



Ex-post adjustment for measurement error in child stunting calculations

An illustration from Egypt

José Luis Figueroa and Sikandra Kurdi

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ABSTRACT

Objective: This study provides estimated ranges for the magnitude of bias caused by measurement error in stunting rates in young children, a widely used proxy for long-term nutritional status.

Design: Stunting, which is determined by the number of cases of height-for-age z-scores (HAZ) in the population that fall below -2 standard deviations from the mean, mechanically increases with higher variance. This variance stems from both natural heterogeneity in the population and measurement error. To isolate the effect of measurement error, we model the true distributions which could give rise to the observed distributions after subtracting a simulated measurement error.

Setting: We analyze data from the 2005, 2008, and 2014 rounds of the Egypt Demographic and Health Survey (DHS). Egypt ranks high among developing countries in terms of the poor quality of the anthropometric data collected in its national DHS, which currently is the main source of anthropometric information for the country.

Subjects: This study is a re-analysis of existing DHS data on the height and age of children under 5 years of age.

Results: Under the most conservative assumptions about measurement error, the national stunting rate falls by 4 percentage points for the most recent DHS round when the effect of measurement error is removed from the estimate. Assuming higher levels of measurement error reduces the stunting rate more dramatically.

Conclusions: Researchers should be aware of and adjust for data quality concerns in calculating stunting rates for cross-survey comparisons or when using anthropometric information in communications with policy-makers.

Keywords: Anthropometry, measurement error, stunting, simulations, Demographic and Health Survey, Egypt

INTRODUCTION

The child stunting rate, defined as the share of children with height for age z-scores (HAZ) less than -2.0, is extensively used as a proxy for the average nutritional status of children in a community (Svedberg 2000). While having a HAZ score less than -2 is not highly predictive of health status at the individual level, at the population level it can serve as an indicator of the overall incidence of linear growth faltering (Perumal, Bassani, and Roth 2018). Economists and policy makers often use the stunting rate to make cross-country comparisons or to evaluate how average child nutritional status has changed over time (de Onis, Blössner, and Borghi 2012; Garrett and Ruel 2005; Mukuria, Cushing, and Sangha 2005).

However, focusing only on differences in the stunting rate, rather than the distribution of HAZ, can be misleading. Increasing the variance of z-scores in a population mechanically increases the stunting rate. While some variation in height is expected due to individual genetic or environmental factors (Jelenkoic et al. 2016), the population variance may be artificially inflated due to measurement error, potentially leading to an overestimation of the actual stunting rate. In the case of Egypt, we show that the measurement error in the anthropometric measurements of young children in the Demographic and Health Surveys (DHS) is both high and differs from one survey round to another. Therefore, adjustment for measurement error is necessary to make statements about the evolution of young child stunting rates over time and how Egypt compares to other countries.

Age misreporting and inaccurate height recording are common in anthropometric surveys and lead to errors in the HAZ score. For example, it has been shown that age misreporting is the major source of error in calculating HAZ scores in national representative surveys in developing countries in sub-Saharan Africa and in Asia (Comandini, Cabras, and Marini 2009, 2015) and that an error of 1.5 months for a 12-month old child can increase the standard deviation of HAZ by about 20 percent (Grellety and Golden 2016). Height measurement is also prone to measurement errors by enumerators, especially when measuring younger children (ICF International 2013).

In an analysis of DHS anthropometric data quality in 52 countries, Egypt is one of the seven countries listed as having the most concerns raised across a variety of different quality indicators (Assaf, Kothari, and Pullum 2015). Nonetheless, the DHS stunting rate for Egypt is widely used and cited by researchers, policy makers, and development organizations (Ecker et al. 2016; Kavle et al. 2015; Sharaf and Rashad 2016).

In this paper, we show the potential ranges of stunting after removing measurement error under different assumptions about the magnitude of this error for three rounds of the Egypt DHS, 2005, 2008, and 2014 (El-Zanaty and Way 2006, 2009; Ministry of Health-Egypt, El-Zanaty and Associates, and ICF International 2015).

METHODS

We present three scenarios which show the range of true values which could give rise to the observed data depending on how much measurement error we assume: a conservative scenario, an aggressive scenario, and a moderate scenario between these two extremes. In all scenarios, we assume classical measurement error uncorrelated with the measurements and with a mean of zero. The standard deviation of the measurement error differs in each scenario.

