

# Diagnosing Pediatric Malnutrition: Paradigm Shifts of Etiology-Related Definitions and Appraisal of the Indicators

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## Abstract

The publication of the landmark paper “Defining Pediatric Malnutrition: A Paradigm Shift Toward Etiology-Related Definitions” launched a new era in diagnosing pediatric malnutrition. This work introduced the paradigm shift of etiology-related definitions—nonillness and illness related—and the use of anthropometric *z* scores to help identify and describe children with malnutrition (undernutrition) in the developed world. Putting the new definition into practice resulted in some interesting observations: (1) Etiology-related definitions result in etiology-related interventions. (2) Illness-related malnutrition cannot always be immediately “fixed.” (3) Using *z* scores in clinical practice often puts the burden of proof on the clinician to show that a child is not malnourished, rather than the other way around. (4) Children with growth failure severe enough to be admitted with “failure to thrive” should always be assessed for malnutrition, and when they meet the criteria, malnutrition should be documented and coded. The publication of the consensus statement came next, announcing the evidence-informed, consensus-derived pediatric malnutrition indicators. Since the indicators are a work in progress, clinicians are encouraged to use them and give feedback through an iterative process. This review attempts to respond to the consensus statement’s call to action by thoughtfully appraising the indicators and making recommendations for future review. Coming together as a healthcare community to identify pediatric malnutrition will ensure that this vulnerable population is not overlooked. Outcomes research will validate the indicators and result in new discoveries of effective ways to prevent and treat pediatric malnutrition. (*Nutr Clin Pract.* 2017;32:52-67)

## Keywords

pediatrics; nutrition assessment; malnutrition; nutritional status; failure to thrive

The publication of the landmark paper by Mehta and colleagues entitled “Defining Pediatric Malnutrition: A Paradigm Shift Toward Etiology-Related Definitions” launched a new era in diagnosing pediatric malnutrition.<sup>1</sup> Gone are the days of looking at children and thinking that they are probably malnourished but not really knowing how to prove it. Instead, the focus has become to uniformly diagnose pediatric malnutrition (undernutrition) in a variety of settings and in all parts of the world. In the past, the lack of a uniform definition of pediatric malnutrition that addressed it in both developing and developed countries resulted in widely varying prevalence rates (6%–51%) and heterogeneous nutrition screening practices.<sup>1</sup> While it is well known that malnutrition results in poorer clinical outcomes (eg, immune dysfunction, poor wound healing, developmental delay) and increased hospital costs (eg, prolonged hospital stay, increased use of nutrition support), identifying pediatric malnutrition remained elusive.<sup>2-5</sup>

To address this need, an interdisciplinary workgroup from the American Society for Parenteral and Enteral Nutrition (ASPEN) was convened to review existing literature and to arrive at an agreement on the important elements to include in a uniform definition of pediatric malnutrition. This interdisciplinary workgroup proposed a novel and comprehensive definition that includes 5 key domains: anthropometric variables, growth, chronicity of malnutrition, etiology of malnutrition

(including the mechanism of nutrient imbalance), and the impact of malnutrition on functional status (see Figure 1).<sup>1</sup> Malnutrition includes undernutrition and overnutrition, but the new definition addresses only undernutrition and does not include premature infants and neonates (infants <1 month old). The ASPEN workgroup defined pediatric malnutrition (undernutrition) as “an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein, or micronutrients that may negatively affect growth, development, and other relevant outcomes.”<sup>1</sup> The new definition was endorsed by ASPEN, the Academy of Nutrition and Dietetics, and, notably, the American Academy of Pediatrics. Please refer

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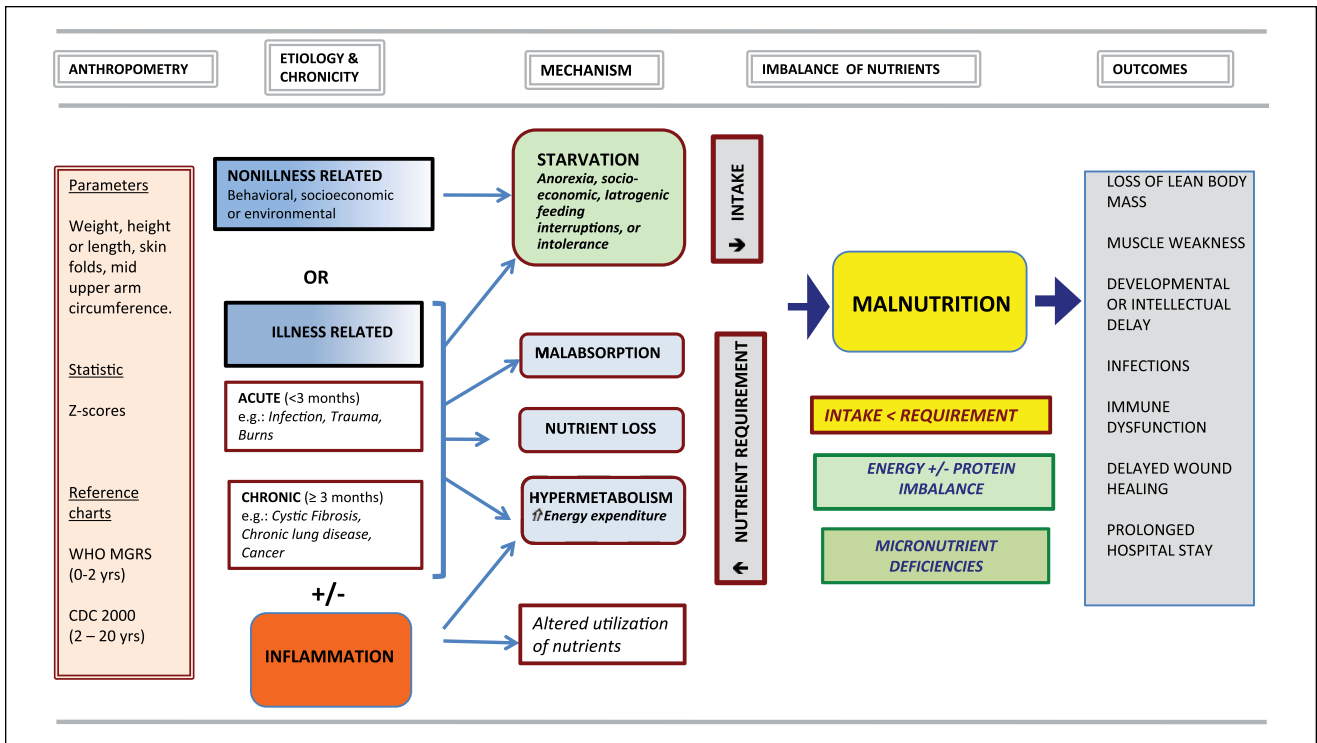
Conflicts of interest: None declared.

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**Figure 1.** Defining malnutrition in hospitalized children: key concepts. CDC, Centers for Disease Control and Prevention; MGRS, Multicentre Growth Reference Study; WHO, World Health Organization. Reprinted with permission from Mehta N, Corkins M, Lyman B. Defining pediatric malnutrition: a paradigm shift toward etiology-related definitions. *JPEN J Parenter Enteral Nutr.* 2013;37(4):460-481.

**Table 1.** Consensus Statement Primary Indicators of Pediatric Malnutrition When Single Data Point Is Available.

Indicator	Mild Malnutrition	Moderate Malnutrition	Severe Malnutrition
Weight-for-height z score	-1 to -1.9 z score	-2 to -2.9 z score	-3 z score or below
BMI-for-age z score	-1 to -1.9 z score	-2 to -2.9 z score	-3 z score or below
Length/height-for-age z score	No data	No data	-3 z score or below
Mid-upper arm circumference	-1 to -1.9 z score	-2 to -2.9 z score	-3 z score or below

BMI, body mass index. Adapted with permission from Becker PJ, Carney LN, Corkins MR, et al. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: indicators recommended for the identification and documentation of pediatric malnutrition (undernutrition). *Nutr Clin Pract.* 2015;30(1):147-161.

to this excellent publication for a comprehensive review of the new etiology-related definitions of pediatric malnutrition, including the 5 key domains, an executive summary, and a thorough review of the literature.<sup>1</sup>

A uniform definition is an essential first step to meeting a number of important goals. A uniform definition will (1) identify those at risk of malnutrition in a timely manner, (2) allow for comparisons between studies and health centers, (3) encourage the development of uniform screening tools, (4) standardize thresholds for intervention, and (5) enable the collection of meaningful data to analyze the impact of malnutrition and its treatment on clinical outcomes.<sup>1</sup> Soon after the publication of the new definition, another workgroup was

formed of members of ASPEN and the Academy of Nutrition and Dietetics to start addressing these goals. Their mandate was to identify a basic set of characteristics, or “indicators,” of pediatric malnutrition “that can be used to diagnose and document undernutrition in the pediatric population ages 1 month to 18 years.”<sup>6</sup> To that end, the workgroup published the consensus statement, which included 2 sets of pediatric malnutrition indicators: a set that requires 1 data point (ie, value) and a set that requires the comparison of 2 data points (see Tables 1 and 2). Clinicians assess all the indicators in both sets, but only 1 indicator is needed to diagnose pediatric malnutrition. By contrast, to diagnose malnutrition in adults, 2 characteristics are required.<sup>7</sup> To determine the severity of pediatric malnutrition,

