# Estimating the changing burden of disease attributable to childhood stunting, wasting and underweight in South Africa for 2000, 2006 and 2012

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**Background.** National estimates of childhood undernutrition display uncertainty; however, it is known that stunting is the most prevalent deficiency. Child undernutrition is manifest in poor communities but is a modifiable risk factor. The intention of the study was to quantify trends in the indicators of child undernutrition to aid policymakers.
**Objectives.** To estimate the burden of diseases attributable to stunting, wasting and underweight and their aggregate effects in South African (SA) children under the age of 5 years during 2000, 2006 and 2012.
**Methods.** The study applied comparative risk assessment methodology. Data sources for estimates of prevalence and population distribution of exposure in children under 5 years were the National Food Consumption surveys and the SA National Health and Nutrition Examination Survey conducted close to the target year of burden. Childhood undernutrition was estimated for stunting, wasting and underweight and their combined 'aggregate effect' using the World Health Organization (WHO) 2006 standard. Population-attributable fractions for the disease outcomes of diarrhoea, lower respiratory tract infections, measles and protein-energy malnutrition were applied to SA burden of disease estimates of deaths, years of life lost, years lived with a disability and disability-adjusted life years for 2000, 2006 and 2012.
**Results.** Among children aged under 5 years between 1999 and 2012, the distribution of anthropometric measurements <−2 standard deviations from the WHO median showed little change for stunting (28.4% v. 26.6%), wasting (2.6% v. 2.8%) and underweight (7.6% v. 6.1%). In the same age group in 2012, attributable deaths due to wasting and aggregated burden accounted for 21.4% and 33.2% of the total deaths, respectively. Attributable death rates due to wasting and aggregate effects decreased from ~310 per 100 000 in 2006 to 185 per 100 000 in 2012.
**Conclusion.** The study shows that reduction of childhood undernutrition would have a substantial impact on child mortality. We need to understand why we are not penetrating the factors related to nutrition of children that will lead to reducing levels of stunting.

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## The article in context

**Evidence before this study.** The first South African Comparative Risk Assessment (SACRA1) study estimated the burden attributable to being underweight as an indicator of undernutrition in children under 5 years of age and in pregnant women for the year 2000. Childhood and maternal underweight ranked twelfth in terms of mortality and sixth in terms of disability-adjusted life years (DALYs) among 17 risk factors evaluated. Among children under 5 years, 12.3% of deaths were attributable to being underweight, which accounted for 10.8% of DALYs in the same age group.
**Added value of this study.** This study applied comparative risk assessment methodology for three time points: 2000, 2006 and 2012. Three national surveys were used to determine the trends in childhood stunting, wasting and underweight and their aggregate effects, and updated evaluation of the epidemiological evidence of the relative risks of health outcomes from the global burden of disease studies was utilised. The study revealed little change in the prevalence of the three indicators of undernutrition between 2000 and 2012, and that in 2012 an estimated 33% of child deaths in SA were attributable to undernutrition.
**Implications of the available evidence.** To reduce the prevalence of child undernutrition, a multisectoral approach is needed. Aside from input from the health sector, addressing undernutrition must include measures that address household poverty and food security, fixing prices of basic foodstuffs and ensuring essential nutrition as a fundamental human right as enshrined in the Constitution. A second essential component to improving nutritional status of children is strengthening the health sector response, particularly at primary healthcare level. Evidence has highlighted the need to monitor the nutritional status of children routinely, as well as to evaluate the programmes currently in place.

Child undernutrition, measured as poor anthropometric status, is internationally recognised as an important public health indicator for monitoring nutritional status and health in populations. The need for better nutrition is recognised in the United Nations Sustainable Development Goal (SDG) target 2, which aims to end all forms of malnutrition by 2030.[1] It is also important to contextualise that at least 12 of the 17 SDGs contain indicators that are highly relevant to nutrition, because undernutrition results not only from a lack of sufficient and adequately nutritious and safe food, but from a host of intertwined factors linking healthcare, education, water, sanitation and hygiene, access to food and resources and more.[2] The goal acknowledges that efforts to combat hunger and malnutrition have advanced significantly since 2000.[3]

Numerous studies have demonstrated the association between increasing severity of anthropometric deficits and mortality, and that undernutrition is an important contributing factor in the mortality and morbidity of children under the age of 5 years in developing countries.[4-6] However, in 2006, new growth standards for categorising undernutrition were based on the World Health Organization (WHO) Multicentre Growth Reference Study (MGRS) that was undertaken between 1997 and 2003 and used breast-fed children as the norm.[7] Depending on the anthropometric measure and the age of the child, the prevalence of undernutrition is often higher when using the new growth standard.

Importantly, adequate nutrition plays a profound role in child health and development, because malnutrition serves as the underlying cause of almost 50% of child deaths.[8] The Global Burden of Disease, Injuries, and Risk Factors Study (GBD) refers to undernutrition as child growth failure, estimated using stunting, wasting and underweight, whereas undernutrition or malnutrition include other risk factors such as iron deficiency and vitamin A deficiency. In this article we refer to the estimation of stunting, wasting and underweight as the risk factor undernutrition.

