Revisiting the Relationship of Weight and Height in Early Childhood[1,2]

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ABSTRACT

Ponderal and linear growth of children has been widely studied; however, epidemiologic evidence of a relationship between the two is inconsistent. Child undernutrition in the form of low height for age and low weight for height continues to burden the developing world. A downward shift in the distribution of height for age in the first 2 y of life is commonly observed in many developing countries and is usually summarized as the percentage stunted (height for age Z-score <−2). Similar shifts are seen in weight for height; however, weight-for-height shifts are often less extreme, perhaps because weight for height is more tightly biologically controlled. Low height for age and low weight for height in childhood share some common factors, including food insecurity, infectious diseases, and inappropriate feeding practices. Reductions in weight for height, generally seen as a short-term response to inadequate dietary intake or utilization, are thought to precede decreases in height for age; however, given an adequate diet and no further insults, catch-up linear growth can occur. Serial instances of decreased weight for height, however, are thought to limit the degree of catch-up growth attained, contributing to linear growth retardation. Additional research is needed to identify the factors associated with recovery of linear growth after a child experiences decreased weight for height. Although the direct relationship between weight for height and height for age is likely limited, each of these measurements indicates important information about the general health of children and their risk of the development of illness or dying; therefore, eliminating the downward shift of height for age and weight for height in developing countries should be prioritized as a public policy. *Adv. Nutr. 3: 250–254, 2012.*

Introduction

Although progress is being made in decreasing undernutrition in low- and middle-income countries, wasting (weight for height Z-score <−2) and stunting (height for age Z-score <−2) during childhood continue to burden the poorest regions in the developing world (1,2). The first Millennium Development Goal aims to decrease the population experiencing hunger by half from 1990 to 2015. The indicator for this is the proportion of underweight children younger than 5 y of age with a weight-for-age Z-score <−2 (3). Because weight for age reflects low height for age (shorter children may weigh less than taller children), low weight for height, or a combination of the 2 (4,5), the first Millennium Development Goal can be attained by decreasing the prevalence of stunting, wasting, or both. Inconsistent relationships between weight for height and height for age have been identified, depending on the type of data that one is considering (e.g., population or individual level, cross-sectional or longitudinal). Understanding the relationship between weight for height and height for age will allow organizations to better justify, design, and evaluate programs to improve childhood nutrition. For example, justification of an intervention that aims to improve weight-for-height in early childhood is strengthened if one can link weight changes with long-term linear growth. Interventions that aim to decrease stunting in early childhood will benefit from understanding the many pathways in the stunting process, not only for designing programs but also for evaluation of the program, taking into account lag times between improvements in weight and height.

More than 177 million children younger than the age of 5 y in the developing world are stunted (6), most likely as a result of dietary inadequacy and high infectious disease burden early in life. Although some children are born stunted and never recover (7), many are born with lengths consistent with the WHO standard (8), and stunting

[1] Published as a supplement to *Advances in Nutrition*. Presented at a symposium titled "Building Convergence among Scientific, Programmatic, and Policy Communities: Working on Childhood Undernutrition in Developing Countries" given at the annual Experimental Biology meeting, Monday, April 11, 2011, in Washington, DC. The symposium was partly supported by the American Society for Nutrition. The symposium was chaired by Purnima Menon and Rebecca Stoltzfus. Guest Editors for this symposium publication were Rebecca J. Stolzfus and Edward A. Frongillo. Guest Editor disclosures: Rebecca J. Stolzfus had no conflicts to disclose. Edward A. Frongillo had no conflicts to disclose.

[2] Author disclosures: W. Checkley, R. E. Black, and S. A. Richard, no conflicts of interest.

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  Adv. Nutr. 3: 250–254, 2012; doi:10.3945/an.111.001099.

develops over time. A downward shift in height for age as children age is observed in many developing countries and is generally summarized as the percentage stunted (height-for-age Z-score <-2). This method of categorizing children as stunted or not stunted identifies those children who are growing most poorly; however, because the entire distribution of child heights in developing countries appears to be shifted downward compared with the WHO standard, it appears that many, if not most, children are not growing to their full potential, not just those who happen to fall below the <-2 cutoff. Linear growth is not a constant or graded process; rather, it is a process in which periods of slow linear growth are punctuated by periods of faster growth (9). Linear growth retardation is generally considered to reflect long-term exposure to nutritional stresses, including an inadequate diet and a high burden of infections, from which catch-up growth is insufficient (10).