**Table 2.** Consensus Statement Primary Indicators of Pediatric Malnutrition When  $\geq 2$  Data Points Are Available.

Indicator	Mild Malnutrition	Moderate Malnutrition	Severe Malnutrition
Weight gain velocity (<2 y of age)	<75% <sup>a</sup> of the norm <sup>b</sup> for expected weight gain	<50% <sup>a</sup> of the norm <sup>b</sup> for expected weight gain	<25% <sup>a</sup> of the norm <sup>b</sup> for expected weight gain
Weight loss (2–20 y of age)	5% usual body weight	7.5% usual body weight	10% usual body weight
Deceleration in weight-for-length/height z score	Decline of 1 z score	Decline of 2 z score	Decline of 3 z score
Inadequate nutrient intake	51%–75% estimated energy/protein need	26%–50% estimated energy/protein need	$\leq 25\%$ estimated energy/protein need

Adapted with permission from Becker PJ, Carney LN, Corkins MR, et al. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: indicators recommended for the identification and documentation of pediatric malnutrition (undernutrition). *Nutr Clin Pract*. 2015;30(1):147-161.<sup>6</sup>

<sup>a</sup>Guo S, Roche AF, Foman SJ, et al. Reference data on gains in weight and length during the first two years of life. *Pediatrics*. 1991;119(3):355-362.

<sup>b</sup>World Health Organization. Data for patients <2 years old. [http://www.who.int/childgrowth/standards/w\\_velocity/en/index.html](http://www.who.int/childgrowth/standards/w_velocity/en/index.html).

the most severe indicator is used. The goal is to identify pediatric malnutrition in a timely manner and to prioritize the most severe indicator.<sup>8</sup> Additional information about using the indicators can be found in the consensus statement paper.<sup>6</sup>

The authors of the consensus statement recognized that these indicators are a starting point to standardize the diagnosis and documentation of pediatric malnutrition. They encourage nutrition providers to use the indicators, and they wisely urge clinicians to place numeric values in searchable fields in the electronic medical record, if available, so that further analysis and feasibility testing can take place on a broad scale. Indeed, the authors expect that the indicators recommended in the consensus statement will be reviewed and revised as validation results and evidence of efficacy become available. Since the indicators are a work in progress, it is likely that changes will occur as clinicians put the new definition and the recommended indicators into practice.<sup>6</sup>

This report details the experience of using the new definition over the past several years. The purpose of this review is (1) to explore the new definition's paradigm shifts and (2) to describe some of the practical implications of putting each consensus statement indicator into clinical practice. The hope is that these considerations will encourage dialogue as we continue to move toward the uniform diagnosis and documentation of pediatric malnutrition. Note that for the remainder of this review, the phrase "new definitions paper" refers to the article by Mehta et al<sup>1</sup> and "consensus statement" to the article by Becker et al.<sup>6</sup>

## Paradigm Shifts

### *Etiology-Related Definitions*

The title of the new definitions paper gives an early clue that the new pediatric malnutrition definitions are about paradigm shifts. The primary paradigm shift described in the new definitions paper is the "etiology-related" paradigm shift. For better or for worse, when most of us think of pediatric malnutrition, we picture a child who is wasted, mostly skin and bones, and we would be right: that is the face of starvation-related malnutrition.

Nonillness-related malnutrition is starvation due to environmental or behavioral factors that result in a reduced nutrient intake that may be associated with adverse clinical and developmental outcomes.<sup>1</sup> The mechanism of nonillness-related malnutrition is nutrient imbalance due to decreased dietary intake.

The advent of new definitions of pediatric malnutrition brings the concept of illness-related malnutrition. Illness-related malnutrition is associated with an acute incident (ie, trauma, burns, infection) or a chronic medical condition (eg, cancer, cystic fibrosis, inflammatory bowel disease, chronic renal disease, congenital heart disease). Whereas nonillness-related malnutrition has only 1 mechanism—decreased dietary intake (ie, starvation)—illness-related malnutrition has several possible mechanisms: decreased dietary intake, increased nutrient requirements, increased nutrient losses, and altered utilization of nutrients. Children with illness-related malnutrition may show signs of fat and muscle wasting, but depending on the etiology, a child with illness-related malnutrition can also appear proportionate. For example, sometimes both height and weight are affected by malabsorption, resulting in chronic malnutrition (ie, failure to grow and failure to gain weight).<sup>9</sup> These children appear proportional, but they often show signs of developmental delay. Additionally, children who have a high body mass index (BMI) can be diagnosed with undernutrition if they experience an acute injury resulting in hypermetabolism. Increased nutrient requirements compounded by decreased nutrient intake in the setting of an acute injury can result in a dramatic weight loss, particularly muscle loss.<sup>10,11</sup>

The new definition specifies malnutrition by duration (acute, <3 months; chronic, >3 months) and severity (mild, moderate, severe) resulting in 6 possible permutations: acute mild, acute moderate, acute severe, chronic mild, chronic moderate, and chronic severe.<sup>1</sup> In addition, an etiology-related definition could include a child with a chronic disease who is chronically undernourished and working on growth recovery but is admitted to the hospital with acute malnutrition in the setting of an infection, surgery, or a disease "flare-up."

Inflammation is considered in the new definition because it can contribute to the etiology and mechanism of malnutrition.

Inflammation can affect appetite and alter nutrient utilization, the overall effect of which depends on whether the inflammation is acute (classical inflammation) or low grade and chronic (metaflammation).<sup>12-14</sup> Albumin and prealbumin are no longer considered meaningful biomarkers for diagnosing malnutrition. Changes in negative acute-phase proteins such as albumin, prealbumin, and transferrin do not reflect changes in nutrition status and are affected by inflammation, fluid status, and other factors. Consequently, they lack the sensitivity and specificity required to be reliable biomarkers of malnutrition.<sup>7,15</sup>

Finally, a type of malnutrition that is unique to pediatrics is “retarded development following protein-calorie malnutrition” (code E45 of the *International Classification of Diseases, Tenth Revision*). This diagnosis is reserved for children who are chronically stunted as a result of undernutrition. Stunting, per the World Health Organization (WHO) definition, is a height-for-age or length-for-age  $z$  score  $\leq -2$ .<sup>16,17</sup> Children who are stunted following protein calorie malnutrition are often at risk of becoming overweight or obese.<sup>18-20</sup>

In summary, an etiology-related paradigm shift means that there are numerous types of pediatric malnutrition. The emphasis is placed on the mechanisms and dynamic interactions that occur with malnutrition, and less attention is given to merely describing the effects of malnutrition (ie, kwashiorkor, marasmus). Simply put, the new definitions paper wants us to ask “Why?”

### Z Scores and “Burden of Proof”

Using  $z$  scores to determine mild ( $z$  score,  $-1$  to  $-1.99$ ), moderate ( $-2$  to  $-2.99$ ), and severe ( $\leq -3$ ) malnutrition has opened up a new way of looking at pediatric malnutrition. A  $z$  score is the number of standard deviations (SD) above or below the mean in a normal distribution of values from a study population (see Figure 2). The study population provides a *growth standard* when the distribution is from a longitudinal sample of well-nourished individuals living in a health-promoting environment. Growth standards, such as those from the WHO’s 2006 Multicentre Growth Reference Study (MGRS), describe optimal growth.<sup>21</sup> By contrast, a study population provides a *growth reference* when the distribution is from a large cross-sectional sample. The 2000 growth charts of the National Center for Health Statistics, Centers for Disease Control and Prevention, are a growth reference taken from a number of national U.S. surveys and can be used in clinical and research settings to compare and evaluate the growth of children.<sup>22</sup> In summary, growth standards describe how children “should” grow, and growth references describe how children “do” grow. The new definitions paper advises the uniform use of (1) the MGRS growth standard for infants and toddlers  $<2$  years of age and (2) the Centers for Disease Control and Prevention’s growth charts as a growth reference for children  $>2$  years of age. In malnourished children with a history of prematurity, it is best to correct for gestational age through 3 years of age.<sup>1</sup> This helps smooth the transition at age 2, when

the child is moving from one growth chart to the next and from supine lengths to standing heights. Online tools, such as [www.peditools.org](http://www.peditools.org), can be a useful resource for  $z$  scores if they are not available in the electronic health record.

