Towards standardised and valid anthropometric indicators of nutritional status in middle childhood and adolescence

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Summary

There is growing recognition of the significance of nutrition across middle childhood (5-9 years) and adolescence (10-19 years), particularly in the context of global food insecurity and rising overweight and obesity. Until now, policymakers have been slow to respond to rapidly changing patterns of malnutrition across these years. One barrier has been a lack of consistent and regular nutrition surveillance systems for this age group. There is ongoing debate around what should be measured, as well as how best to operationalise anthropometric indicators that have been the cornerstone of nutrition surveillance in younger children and adults. Even with consensus on the importance of a given anthropometric indicator, different terminologies, reference data and cut-offs present difficulties in interpreting trends over time and between countries. We highlight the need for revisiting anthropomtric indicators across middle childhood and adolescence, a process that will require WHO and UNICEF coordination, with the engagement of national implmentors and policymakers, and partnership with the research communities and donors.

Key Messages:

- Nutrition across middle childhood and adolescence (5-19 years) affects health, growth, and learning for current and future generations.
- Compared with other age groups there are few standardised monitoring systems to track nutritional status
- A lack of consensus on anthropometric indicators has limited efforts to track trends and constrains our ability to set global and national targets.
- Research needs range from the establishment of contemporary references and cut-offs, harmonisation of anthropometric indicators across age groups, to considering the place of anthropometry in a broader context of nutrition indicators for children and adolescents 5-19 years of age.
- WHO and UNICEF, in partnership with the implementing and research community, have a major role in revisiting definitions of anthropometric indicators for this age group.

Introduction

The United Nations estimates that there are approximately 1.8 billion children and adolescents in the world aged between five and 19 years (1). Although the risk of dying from malnutrition is smaller during middle childhood (5-9 years of age) and adolescence (10-19 years of age) compared to infancy and early childhood, optimising nutritional status during this period is critical to ensuring healthy and productive populations, both now and in the future (2).

Globally, children and adolescents experience persistently high rates of undernutrition, including macro- and micronutrient deficiencies, alongside increasing rates of overweight and obesity (3). The world is also facing an unprecedented nutrition transition, as well as other challenges including ongoing food insecurity, climate change, conflict and natural disasters, many of which have a disproportionate impact on children and adolescents (4).

Despite their nutritional sensitivity, a recent *Lancet* series highlights a stark lack of investment in adolescents' nutrition (5). One major challenge has been uncertainty in selecting appropriate and standardised tools to classify malnutrition during middle childhood and adolescence. While anthropometric indicators are only part of the picture, they have been the cornerstone of nutrition surveillance in younger children and adults. Their relevance and how best to operationalise them across the 5–19-year age range, however, remains only partly established (6, 7). This has tended to result in limited and often fragmented data to facilitate multisectoral action towards improved nutrition, with multi-country health surveys typically focused on adolescents 15-19 years, and on girls in particular (8). While many high- and middle-income countries measure anthropometric status of all pupils at specific ages, these data are often collected and held by the national education agencies and are therefore not generally utilised by nutrition programmers. Other issues with school-based surveys include the reliance on school enrolment rates to be representative, which is a particular issue for adolescent girls in some settings; measuring anthropometry in some school settings can be challenging therefore some surveys rely on self-reported values; and further, there is currently no mechanism to collate school-based anthropometry data globally (3).

