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Trends of mortality attributable to child and maternal undernutrition, overweight/obesity and dietary risk factors of non-communicable diseases in sub-Saharan Africa, 1990–2015: findings from the Global Burden of Disease Study 2015

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Abstract

Objective: To assess trends of mortality attributable to child and maternal undernutrition (CMU), overweight/obesity and dietary risks of non-communicable diseases (NCD) in sub-Saharan Africa (SSA) using data from the Global Burden of Disease (GBD) Study 2015.

Design: For each risk factor, a systematic review of data was used to compute the exposure level and the effect size. A Bayesian hierarchical meta-regression analysis was used to estimate the exposure level of the risk factors by age, sex, geography and year. The burden of all-cause mortality attributable to CMU, fourteen dietary risk factors (eight diets, five nutrients and fibre intake) and overweight/obesity was estimated.

Setting: Sub-Saharan Africa.

Participants: All age groups and both sexes.

Results: In 2015, CMU, overweight/obesity and dietary risks of NCD accounted for 826 204 (95 % uncertainty interval (UI) 737 346, 923 789), 266 768 (95 % UI 189 051, 353 096) and 558 578 (95 % UI 453 433, 680 197) deaths, respectively, representing 10·3 % (95 % UI 9·1, 11·6 %), 3·3 % (95 % UI 2·4, 4·4 %) and 7·0 % (95 % UI 5·8, 8·3 %) of all-cause mortality. While the age-standardized proportion of all-cause mortality accounted for by CMU decreased by 55·2 % between 1990 and 2015 in SSA, it increased by 63·3 and 17·2 % for overweight/obesity and dietary risks of NCD, respectively.

Conclusions: The increasing burden of diet- and obesity-related diseases and the reduction of mortality attributable to CMU indicate that SSA is undergoing a rapid nutritional transition. To tackle the impact in SSA, interventions and international development agendas should also target dietary risks associated with NCD and overweight/obesity.

Keywords
Child and maternal undernutrition
Overweight and/or obesity
Dietary risks of non-communicable diseases
Double burden of malnutrition
Mortality

Long-standing food and nutrition insecurity in sub-Saharan Africa (SSA) has caused a high burden of communicable, maternal, neonatal and nutritional (CMNN) diseases[1,2] and economic loss[3]. In recent years, however, the unprecedented rising burden of non-communicable diseases (NCD)[4] associated with increased metabolic[5] and behavioural risks[6,7] is a major public health concern. Particularly, dietary risk factors and overweight/obesity

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are the major contributors to the rising burden of NCD in the region[6,8]. Available data suggest that the consumption of processed foods in SSA[9] and the prevalence of obesity[10] in the region have increased significantly over the past two decades. Obesity rates[11] have increased while rates of undernutrition, especially stunting among children, have stagnated[12], hence translating into the double burden of malnutrition, a phenomenon characterized by the coexistence of undernutrition, overweight/obesity and diet-related NCD[13]. The majority of intervention efforts in SSA still focus on addressing child and maternal undernutrition (CMU). Investigating the impact of the double burden is imperative to design appropriate interventions.

As part of the Global Burden of Disease (GBD) studies, a recent analysis demonstrated the increasing prevalence of overweight/obesity and related burden of disease at the global level. The study reported that 4 million deaths were attributable to excess body weight worldwide in 2015[11]. Another study also found different levels (prevalence and rate) of nutrition-related disorders and diseases (such as low birth weight, stunting, underweight, infant mortality rate, overweight/obesity and NCD mortality) in forty SSA countries[14]. However, these studies did not comprehensively look at the impact of the double burden because they did not include important risk factors and/or did not focus on SSA. In addition, although studies have shown the presence of the double burden of malnutrition (high rates of undernutrition, increasing prevalence of overweight/obesity and diet-related NCD) in SSA[15–17], the proportion and trend of mortality attributable to this phenomenon have not been investigated at different levels (SSA, SSA sub-regions and countries). One of the challenges in SSA, where the health infrastructure is poor, is the limited epidemiological data that are readily or reliably available[18], particularly on overweight/obesity and dietary risk factors of NCD. In the current paper, using the GBD 2015 data[19], we aimed to assess the impact of the double burden of malnutrition, specifically by reporting and comparing estimates and mortality trends associated with CMU, overweight/obesity and dietary risk factors of NCD in SSA between 1990 and 2015. We examined the patterns of attributable mortality by year, sex and age across the SSA sub-regions and countries.