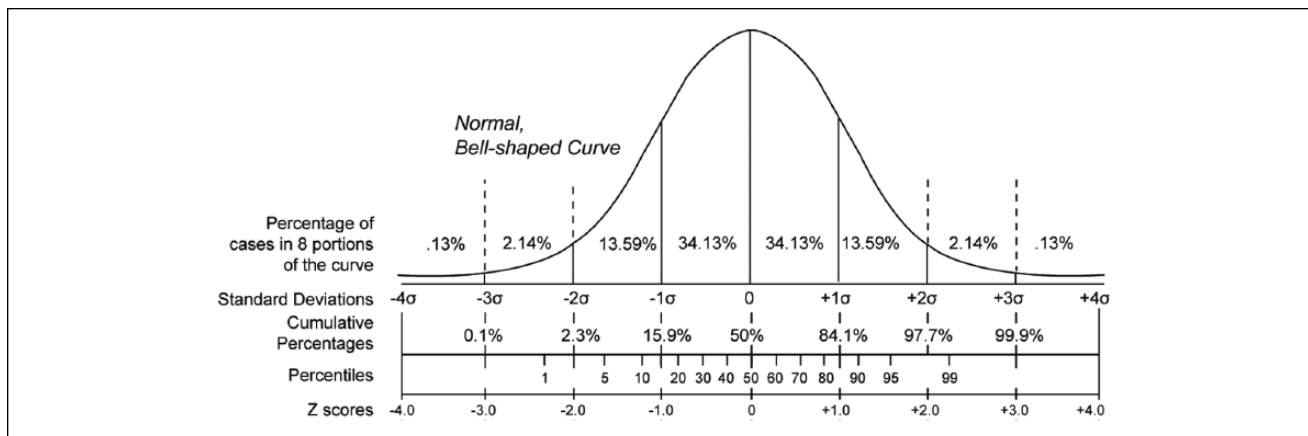
While  $z$  scores need not replace traditional growth charts that use percentiles, they offer several advantages over percentiles when diagnosing pediatric malnutrition<sup>1,23</sup>:  $z$  scores allow for comparisons across ages and sex;  $z$  scores are good for assessing longitudinal changes; and, perhaps most significant,  $z$  scores help identify children with extreme values. Instead of saying that a child is  $<3$ rd percentile (or  $\lll 3$ rd percentile when clinicians really wanted to get the point across!),  $z$  scores always give a value (eg,  $-4.25$ ) since, statistically, a bell-shaped curve has an infinite tail at each end of the curve. This means that improvement can be measured and growth trajectories followed even for children who are growing “below the curve.” Following  $z$  scores for children with extreme values is like being able to see under the surface.

Thinking in term of  $z$  scores also helps our understanding of how the growth of well-nourished children is distributed. In a study population like the MGRS, the majority of well-nourished children (ie, 95%) will fall between  $-2$  and  $+2$  SD from the norm. This means that only a small fraction of well-nourished children ( $\sim 2\%$ ) have  $z$  scores  $-2$  and  $-2.99$  and next to no healthy children ever have a  $z$  score  $< -3$  (only 0.13%<sup>24</sup>; see Figure 2). Understanding this concept leads quite naturally to another paradigm shift: the “burden of proof.” That is, when a child presents with a  $z$  score  $\leq -2$ , the burden of proof is on the clinician to prove that the child is not malnourished, rather than the other way around. It is statistically possible, though not likely, that the clinician is seeing a healthy child who happens to fall at the extreme low end of the normal growth distribution. However, most previously healthy children who, in the setting of a medical illness, are  $>2$  SD below the norm and nearly every child who is  $>3$  SD below the norm have a high probability of being malnourished or having growth retardation following malnutrition. Therefore, the burden of proof is to show that they are not malnourished, because they probably are.

### Illness-Related Malnutrition Cannot Always Be Immediately “Fixed”

This paradigm is perhaps the most difficult to digest. No one wants to see a child starve. In nonillness-related malnutrition, the intervention is straight forward: feed, feed, feed. Over time, depending on the severity, catch-up growth is expected with the provision of food.<sup>24</sup>

However, with illness-related malnutrition, children are malnourished in the setting of a medical illness. Sometimes malnutrition cannot be avoided while one is trying to provide the best medical or surgical therapy. To “fix” the malnutrition, the medical condition may need to be “fixed” first. It is tempting to think that if malnutrition cannot be fixed under the current medical situation, then the child is not really malnourished. Nothing could be further from the truth. If a child meets the



**Figure 2.** Breakdown of z scores and corresponding percentiles in a normal study distribution.

uniform criteria for illness-related malnutrition, she or he needs to be diagnosed with malnutrition so that it can be addressed. In situations where a chronic medical condition must be monitored rather than fixed, it is reasonable to assume that optimizing nutrition so that the child is less malnourished (ie, mild instead of severe) would result in more favorable outcomes. For example, a child with cardiac or renal disease may be on a fluid restriction that limits the amount of nutrition support that one can receive. If the medical condition lasts for some time, the child could eventually meet the criteria for mild pediatric malnutrition. The nutrition goal would be to keep the child from developing moderate or severe malnutrition. Once the disease or condition is treated, nutrition goals can be modified to achieve accelerated growth to reach a point where the child is no longer malnourished and is growing along his or her growth trajectory again. Another example is a child with increased energy expenditure due to thermal injury who transferred from another facility with acute severe malnutrition. With care to prevent refeeding syndrome, the nutrition goal is to improve the patient's malnutrition to moderate and then mild during the recovery process. In these situations, the restraints of the child's medical condition means that even the best nutrition therapy may be less than what is needed to maintain normal growth until the medical condition is resolved or controlled.

Malnutrition must be identified before it can be addressed. A uniform set of indicators allows for children to be diagnosed with pediatric malnutrition, to receive the interventions that they need to optimize nutrition in the setting of their current medical therapy, and to continue to achieve growth once the medical condition has resolved or is under control. Research is urgently needed to determine if children with less severe malnutrition have better outcomes than children with severe malnutrition indicators and if modifying their malnutrition status (ie, preventing severe malnutrition or improving from severe to moderate to mild) results in better outcomes. Tracking the pediatric malnutrition indicators on a broad scale will help yield these results.

### *Etiology-Related Interventions*

Illness-related malnutrition can often be addressed by confronting modifiable barriers to receiving adequate intake, such as avoiding unnecessary disconnection from enteral feeds, using volume-based enteral feeding regimens, cycling parenteral nutrition to allow for medication administration, using oral nutrition supplements to take oral medications, adding modular nutrition supplements to increase energy or protein intake, using incentive charts to target nutrition goals, and changing the eating environment to be more "kid friendly." Sometimes, however, calorie and protein intake may already exceed dietary estimates, and providing more will not result in growth. For example, in the setting of malabsorption, changing to a hydrolyzed or free amino acid formula is the preferred intervention, not increasing calories. In fact, fewer calories may be needed to promote growth once the formula is changed to one that is more readily absorbed.

Children who are stunted as a result of protein-calorie malnutrition are at risk of becoming overweight or obese.<sup>20,25</sup> Indeed, the provision of excessive calories to a stunted child can lead to growing "out" rather than "up." This situation is becoming increasingly common in the developing world.<sup>20,26</sup> Well-defined nutrition interventions that target longitudinal growth are being explored. Some studies suggest that optimizing protein and zinc intake may help with stunting due to malnutrition either directly or indirectly by improving immune function and decreasing infections.<sup>20,27-30</sup> According to a recent meta-analysis, zinc supplementation has been associated with improvements in growth in developing countries.<sup>31</sup> Further study is needed to fill the demand for effective interventions to prevent and treat stunting that results from chronic malnutrition. By contrast, nonnutrition causes of stunting require endocrine or other medical therapy.

### *Diagnosing Malnutrition in Children Admitted With "Failure to Thrive"*

Growth failure is a unique feature of malnutrition in children, compared with adults. Any child admitted with "failure to thrive"

(FTT) should be evaluated with the pediatric malnutrition indicators. Under the new etiology-related definition of pediatric malnutrition, faltering growth and growth failure are often the first signs of malnutrition—illness and nonillness related. Interdisciplinary teamwork is necessary when evaluating a child with FTT to determine the etiology (or etiologies) of the growth failure. FTT includes failure to grow, failure to gain weight, and failure to grow and gain weight.<sup>9</sup> A small number of the FTT patients may have short stature due to teratologic conditions, genetic syndromes, or endocrine conditions.<sup>32</sup> Nevertheless, a nutrition assessment is critical to rule out pediatric malnutrition in any infant or children that is failing to thrive. Previously published differential diagnoses for FTT can be helpful when diagnosing pediatric malnutrition with the indicators.<sup>32</sup>

If a child with FTT meets the criteria for pediatric malnutrition, it is important to use the appropriate malnutrition code with coding for FTT. Unlike FTT codes, malnutrition codes are designated as (1) major complication and comorbidity or (2) complication and comorbidity. Codes with either designation affect reimbursement.<sup>33</sup> Consequently, malnutrition codes may affect reimbursement, whereas FTT codes may not. Diagnosing the severity of pediatric malnutrition with uniform cutoffs in children with FTT will allow for the appropriate allocation of resources, resulting in the correct level of reimbursement.<sup>1,2</sup> By using the malnutrition-specific codes in malnourished children with FTT, providers and researchers will be able to determine which interventions result in improvement in the severity of malnutrition. As outcomes research results become available, cutoffs for defining the degree of malnutrition will become even more clear.<sup>1,2</sup>

### Using the Indicators in Clinical Practice

During the 17-month gap between the publication of the new definitions paper (July 2013) and the consensus statement (December 2014), various institutions were utilizing their own evidence-informed, consensus-derived process to come up with indicators for pediatric malnutrition based on the new definition. Not surprising, many of the indicators are the same as the consensus statement indicators because they all were based on the suggestions made in the new definitions paper. Since the pediatric malnutrition indicators are a work in progress, it is important to consider all reasonable indicators that are being used and determine which ones are the most sensitive and the most specific for diagnosing pediatric malnutrition. Using the indicators and addressing their benefits and limitations will help us move toward valid, uniform criteria.

