# Meta analysis: age-related measurement error can lead to systematic overestimates of childhood stunting rates

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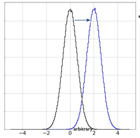
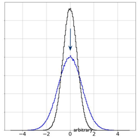
## Measurement error and SDs

- Directional measurement errors:
  - every measurement changes by the same amount - the distribution *shifts*
  - changes the **position (mean)** but not the **width** (SD)




- Examples in children's anthropometry:
  - children wear bulkier clothes in colder climates
  - measuring device systematically flawed
  - all birth records under-estimated

- Non-directional (or, *random*) measurement errors:
  - any given measurement may be incorrect, but there is no *net* effect
  - increases the **width** (SD) of the distribution but not the **position (mean)**




- Examples in children's anthropometry:
  - squirming children
  - transcription errors
  - all birth records equally under- and over-estimated

**Any distribution's standard deviation (SD) value is strongly influenced by measurement data quality.**
(of course, genuinely heterogeneous distributions can also lead to large SDs!)

Box A

## Anthropometry and stunting

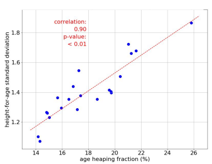
- Accurate nutritional monitoring for the world's youngest citizens is a critical tool in evaluating past, present, and future health trajectories in vulnerable communities
  - nutrition-based indicators must be able to be collected **accurately** and **efficiently** in the context of large-scale surveys
- **Height-for-age** measurements are among the highest-level childhood nutrition indicators supported by **Feed The Future** and plays a key role in the UN's **Sustainable Development Goals**.
- Typically, height-for-age results are distilled into a single quantity: the prevalence of **stunting**. This indicator is defined by the proportion of observations falling 2 or more SDs below a healthy reference population (see **Box C**).

- This work presents simulations and a meta-analysis that demonstrates how a particular **measurement error** type (see **Box F**) has led to **significant historical biases for this stunting indicator**.

Box B

## Datasets included and primary findings

- Included in this meta-analysis are the height-for-age distributions measured in **21 population-based surveys related to USAID-supported resilience activities** collected within the past 10 years. Inclusion criteria was defined prior to any analysis.
- In these datasets, a **strikingly strong correlation** (ρ=0.90, p-value ≪ 0.01) was found between the 'age heaping fraction' variable (defined in **Box F**) and the output height-for-age z score SD. Important implications include:
  - **age heaping is a driving factor in the height-for-age data quality in these survey.**
  - the SD values in this dataset are inflated due to measurement error. As demonstrated in **Box C**, this can lead to **overestimating the true stunting prevalence.**
  - as simulated results show in **Box E**, **this bias can exceed 10 percentage points for some surveys in this set! Improved stunting results could be attained by correcting the historical results by these amounts.**



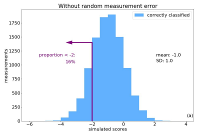

- Study limitations:
  - the corrections simulated in **Box E** do not address of directional error, which can also influence prevalence rates.
  - the corrections simulated in **Box E** assume the SD value should be 1.0 in the absence of non-directional measurement error (a range of values between 0.8 and 1.2 is reasonable).

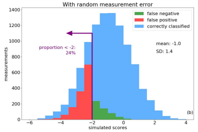
Box D

## SDs and threshold-based prevalence indicators

- As discussed in **Box A**, non-directional measurement error leads to an increase in distributional SD values.
- For the many indicators that track distributional mean values, SD increases do not influence the result.
- **However**, the definition of the **stunting** indicator involves the proportion of observations falling two or more SDs below the healthy reference population. **This box demonstrates how an inflated SD can lead to a bias in the prevalence of stunting**.