Stunting is the result of poor nutrition *in utero* and in early childhood. Children suffering from stunting may never attain their full possible height and their brains may never develop to their full cognitive potential. Globally, 144 million children under the age of 5 years suffer from stunting.[9]

Wasting in children is the result of poor nutrient intake and/or disease. Children suffering from wasting have weakened immunity, are susceptible to long-term developmental delays and face an increased risk of death, particularly when wasting is severe. These children require urgent feeding, treatment and care to survive. In 2019, 47 million children under 5 were wasted, of whom 14.3 million were severely wasted.[5]

Underweight in children is mainly caused by inadequate food intake and repeated infections and is an indicator of current undernutrition, in contrast to stunting, which is chronic, and wasting, which indicates severe undernutrition. An estimated 112 million children worldwide are underweight, making malnutrition the most common 'disease' of children.[10]

Undernutrition, defined as the outcome of insufficient food intake and repeated infectious diseases, includes being underweight for one's age, too short for one's age (stunted), dangerously thin (wasted) and deficient in vitamins and minerals or having micronutrient malnutrition.[11]

A systematic review of stunting prevalence in SA[4] reported an overall decline in stunting from 25.4% in 1999 to 19.5% in 2013 in children under 6 years of age; however, geographical and racial differences persist, and these are highly correlated with low socioeconomic status and environmental conditions. The stark inequalities are confirmed in a study conducted in 2018 by Senekal *et al.*[12] in Gauteng and Western Cape provinces, which found that the highest prevalence of stunting (34.5%) prevailed in informal urban areas of Gauteng, while the highest prevalence of underweight (12.2%) was found in rural areas of Gauteng and the Western Cape.

The 2001 WHO Comparative Risk Assessment (CRA) study[13] calculated the attributable burden of underweight resulting from childhood and maternal underweight by making use of a pooled analysis to estimate the increased risk of mortality associated with childhood underweight. The analysis used four categories of underweight based on the 1977 US National Center for Health Statistics (NCHS)/WHO International Growth Reference.[14] SACRA1 made use of the relative risk (RR) estimates from Fishman *et al.*,[13] together with local estimates of the prevalence of mild, moderate and severe childhood underweight, based on the NCHS/WHO growth standards.[15] The 1999 National Food Consumption Survey found that the prevalence of mild, moderate and severe underweight in children under the age of 5 years was 30.0%, 9.7% and 1.9%, respectively.

Recent measurements of stunting, wasting and underweight were defined using *z*-scores, calculated by applying the WHO 2006 standards[7] and the 1977 NCHS/WHO reference to estimate all-cause and cause-specific mortality hazard ratios using proportional hazards models comparing children with mild ($-2 \leq z < -1$), moderate ($-3 \leq z < -2$) or severe ($z < -3$) anthropometric deficits with the reference category ($z \geq -1$).[16] All degrees of underweight, wasting and stunting were associated with significantly increased mortality. The aim of this study was to estimate the burden of disease attributable to stunting, wasting and underweight and their joint effects in SA children under the age of 5 in 2000, 2006 and 2012.

## Methods

In the 2008 series on maternal and child undernutrition published in the *Lancet,*[8] the association of additional anthropometric data with childhood mortality was analysed based on stunting, wasting and underweight in an updated pooled analysis, using the new WHO 2006 growth standard. Olofin *et al.*[16] further updated the pooled analysis, based on data involving children of 1 week - 59 months of age in 10 prospective studies in Africa, Asia and South America. The authors highlight that the mortality burden attributable to childhood undernutrition was considerably different to the results obtained with lower estimates of RR than those of Fishman *et al.*[13]

Childhood undernutrition for this study was estimated using three indicators: stunting, wasting and underweight, and for each of these three indicators mild, moderate and severe categorical prevalence were estimated. The disease burden attributable to childhood undernutrition was estimated by comparing levels of observed prevalence of stunting, wasting and underweight in each category in the SA population with a counterfactual risk factor distribution conferring the lowest possible population risk, as defined by the WHO 2006 reference standard. The theoretical minimum risk exposure level (TMREL) for underweight, stunting and wasting was defined as ≥−1 standard deviation (SD) of the WHO 2006 standard weight-for-age, height-for-age and weight-for-height curves, respectively.

Following the framework developed by the GBD study,[17] the contribution of childhood stunting, wasting and underweight to child mortality was measured indirectly through their contribution as a risk factor for several diseases, and added to the direct effects of undernutrition. The reviewed outcomes were globally significant diseases commonly associated with undernutrition, and included child mortality due to diarrhoeal disease, lower respiratory infections, measles and protein-energy malnutrition (PEM) derived from Olofin *et al.*[16]

The three anthropometric indicators are not independent, and there is a high degree of correlation between stunting, wasting and underweight. To avoid overestimating the total burden, a method was developed in GBD[17] that considers the covariance between them and adjusted the RRs of Olofin *et al.*[16] using data from a meta-analysis by McDonald *et al.*[18] The adjusted RRs for cause-specific mortality based on low height-for-age/length-for-age (stunting), weight-for-height (wasting) and weight-for-age (underweight) categories are presented in Table 1. We also attributed 100% of PEM to childhood wasting and underweight but not stunting.