While data gaps in this age group are increasingly being recognised, such as recent efforts to describe the burden of malnutrition through the collation of a large number of population-based studies, there is still a need to better understand healthy growth and developmental trajectories for children older than five years (2, 4, 9). There is also a negative cycle between the availability of data and the lack of global and national nutrition targets during middle childhood and adolescence; the lack of data makes it difficult to set targets and the lack of targets disincentivises the collection of national-level data (5, 10). Currently, anaemia prevalence in women and girls 15-49 years is the sole nutrition indicator for (a portion of) this age group within the global nutrition targets endorsed by the World Health Assembly and Sustainable Development Goals. The WHO Global Action Plan for the prevention and control of non-communicable diseases (NCDs) 2013-2020 did include a target to halt the rise in obesity for adolescents (11), and it is likely to be extended to 2030. Revisiting and establishing standard indicators of malnutrition for 5-19 year olds with associated health and metabolic implications and accounting for secular trends in linear growth, pubertal timing, and changing diets, may potentially help to break this cycle. A new UNICEF platform on adolescent health (https://data.unicef.org/adp/) includes indicators for thinness and overweight in 10-19 year olds; having regular, quality data to track these will be key to informing programmes and actions. Ultimately, well-established indicators could contribute to: strengthening national nutrition surveillance systems; a greater availability of data; the creation of global and national targets; and the development of interventions to tackle malnutrition during middle childhood and adolescence.

What are we measuring and why?

To understand health and nutritional status during middle childhood and adolescence, standardised and evidence-based indicators are likely to include anthropometry, dietary intake, body composition, and nutrient status (7, 12). There is currently a lack of standardised indicators across all these necessary fields for the 5-19 years age bracket. While the urgent need to develop standardised and validated indicators is acknowledged, particularly in low- and middle-income countries (LMICs), to assess fat and lean mass, and dietary quality among children and adolescents, this paper focuses on anthropometric indicators, references, and cut-offs (see definitions in **Box 1**) (13, 14).

Historically, anthropometric indicators have been the focus of nutrition surveillance systems used to explore the determinants and consequences of malnutrition and to target and assess the response to interventions (15). Developing indicators that are both valid, i.e., capture what is intended to be measured, and practical to measure, can be challenging. Each anthropometric indicator (wasting, stunting, underweight, thinness, and overweight/obesity) is defined for populations according to whether a measurement of individuals in the population falls beyond a set cut-off compared to a growth standard or a reference population. This paper considers the underlying assumptions, limitations and associated physiological and health implications of indicator constructs and suggests several potential ways forward for improving the use and harmonisation of current options.

Box 1: Key definitions

- ***Indicator construct*** refers to the meaning beyond what is captured by the indicator (16). When an indicator is representative of the functional or health risk it is intending to capture, the construct is considered 'valid'.
- An ***indicator*** is a variable measured to monitor progress or to assess what does and does not work (17). Anthropometric indicators are intended as 'risk factor' indicators but are also sometimes used as 'health outcome' indicators. They are usually expressed as a percentage of a population that is falling below a set cut-off as compared to a reference population or standard.
- ***Growth standards*** demonstrate how healthy children grow under ideal circumstances allowing unconstrained growth, based on primary data collected from children across a range of settings.
- ***Growth references*** describe how a population has grown but do not necessarily reflect optimal growth.
- A ***cut-off*** is a threshold beyond which an individual is classified as malnourished. It also identifies the severity of undernutrition or overweight in an individual. The units of the cut-off may be absolute, i.e. cm, kg, kg/m^2 etc, or relative to age/sex-adjusted populations, such as centiles and z-scores.
- At the population level, ***prevalence*** of a nutrition indicator above a specific threshold can be used to indicate when a nutrition situation is of public health concern (18).

Current indicators across age groups

The indicators, references, and cut-offs currently used to assess anthropometric status across age groups are summarised in **Figure 1**. Since the risks and consequences of malnutrition differ by age from birth to adulthood, some indicators may be more valid for certain age groups than for others. Well-defined and standardised anthropometric indicators are used to assess malnutrition in children under five years of age and in adults, however, they were derived using distinct approaches. Child under-five anthropometric indicators were derived based on distribution in 'normative' data, and later linked to nutritional status and mortality risk (19-21); adult anthropometric indicators were established based on their health implications and later linked to nutrition (22).