1. Conservative Scenario

This approach is based on looking at the high side of the distribution. In line with World Health Organization (WHO) recommendations, we assume that the share of overly tall children in a population should be no greater than that found in the WHO reference populations used to construct the international growth standards (WHO Multicentre Growth Reference Study Group 2006). So, any excess must be due to measurement error.¹

$$H = \int_{1.96}^{\infty} \frac{1}{\sqrt{2\pi\tilde{\sigma}^2}} e^{-\frac{1}{2}\left(\frac{x}{\tilde{\sigma}}\right)^2} dx$$

Let H represent the proportion of children with z-scores more than two standard deviations above the mean. We solve (computationally) for the standard deviation of a normal distribution that would give this share of extremely tall children, denoted as $\tilde{\sigma}$. The difference between $\tilde{\sigma}$ and the reference population standard deviation of 1.0 is attributable to measurement error. We denote the variance of this measurement error as σ_{ϵ}^2 .

$$\sigma_{\epsilon}^2 = \tilde{\sigma}^2 - 1$$

While we are confident that our conservative approach identifies a minimum amount of variance that must be due to measurement error, accounting for this measurement error still leaves the observed variance much higher than expected. So, we proceed also to show how much the stunting rate would change under more aggressive assumptions.

2. Aggressive Scenario

As a benchmark of the maximum measurement error that could be assumed, we make the strong assumption that all variance beyond that in the reference population, in which the variance is equal to 1.0, is attributed to measurement error. In effect, this assumes that there is no heterogeneity of malnutrition due to regional differences or other household characteristics and that any impact of malnutrition on growth is diffused equally throughout the population. This assumption of no heterogeneity is unrealistic, but by making the strongest possible assumption, we obtain the minimum true stunting rate that could be inferred from the observed data.

In this case, we define measurement error based on the difference between the variance of the observed z scores ($\tilde{\sigma}^2$) and 1.

$$\sigma_{\epsilon}^2 = \tilde{\sigma}^2 - 1$$

3. Moderate Scenario: True Variance Inferred from a Better-quality Survey

Instead of the extreme assumption that the true values are distributed with a variance of 1.0, we can look to better quality survey data for some guesses about the actual value of the true variance. Here, we use the variance found in a 2018 survey of households in rural areas in Upper Egypt² where we know that the enumerator training was done more carefully than for the Egypt DHS data

¹ Recent research has found that there is more national level diversity in growth curves for healthy children than the WHO standards imply. Nonetheless, for most countries, the international growth curves are a reasonable fit (Natale and Rajagopalan 2014). In countries where it is available, using a national reference population to calculate z-scores would eliminate concern about the comparability with the WHO reference population. We have established that for anthropometric survey data from Egypt where enumerators had better training than in the DHS (see footnote 2), there is no evidence that the share of overly tall children differs substantially from the 2.5 percent expected in the WHO reference population.

² The International Food Policy Institute, with funding from USAID, collected anthropometric information on 1,255 children aged 6 to 59 months in May 2018. These children came from small villages in rural areas in five governorates in Egypt: Luxor, Sohag, Qena, Beni Suef, and Menya.

collection. We define measurement error based on the difference between the variance of the observed z scores ($\tilde{\sigma}^2$) in the DHS and the variance in our higher quality survey $\tilde{\sigma}_S^2$.

$$\sigma_\epsilon^2 = \tilde{\sigma}^2 - \tilde{\sigma}_S^2$$

SIMULATIONS

We turn to simulations to model what true distributions would give rise to the observed distribution after the addition of measurement error. Because we assume that errors are uncorrelated with the true values, the expected variance of this true distribution, denoted as $\hat{\sigma}^2$, is equal to the observed variance ($\tilde{\sigma}^2$) minus the variance of the hypothesized measurement error.

$$\hat{\sigma}^2 = \tilde{\sigma}^2 - \sigma_\epsilon^2$$

We then define a random variable representing simulated measurement error, $\hat{\epsilon}$, such that $\hat{\epsilon}$ is distributed $N(0, \sigma_\epsilon^2)$ and subtracting $\hat{\epsilon}$ from our observed data reduces the variance to $\hat{\sigma}^2$. Because the observed measurements (\tilde{z}) are the sum of the true values and the measurement error, $\hat{\epsilon}$, is positively correlated with \tilde{z} . Consequently, the correlation (ρ) between $\hat{\epsilon}$ and \tilde{z} can be defined based on σ_ϵ^2 and $\tilde{\sigma}^2$:

$$\hat{\sigma}^2 = \tilde{\sigma}^2 - \sigma_\epsilon^2 = \tilde{\sigma}^2 + \sigma_\epsilon^2 - 2\tilde{\sigma}\sigma_\epsilon\rho$$