The reference dates for the anthropometric data and the disease outcomes differed slightly. The data sources for prevalence and population distribution of exposure in children under 5 years (0 - 59 months) are national survey data from the National Food Consumption Survey 1999[19] applied to estimates during 2000 of disease burden, and the National Food Consumption Survey 2005[20] applied to estimates in 2006 of disease burden, as well as the South African National Health and Nutrition Examination Survey (SANHANES-1) 2012 applied to 2012 estimates of disease burden.[21]

Population attributable fractions (PAFs) by cause were calculated by a multilevel extension of the usual attributable fraction formula, as follows:

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

where $P_i$ is the prevalence of exposure level $i$; $RR_i$ is the RR of disease in exposure level $i$; $P'_i$ is the proportion of population in exposure category $i$ in the counterfactual distribution and $n$ is the total number of exposure levels.

### Estimating the joint effects of childhood undernutrition as a risk factor

As these multiple risk factors affect the same outcomes, a multiplicative aggregation of the PAFs of the individual risk factors was used; however, because all three indicators are based on two independent measures (height and weight), the aggregate effect for wasting and underweight were calculated,[22] as follows:

$$\text{aggregate PAF} = 1\text{-}(1\text{-PAF}_{wasting}) * (1\text{-PAF}_{underweight}).$$

A standardised burden of disease approach was used to adjust for underreporting of deaths in the vital registration and the ill-defined causes were redistributed proportionately across defined causes by age and sex.[23] The PAFs were then applied to SA burden of disease estimates of deaths, years of life lost (YLLs), years lived with a disability (YLDs) and DALYs for the relevant diseases for 2000, 2006 and 2012.[24]

Monte Carlo simulation modelling techniques were used to estimate bounds of uncertainty using Ersatz Add-in Version 1.35 for Microsoft Excel (Microsoft Corp., USA).[25] For the mild, moderate and severe exposure categories for underweight, wasting and stunting, a Dirichlet distribution (a conjugate of the multinomial distribution) was specified that ensures that the returned random deviates (with beta distributions) always sum to 1. For the RR input variables we used the Ersatz function ErRelativeRisk. For each of the output variables (i.e. attributable YLLs, YLDs and DALYs in SA for 2000, 2006 and 2012 for child underweight, wasting, stunting and the aggregate effects of these risks), 95% uncertainty intervals (UIs) were calculated, bounded by the 2.5th and 97.5th percentiles of 2000 iteration values generated.

## Results

Between 1999 and 2012 the distribution of anthropometric measurements <−2 SD from the MGRS median showed barely any change for stunting (28.4% v. 26.6%), wasting (2.6% v. 2.8%) and underweight (7.6% v. 6.1%) (Fig. 1). The PAFs of mortality due to the selected outcomes, the attributable burden due to death and DALYs, the attributable burden as a proportion of the total child burden and the total population burden are shown in Table 2. The results demonstrate the size of the contribution of each risk outcome to the PAFs, showing the relatively smaller contribution that diarrhoea, lower respiratory infection and measles make to stunting and underweight, compared with their more substantial contribution, including PEM, to wasting and the combined aggregate effects. In 2012, attributable deaths due to wasting and aggregated burden accounted for 21.4% and 33.2% of the total deaths in children under 5 years of age, respectively. The attributable DALYs due to wasting and aggregated burden accounted for 20.2% and 20.8% of total DALYs in this age group, respectively.

Interpreting the trend in child undernutrition status, it is important to note that under-5 mortality began to decline significantly after 2006, mostly due to decreasing numbers of children dying due to HIV infection; therefore, proportionally more children began dying from other conditions after this period.[26] The attributable

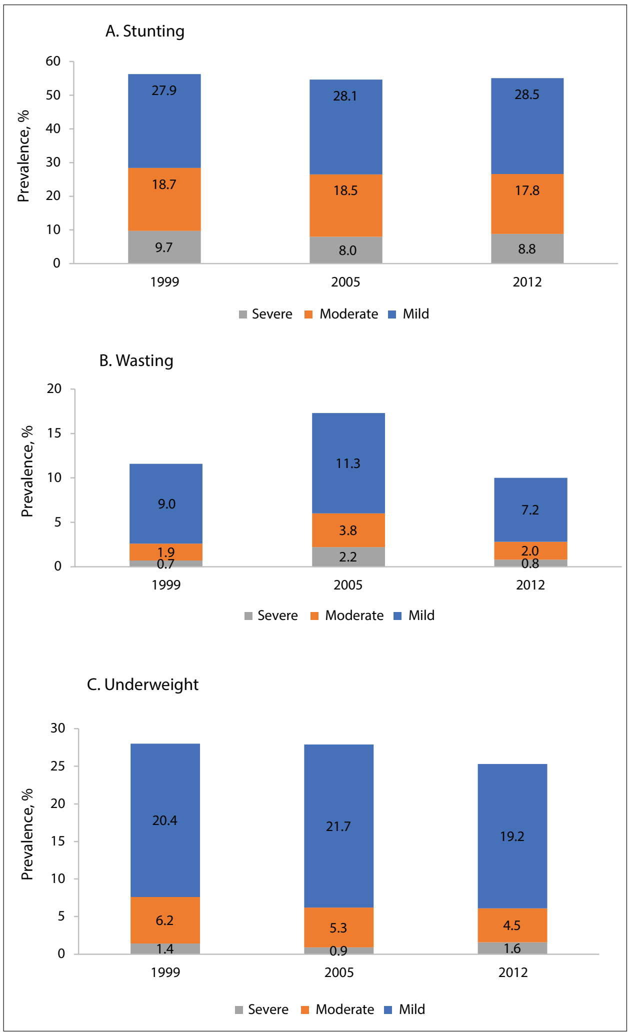


*Fig. 1. Distribution of (A) stunting, (B) wasting and (C) underweight categories in children under 5 years of age in South Africa for 1999, 2005 and 2012.*