For children and adolescents 5-19 years of age, it is more difficult to use a normative approach towards defining indicators that reflect either nutritional status or health risks, or, ideally, both. Indicator constructs currently applied in middle childhood and adolescence, i.e., those related to 'undernutrition' and 'adiposity' have largely been extrapolated from those used to define malnutrition in younger children and/or in adults. While such indicators are important and practical, they are only proxies for nutritional status and their respective cut-offs should define levels of malnutrition that are associated with health risks. Consideration of whether the constructs of stunting, wasting, underweight and overweight/obesity are applicable in middle childhood and adolescence is important and should determine which indicators are most suitable at any given age.

For example, stunting in children under five has quite different implications to 'short stature' in adolescents and adults: low height-for-age in children is indicative of cumulative poor nutritional status and may be partially modifiable, whereas adult short stature is no longer modifiable since epiphyses have closed (23). More useful indicator constructs and terminology for "stunting" or short stature in adolescence should relate to risk of later obesity, poor metabolic health, obstructed labour, or poor birth outcomes in offspring.

Figure 1: Summary of the current indicators, references, and cut-offs used to assess anthropometric status, by age group

*NB. The arrows that go beyond 25 years on the y-axis are those that also apply to older adults. Abbreviations: MUAC, mid-upper arm circumference; BMI, body mass index (kg/m^2); WHZ, weight-for-height z-score; WAZ, weight-for-age z-score; BAZ, BMI-for-age z-score; HAZ, height-for-age z-score; IOTF, International Obesity Task Force; WHO, World Health Organization

The indicators for adolescent thinness, overweight and obesity were largely inspired by adult indicators. In adults, overweight and underweight are defined according to simple body mass index (BMI) measurements (i.e., BMI>25 or <18.5 kg/m^2 respectively) whereas in older children and adolescents, BMI measurements that are converted to age- and sex-adjusted z-scores (BAZ) are used (24, 25). Adult BMI cut-offs for overweight and obesity were based on evidence from large prospective studies that reported associations between high BMI and increased risk of cardiovascular disease, diabetes, hypertension, and NCD-related and all-cause mortality (26-31). Whereas child and adolescent definitions of overweight were statistically derived and later linked to increased risk of NCDs and death in later life, although this evidence was generated primarily from high-income settings (15, 32, 33).

The indicator construct behind low BMI-for-age ("thinness") in adolescence is less clear. The term 'thin' for low BMI-for-age was introduced to distinguish this indicator from those based on weight-for-age ("underweight") and weight-for-height ("wasted"), however, it is sometimes used interchangeably with the term 'underweight', which can result in erroneous comparisons of data. Confusion is further exacerbated by use of the term 'underweight' for adults with low BMI. Clarifying the meaning behind these different constructs for different age groups and standardising the terminology used would solve some of these issues.

Besides the terminology, clear evidence of the health associations with adolescent thinness is currently very limited. In high and middle-income countries low BAZ is likely to reflect poor mental health such as anorexia nervosa, whereas in low-income settings it may reflect current or past food security status. In children under 5 years, mid-upper arm circumference (MUAC) is used to assess undernutrition in food insecure contexts and may be applicable to older children and adolescents since there is some evidence linking MUAC-for-age z-score or age-stratified MUAC categories to mortality risk in this group (34, 35).

While much work has already taken place focusing on data-driven solutions, evidence linking anthropometric indicators (and their cut-offs) to health outcomes for this age group is generally still scarce (7, 36, 37). Given the rapid growth and development experienced by children and adolescents between five and 19 years of age, z-scores may represent varying levels of risk depending on age and stage of development, even within this age bracket (24). Research is needed to improve our understanding of the health outcomes associated with different malnutrition indicators and cut-offs in middle childhood and adolescence – especially for thinness (low BAZ) and MUAC (6), which are currently the least well-defined. While ideally long-term cohort data with overt health and nutrition outcomes from diverse populations are needed, a more short-term solution could include the use of existing long-standing cohorts and/or intermediate risk factors (38-41).