Methods

Study overview

GBD is a large epidemiological study that measures and evaluates health status and its determinants across the global population. It includes assessments of diseases, injuries, sequelae and risk factors. In particular, the 2015 GBD risk factors study covers seventy-nine risk factors of health across seven regions, twenty-one sub-regions and 195 countries[2]. The study uses a comparative risk assessment approach, which is a causal web and hierarchy of risk factors that enables the quantification of risk factors and their impact on health at different levels[20]. In the framework, risk factors are organized in four hierarchies. The first hierarchy includes three categories of risk factor clusters: behavioural (including CMU and dietary risks of NCD), environmental/occupational and metabolic (including overweight/obesity). The second (seventeen risk factors) and third (forty-four risk factors) levels contain both granular and cluster risks from within the first level. At the last level (seventy-nine risk factors), granular risk factors are included[2]. A detailed description of the GBD 2015 risk factors study methods has been published elsewhere[2,21].

A summary framework of the risk factors that were included in the current study by each of the hierarchies is depicted in Fig. 1. In the current study, we used the GBD databases[19] to specifically examine the mortality burden attributable to twenty-three behavioural and metabolic risk factors (level 4), which were under CMU and the dietary risks of NCD, including overweight/obesity. The current study focused on SSA which covers five sub-regions (Northern, Eastern, Western, Southern and Central SSA) and fifty-four countries. Assignment of countries in the sub-regions was based on the GBD geographical classifications. We highlight methods specific to the current study in the following sections.

Selection of risk factors

Using the World Cancer Research Fund grading system, risk–disease pairs with convincing or probable evidence were included in the GBD 2015 risk factors study[2,22]. CMU included suboptimal breast-feeding (non-exclusive (receiving predominant, partial or no breast-feeding in children younger than 6 months) and discontinued breast-feeding (not able to receive breast milk in children aged 6–23 months)), child undernutrition (childhood stunting, underweight and wasting), and Fe, Zn and vitamin A deficiencies. Dietary risks of NCD comprised fourteen factors, including eight diets (diets low in fruits, vegetables, milk, nuts and seeds, and whole grains; diets high in processed meat, red meat and sugar-sweetened beverages), five nutrients (diets low in seafood *n*-3 fatty acids, Ca and PUFA; diets high in Na and SFA) and fibre intake (Fig. 1). A BMI of 25·0 kg/m^2 or more was considered the cut-off for being at risk of different diseases including cancer, CVD and musculoskeletal disorders[2]. Specific methods of incidence, prevalence and burden of disease associated with overweight/obesity estimates have been published elsewhere[11]. The list, definition and global data representativeness index (calculated by dividing the number of countries with risk factors data by the total number of countries in the world and multiplying by 100) of the risk factors are provided in the online supplementary material, Supplemental Table 1.