**Table 1. Adjusted relative risks or population attributable fraction for each risk-outcome pair for child growth failure**

| Disease outcome | Stunting: height-for-age/ length-for-age, *z*-score (CI) | Wasting: weight-for-height/ length-for-age, *z*-score (CI) | Underweight: weight-for-age, *z*-score (CI) |
|---|---|---|---|
| Diarrhoea | z≥−1 Ref. | z≥−1 Ref. | z≥−1 Ref. |
| | z≥−1: 1.111 (1.023 - 1.273) | z≥−1: 6.601 (2.158 - 11.243) | z≥−1: 1.088 (1.046 - 1.134) |
| | z≥−2: 1.222 (1.067 - 1.500) | z≥−2: 23.261 (9.020 - 35.845) | z≥−2: 1.23 (1.163 - 1.314) |
| | z≥−3: 1.851 (1.280 - 2.699) | z≥−3: 105.813 (42.198 - 157.813) | z≥−3: 2.332 (2.076 - 2.802) |
| Lower respiratory infections | z≥−1 Ref. | z≥−1 Ref. | z≥−1 Ref. |
| | z≥−1: 1.125 (0.998 - 1.655) | z≥− 1: 5.941 (1.972 - 11.992) | z≥−1: 1.145 (1.044 - 1.364) |
| | z≥−2: 1.318 (1.014 - 2.165) | z≥− 2: 20.455 (70.840 - 37.929) | z≥−2: 1.365 (1.215 - 1.755) |
| | z≥−3: 2.355 (1.150 - 5.114) | z≥−3: 47.67 (15.923 - 94.874) | z≥− 3: 2.593 (1.908 - 4.39) |
| Measles | z≥−1 Ref. | z≥−1 Ref. | z≥−1 Ref. |
| | z≥−1: 1.103 (0.861 - 1.719) | z≥−1: 1.833 (0.569 - 8.965) | z≥−1: 0.995 (0.500 - 1.726) |
| | z≥−2: 1.54 (1.029 - 3.222) | z≥−2: 8.477 (1.130 - 42.777) | z≥−2: 2.458 (1.260 - 5.118) |
| | z≥−3: 2.487 (1.129 - 6.528) | z≥−3: 37.936 (5.088 - 199.126) | z≥−3: 5.668 (1.767 - 12.414) |
| Protein-energy malnutrition | 0% PAF | 100% PAF | 100% PAF |

CI = confidence interval; Ref. = reference; PAF = population attributable fraction.
Source: GBD 2017 Risk Factor Collaborators.[17]

death rates for the three indicators (Fig. 2) show the same declining pattern as all-cause mortality; however, as a proportion of total child deaths the contribution of the aggregate effects of undernutrition increased (Fig. 2, dotted line).

The contribution of the morbidity component of YLDs is negligible compared with that of the mortality component of YLLs for all indicators of child undernutrition (Fig. 3), highlighting that the dominant burden is from premature mortality rather than non-fatal outcomes.

Fig. 4 shows the breakdown of the diseases resulting in deaths attributable to undernutrition. The relative contribution of diarrhoea, lower respiratory infections, PEM and measles is consistent across wasting, underweight and aggregate effects, while stunting has no deaths attributed to PEM. However, the numbers of deaths make it clear that the magnitude of burden is far more manifest in wasting and the aggregate effects than in stunting and underweight.

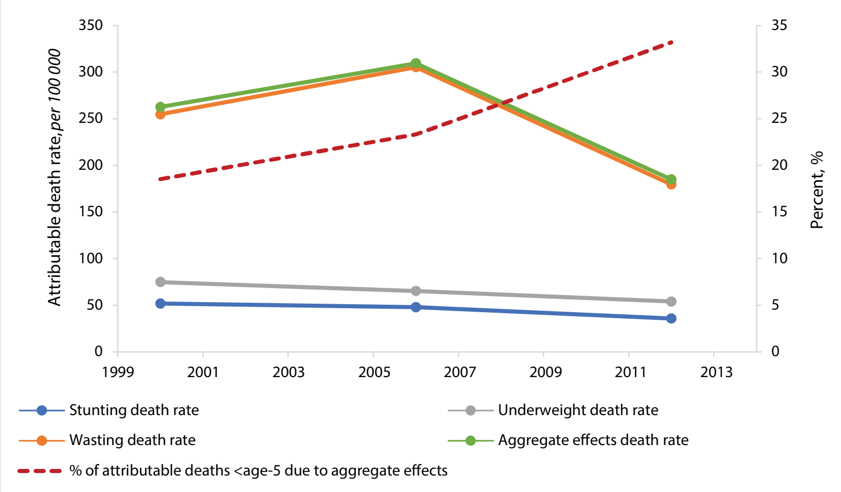


*Fig. 2. Trend in attributable death rates (per 100 000) due to undernutrition and trend in the proportion of attributable deaths due to aggregate effects of undernutrition in children under 5 years of age.*

## Discussion and conclusion

The findings of this study highlight the substantial burden due to undernutrition status in children younger than 5 years in SA over the period 2000 - 2012. In 2012, 10 549 deaths were attributable to the aggregate effects (based on assuming independence of two dimensions of undernutrition), accounting for 33.2% (95% UI 33.2 - 33.2) of deaths in this age group.