#### *MTool: Michigan's Pediatric Malnutrition Diagnostic Tool*

Our own institution, the University of Michigan Health System, designed MTool: Michigan's pediatric malnutrition diagnostic tool.<sup>34</sup> MTool was created to incorporate the standardized language from the Nutrition Care Process of the Academy of Nutrition and Dietetics into the etiology-related

<p><b>MALNUTRITION</b> (acute, chronic) (mild, moderate, severe) <b>related to</b> (↓ nutrient intake, ↑ energy expenditure, ↑ nutrient losses, altered nutrient utilization) <b>in the setting of</b> (medical illness and/or socioeconomic, behavioral, environmental factors) <b>as evidenced by</b> (z scores, growth velocity, weight loss, ↓ dietary intake, nutrition focused physical findings)</p>
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**Figure 3.** Sample format for the nutrition diagnosis PES (problem, etiology, signs/symptoms) statement for pediatric malnutrition. Adapted with permission from MTool. On the basis of clinical findings, nutrition providers choose the appropriate responses suggested in the parentheses, making sure to include specific phrases and data points where appropriate. Example: *Malnutrition (chronic, severe) related to decreased nutrient intake in the setting of cleft palate and history of caregiver neglect as evidenced by weight-for-length z score of -3.2, consuming <75% of estimated needs, severe fat wasting (orbital, triceps, ribs), and severe muscle wasting (temporalis, pectoralis, deltoid, trapezius); also decreased functional status, as this 9-month-old infant cannot sit up without support.*

definitions of pediatric malnutrition. MTool provides a method for diagnosing pediatric malnutrition, as well as a framework. Indeed, to our knowledge, the wording for the PES (problem, etiology, signs/symptoms) statement for the malnutrition nutrition diagnosis was first described in the MTool (see Figure 3).

Table 3 outlines the similarities and differences between MTool and the consensus statement. Both use the z scores for BMI, weight for length, mid-upper arm circumference, and height/length. However, in keeping with the WHO definition of moderate stunting, MTool includes a height/length-for-age z score of -2 to -2.99 as an indicator for moderate malnutrition.<sup>35</sup> MTool and the consensus statement differ in their definition and cutoffs for growth, weight loss, and drop in z score. Variations are not surprising given that the indicators for growth and weight loss are among the least evidence informed. Validation studies are urgently needed for these indicators in particular. Until further evidence is available, MTool uses a general approach that takes into account duration of poor growth or weight loss and the child's prediagnosis weight. The rationale for this is that no child should lose weight unintentionally over a short period and that suboptimal growth over a longer period is a risk factor for undernutrition. The specific nonevidence-based guidelines used in MTool were based on guidelines for the initiation of pediatric enteral nutrition.<sup>36</sup> These guidelines were adopted by others, including the European Society for Pediatric Gastroenterology, Hepatology and Nutrition.<sup>37,38</sup> Second, MTool uses a drop in weight-for-age z score (WAZ) rather than a drop in BMI/weight-for-length z score (referred to as WHz) because WAZ is used in the reference literature.<sup>39-41</sup> WAZ also eliminates height/length as

**Table 3.** Moving Toward Uniformity: Comparing MTool and the Consensus Statement Pediatric Malnutrition Indicators.<sup>a</sup>

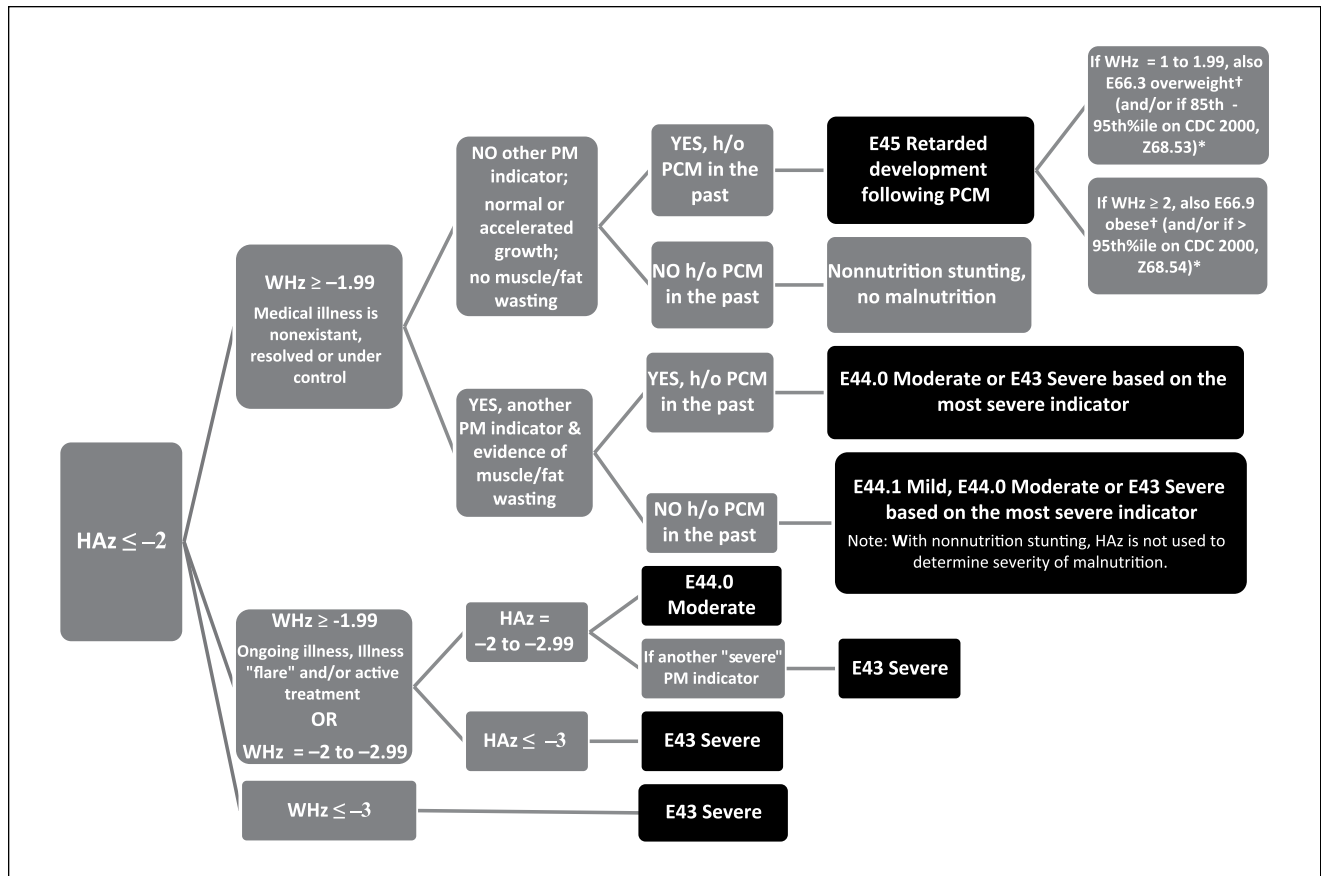
Comparison	MTool Pocket Guide	Consensus Statement Indicators	Comments
No. of data points	Does not distinguish—all data points must be interpreted within the clinical context	Distinguishes between indicators that need 1 data point and 2	Both encourage the use of as many data points as available
z scores	Check all parameters; use most severe BMI/weight for length MUAC Height <−2— <i>moderate and severe</i>	Needs only 1 data point (all other indicators need 2): BMI/weight for length MUAC Height <−3— <i>severe only</i>	MT includes height/length-for-age z score <−2 per the WHO definition MT may capture PCM due to malabsorption and retarded development following PCM MT helps link <i>ICD-10</i> codes to nutrition diagnoses
Growth velocity	<2 y: suboptimal growth ≥1 mo >2 y: suboptimal growth ≥3 mo Mild, unless initial WAZ was −1, then moderate; or −2, then severe	<2 y: <75% of the norm for expected weight gain (mild) <50% of the norm (moderate) <25% of the norm (severe) >2 y: N/A	Both use WHO 2006 growth velocity standards MT uses growth velocity and weight loss for all ages CS separates the 2 by age CS uses “% norm,” but sometimes 25% of the norm is within 1 SD of the norm CS does not specify duration or initial WAZ
Weight loss	<2 y: weight loss ≥2 wk >2 y: weight loss ≥6 wk Mild, unless initial WAZ was −1, then moderate; or −2, then severe	<2 y: N/A >2 y: 5% usual body weight (mild) 7.5% usual body weight (moderate) 10% usual body weight (severe)	MT gives general guidelines and takes into account growth curve trends, z scores, duration, and initial WAZ Neither MT nor CS is strongly evidence informed for growth velocity or weight loss indicators at this point
Drop in z score	Use WAZ: >1-SD drop = moderate >2-SD drop = severe	Use WHz: >1-SD drop = mild >2-SD drop = moderate >3-SD drop = severe	Drop in WAZ is used in the literature, provides an indicator that is not based on stature, and is sensitive to catching acute PCM in stunted children Drop in WHz runs the risk of overdiagnosing PCM in tall children and underdiagnosing PCM in stunted children
Inadequate nutrient intake	<60% of usual intake 45%–59% of usual intake 30%–44% of usual intake <30% of usual intake Note: in cases of malabsorption, intake may be >100% of estimated needs	51%–75% estimated energy/protein needs (mild) 26%–50% estimated energy/protein needs (moderate) <25% estimated energy/protein needs (severe)	Suggested cutoffs are very similar MT sees dietary intake as a mechanism contributing to the etiology, not as a stand-alone indicator CS has a strong emphasis on estimated energy equations CS does not address malabsorption as an etiology
Types of malnutrition	6 combinations using acute/chronic along with mild, moderate, and severe as well as acute superimposed on chronic	Equates acute with mild malnutrition and chronic with severe malnutrition	MT allows for more types of malnutrition with differing etiologies and individualized interventions
Nutrition-focused physical examination	Included	Not included	Nutrition-focused physical examination can be especially helpful in diagnosing malnutrition in children who are mildly malnourished, are difficult to measure, are fluid overloaded, and have genetic disorders affecting growth
Nutrition diagnosis	Provides a process which focuses on the etiology and efficiently forms a PES statement	Does not include guidelines for forming a PES statement	MT and CS can be used by all clinicians MT helps write a nutrition diagnosis Can use CS indicators within the MT process, if desired

