical officer | 1.9 (0.8 to 4.8) | 0.2 | 1.6 (0.6 to 4.7) | 0.4 |
| Doctor | 0.7 (0.3 to 1.4) | 0.3 | 0.6 (0.3 to 1.2) | 0.1 |
| Newly qualified (0–3 years) | 1 (ref) | | 1 (ref) | |
| Experienced (4–6 years) | 0.4 (0.2 to 0.9) | 0.04 | 0.4 (0.2 to 1.0) | 0.06 |
| Very experienced (≥7 years) | 0.6 (0.3 to 1.1) | 0.07 | 0.4 (0.2 to 0.8) | 0.01 |
| Factors influencing management advice to refer or admit | | | | |
| Overall | 5.1 (2.4 to 10.8) | <0.01 | 1.3 (0.6 to 2.6) | 0.5 |
| Health surveillance assistant | 1 (ref) | | 1 (ref) | |
| Clinical officer | 1.4 (0.4 to 4.6) | 0.6 | 3.0 (0.7 to 12.5) | 0.1 |
| Doctor | 0.3 (0.1 to 0.8) | 0.01 | 0.5 (0.2 to 1.1) | 0.1 |
| Newly qualified | 1 (ref) | | 1 (ref) | |
| Experienced | 0.2 (0.1 to 0.7) | 0.01 | 0.3 (0.1 to 0.7) | 0.01 |
| Very experienced | 0.3 (0.1 to 0.7) | <0.01 | 0.4 (0.2 to 0.9) | 0.03 |
| Factors influencing feeding advice which will interrupt exclusive breastfeeding | | | | |
| Overall | 2.4 (1.2 to 4.9) | 0.01 | 1.5 (0.8 to 3.1) | 0.2 |
| Health surveillance assistant | 1 (ref) | | 1 (ref) | |
| Clinical officer | 2.5 (0.8 to 8.3) | 0.1 | 3.1 (0.8 to 12.5) | 0.1 |
| Doctor | 0.7 (0.3 to 1.7) | 0.4 | 0.6 (0.2 to 1.3) | 0.2 |
| Newly qualified | 1 (ref) | | 1 (ref) | |
| Experienced | 0.4 (0.1 to 1.1) | 0.06 | 0.5 (0.2 to 1.3) | 0.1 |
| Very experienced | 0.2 (0.1 to 0.5) | <0.01 | 0.3 (0.1 to 0.5) | <0.01 |

†Adjusted for type and experience of healthcare worker. aOR, adjusted odds ratio.

Secondly, some may question generalisability to staff working in other settings. Though weight-for-age charts that we used are typical of those in many developing countries, our study is not definitive. We do however hope that it stimulates others to ask similar research questions in other environments and countries, for example, where socio-economic and morbidity/mortality profiles differ and other assessment methods are used (e.g. different charts).²⁰ However, we note that our research was set around a teaching hospital with good supervision and a proactive teaching and continuous medical education programme. More isolated staff working in remote settings are likely to perform even worse. Our study is also consistent with existing evidence from developed country settings which suggest that carers often misuse growth charts by focusing unduly on final weight and body size rather than growth trend.^{21–24} Such problems experienced in resource-rich settings are likely to be exacerbated in developing countries with fewer resources, less time per patient and weaker health-care systems.

Finally, our respondents had not been formally trained on the use of WHO growth standards. We considered this when designing our study but noted that our hypothetical infant would have come under this advice in one online training resource . . . 'A point or trend that is far away from the median –3 or 3 [Z-score] indicates a problem'.²⁵ Such statements do not consider the possibility that some infants are small but otherwise well and do not clearly highlight the need for a broader clinical, feeding and

growth assessment before concluding that a child has a problem. Had we included this current advice in our study charts, we suspect the issues observed would have exacerbated rather than reduced.

Implications

As countries are currently fast rolling out WHO standards,^{15,26} we believe that the results of our study warrant both attention and action. We call for training materials to be updated in light of our findings. As both training and updates are likely to be happening anyway, this would involve relatively limited costs to gain potentially great patient benefits. Any doubts about the generalisability of our findings should consider the alternative scenario of inaction: this has potentially great patient risks in terms of undermining breastfeeding. Future research should thus focus on *how* to best improve growth chart use and interpretation rather than the question of whether this is needed.