Two interesting themes that emerged from the results (Fig. 2) are, firstly, that the increasing death rates attributable to the three indicators of undernutrition and their aggregate effects mirror the pattern of all-cause mortality.[27] The increase in the under-5 mortality rate is accompanied by a corresponding increase in the proportion of HIV/AIDS deaths (35% in 2000 - 47% in 2006), while the decrease in the rate is accompanied by a substantial drop of the HIV/AIDS proportion to 19% in 2012.[26] As this large proportion decreases, the contribution of the proportions of other causes of death in children increases. This is demonstrated by the attributable death rates for the three indicators (Fig. 2), showing the same declining trend as all-cause mortality; however, as a proportion of total child deaths, the contribution of the aggregate effects of undernutrition increases.

The second theme is the pattern of the relative contributions of the indicators, whereby wasting and aggregate effects contribute substantively more burden than stunting and underweight, and the major burden is accounted for by the mortality component of DALYs. This is due to the predominant role that PEM plays in the manifestation of severe acute malnutrition and related mortality, and therefore needs to be closely monitored. Schneider *et al.*[28] describe health system strengthening interventions that created ‘enabling environments’ for maternal and child nutrition in three rural districts in Mpumalanga Province, which resulted in significant declines in hospital admissions for severe acute malnutrition over a 5-year period (2013/2014 - 2017/2018). The authors attribute the success to national policy, evidence-based guidelines and local child mortality audits playing important roles in creating district-wide attention and commitment to addressing malnutrition. The article concludes that district health system strengthening interventions and the manner in which these were implemented produced three kinds of system-level change that together achieved success. These are knowledge and use of evidence by

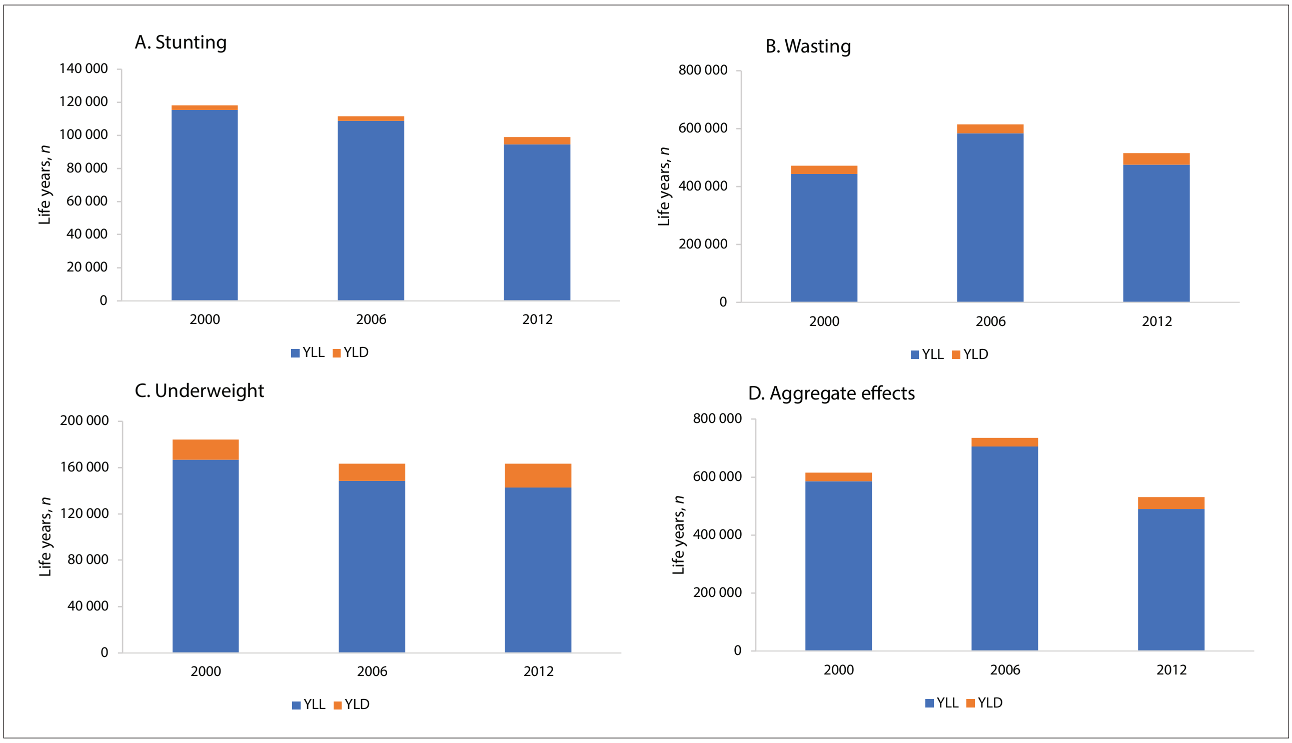


*Fig. 3. Fatal (YLLs) and non-fatal (YLDs) life years attributable to (A) stunting, (B) wasting, (C) underweight and (D) aggregate effects for 2000, 2006 and 2012. (YLLs = years of life lost; YLDs = years lived with a disability.)*