BMI, body mass index; CS, consensus statement; *ICD-10*, *International Classification of Diseases, Tenth Revision*; MT, MTool; MUAC, mid-upper arm circumference; N/A, not applicable; PCM, protein-calorie malnutrition; PES, problem, etiology, signs and symptoms; WAZ, weight-for-age z score; WHz, BMI/weight-for-length z score; WHO, World Health Organization.

<sup>a</sup>Adapted with permission from MTool (addendum 2).

a potential confounding factor, which is especially important in stunted children. Finally, in keeping with the new definitions paper, MTool considers inadequate dietary intake as a mechanism of etiology-related malnutrition.<sup>1</sup> Low anthropometric variables (low z scores, weight loss, poor growth, stunting) and

nutrition-focused physical findings (fat and muscle wasting) are evidence of an inadequate dietary intake (and/or, in illness-related malnutrition, increased nutrient loss, increased energy expenditure, and altered nutrient utilization). These points are addressed in detail in the following section.



**Figure 4.** Decision tree for diagnosing malnutrition in stunted children according to *International Classification of Diseases, Tenth Revision* codes. Adapted with permission from MTool (addendum 1). %ile, percentile; CDC, Centers for Disease Control and Prevention; HAZ, height/length-for-age z score; h/o, history of; PCM, protein-calorie malnutrition; PM, pediatric malnutrition; WHz, BMI/weight-for-length z score. †de Onis M, Onyango AW, Borghi E, et al. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ.* 2007;85:660-667.

\*Kuczmarski RJ, Ogden CL, Guo S, et al. 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat.* 2002;11:1-190.

The third addition of MTool offers a suggested method of diagnosing the pediatric-specific code for “retarded development following protein-calorie malnutrition” (E45: *International Classification of Diseases, Tenth Revision*). A decision tree for diagnosing malnutrition in stunted children is outlined in Figure 4. This decision tree is adapted from MTool (addendum 1). The proposed key features of “retarded development following protein-calorie malnutrition” are as follows: (1) a child must have a HAZ < -2 and a WHz ≥ -1.99, normal or accelerated growth, and no other pediatric malnutrition indicators; (2) the etiology of the stunting must be nutrition related (ie, the child must have a history of protein-calorie malnutrition); and (3) no active or ongoing medical illness is present, or in the case of illness-related pediatric malnutrition, the medical condition must be resolved or under control. If a child has other indications of pediatric malnutrition in the setting of nonnutrition-related stunting or if a child with nutrition-related stunting has a medical condition that is active, is ongoing, or “flares,” then the mild, moderate, or severe malnutrition code should be used (see Figure 4).

The following section examines the consensus statement indicators and describes the practical implications of using them in clinical practice. Advantages and disadvantages are presented. When limitations are uncovered, additional or alternative indicators are proposed.

### *BMI and Weight-for-Length z Score*

BMI and weight-for-length z score (ie, WHz) are 2 indicators that require only 1 data point to diagnosis pediatric malnutrition (see Table 1). WHz is a strong indicator of pediatric malnutrition because it can catch early signs of wasting. Waterlow promoted the idea of using weight for length to assess nutrition status since it is helpful in situations when age is unknown—a situation that is not unusual in poorly resourced countries.<sup>42,43</sup>

Using WHz may be helpful when evaluating children with neurologic impairment or genetic syndromes that impair growth; however, careful interpretation is necessary given the differences in body composition and the difficulty obtaining



accurate stature measurements in this population. Specialized growth charts are available allowing for comparison of children with similar medical conditions and levels of motor disability.<sup>44</sup> It is important to keep in mind that some specialized growth charts were produced from very small numbers of children and may include children who were malnourished. Monitoring trends in growth and body composition for a child with a neurologic impairment can help detect early signs of pediatric malnutrition.<sup>45</sup> Dietary intake and a nutrition-focused physical assessment that includes a careful examination of hair, eyes, mouth, skin, and nails to look for signs of micronutrient deficiencies are key components in determining pediatric malnutrition in this population.

A number of practical considerations need to be taken into account when using WHz in clinical practice. First, like all the indicators, WHz relies heavily on accurate measurements. Indeed, the consensus statement states that all measurements must be accurate, and it encourages clinicians to recheck measurements that appear inaccurate (eg, when a child's height or length is shorter than the last measurement). Inaccurate heights or lengths can drastically change the child's WHz measurement, since WHz is a mathematic equation. For this reason, it is important to look at trends in the WHz and disregard measurements that appear inaccurate. Good technique requires 2 people to measure infants on a length board.<sup>46,47</sup> Children  $\geq 2$  years should be measured with a stadiometer while they are standing.<sup>48</sup> Figure 5 provides a sample list of desired qualifications for anyone assigned to measure anthropometrics in infants and children.

Second, even when measurements are accurate, it is important to take into account the height or length of the child being assessed. Again, because WHz is a mathematic equation, it has a tendency to overdiagnose malnutrition in tall children and underdiagnose it in short children. The WHz indicator may miss children who are stunted as a result chronic malnutrition because a decrease in linear growth velocity in the absence of severe weight loss causes the WHz to increase. At first glance, it would be tempting to see this as an improvement in nutrition status when in fact it is an indication that chronic malnutrition has started to affect height/length. Monitoring linear growth velocity and reviewing all the indicators will help decrease the risk of missing the pediatric malnutrition diagnosis in these children.

Last, WHz does not reliably reflect body composition. A child with a high BMI may actually be muscular and not obese. Likewise, a child who has a normal or low BMI may actually have a low muscle mass and high percentage of body fat.<sup>49</sup> Obtaining a thorough nutrition and physical activity history with a nutrition-focused physical examination may help tease out these differences.<sup>50,51</sup> Grip strength may also prove to be a valuable indicator of pediatric malnutrition, especially in overweight or obese children, because it measures muscle function—a valuable outcome measure—and can serve as a proxy for muscle mass.<sup>52-55</sup> In addition, grip strength that is normalized for body weight (ie, absolute grip strength/body mass) has been correlated with cardiometabolic risk in adolescents.<sup>56</sup>

#### Attitude

- Take pride in their work
- Recognize the importance of anthropometrics for assessing nutritional status and growth
- Aware of the importance of good nutrition for a child's growth and development especially when the child is also receiving medical treatment for a chronic illness
- Always willing to recheck measurements because they want them to be as accurate as possible

#### Accuracy

- Proper technique (i.e. supine length board until 2 years, then standing height using a stadiometer)
- Correct equipment (i.e. do not use measuring tapes)
- Weigh patients with minimal clothing (removing shoes and heavy outerwear)
- Zero the scale if an infant is wearing a diaper
- Use scales that are accurate to at least 100 grams

#### Ability

- Notice discrepancies and repeat measurements without being asked
- Is able to soothe an uncooperative child in order to get the best measurement possible

**Figure 5.** Essential job qualifications for a medical assistant or any clinician performing anthropometric measurements in children.