We suggest, for example, that key guidance be noted on the chart itself. This might be especially helpful for less experienced health-care staff who, as we have shown, are most likely to misinterpret the charts. There also needs to be more emphasis on clinical assessment (including growth trend) and breastfeeding assessment as essential complements to anthropometric measurement of infants. This includes consideration

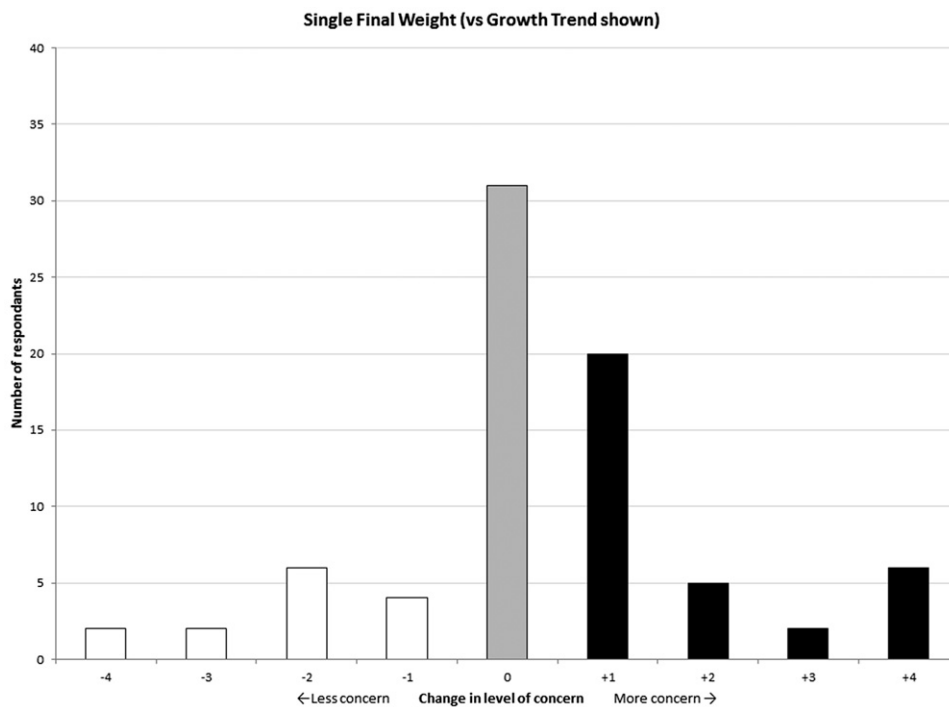


Fig. 5 Difference in level of concern (expressed on a 1–5 Likert scale) when the same infant's weight is plotted with or without a growth trend line. 0 = no difference in concern; ≤ -1 = less concern with a single-point plot; $\geq +1$ greater concern with a single-point plot.

of HIV and related issues in high-prevalence areas: especially critical because breastfeeding advice in this area has changed markedly over the past years.²⁷ The need for such a wide-ranging and thorough assessment is already acknowledged in some materials²⁸ which advise that nutritional concern in the infant should first trigger a thorough investigation of causes including assessment of breastfeeding technique and psychosocial well-being by the health-care worker. It should be explicit in all support materials.

In the longer term, we call for more work on assessment of infant under-nutrition in general. Appearance alone (i.e. visible wasting) is a poor predictor of under-nutrition and should not be relied on.^{29,30} Even by their supporters, and in resource-rich settings, the challenges of growth charts are often highlighted.^{31,32} Weight-for-age, weight-for-height and length-for-age charts all measure different aspects of nutritional status and hence have different purposes and different strengths and weaknesses. One issue common to all such indices is that z-scores and centiles, as commonly used in growth charts, represent statistical cut-offs for under (and over) nutrition. While suitable to express population-level malnutrition prevalence, z-scores and centiles may not be so good applied to individual-level assessment. For example, growing evidence in acutely malnourished older children suggests that weight-for-height z-score cut-offs are relatively poor indicators of malnutrition-associated risk: a key aim of anthropometric assessment being to accurately identify individuals at high risk of death so that they can be admitted for treatment.³³ Much better is MUAC: not only does it much

better identify high-risk individuals, but it is quick, cheap and easy to do.^{34,35} Evidence is also emerging about the use of MUACs in young infants,³⁶ but more is needed. More evidence is also needed on non-anthropometric criteria (e.g. clinical signs, breastfeeding assessment tools) to identify high-risk infants, and more evidence is needed on how to best manage infants having identified them.^{19,37}