Defining indicators for middle childhood and adolescence

As previously mentioned, age- and sex- adjusted anthropometric indicators need a numerator and a denominator. While this paper focuses largely on issues around the denominator (i.e., the reference population and cut-off point), it is critically important to have an accurate and valid numerator for nutrition surveillance systems. This requires accurate and reliable assessments of anthropometry and age, and representative sampling methods (42, 43). There are also a number of factors specific to this age group, which include individual as well as ethnic or environmentally-driven differences in the adolescent growth spurt along with varying levels of muscle accretion, that can complicate the accurate assessment of individuals (7).

The age range defined as 'adolescence' is also an important consideration when constructing indicators (44). There is currently a mismatch in both the nomenclature and the classifications of age categories within health and development (i.e., middle childhood 5-9 years, adolescence 10-19 years, and adulthood 20+ years) and those commonly applied to nutrition indicators (44, 45). Although WHO defines adolescence as ending at 19 years, the legal age of adulthood in many countries is 18 years, which means adult BMI sometimes gets applied at that point. In addition, many global estimates, especially for women, are defined by reproductive age (15-49 years) and often result in adult BMI definitions being inappropriately applied to adolescent populations within that bracket.

Which reference data should be used?

Once indicator constructs are defined and the numerators appropriately measured, indicators require a reference population or growth standard as the denominator. Currently, multiple growth references are routinely used internationally to classify anthropometric status during middle childhood and adolescence, including: WHO 2007, International Obesity TaskForce (IOTF), and Centers for Disease Control (CDC) (further summarised in **Appendix page1-2**). Some context-specific references are also used, such as a contemporary Indian reference for children 5-18 years of age constructed from data collected on 20,000 urban, affluent Indian children in 2007 (46).

There is continued debate on whether the use of ethnicity-specific references improves the validity for identifying associated health risks (46-48). Differences in diets and other environmental exposures should be reflected in a global reference, however, any unmodifiable differences, such as genetic factors and, arguably, historical context that may vary by ethnicity and influence anthropometry, body composition and subsequent health risks, need further research (49, 50). Even so, it is still important that we have global standardisation of anthropometric indicators, including the reference population, to facilitate analogous interpretation of data. The provision of standardised, global definitions of malnutrition according to a universal benchmark also promotes equality in adolescent and children's right to health and can help to hold governments and other stakeholders equally accountable.

Consensus around the use of a single, international reference for populations 5-19 years of age would improve the comparability of malnutrition estimates. The routine use of different international references during middle childhood and adolescence makes it difficult to track trends and often adds unnecessary complexity when advocating to policymakers (5, 51). While there is some alignment across the current international reference options when similar cut-offs are applied, comparative analyses suggest substantial differences in estimates of obesity, as well as variations by sex, age and context between the references (6, 52, 53).

All the commonly used references have underlying assumptions and limitations that must be considered if one reference is to be recommended ahead of the others. Important factors for acceptability and applicability of a reference include contemporary and global representativeness, and how 'healthy' the reference population is. The CDC and WHO 2007 references are both based on data from the USA, which raises questions about their global applicability. The data included in the WHO 2007 reference are also over 50 years old, raising questions around its relevance to today's populations. While the CDC reference incorporates newer data, the substantial shift in the nutrition profile across the population of the USA means that the sample has a higher average BMI than the WHO 2007 reference, potentially reducing estimates of overweight and obesity prevalence when applied globally (54). On the other hand, secular trends have resulted in increases in height and decreases in both the age of puberty and the onset of the adolescent growth spurt, particularly among girls, which are not represented in historical data (55). Thus, there are some important trade-offs to consider when deciding whether historic or current data is most useful in determining health risks for today's population. The IOTF reference is more geographically diverse, but the data are still predominantly from high-income settings and are several decades old. It also does not provide growth curves for nutritional indicators beyond those based on BMI. The tension is that these historic data are in one sense out of date, yet because they are relatively unaffected by the obesity epidemic they could act as the basis for a growth standard.