An exciting development is the recent publication of growth reference charts for grip strength and normalized grip strength based on National Health and Nutrition Examination Survey (NHANES) data from 2011–2012 (ages, 6–80 years).<sup>57</sup> Growth charts and curves were created with output from quantile regression from reference values of absolute and normalized grip strength corresponding to the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles across all ages for males and females. These charts include data from 7119 adults and children. They can be used to supplement, perhaps even improve upon, the hand dynamometer manufacturer's reference data. For example, reference data for the Jamar Plus+ digital dynamometer (Patterson Medical/Sammons Preston, Warrenville, IL) are identical to data gathered from several studies by Mathiowetz and colleagues published in the 1980s that include 1109 adults and children.<sup>58,59</sup>

Grip strength is highly correlated with total muscle strength in children and adolescents and has excellent criterion validity and intrarater and interrater reliability.<sup>60-62</sup> Measuring grip strength with a hand dynamometer is well received by individuals and takes <5 minutes to perform.<sup>52,63,64</sup> Yet, there is surprisingly little information about using hand grip strength as a measure of nutrition status in hospitalized children, especially in the United States. One study in Portugal found that low grip strength is a potential indicator of undernutrition in children.<sup>65</sup> However, this study was limited by the lack of age-specific and sex-specific reference data. Feasibility studies that use grip strength to assess nutrition status in children at risk of malnutrition are urgently needed. Large multicenter trials using the NHANES percentiles could help delineate absolute grip strength cutoffs for severe versus nonsevere pediatric malnutrition and as well as normalized grip strength cutoffs for cardiometabolic risk.<sup>66</sup>

**Table 4.** Comparison of MUAC Growth Standard and Growth Reference Choices.

Age: Standard/Reference	Source	Years When Data Were Collected	Percentiles or <i>z</i> Scores
6–60 mo: WHO (2007) <sup>a</sup>	MGRS	1997–2003	<i>z</i> scores
61 mo–19 y			
CDC (2012)	NHANES	2007–2010	percentiles
Frisancho book (2008), <sup>b</sup> 2nd ed, with CD	NHANES	1994–1998	<i>z</i> scores
Frisancho <i>AJCN</i> paper (1981) <sup>c</sup>	NHANES	1971–1974	percentiles

*AJCN*, *American Journal of Clinical Nutrition*; CDC, Centers for Disease Control and Prevention; MGRS, Multicentre Growth Reference Study; MUAC, mid-upper arm circumference; NHANES, National Health and Nutrition Examination Survey; WHO, World Health Organization.

<sup>a</sup>Growth standard; all the others are growth references.

<sup>b</sup>Frisancho AR. *Anthropometric Standards: An Interactive Nutritional Reference of Body Size and Body Composition for Children and Adults*. Ann Arbor, MI: University of Michigan Press; 2008.

<sup>c</sup>Frisancho AR. New norms of upper limb fat and muscle areas for assessment of nutritional status. *Am J Clin Nutr*. 1981;34(11):2540-2545.

### MUAC *z* Score

MUAC is a valuable indicator to determine the risk of malnutrition in children. WHO uses MUAC to diagnosis malnutrition in children around the world.<sup>24</sup> MUAC is correlated with changes in BMI and may reflect body composition.<sup>1,6,67</sup> MUAC is a useful indicator in children with ascites or edema whose upper extremities are not affected by the fluid retention.<sup>1,6</sup> Good technique is required and is described on the website of the Centers for Disease Control and Prevention.<sup>68</sup> A flexible but stretch-resistant tape measure with millimeter markings is needed to measure MUAC to the nearest 0.1 cm. Paper tapes have the added benefits of being disposable, which is useful for measuring children who are in isolation due to contact precautions. The UNICEF tapes have a place in nutrition programs in the developing world but may not transfer well to hospital and clinic settings in the United States. At a trial in our institution, we found the UNICEF tapes cumbersome to carry, difficult to clean, and not feasible for accurately determining the mid upper arm midpoint. The red/yellow/green indicators were misleading because they rely on absolute values instead of the consensus statement's recommended age-specific and sex-specific *z* score cutoffs.

A limitation of the MUAC *z* score is that the consensus statement recommends that it can be used only for infants and children aged 6 months to 6 years since MGRS growth standard *z* scores are available only for those aged 3–60 months. Measuring MUAC in infants <6 months and children ≥6 years is still recommended, as it is useful for monitoring growth changes over time. The challenge is deciding which reference data to use. Table 4 provides details for the various options available at this time.

### Length/Height-for-Age *z* Score

Stunting is defined worldwide as a length/height-for-age *z* score (HAZ) ≤−2.<sup>16</sup> A HAZ ≤−3 is an indicator for severe pediatric malnutrition. The WHO Global Database on Child Growth and Malnutrition uses a HAZ cutoff of −2 to −2.99 to classify low height for age as moderate undernutrition,<sup>69</sup> whereas the consensus statement does not include a HAZ of −2 to −2.99 as an indicator for moderate malnutrition. It seems prudent to diagnosis moderate malnutrition when the HAZ drops to a *z* score of

−2, for a number of reasons: (1) Stunting is a result of chronic malnutrition, so identifying stunting as early as possible allows for timely intervention. This rationale is consistent with that of using 1 data point: to catch malnutrition and intervene as quickly as possible. (2) The other indicators that require only 1 data point (WHz and MUAC *z* score) run the risk of missing the severity of malnutrition in stunted children because a decrease in linear growth velocity in the absence of severe weight loss causes the WHz to increase. MUAC is modestly associated with both fat mass and fat-free mass independent of length in healthy infants<sup>67</sup> but may not catch the malnutrition diagnosis in stunted children who are regaining weight. Naturally, nonnutrition causes of stunting (eg, normal variation, genetic defects, growth hormone deficiency) should be ruled out; however, missing the malnutrition diagnosis in chronically malnourished children must be avoided. This is especially crucial in the first 2 years of life because linear growth in the first 2 years is positively associated with cognitive and motor development<sup>70</sup> and because chronic undernutrition, as well as acute severe malnutrition and micronutrient deficiencies, clearly impairs brain development.<sup>71</sup> Further discussion and data from validation studies will help evaluate the HAZ cutoff.

### Percent Weight Gain Velocity

The consensus statement defines a decrease in growth velocity for infants and toddlers (1 month to 2 years of age) as a “% of the norm” based on the MGRS tables (see Table 2). Two data points are required to calculate the difference in weight over time. MGRS tables are available for both sexes and provide *z* scores for a number of time increments (1, 2, 3, 4, and 6 months) from birth to 24 months old. The idea is to calculate the difference in weight between 2 time points and compare this number (in grams) to the median by taking a percentage. For example, if a 23-month-old girl gains 85 g between 21 and 23 months old, she would have gained only 22% of the median weight gain for girls her age: 85 g / 381 g = 22.3%. Since the cutoff for severe malnutrition is <25% of the norm for expected weight gain, this child may be severely malnourished depending on the overall clinical picture—that is, accurate measurements with no fluid losses over the past month (see Figure 6).

## Simplified field tables

2-month weight increments (g) GIRLS Birth to 24 months (z-scores)							
Interval	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
0-2 mo	742	1085	1469	1897	2368	2884	3445
1-3 mo	695	991	1330	1714	2146	2630	3167
2-4 mo	465	709	989	1307	1667	2071	2522
3-5 mo	304	528	783	1074	1400	1766	2172
4-6 mo	156	367	609	883	1189	1528	1901
5-7 mo	34	241	477	742	1037	1361	1714
6-8 mo	-61	148	386	651	944	1263	1607
7-9 mo	-136	75	315	581	872	1186	1522
8-10 mo	-199	13	253	517	803	1110	1437
9-11 mo	-246	-30	212	478	765	1070	1393
10-12 mo	-280	-60	188	458	748	1055	1378
11-13 mo	-311	-86	167	441	734	1043	1367
12-14 mo	-336	-107	150	428	724	1037	1363
13-15 mo	-358	-125	137	420	721	1038	1368
14-16 mo	-375	-138	128	416	723	1046	1383
15-17 mo	-389	-149	123	418	731	1062	1406
16-18 mo	-402	-159	117	417	738	1076	1428
17-19 mo	-414	-171	108	413	739	1083	1443
18-20 mo	-426	-183	99	407	738	1088	1455
19-21 mo	-438	-194	89	402	738	1093	1466
20-22 mo	-450	-207	78	393	733	1093	1471
21-23 mo	-462	-221	64	381	722	1085	1466
22-24 mo	-474	-234	50	367	710	1074	1457

**WHO Growth Velocity Standards**

**Figure 6.** Sample growth velocity table for girls, 0–24 months, in 2-month increments. Available online from [http://www.who.int/childgrowth/standards/w\\_velocity/en/](http://www.who.int/childgrowth/standards/w_velocity/en/). To determine severity of malnutrition for the “% of the norm for expected weight gain” indicator, take actual growth / median growth  $\times$  100 and compare with cutoffs in Table 2. Example: A 23-month-old girl gained 85 g in the past 2 months. Is she malnourished?  $85/381 \times 100 = 22.3\%$ . Since the cutoff for severe malnutrition is “<25% of the norm for expected weight gain,” this indicator equals severe malnutrition. Notice, however, that 34% of healthy 23-month-old girls fall between 64–381 g (–1 SD and median) during this period. Clinical judgment and evaluation of the other indicators will help make the final diagnosis.