In conclusion, health-care workers take insufficient account of linear growth trend, clinical and feeding status when interpreting a low weight-for-age plots. Because more infants <6 months fall below low centile lines on WHO growth charts, their use may increase inappropriate referrals and risks undermining already low rates of EBF. This potentially harmful misinterpretation of WHO-based growth charts does not call into question their overall value. As with any clinical tool, it is vital however that they are properly understood and appropriately used. Rollout of WHO standards represents a great opportunity to improve health and reduce mortality by promoting higher rates of EBF. This will not happen automatically: risks can only be addressed if they are first recognised.

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References

- Black RE, Allen LH, Bhutta ZA *et al.* Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* 2008; **371**: 243–60.
- Horton R. Maternal and child undernutrition: an urgent opportunity. *Lancet* 2008; **371**: 179.
- Kerac M, Blencowe H, Grijalva-Eternod C *et al.* Prevalence of wasting among under 6-month-old infants in developing countries and implications of new case definitions using WHO growth standards: a secondary data analysis. *Arch. Dis. Child.* 2011; **96**: 1008–13.
- de Onis M, Wijnhoven TMA, Onyango AW. Worldwide practices in child growth monitoring. *J. Pediatr.* 2004; **144**: 461–5.
- Kerac M, Egan R, Mayer S, Walsh A, Seal A. New WHO growth standards: roll-out needs more resources. *Lancet* 2009; **374**: 100–2.
- Garza C, de Onis M. Rationale for developing a new international growth reference. *Food Nutr. Bull.* 2004; **25** (Suppl. 1): S5–14.
- World Health Organization. The WHO Child Growth Standards. Available from: <http://www.who.int/childgrowth/standards/en/> [accessed 19 September 2013].
- WHO. Enrolment and baseline characteristics in the WHO Multicentre Growth Reference Study. *Acta Paediatr. Suppl.* 2006; **450**: 7–15.
- Seal A, Kerac M. Operational implications of using 2006 World Health Organization growth standards in nutrition programmes: secondary data analysis. *BMJ* 2007; **334**: 733–9.
- World Health Organization and United Nations Children's Fund. 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. May, 2009. Available from: <http://www.who.int/nutrition/publications/severemalnutrition/9789241598163/en/> [accessed 19 September 2013].
- Prost MA, Jahn A, Floyd S *et al.* Implication of new WHO growth standards on identification of risk factors and estimated prevalence of malnutrition in rural Malawian infants. *PLoS ONE* 2008; **3**: e2684.
- Binns C, Lee M. Will the new WHO growth references do more harm than good? *Lancet* 2006; **368**: 1868–9.
- de Onis M, Onyango AW. WHO child growth standards. *Lancet* 2008; **371**: 204.
- Binns C, Lee MK. Will introducing the new World Health Organization growth reference to Australia reduce breastfeeding rates: why not a randomised controlled trial first? *J. Paediatr. Child Health* 2012; **48**: 347–9.
- Zorlu G. New WHO child growth standards catch on. *Bull. World Health Organ.* 2011; **89**: 250–1.
- Bhutta ZA, Ahmed T, Black RE *et al.* What works? Interventions for maternal and child undernutrition and survival. *Lancet* 2008; **371**: 417–40.
- World Health Organization. WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatr. Suppl.* 2006; **450**: 76–85.
- Ruel MT, Pelletier DL, Habicht JP, Mason JB, Chobokoane CS, Maruping AP. Comparison of two growth charts in Lesotho: health workers' ability to understand and use them for action. *Am. J. Public Health* 1991; **81**: 610–15.