A potential solution could be to create a new, geographically-representative, international reference for children and adolescents 5-19 years of age. There would, however, be two considerable challenges associated with this; i) finding populations which represent "healthy" growth due to the high and rising prevalence of overweight and obesity in many child and adolescent populations, and ii) the difficulty with defining "optimal" growth due to heterogeneity in growth profiles among individuals 5-19 years of age. While use of contemporary population samples would account for secular trends in linear growth, it would also likely result in the generation of weight-based curves that are positively skewed, thereby redefining categories of normal weight, overweight and obesity at the higher end of the BMI spectrum (24). As such, it would be difficult, if not impossible, to create a growth standard for this age group similar to that which exists for children under 5 years of age. Yet the generation of a new reference may still be possible using an empirical method that incorporates stringent data cleaning methodologies and additional biomarkers of health. This could either be based on primary data or more recent and more diverse existing data – or a combination of the two. Data should be of good quality and include mostly healthy children living in environments believed to allow for healthy growth. We do however acknowledge that this would require a very large-scale effort, both in terms of financing and sample size, involving multiple stakeholders across a wide range of contexts.

Which cut-offs should be used?

Currently, cut-offs for defining nutritional status during middle childhood and adolescence differ depending on the reference being used (see **Appendix page 1-2**). The IOTF cut-offs for overweight and obesity are, by design, directly aligned with BMI 25 kg/m^2 and BMI 30 kg/m^2 at 18 years, which equates to approximately +1.3 z-scores (with slight differences for boys and girls) (53). While not by design, the WHO 2007 BAZ curves for overweight at 19 years closely align with the adult overweight cut-off (BMI 25 kg/m^2) at +1 and the adult obesity cut-off (BMI 30 kg/m^2) at +2. Hence, cut-offs of +1 and +2 were selected to define overweight and obesity, respectively, and were extended down to five years of age (21). In contrast, for children under five years of age, cut offs of >+2 (weight for height z-score (WHZ)) and >+3 are used to define overweight and obesity. While body composition studies show that younger children rarely have very high levels of adiposity and the WHZ>+2 cut-off is therefore warranted, the lack of alignment in definitions across age groups is challenging in practice (57).

For thinness, the WHO 2007 cut-off (BAZ<-2) does not align with adult underweight (BMI<18.5), but has good alignment with the growth standard for children under-five (36). **Table 1 & Figure 2** use pooled DHS data to illustrate the misalignments between adolescent and adult cut-offs for under- or over-nutrition in girls 15-20 years of age across the different growth references (breakdown by country in **Appendix page 3-4;** data for boys in **Appendix page 5**). The IOTF reference uses three grades of thinness. Using the WHO 2007 and IOTF references results in very different prevalence estimates for thinness depending on the cut-off selected. Prevalence estimates for BAZ<-2 and IOTF grade 2 (BMI<17 kg/m^2) are similar, but these estimates are substantially higher than for adults BMI<18.5 kg/m^2. The differences are larger among younger adolescents and boys **(Appendix page 5)**. As many studies commonly present thinness using IOTF Grade 1 (BMI<18.5 kg/m^2), this results in a significantly larger prevalence than if the WHO reference was used (47, 51, 58, 59). Our example demonstrates that it may be appropriate to define thinness as BAZ<-1 (mild) and BAZ<-2 (moderate and severe) when using the WHO 2007 reference, which would also improve alignment with the IOTF definitions and with the adult BMI definition, but would result in sharp increases in the prevalence of thinness when transitioning between cut-offs for those under and over five years of age. Smoothing the transition between methods used across age groups is important as it not only affects classifications of nutritional status at the individual level and therefore access to appropriate interventions, but also impacts national prevalence estimates.

There is also some ambiguity in the terminology used to describe the severity of thinness in middle childhood and adolescence. In children under five years of age, there are two grades of severity for wasting, underweight, and stunting: moderate (<-2 z-scores) and severe (<-3 z-scores). These terms are correlated with the risk of mortality and morbidity associated with these cut-offs (60). For children and adolescents 5-19 years of age, however, WHO refers to thinness as <-2 z-scores, with only informal discussions and some academic papers referring to “mild” and “severe” thinness at <-1 and <-3 z-scores respectively (61). The IOTF grades of thinness – termed Grades 1, 2 and 3 - are equivalent to the terminology of mild, moderate, and severe for low BMI in adults.