It is unclear how these particular cutoffs were determined, and it remains to be seen if they will hold up in validation studies.

Future review of the indicators should consider using the weight gain velocity  $z$  scores rather than “% of the norm for expected weight gain,” for the following reasons: (1) The paper that provides the best evidence for making weight gain velocity one of the pediatric malnutrition indicators used a weight gain velocity  $z$  score  $\leq -3$  as a cutoff, not a percentage of the median.<sup>72</sup> (2) The new definition of pediatric malnutrition is moving away from “% of norm” methods and using  $z$  scores instead. (3) The MGRS provides easy-to-use weight gain velocity growth standards in  $z$  scores in their simplified field tables.<sup>73</sup> (4) Using  $z$  scores rather than a percentage of the median allows for normal

growth plasticity. For example, when “% of the norm” is used, sometimes 25% of the norm (indicating severe malnutrition) is actually within 1 SD of the norm (which would be in the normal range for 34% of healthy children), as seen in Figure 6. (5) Using “% of the norm” compromises the pediatric malnutrition indicators’ content validity. For example, an infant who is growing but at only 25% of the norm for expected weight gain is considered severely malnourished, whereas an infant who is losing enough weight to have a deceleration of 1 SD in WHZ is considered only mildly malnourished under the current consensus statement cutoffs.

When conducting their review, experts might also consider whether the growth velocity indicator might require 3 data

Sample growth data for a 4½-year-old boy under treatment for a serious illness						
Which weight?	Age	Weight	%ile	WAZ	Weight loss (% usual body weight)	Malnutrition diagnosis
<b>Current weight (while receiving treatment)</b>	4½ yrs	15 kg	11%	-1.22	—	—
What is this child's "usual" weight?						
<b>Recent weight?</b>	4 yrs, 5 mos	15.2 kg	16%	-1.01	1% wt loss/1 month	<b>None</b>
<b>Prediagnosis weight?</b>	4 yrs	16 kg	45%	-0.12	6% wt loss/6 months	<b>Mild</b>
<b>Growth trajectory weight?</b>	@ 4½ yrs	17 kg	45%	-0.12	12% wt loss from expected wt	<b>Severe</b>
<b>By comparison, per MTool criteria, a drop in WAZ of -1.10 from trajectory weight</b>						<b>Moderate</b>

**Figure 7.** Comparison of possible “% usual body weight” weight loss calculations at 4.5 years based on recent weight, prediagnosis weight, and growth trajectory weight. %ile, percentile; MTool, Michigan’s pediatric malnutrition diagnostic tool; WAZ, weight-for-age z score; wt, weight.

points, if children are being followed frequently enough, since normal variation can occur from month to month due to mild illness and other factors. For example, a 11-month-old boy may have lost 150 g from 10–11 months old (~2 SD below the median) because he had a mild viral infection that affected his appetite, but 1 month later, having healed, that same child gained 725 g (catch-up growth) by 12 months old. It is noteworthy that the MGRS tables do not indicate the median weight gains that individual infants and toddlers need to “stay on their curve”; rather, they include cross-sectional data from a cohort of healthy infants and toddlers of the same age who are all different sizes and weights. Once again, clinical judgement is crucial when using the pediatric malnutrition indicators; they should always be interpreted within the context of the larger clinical picture.

### Percentage Weight Loss

The consensus statement indicator for weight loss applies to children  $\geq 2$  years of age. Children are meant to grow. Weight loss should never happen in children at risk of malnutrition, and it is likely a sign of undernutrition. The etiology for weight loss should be carefully considered, along with the severity, timing, and duration of the weight loss. The consensus statement indicator for weight loss is measured in terms of “percent usual body weight” (see Table 2). The cutoffs appear to be a variation of Dr Blackburn’s criteria for adults,<sup>7,74</sup> but unlike Blackburn’s criteria, no duration is given. The thought is that since weight loss should be a “never event” in children at risk of malnutrition, any weight loss is unacceptable, irrespective of time.<sup>75</sup> While this is true, the real issue with this indicator is how to determine a child’s “usual body weight.” Unlike adults and mature adolescents whose height and weight have plateaued and typically remain within a “usual” range, children are still growing. In fact, their weight should not be stable or “usual.” A child with a stable weight is essentially a child who has “lost” weight. Figure 7 shows the weight history of a 4.5-year-old boy who was diagnosed with a serious illness at 4 years of age that resulted in weight fluctuations and faltering growth. It is difficult to determine which weight should be considered the “usual

weight” in this child when he is assessed during active treatment at 4.5 years old.

Even though children do not have a “usual weight,” they do have a usual “growth channel for weight” or “weight trajectory.” In a normal study distribution, this weight trajectory translates into a z score. The child in Figure 7 was following the 45th percentile growth channel. His weight trajectory was a z score of -0.12 from ages 2 to 4 years. It is reasonable to assume that his weight would have more or less followed this trajectory had he not become ill. Comparing the weight trajectory z score (in this case, -0.12) with any subsequent WAZ can help determine the severity of a child’s weight loss and monitor weight fluctuations by calculating the difference in the WAZ. Using a drop, decline, or deceleration in WAZ score may be a more sensitive indicator than using a deceleration in WHz (discussed in the next section).

The lack of a specified duration for the weight loss indicator allows for clinical judgment and does not imply that duration is unimportant. A large unintentional weight loss over a short period (weeks, months) can mean something entirely different than a gradual weight loss over months or years. Weight fluctuations are also important to monitor. A recent Children’s Oncology Group study found that, among pediatric patients with acute lymphoblastic leukemia, duration of time at the weight extremes affected event-free survival and treatment-related toxicity and may be an important, potentially addressable prognostic factor.<sup>76</sup> Having nutrition protocols or “tags” in the electronic medical record can be useful for determining the need for nutrition assessment and interventions at both weight extremes (unexpected weight loss and unexpected weight gain).

### Deceleration in WHz

The consensus statement uses a deceleration of 1 SD in WHz, which matches the equivalent of crossing at least 2 channels on the weight-for-length/BMI growth curve as an indicator for mild pediatric malnutrition. Drops of 2 and 3 SD in WHz are required for moderate and severe malnutrition (see Table 2). A child whose growth drops in an order of magnitude to match these cutoffs is very likely malnourished. However, this

indicator does not appear sensitive enough to detect malnutrition in children who are short or stunted following protein-calorie malnutrition, as previously discussed (see BMI and Weight-for-Length  $z$  Score section). The cutoffs used for deceleration of WHz may also threaten content validity. For example, notice that a child who is <2 years old and growing, though poorly (ie, <25% of the norm for expected weight gain), is considered severely malnourished. If the suboptimal growth continues, the child will be severely malnourished until the day of his or her second birthday, in which case, the child now has to lose 3 SD in WHz to be considered severely malnourished. These situations emphasize the importance of allowing for adjustments in the cutoff values as outcomes research becomes available. Meanwhile, it is important to evaluate *all* of the pediatric malnutrition indicators to diagnosis pediatric malnutrition.