- Emergency Nutrition Network, UCL Centre for International Health & Development, Action Contre la Faim. Management of Acute Malnutrition in Infants (MAMI) Project. Emergency Nutrition Network, UCL Centre for International Health & Development, Action Contre la Faim. 2010. Available from: <http://www.ennonline.net/research/mami> [accessed 19 September 2013].
- Rolland-Cachera MF, Peneau S. Assessment of growth: variations according to references and growth parameters used. *Am. J. Clin. Nutr.* 2011; **94** (Suppl. 6): 1794S–8S.
- Laraway KA, Birch LL, Shaffer ML, Paul IM. Parent perception of healthy infant and toddler growth. *Clin. Pediatr. (Phila)* 2010; **49**: 343–9.
- Ben-Joseph EP, Dowshen SA, Izenberg N. Public understanding of growth charts: a review of the literature. *Patient Educ. Couns.* 2007; **65**: 288–95.
- Senanayake MP, Gunawardena MK, Peiris DS. Maternal comprehension of two growth monitoring charts in Sri Lanka. *Arch. Dis. Child.* 1997; **76**: 359–61.
- Aden AS, Brannstrom I, Mohamud KA, Persson LA, Wall S. The growth chart – a road to health chart? Maternal comprehension of the growth chart in two Somali villages. *Paediatr. Perinat. Epidemiol.* 1990; **4**: 340–50.
- World Health Organization. 2008. Training Course on Child Growth Assessment, WHO Child Growth Standards. Boy's Growth Record (Your Child's Growth from Birth to 5 years). Geneva. Available from: http://www.who.int/childgrowth/training/boys_growth_record.pdf [accessed 19 September 2013].
- de Onis M, Garza C, Onyango AW, Rolland-Cachera MF. WHO growth standards for infants and young children. *Arch. Pediatr.* 2009; **16**: 47–53.
- World Health Organization. Rapid Advice: Infant Feeding in the Context of HIV. 2009. Available from: <http://www.who.int/hiv/pub/paediatric/advice/en/> [accessed 19 September 2013].
- World Health Organization. *Job-aid: Investigating Causes of Undernutrition*. Geneva: World Health Organization, 2006.
- Hamer C, Kvatum K, Jeffries D, Allen S. Detection of severe protein-energy malnutrition by nurses in The Gambia. *Arch. Dis. Child.* 2004; **89**: 181–4.
- Mogeni P, Twahir H, Bandika V *et al.* Diagnostic performance of visible severe wasting for identifying severe acute malnutrition in children admitted to hospital in Kenya. *Bull. World Health Organ.* 2011; **89**: 900–6.
- Ramsden L, Day AS. Paediatric growth charts: how do we use them and can we use them better? *J. Paediatr. Child Health* 2012; **48**: 22–5.
- Dugdale A. Paediatric growth charts: how do we use them and can we use them better? *J. Paediatr. Child Health* 2013; **49**: E257.
- Myatt M, Khara T, Collins S. A review of methods to detect cases of severely malnourished children in the community for their admission into community-based therapeutic care programs. *Food Nutr. Bull.* 2006; **27** (Suppl. 3): S7–23.
- Briend A, Maire B, Fontaine O, Garenne M. Mid-upper arm circumference and weight-for-height to identify high-risk malnourished under-five children. *Matern. Child Nutr.* 2012; **8**: 130–3.
- Berkley J, Mwangi I, Griffiths K *et al.* Assessment of severe malnutrition among hospitalized children in rural Kenya: comparison of weight for height and mid upper arm circumference. *JAMA* 2005; **294**: 591–7.
- Mwangome MK, Fegan G, Fulford T, Prentice AM, Berkley JA. Mid-upper arm circumference at age of routine infant vaccination to identify infants at elevated risk of death: a retrospective cohort study in the Gambia. *Bull. World Health Organ.* 2012; **90**: 887–94.
- WHO. World Health Organization NUGAG (Nutrition and Growth Advisory Group) Expert Consultation on Severe Acute Malnutrition. February 1st-3rd.; 2012; Geneva; 2012.