$$\rho = \frac{\sigma_\epsilon}{\tilde{\sigma}}$$

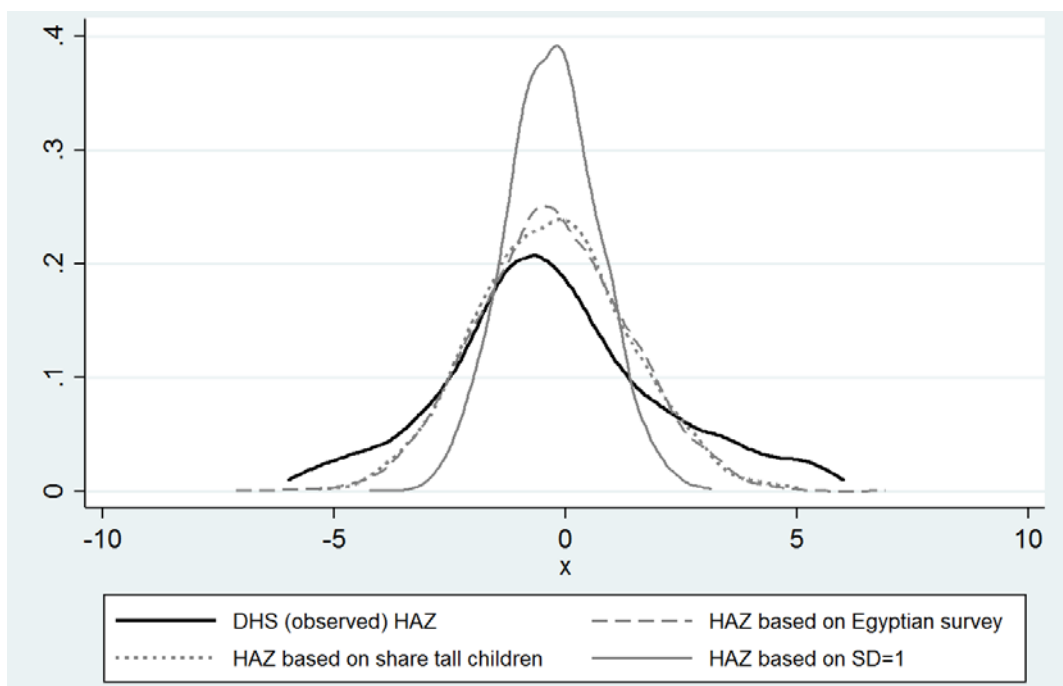
In each iteration, we randomly select values of $\hat{\epsilon}$ correlated by ρ with the observed distribution; subtract $\hat{\epsilon}$ from \tilde{z} to generate our simulated measurement error-free data; and calculate the resulting stunting rate. For all summary statistics, we follow the standard practice of excluding flagged values ($\text{HAZ} > 6$ or $\text{HAZ} < -6$). We present the results of 1,000 iterations of the simulations.

We choose values for σ_ϵ^2 and perform the simulations separately for children ages 6 to 23 months and 24 to 59 months because we expect the measurement errors to differ between these two groups.

RESULTS

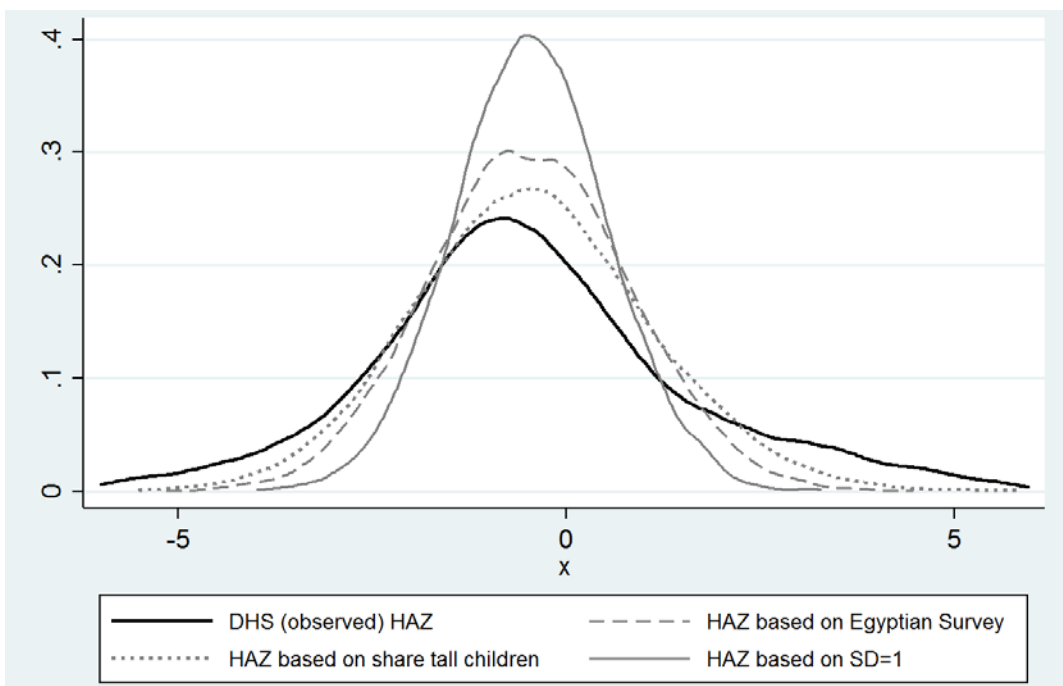
Figures 1 and 2 illustrate the effect of removing measurement error under the three scenarios. These figures show a single iteration in our simulations: the distribution of corrected z-scores resulting from one randomly drawn vector of measurement error. Removing the error leads to tighter distributions with fewer cases of stunting than was observed in the Egypt DHS data.