As mentioned previously, using the indicators in clinical practice may reveal that a deceleration in WAz is a more sensitive indicator than a deceleration in WHz to detect pediatric malnutrition. Indeed, the new definitions paper discusses recent studies that use of a decrease in WAz, not WHz, to define growth failure and evaluate outcomes. A decrease of 0.67 in WAz was strongly associated with growth failure in extremely low birth weight infants<sup>41</sup> and increased late mortality in children with congenital heart defects.<sup>39</sup> Declines in both weight and height/length  $z$  scores successfully predicted growth and outcomes in children on ketogenic diets, suggesting that both these indicators could reveal valuable information when diagnosing pediatric malnutrition.<sup>40</sup>

Research that evaluates the growth of premature infants uses the concept of “delta  $z$  score” to capture a decline or deceleration in WAz.<sup>77,78</sup> For example, a delta  $z$  score of 0 (or within a small range of 0) could reflect normal growth along or near a growth trajectory; a positive delta  $z$  score would reflect accelerated growth; and a negative delta  $z$  score would reflect a deceleration in growth. If the prediagnosis weight trajectory  $z$  score is recorded in searchable fields in the electronic medical record, outcomes research can help determine thresholds for intervention. The advantage of using a delta  $z$  score is that a deceleration in  $z$  score could apply to both infants and children (1 month to 17 years). It is quite possible that the delta  $z$  score cutoffs will vary with age since growth varies with age. For example, the cutoff for mild malnutrition in infants and toddlers might be delta  $z$  score of  $-0.67$ , whereas in older children, it may be more or less. Depending on the results of outcomes research studies, this indicator could replace 2 indicators: growth velocity (“% of the norm for expected weight gain”) and weight loss (“% usual body weight”). Validation studies and clinical practice should evaluate the deceleration in all 3 anthropometric  $z$  scores (WAz, HAz, WHz) to determine the most sensitive and most specific indicators of pediatric malnutrition.

### Percentage Dietary Intake

Before the diagnosis of malnutrition is made, it is essential to assess dietary intake, which will help to determine if poor growth

is due to nutrient imbalance, an endocrine or neurologic disease, or both. Registered dietitians are uniquely trained to have the necessary skills to assess dietary intake. Energy expenditure is most precisely measured by indirect calorimetry, but when equipment is not available, predictive equations are used. The consensus statement provides a comprehensive overview of standard equations to estimate energy and protein needs in various pediatric populations.<sup>6</sup> Dietary intake can be compared with estimated needs through a percentage. This percentage is included as one of the pediatric indicators requiring 2 data points (see Table 2).

The use of this indicator to support the diagnosis of malnutrition is obvious. Indeed, decreased dietary intake is often the etiology of pediatric malnutrition, illness and nonillness related. It is unclear, however, whether a decreased dietary intake can stand alone as an indicator for pediatric malnutrition. Given that a child’s appetite will waiver from one day to the next and with one illness to another, it seems reasonable that the diagnosis of malnutrition should not be made unless poor dietary intake has resulted in fat and muscle wasting and/or anthropometric evidence—that is, weight loss, poor growth, or low  $z$  scores. Conversely, if a child has a WHz or MUAC  $z$  score between  $-1$  and  $-1.99$ , is eating 100% of one’s dietary needs, has no underlying medical illness, and shows no other signs of pediatric malnutrition, this child is likely thin and healthy. Indeed, in a normal study distribution, 13.59% of normally growing children fall in this category (see Figure 2). As with all children, the growth of a child who has a WHz  $<-1$  should be monitored. Sometimes it is appropriate to use one of the “at risk” nutrition diagnoses, such as “underweight” or “growth rate less than expected.”<sup>79</sup> It seems reasonable that to be diagnosed with mild malnutrition, a child with a WHz or MUAC  $z$  score of  $-1$  to  $-1.99$  should have at least 1 additional indicator, such as poor dietary intake, faltering growth, unintentional weight loss, muscle/fat wasting, and/or a medical illness frequently associated with malnutrition. The goal is to avoid diagnosing mild malnutrition in well-nourished thin children while catching true malnutrition early (ie, when it is mild) rather than letting it deteriorate into moderate or severe malnutrition.

### Missing Indicators

Unlike adult malnutrition characteristics, muscle/fat wasting and grip strength were not included in the pediatric indicators. Physical examination to determine muscle/fat wasting was thought to be “too subjective.”<sup>8</sup> However, physically touching a child’s muscle, bones, and fat provides empirical evidence that is arguably more “objective” than asking parents to remember what their child has eaten over the past several days, weeks, or months. In practice, dietary intake and nutrition-focused physical examination are invaluable when diagnosing pediatric malnutrition.<sup>6,50,80,81</sup> Measuring grip strength is feasible in children<sup>64,65,82</sup> and yields reliable information that could inform the malnutrition diagnosis. At the time of the publication of the consensus statement, there was a lack of training in nutrition-focused physical examination and very little reference data for grip strength in children, especially in

**Table 5.** Recommendations for Future Reviews of the Pediatric Malnutrition Indicators, Validation Studies, and Outcomes Research.

Recommendation	Rationale
1. Include HAZ of $-2$ to $-2.99$ as a pediatric indicator of moderate malnutrition.	Consistent with WHO definition of moderate malnutrition. Catch the effects of chronic malnutrition as soon as possible.
2. Make $z$ scores for MUAC more accessible for individuals who are $>5$ y old.	Allows for following $z$ scores throughout the life span.
3. Use WHO 2006 growth velocity $z$ scores for children $<2$ y old instead of “% of the norm for expected weight gain.”	Weight velocity $z$ scores are used in the literature. “% of the norm for expected weight gain” compromises content validity. “% of the norm” is difficult to evaluate in children with significant growth fluctuations; may need 3 data points.
4. Use a decline in WAZ along with WHO 2006 growth velocity $z$ scores and in place of the “% usual body weight” and “deceleration in WHz” indicators.	Growing children do not have a “usual” weight. Can use the same indicator before and after 2 y of age. Decline in WAZ, not WHz, is used in the pediatric malnutrition literature. Validation research can determine cutoffs, but literature suggests that a drop of 0.67 could possibly be used for mild, 1.34 for moderate, and 2 for severe. WAZ eliminates height as a confounding factor. Consistent with neonatal intensive care unit literature method for measuring growth.
5. Consider how to include duration of weight loss and weight fluctuations into the diagnosis of pediatric malnutrition.	Makes sense to address the effect of duration of weight loss on pediatric malnutrition. Duration of weight extremes may affect outcomes.
6. Encourage the use of NFPE to look for fat and muscle wasting as an indicator of pediatric malnutrition.	Used in Subjective Global Nutritional Assessment, a validated pediatric nutrition assessment tool. NFPE is a standard of practice in nutrition care, is one of the five domains of a nutrition assessment and is a standard of professional performance for RDs. Training is available, if needed. NFPE (fat and muscle wasting) is included in the adult malnutrition characteristics. Physical evidence may prove useful in supporting the early identification of mild malnutrition to allow for timely intervention.
7. Encourage research to validate the use of grip strength as a reliable indicator of pediatric malnutrition and determine cutoffs for intervention.	Measuring grip strength is feasible in children. Grip strength measurement has good interrater and intrarater reliability. Poor grip strength is included in the adult malnutrition characteristics. May prove useful in diagnosing undernutrition and cardiometabolic risk in overweight and obese children.

HAZ, height/length-for-age  $z$  score; MUAC, mid-upper arm circumference; NFPE, nutrition-focused physical examination; RDs, registered dietitians; WAZ, weight-for-age  $z$  score; WHO, World Health Organization; WHz, BMI/weight-for-length  $z$  score.

the United States. These gaps are being addressed. Training on nutrition-focused physical examination is now available through continuing education programs,<sup>83</sup> and as previously mentioned, grip strength reference tables based NHANES data are now available in percentiles.<sup>57</sup> Further review of the consensus statement pediatric malnutrition indicators will undoubtedly consider including these missing indicators.

## Conclusion

The work of the authors of the new definitions paper and the consensus statement is an exceptional example of using an evidence-informed, consensus-derived process. For their work to continue, the medical community must use the consensus statement indicators and provide feedback through an iterative process. Nutrition experts dialogue within their institutions, at conferences, and on email lists about their experience using the consensus statement pediatric malnutrition

indicators. They also discuss alternative definitions for the indicators that are based on the new definitions paper. Members surveys from ASPEN and the Academy of Nutrition and Dietetics provide a valuable mechanism for feedback. Going forward, perhaps an online centralized forum for discussion and questions would help inform the design of validation and outcomes research studies.

The authors of the consensus statement conclude their paper by providing this eloquent “call to action.”<sup>6</sup>

1. Use the pediatric indicators as a starting point, and provide feedback.
2. Document the diagnostic indicators in searchable fields in the electronic medical record
3. Use standardized formats and uniform data collection to help facilitate large feasibility and validation studies.
4. Come together on a broad scale to determine the most or least reliable indicators.

5. Review and revise the indicators through an iterative and evidence-based process.
6. Identify education and training needs.

This review responds to that call to action by attempting to offer thoughtful feedback as part of the iterative process and provide helpful insight to inform future validation studies. Table 5 presents a summary of recommendations to consider when using the indicators in clinical practice and when designing validation studies. Coming together as a health community to identify pediatric malnutrition will ensure that this vulnerable population is not overlooked. Outcomes research will validate the indicators and result in new discoveries of effective ways to prevent and treat malnutrition. Creating a national culture attuned to the value of nutrition in health and disease will result in meaningful improvement in nutrition care and appropriate resource utilization and allocation.<sup>3,15,33,84</sup>

### Statement of Authorship

S. Bouma designed and drafted the manuscript, critically revised the manuscript, agrees to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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