Unlike linear growth retardation, decreased weight for height appears to be short term in nature and reversible if the child has access to adequate dietary intake and absence of infectious disease. More than 19 million children younger than the age of 5 y are severely wasted (weight-for-height Z-score <-3) in the developing world, with a prevalence of severe wasting that ranges from 1 to 4% in most regions (6). Wasted children (weight-for-height Z-score -3 to <-2) are 3 times (95% CI: 2.0–4.5) more likely to die and severely wasted children (weight-for-height Z-score <-3) are >9 times (95% CI: 5.3–16.8) more likely to die than are children with weight-for-height Z-scores >-1 (6). Although wasting is thought to be a short-term health issue, repeated bouts of wasting may preclude linear catch-up growth over the long term (11,12). Similar to the height-for-age distribution shift toward lower values, weight-for-height distributions are also sometimes shifted down in developing countries.

Children worldwide will likely grow both ponderally and linearly within a standard range as suggested by the WHO Multicenter Growth Reference Study, provided they are given adequate nutrition and limited exposure to infectious diseases (8). Most (70%) of the variability in linear growth observed in the Multicenter Growth Reference Study was observed in individuals in each site, with only 3% of the variability attributable to site differences, indicating a common human growth potential (13). The recent transition from the National Centers of Health Statistics growth reference to the WHO Multicenter Growth Reference standard may provide researchers with a better tool with which to monitor rapid changes in growth in early childhood (8). Specifically, under the new WHO standard, children were ∼2 times more likely to be identified as wasted in the first 2 y of life, and wasting occurs at an earlier age than was observed with the previous National Center for Health Statistics reference (14). The relative increase in wasting was much greater than the relative increase (~10%) in stunting (14). It is important to note that many of the earlier analyses (15) used the National Centers for Health Statistics growth reference (16).

The geographic differences observed in linear and ponderal growth are likely due to a combination of factors, including maternal nutritional status, exposure to and treatment of infectious diseases, and dietary factors (17). Maternal stature and weight gain during pregnancy have been shown to be associated with both length and weight at birth in developing countries (18,19). Infectious diseases, including, but not limited to, enteric and respiratory infections, can result in decreased weight for height and height for age through decreased or altered dietary intake, impaired intestinal absorption, and increased metabolism due to fever (20–28). Dietary factors such as household food insecurity, insufficient or absent breastfeeding in the first 6 mo of life, and the addition of complementary foods that are of low quantity or quality can lead to poor ponderal and linear growth (29–32). Zinc deficiency has been associated with linear growth faltering as have vitamin A and iron deficiencies, although the latter 2 were found to have an effect only when deficiency was severe (33). If a child has an acute illness or dietary deficiency that results in weight loss, linear growth may slow down or cease until weight is recovered (34). Once the child regains weight, linear growth will continue and, given adequate nutritional resources and no further infections, catch-up growth may occur, returning the child to the original growth trajectory (11,34–37); however, children in developing countries often experience multiple insults with limited recovery time, leading to persistent height deficits.

Although many interventions to improve nutritional status are in use today, understanding the relationship between weight and height acquisition will augment our ability to justify one intervention over another. Population-level investigations have demonstrated inconsistent cross-sectional relationships between prevalence of stunting and wasting in childhood (15,38). In addition, weight for height and height for age have been found to be independent on an individual level (4,39). Longitudinal studies are better suited to determine whether 1 or more bouts of reduced weight for height precede linear growth–faltering in children.