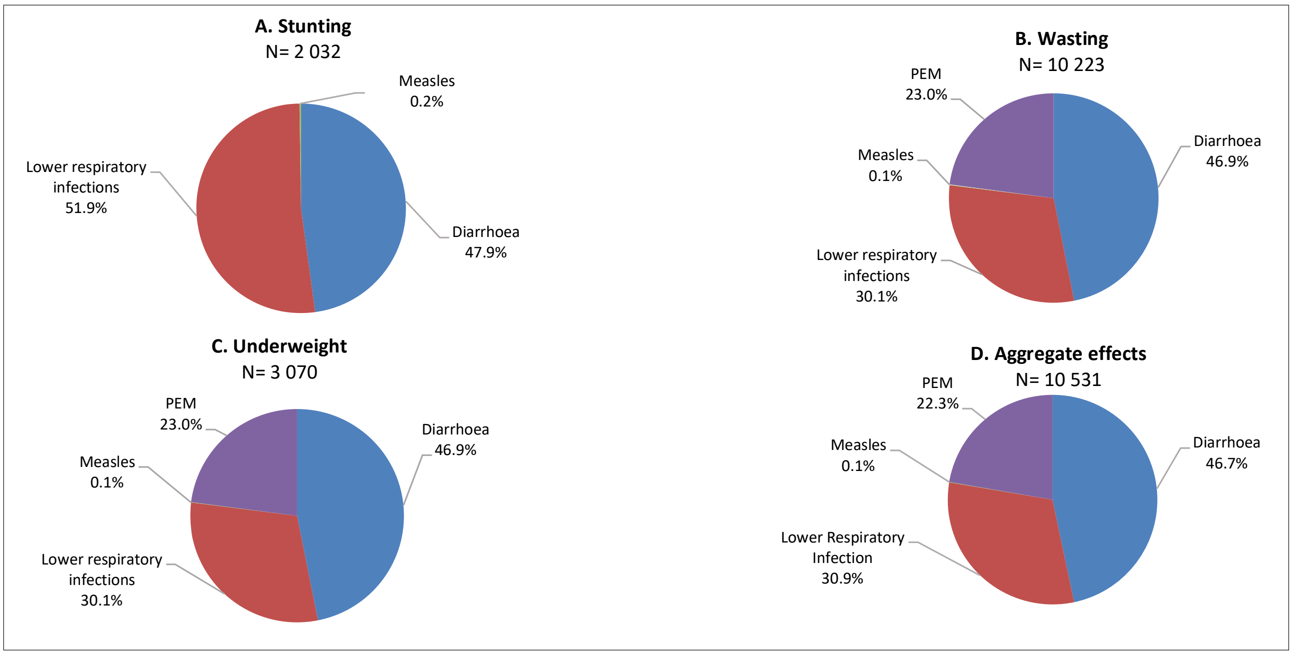


*Fig. 4. Attributable deaths due to (A) stunting, (B) wasting, (C) underweight and (D) aggregate effects by disease outcome for 2012. (PEM= protein-energy malnutrition.)*

providers and managers ('ways of thinking'), leadership, participation and co-ordination ('ways of governing') and inputs and capacity ('ways of resourcing').

This study has used a regular series of anthropometric data for children (1999 - 2012). Anthropometric measurements <-2 SD from the MGRS median showed barely any change over the period for stunting (28.4 - 26.6%), wasting (2.6 - 2.8%) and underweight (7.6 - 6.1%). Furthermore, the 2016 Demographic and Health Survey[29] reported the prevalence of stunting (27.4%), wasting (2.5%) and underweight (5.9%), suggesting a slight decrease in underweight but no change in stunting or wasting. These high levels of child undernutrition have persisted for many years, and it is against this baseline that the COVID-19 pandemic exacerbated poverty and hunger, raising concerns about the impact of nutritional status in children.[30]

Aside from these national surveys, the national income dynamics surveys also provide assessment of the nutritional status of children; however, the estimated prevalence of children at risk is notably

**Table 2. Related outcomes and their attributable fractions to mortality and burden of childhood stunting, wasting and underweight and aggregated burden, South Africa for 2000, 2006 and 2012**