Figure 1. Height-for-Age Z-score (HAZ) distributions for children 6 to 23 months old based on different measurement error correction scenarios



Source: Authors' analysis.

Figure 2. Height-for-Age Z-score (HAZ) distributions for children 24 to 59 months old based on different measurement error correction scenarios



Source: Authors' analysis.

Table 1 summarizes the results of the three simulation scenarios for each of the three rounds of DHS data from Egypt.

Table 1. Estimates for height-for age z-scores and stunting prevalence based on conservative, aggressive, and moderate measurement error correction scenarios

Panel A. DHS data									
	2005			2008			2014		
	Mean	SD ($\hat{\sigma}$)	Stunting rate, %	Mean	SD ($\hat{\sigma}$)	Stunting rate, %	Mean	SD ($\hat{\sigma}$)	Stunting rate, %
6-23 months	-1.04	2.22	31.0	-0.91	2.24	30.2	-0.28	2.32	20.4
24-59 months	-1.09	1.71	25.6	-1.25	1.86	32.0	-0.46	2.02	19.8

	σ_{ϵ}^2	$\hat{\sigma}^*$	Stunting rate, % *	σ_{ϵ}^2	$\hat{\sigma}^*$	Stunting rate, % *	σ_{ϵ}^2	$\hat{\sigma}^*$	Stunting rate, % *
Panel B. Conservative Scenario: Confidence intervals based on data inferred from share of overly tall children in DHS									
6-23 months	1.30	[1.77 - 1.82]	[28.5 - 30.7]	1.38	[1.72 - 1.79]	[25.6 - 28.0]	1.51	[1.73 - 1.79]	[15.2 - 17.0]
24-59 months	0.98	[1.38 - 1.42]	[23.5 - 24.9]	1.16	[1.43 - 1.47]	[28.9 - 30.8]	1.32	[1.51 - 1.55]	[14.5 - 15.7]
Panel C. Aggressive Scenario: Confidence intervals assuming all variance is due to measurement error									
6-23 months	1.98	[0.98 - 1.02]	[15.7 - 18.0]	2.01	[0.97 - 1.02]	[12.5 - 14.8]	2.10	[0.98 - 1.02]	[3.7 - 4.7]
24-59 months	1.39	[0.98 - 1.01]	[16.9 - 18.5]	1.57	[0.98 - 1.02]	[21.6 - 23.6]	1.76	[0.98 - 1.01]	[5.6 - 6.5]
Panel D. Moderate Scenario: Confidence intervals assuming variance over other survey is due to measurement error									
6-23 months	1.49	[1.61 - 1.67]	[26.8 - 29.1]	1.53	[1.16 - 1.68]	[24.1 - 26.6]	1.64	[1.61 - 1.67]	[13.6 - 15.3]
24-59 months	1.11	[1.29 - 1.32]	[22.3 - 23.9]	1.32	[1.28 - 1.32]	[27.0 - 29.0]	1.55	[1.29 - 1.32]	[11.0 - 12.1]

* 95% confidence intervals based on 1,000 simulations

$\hat{\sigma}$ = observed standard deviation of z-scores

σ_{ϵ}^2 = hypothesized measurement error

$\hat{\sigma}$ = modelled standard deviation of z-scores after removing measurement error

In Panel A in Table 1, we summarize the DHS data on HAZ, including means, standard deviations, and the prevalence of stunting in the population of children. These values were calculated using the Stata module *zscore06*, which is based on the 2006 WHO reference values (Leroy 2011). Standard deviations of the z-scores are extremely high, ranging from a minimum of 1.71 for older children in 2005 up to a maximum of 2.32 for younger children in 2014. There is also a striking increase in stunting among the older children from 2005 to 2008, followed by a decline between 2008 and 2014.