The terminology used to define nutritional status is important because it influences the appraisal of the severity of a public health problem and the resulting implications for advocacy and intervention. As previously discussed, the risks associated with thinness cut-offs in middle childhood and adolescence are not fully understood and this has likely contributed to the difficulties in generating clear and standardised terminology. Yet clear terminology for thinness and its associated construct in this age group is particularly relevant when navigating the perception of the double burden of under- and over-nutrition, and maintaining a balanced focus of nutrition interventions according to the severity of thinness vs. overweight/obesity.

A further issue is the age at which cut-offs are applied; WHO BAZ cut-offs are applied at 19.0 years and IOTF BAZ at 18.0 years of age. However, to fully align with the age definition of adolescence (10 – 19 years), BAZ cut-offs should be applied up until the end of the 19th year. For IOTF, anchoring the growth curves at 19.9 years instead of 18 years could be considered. A practical demonstration of this issue is seen in **Table 1** where estimates above 19.0 years (WHO) and 18.0 years (IOTF) were calculated by creating a dummy age variable at the final available age since the references do not extend high enough. The decision of when cut-offs and indicators should transition between age groups must be grounded in growth trajectories and health risks, but also needs to be practical within societal norms (44). Most importantly, especially in the short term, the decision needs to be clear and consistent.

With regard to MUAC, while a growth reference for MUAC-for-age has recently been proposed (35), appropriate cut-offs have not yet been established for children and adolescents 5-19 years of age at a global level. The WHO Integrated Management of Adolescent and Adult Illness (IMAI) Acute Care guidelines suggest that severe wasting in adolescents be defined as MUAC<16 cm. Some countries have also developed their own cut-offs starting at <13 cm for those at the younger end of middle childhood (62, 63). Given that arm circumference grows substantially between five and 19 years of age, a MUAC-for-age z-score cut-off is likely more appropriate (35, 64).

Figure 2: Girls aged 15-20 years: summary of percentage point differences in thinness and overweight prevalence for age-specific BMI cut-offs compared to WHO adult BMI cut-offs according to 63 pooled DHS datasets

Ways Forward

Optimal nutrition in middle childhood and adolescence is critical to improving growth, development, and learning outcomes, as well as overall health in current and future generations. Compared with other age groups there are limited standardised data and monitoring systems describing the nutritional status of children and adolescents 5-19 years of age. A lack of consensus on indicators, construct validity, references, and cut-offs for classifying anthropometric status leads to confusion amongst researchers, programmers and policy makers; limits efforts to estimate and track trends; and constrains our ability to set global and national targets. This creates major challenges in fostering the required political will to increase investment to tackle malnutrition in this age group.

Given rapidly changing nutritional trends, there is a pressing need to revisit and refine the use of anthropometry across middle childhood and adolescence. We propose that an expert group be convened by WHO and UNICEF to: (i) create a research agenda towards filling evidence gaps on the associations between nutrition indicators, specific cut-offs, and health risks (either intermediate risk factors or overt health outcomes); (ii) provide guidance on how to interpret existing references, cut-offs and prevalence estimates within the context of ongoing undernutrition and an increasingly obesogenic environment, as well as reflect on the applicability of indicator constructs for this age group; (iii) explore if and how malnutrition cut-offs could be harmonised across age groups; and (iv) assess the need and feasibility of creating a globally representative and contemporary growth reference for children and adolescents 5-19 years of age using existing and/or new data. There are some long-standing cohort studies with anthropometric data in adolescence and adult health measures that could be a good starting place for some of these recommendations. A new Technical Advisory Group which has recently been convened by UNICEF to improve the monitoring and evaluation of programs targeting school-age children and adolescents could also be a great starting platform. Since anthropometry is only a proxy for nutritional status or the environment in which children and adolescents grow or grew (65-67), standardised anthropometry needs to be complemented by indicators of body composition, nutrient status, and diet quality that are practical and validated (7).

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