| | Stunting | | | Wasting | | | Underweight | | | Aggregate effect of childhood undernutrition | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Disease outcomes** | **AF, %** | **Deaths, *n*** | **DALYs, *n*** | **AF, %** | **Deaths, *n*** | **DALYs, *n*** | **AF, %** | **Deaths, *n*** | **DALYs, *n*** | **AF, %** | **Deaths, *n*** | **DALYs, *n*** |
| **2000** | | | | | | | | | | | | |
| Diarrhoeal disease | 13.4 | 1 393 | 67 413 | 62.4 | 6 478 | 313 481 | 4.8 | 502 | 24 302 | 64.2 | 6 667 | 322 614 |
| Lower respiratory infections | 19.0 | 1 086 | 50 594 | 53.3 | 3 042 | 141 715 | 6.9 | 396 | 18 436 | 56.5 | 3 227 | 150 326 |
| Measles | 21.5 | 4 | 216 | 32.2 | 7 | 324 | 13.4 | 3 | 135 | 41.3 | 9 | 415 |
| Protein-energy malnutrition | - | - | - | 100 | 2 687 | 141 326 | 100 | 2 687 | 141 328 | 100 | 2 687 | 141 328 |
| **Total burden** (95% UI) | - | **2 484** (1 332 - 3 562) | **118 224** (63 842 - 168 862) | - | **12 214** (9 950 - 13 945) | **596 846** (488 282 - 679 876) | - | **3 588** (3 331 - 3 879) | **184 201** (171 961 - 198 011) | - | **12 590** (10 463 - 14 232) | **614 683** (512 544 - 692 583) |
| **% of total child burden (95% UI)** | - | **3.7 (2.0 - 5.2)** | **3.5 (1. 9 - 4.9)** | - | **18.0 (14.6 - 20.5)** | **17.4 (14.3 - 19.9)** | - | **5.3 (4.9 - 5.7)** | **5.4 (5.0 - 5.8)** | - | **18.5 (23.5 - 25.9)** | **17.9 (22.7 - 25.0)** |
| **% of total all-age burden (95% UI)** | - | **0.5 (0.3 - 0.7)** | **0.6 (0.3 - 0.9)** | - | **2.4 (2.0 - 2.8)** | **3.1 (2.6 - 3.6)** | - | **0.7 (0.7 - 0.8)** | **1.0 (0.9 - 1.0)** | - | **2.5 (2.1 - 2.8)** | **3.2 (2. 7 - 3.6)** |
| **2006** | | | | | | | | | | | | |
| Diarrhoeal disease | 12.3 | 1 313 | 63 570 | 79.1 | 8 443 | 408 924 | 4.0 | 432 | 20 923 | 79.9 | 8 534 | 413 299 |
| Lower respiratory infections | 17.5 | 1 021 | 47 593 | 69.9 | 4 092 | 190 656 | 6.0 | 352 | 16 409 | 71.7 | 4 198 | 195 595 |
| Measles | 19.8 | 7 | 326 | 54.3 | 19 | 893 | 5.9 | 2 | 98 | 57.1 | 20 | 938 |
| Protein-energy malnutrition | - | - | - | 100 | 2 411 | 125 952 | 100 | 2 411 | 125 952 | 100 | 2 411 | 125 952 |
| **Total burden** (95% UI) | - | **2 341** (1 264 - 3 405) | **111 490** (60 597 - 161 582) | - | **14 969** (13 383 - 16 094) | **726 671** (651 046 - 780 031) | - | **3 213** (2 960 - 3 486) | **164 139** (152 180 - 176 982) | - | **15 170** (13 657 - 16 250) | **736 148** (663 884 - 787 675) |
| **% of total child burden (95% UI)** | - | **2.9 (1. 6 - 4.2)** | **2.7 (1.5 - 4.0)** | - | **18.4 (16.4 - 19.8)** | **17.8 (15.9 - 19.1)** | - | **3.9 (3.6 - 4.3)** | **4.0 (3.7 - 4.3)** | - | **23.3 (23.3 - 23.3)** | **18.0 (16.3 - 19.3)** |
| **% of total all-age burden (95% UI)** | - | **0.3 (0.2 - 0.5)** | **0.4 (0.2 - 0.6)** | - | **0.2 (0.2 - 0.2)** | **2.9 (2.6 - 3.1)** | - | **0.2 (0.2 - 0.2)** | **0.7 (0.6 - 0.7)** | - | **2.2 (2.0 - 2.4)** | **2.9 (2.6 - 3.1)** |
| **2012** | | | | | | | | | | | | |
| Diarrhoeal disease | 12.7 | 973 | 49 450 | 62.7 | 4 796 | 243 861 | 4.5 | 354 | 17 988 | 64.4 | 4 930 | 250 512 |
| Lower respiratory infections | 18.1 | 1 055 | 49 164 | 52.7 | 3 082 | 143 570 | 6.4 | 381 | 17 735 | 55.8 | 3 261 | 151 943 |
| Measles | 20.4 | 5 | 229 | 33.5 | 8 | 377 | 6.3 | 1 | 71 | 37.7 | 9 | 424 |
| Protein-energy malnutrition | - | - | - | 100 | 2 349 | 128 043 | 100 | 2 349 | 128 043 | 100 | 2 349 | 128 043 |