For each scenario, the panel shows the measurement error (σ_{ϵ}^2) that we are assuming and the empirical 95 percent confidence intervals of the standard deviation and stunting rate calculated from the simulated data.

Under the conservative scenario (Panel B in Table 1), the assumed measurement errors accounts for between 41 and 46 percent of the variance in the observed data. Removing this error leads to modeled stunting rates in the various DHS rounds from 1 to 5 percentage points lower than in the observed data.

Under the aggressive scenario (Panel C in Table 1), the assumed measurement errors comprise 58 to 68 percent of the variance in the observed data. Removing this measurement error results in a significant decrease in the estimated prevalence of stunting for all groups, particularly among younger children in the 2008 and 2005 samples. For example, in 2008 children aged 6 to 23 months would have a stunting prevalence rate between 12.5 and 14.8 percent in contrast with the 30.2 percent observed in the DHS data.

Under the moderate scenario (Panel D in Table 1), the measurement error comprises 45 to 54 percent of the variance in the observed data. The corrected stunting rates fall between the conservative and aggressive scenario results.

Under our moderate scenario, our simulations for 2014 give a mean true stunting prevalence of 14.7 percent for children aged 6 to 23 months, and 15.3 percent for older children. This is dramatically lower than the DHS rate currently accepted in Egypt (20.4 percent and 19.8 percent, respectively). The results from the alternative conservative and aggressive assumptions give a range from 3.7 percent to 17.0 percent for children aged 6 to 23 months, and from 5.6 percent to 15.7 percent for older children. This shows that at the least child stunting is overestimated nationally by about 4 percentage points in Egypt, that the true stunting rate could be substantially lower than even our moderate scenario suggests, and that there is a very large degree of uncertainty about the true stunting rate.

DISCUSSION

This study shows how measurement error leads to overestimation of the real prevalence of chronic child undernutrition in Egypt, a country where issues with anthropometric data quality have been observed but are not widely appreciated. We show that measurement error has been high and variable across the three most recent rounds of the DHS and simulate a range of potential true values of the stunting rate in young children.

Policy makers were particularly concerned by the high prevalence of stunting observed in 2008 which contrasts with the other two rounds. Previous research had suggested that this effect might be a consequence of an outbreak of avian flu in Egypt in 2006. The disease affected mainly rural areas in Lower Egypt and had significant consequences for household welfare and protein consumption for children (Hosny 2006; Geerlings, Albrechtsen, and Rushton 2007). Our simulations confirm that even accounting for measurement error, the increase in stunting in 2008 is still observed, although the levels and magnitude of the change are lower.

There are important implications of these findings for policy makers in Egypt. However, for the global public health nutrition community, we emphasize that data quality issues in the DHS have been flagged in a number of other countries in addition to Egypt. While one response is to call for improving the accuracy of anthropometric measurements for future rounds of DHS data collection, many researchers and policy makers are faced with the reality that the only data that exists are from surveys with data quality concerns.

We recommend that researchers who only have anthropometric information obtained from surveys with data quality concerns use the types of adjustments described in this paper in time-series or cross-sectional analyses of stunting rates. We also recommend using this approach to communicate to policy makers about the degree of uncertainty surrounding the stunting rate when the only available data is from survey rounds with data quality concerns.

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ABOUT THE AUTHORS

José Luis Figueroa at the time this research was conducted was an Associate Research Fellow in the Egypt Strategy Support Program (ESSP) of the International Food Policy Research Institute (IFPRI), based in Cairo. He is now a Researcher at the National Institute of Public Health of Mexico in Cuernavaca. **Sikandra Kurdi** is an Associate Research Fellow in ESSP of IFPRI, based in Cairo.

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

1201 Eye St, NW | Washington, DC 20005 USA
T. +1-202-862-5600 | F. +1-202-862-5606
Email: ifpri@cgiar.org | www.ifpri.org | www.ifpri.info

IFPRI-EGYPT

World Trade Center, 1191 Corniche El Nile, Cairo, Egypt
T: +20(0)225778612
<http://egyptssp.ifpri.info/>

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