- The figures on the right show the results of a simple simulation.
- In (a), a distribution with no measurement error was simulated. All observations are therefore **correctly classified**
  - note the proportion falling below -2 is 16%
- To create the distributions in (b), non-directional measurement error was added to each observation in figure (a). **Note the SD value has increased.** These measurement errors have introduced the mis-classification categories of **false positives** and **false negatives**.
- Note the **false positives** clearly outnumber the **false negatives**, leading to **an overall shift in the overall prevalence rate** (now at 24%)



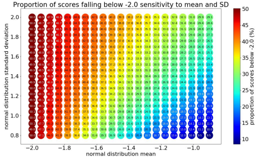

- This simple simulation shows how a realistic increase in SD **due to non-directional measurement error can lead to a significant bias in overall stunting rates** (in this case, 8 percentage points!).
- **Box E** explores the relationship between bias, SD, and mean value in more detail

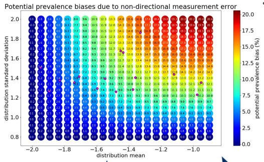
Box C

## Prevalence rate dependence on distribution mean and SD

- Assuming normality, apart from a distribution's SD (see **Box C**), the prevalence for stunting also depends on the distributions mean value (and nothing else!).
  - this is true for **any** indicator defined by the proportion of observations above or below a certain threshold

- To explore this three-dimensional relationship, high-statistics normal distributions were simulated with a variety of mean and SD values. For each of these distributions, the **prevalence** of observations below -2 (*à la stunting*) were calculated and presented to the right as a function of **mean** and **SD** value.




- **So what can we do with this information?** Fortunately, there is guidance in the literature: the vast majority of anthropometric z-score distributions known to have rigorous data quality controls have SD values between 0.8 - 1.2. Therefore, **anthropometric z-score distributions with SD values significantly above 1.2 are likely significantly influenced by non-directional measurement error.**

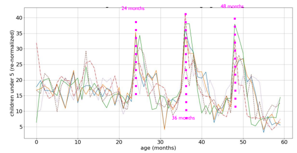
- So, assuming the SD *should have* been close to 1.0 in the absence of random measurement error, we can calculate the **prevalence bias** caused by these data quality issues (graph above).
- Overlaid on this same graph (•) is the height-for-age distribution values for 21 USAID-supported survey height-for-age distributions (see **Box D**). The bias for many are within a few-%, **while the bias for some exceed 10%!**

Box E

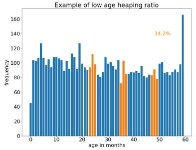
## Clustering near integer ages

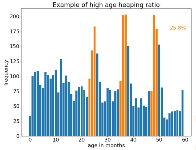
- **Height-for-age data quality review:** as stunting prevalence relies only on measurements of children's height and age, a DQ review of the input distributions showed the following:
  - **no** significant **digit preference** found in the **height distributions**
  - height-for-age z score distributions **sufficiently normal**
  - **however**, strong and consistent peaks in the **age distribution** at **integer-year ages**:

Six age distributions with strong age heaping




- **These features are likely the result of age measurement error.** As described in **Box A**, non-directional measurement error can result in an inflated SD value. **Boxes C** and **E** demonstrate that an inflated SD can result in significant prevalence biases.
- To explore whether these age features are meaningfully related to height-for-age z score SD values, an 'age heaping ratio' quantity was created, defined by the frequency found in the nine months closest to 2, 3, and 4 years (24±1, 36±1, and 48±1 months) divided by the total
  - note that, for a completely age homogeneous distribution, this ratio would be 9/60=15%
  - see **Box D** for results!




Box F

## Conclusions and recommendations

- The simulations and meta analysis presented here have demonstrated that, **due to age-related measurement errors** (see **Boxes F** and **D**), the calculated stunting prevalence rates from the surveys considered are likely **significantly overestimated** (see **Box E**). This challenge, at some level, must be present in other datasets as well.
- The areas of these resilience activities are, by design, challenged. Imperfections in local administrative systems such as birth records should be expected. To recognize these challenges in the future, **a thorough report of the strength of local birth record knowledge and practices should accompany any survey report that relies on their accuracy to calculate high-level outcomes such as stunting rates.**

- Other potential improvement prospects include:
  - include the age distribution and SD value in routine DQ assessments and publish this information in the survey report
  - when stunting results are clearly influenced by measurement error, consider improving the point-estimate via a method such as in **Box E**

Box G

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