Current status of knowledge

Relationship between weight for height and height for age

At a cross-sectional level, there appears to be a limited relationship between ponderal and linear growth. Individual-level, cross-sectional studies have found little association between weight for height and height for age, some even going so far as to call these factors independent (4,39). Cross-sectional, population-level studies have demonstrated that height for age decreases throughout the first 2–3 y of life in many developing countries, whereas weight for-height tends to falter during a more limited age window in the first year of life, after which weight for height stabilizes or increases (40). The precise timing of the weight-for-height faltering likely varies according to the country-specific age of weaning and other local factors (38,40–44). Victora (15) found that the prevalences of wasting and stunting in children 12–23 mo of age were positively associated in Asian and Eastern Mediterranean countries, but not in Latin America or Africa, where some countries were observed to have high levels of stunting but little wasting. Another study confirmed this lack of correlation between stunting and wasting in Africa (39). A later study by Frongillo et al. (45) confirmed Victora's supposition that wasting and stunting have different underlying factors, and quantified the contributions of those factors using national-level characteristics. Frongillo et al. (45) found that although higher energy availability, female literacy, and gross national product were associated with lower stunting prevalence, lower wasting prevalence was associated with higher immunization rate, and, in Asia only, higher energy availability. In summary, the relationship between wasting and stunting is inconsistent in population-based cross-sectional studies. Inconsistent findings across regions suggest that stunting in Latin America and Africa may be associated with a long-term degree of micro- or macronutrient deficiency that does not result in wasting. Alternatively, cross-sectional data can misrepresent the relationships if, for example, the anthropometric survey were performed during a season in which wasting is more or less common, whereas stunting is presumed to vary less with season, particularly in older children.

Longitudinal data were used by several studies to explore the relationship between acquisition of weight and height. In settings with seasonal variations in growth, it has been observed that periods of lowest linear growth follow periods of lowest weight acquisition (38,46–48), although when one of these studies looked at the data on an individual level, this relationship was not observed (48). These findings indicate that there is a lagged effect of weight acquisition on height, although this is best demonstrated using longitudinal data at the individual level.

Several studies have investigated the relationship between change in weight or weight status at baseline and linear growth at an individual level. Walker and Golden (37) observed in a hospital-based study that malnourished children needed to reach 85% weight for height before linear growth could resume, whereas Wiersinga and Van Rens (49) found a simultaneous improvement in both weight and height velocity after supervised feeding. Walker et al. (11) considered the impact of change in weight for height on linear growth in a population of stunted children in Jamaica. Using a 2-stage regression approach, Walker et al. found that a 1-unit change in weight for height during a 6-month interval was associated with a difference of 0.49 cm (95% CI: 0.04–0.95) and 1.09 (95% CI: 0.73–1.44) in height during the following interval. Similarly, Dewey et al. (12) found that initial weight for height and weight change during the previous interval were both significantly, although modestly, correlated with height gain in children during their first year of life ($r = 0.15$–0.36, $P < 0.01$). In Malawi, Maleta et al. (48) also found that weight for height at the beginning of a period explained some of the variation in height gain during that period ($r = 0.10$–0.38; $P < 0.05$), but there was no significant correlation between weight gain in 1 period and height gain in the next period on an individual level when controlling for concurrent weight gain and weight for height at the beginning of the period. Similarly, Costello (50) compared weight and height velocity in children in Nepal and concluded that children with low weight for height at the beginning of the period had higher weight velocities and lower height velocities than children with normal weight for height at the beginning of the period, indicating that these children gained weight at the expense of height. Whether an effect on height for age is associated with weight for height at the beginning of the interval or the change in weight for height in the previous interval, these studies demonstrate a lagged effect of weight on height growth. To further consider the extent to which ponderal growth faltering can increase the risk of linear growth faltering, we need longitudinal studies with frequent measurements across time on the same children. Further research should also include socioeconomic status, feeding practices, and infectious episodes to identify the factors that modify the relationship between weight for height and height for age.

Conclusions

Decreased weight for height and height for age are both important risk factors for illness and death during childhood, and changes in weight appear to have a lagged effect on height during early childhood. Another way to think about this is that weight is maintained or regained under periods of nutritional stress at the expense of height (50). Ponderal and linear growth faltering are both rooted in poverty (51) and are likely to result from a local mixture of environmental, including infectious exposures, dietary, cultural, and socioeconomic factors (52). Both large, multicountry population-level studies and smaller individual-level studies have produced inconsistent results about the cross-sectional relationship between weight for height and height for age. Studies that used longitudinal data found small but significant relationships between weight and height acquisition. Larger studies that combine longitudinal, individual-level anthropometry, diet, infectious disease, and household data from multiple countries will allow us to further elucidate the longitudinal process of stunting and the relationship between acquisition of weight and height at the individual level and potentially clarify the complex nature of child linear growth failure in developing countries. A better understanding of these relationships will enable program managers to devise improved strategies to intervene along the pathway of becoming stunted.

Acknowledgments

We are grateful to Laura Caulfield for helpful discussions on this topic. All authors have read and approved the final manuscript.

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