**...continued...**

**Table 2. (continued) Related outcomes and their attributable fractions to mortality and burden of childhood stunting, wasting and underweight and aggregated burden, South Africa for 2000, 2006 and 2012**

| | Stunting | | | Wasting | | | Underweight | | | Aggregate effect of childhood undernutrition | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Disease outcomes | AF, % | Deaths, *n* | DALYs, *n* | AF, % | Deaths, *n* | DALYs, *n* | AF, % | Deaths, *n* | DALYs, *n* | AF, % | Deaths, *n* | DALYs, *n* |
| **Total burden** (95% UI) | - | **2 033** (1 053 - 2 952) | **98 843** (51 501 - 142 695) | - | **10 236** (8 502 - 11 541) | **515 805** (431 308 - 508 206) | - | **3 085** (2 860 - 3 335) | **163 837** (153 127 - 175 897) | - | **10 549** (8 890 - 11 780) | **530 922** (450 410 - 591 461) |
| **% of total child burden (95% UI)** | - | **4.3 (2.2 - 6.2)** | **3.9 (2.0 - 5.6)** | - | **21.4 (17.8 - 24.2)** | **20.2 (16.9 - 22.7)** | - | **6.5 (6.0 - 7.0)** | **6.4 (6.0 - 6.9)** | - | **33.2 (33.2 - 33.2)** | **20.8 (17.6 - 23.1)** |
| **% of total all-age burden (95% UI)** | - | **0.4 (0.2 - 0.6)** | **0.5 (0.3 - 0.7)** | - | **1.9 (1.6 - 2.1)** | **2.5 (2.1 - 2.8)** | - | **0.2 (0.2 - 0.2)** | **0.8 (0.7 - 0.9)** | - | **2.0 (1.7 - 2.2)** | **2.6 (2.2 - 2.9)** |

AF = attributable fraction based on the numbers of attributable deaths; DALY = disability-adjusted life year; UI = uncertainty interval.

lower. For example, Sartorius *et al.*[31] found a decline in stunting among children under 5 years, from 11.0% to 7.6% ($p$=0.007) between 2008 and 2017, and a decline in wasting from 5.2% to 3.8% ($p$=0.131). In contrast, the study by Senekal *et al.*,[12] representing a similar period, found levels of child undernutrition that were strongly aligned with the results of SANHANES-1.[21]

Although this study notes an improved series of national surveys, shortcomings remain in the collection of indicators related to a more holistic understanding of nutritional status. Among the primary limitations is the lack of assessment due to maternal undernutrition before and after pregnancy, as this is a risk factor for increased intrauterine growth retardation leading to low birthweight,[32] which predisposes to stunting, and is further associated with increased mortality risk.[33] Concerning in this regard is SA's lack of accurate, nationally representative preterm birth estimates, restricting epidemiological understanding of preterm birth and the extent to which health services can respond appropriately.[34]

Also, this study underestimates the true burden of childhood undernutrition, because the analysis does not quantify the impact that undernutrition has on childhood development.

Globally, nutrition-related factors contribute to ~45% of deaths in children under the age of 5 years.[35] This analysis shows that about 33% of child deaths were attributable to undernutrition in SA in 2012. SDG 2 aims to end hunger and achieve food security and improved nutrition, specifically targeting undernutrition – to reduce the number of stunted children by 40% by 2025, and to reduce and maintain childhood wasting at <5%. Although SA has met the target related to wasting, it is the largest contributor to deaths related to undernutrition; hence there is a need to reduce it further. Moreover, we need to understand which factors will have an impact on the levels of stunting.

National Department of Health policy has advocated for a multisectoral approach to combat malnutrition, focusing on the life-cycle concept of the first 1 000 days.[36] While the evidence on what is required to prevent and address child undernutrition is well established, the maternal and child nutrition series published in the *Lancet*[37] went further by identifying a gap in understanding how national commitments to child nutrition are translated and how to secure implementation sub-nationally, and called for more research on how to shape and sustain enabling environments for nutrition.

Other middle- and lower-income countries experiencing transition, such as Brazil and India, which also place emphasis on the first 1 000 days of life, have implemented multisectoral approaches that have resulted in noteworthy decreases in stunting. In a little over 30 years the prevalence of stunting in Brazilian children aged under 5 years decreased from 37.4% to 7.1% (1974 - 2007). The factors that this success is attributed to are important for SA to consider, and include: strong political commitment to improving purchasing power among the poor; levels of female education; safe water, hygiene and sanitation; and access to basic healthcare.[38,39] In India, the Mother-Child Health and Nutrition Mission[33] focused on promoting behavioural changes by convincing policymakers of the importance of targeting the first 1 000 days of life to effect meaningful change through active citizenry and the know-how to measure the impact of the interventions. The results yielded a 50% reduction in the prevalence of stunting in children under 2 years of age between 2005 and 2012.

A recent systematic review[40] of community-level interventions for improving access to food in low- and middle-income countries found little impact on the indicators we investigated. For instance, the review showed that unconditional cash transfers may reduce stunting (although based on low-quality evidence); however, it was very uncertain whether unconditional cash transfers reduced wasting. The effect of conditional cash transfers may make little to no difference to stunting or wasting, although the evidence was assessed to be of low quality. Provision of food vouchers probably reduced stunting (moderate-quality evidence), but resulted in little to no difference in wasting (low-quality evidence), as was the effect of social support interventions such as community grants.[40]

There has been uncertainty regarding the prevalence of childhood undernutrition; however, after reviewing prevalence data from national surveys, we selected national surveys that appeared to provide a more consistent trend over this period. Approximately one-third of children under age 5 are stunted and although levels of wasting and underweight are much lower, the prevalence of all three indicators has remained largely unchanged in post-apartheid SA. Although limited in number, the implementation of health facility systems intervention has seen success in addressing severe acute malnutrition, while internationally community-level interventions for improving access to food show little impact on child undernutrition. Reducing levels of wasting and stunting is a priority and requires understanding of the actions needed for a sustained reduction in levels of stunting in children.

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