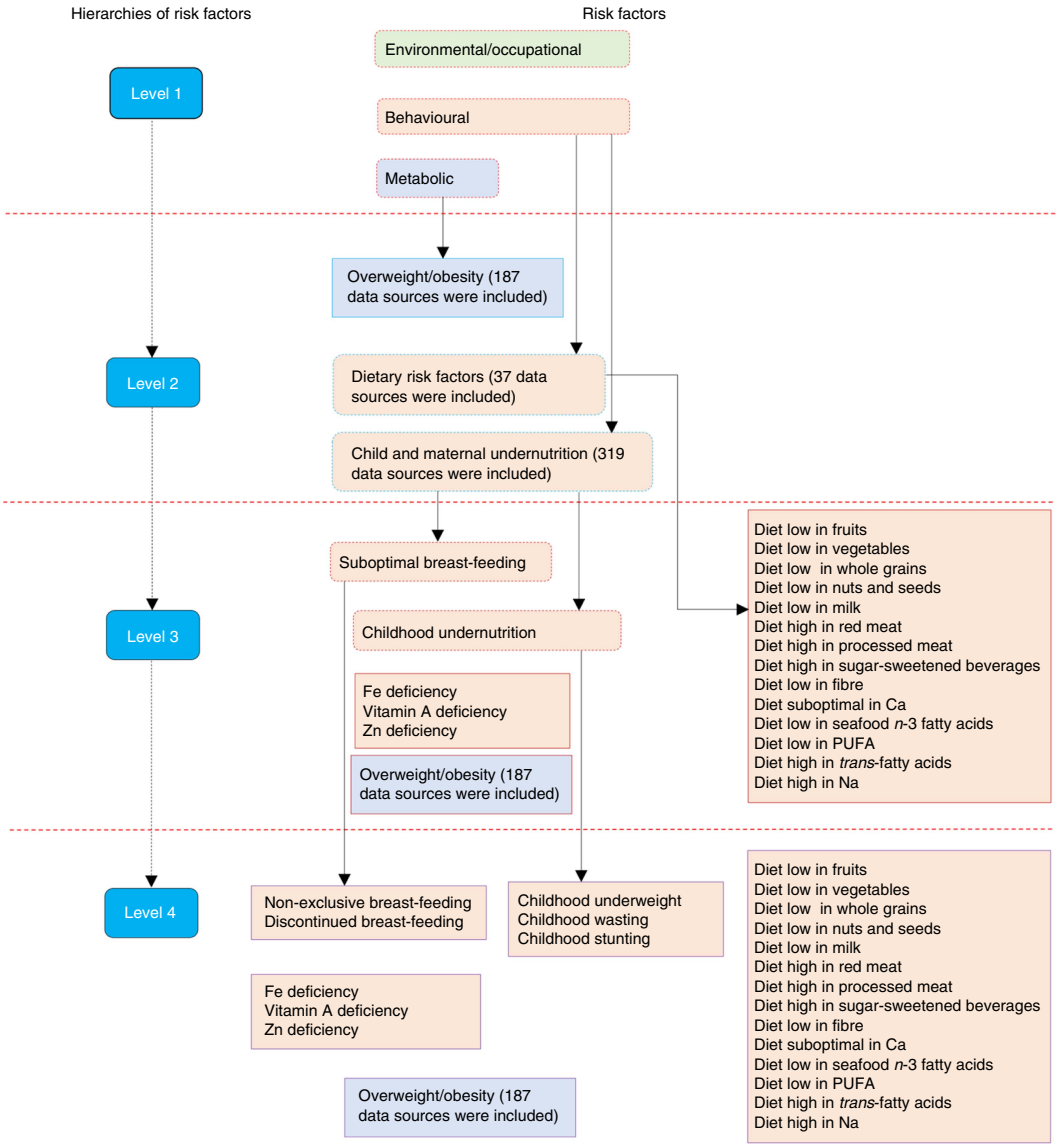

Fig. 1 (colour online) Hierarchies of included risk factors (adapted from the Global Burden of Disease (GBD) 2015 risk factors study[2]). The figure depicts a summary of child and maternal undernutrition, dietary risk factors of non-communicable diseases and overweight/obesity as risk factors of mortality; more detailed methods can be accessed elsewhere[2]

Data sources and exposure levels

For each risk factor, the literature was systematically searched to identify studies that could potentially provide exposure levels. In the GBD 2015 risk factors study, a total of 543 data sources were included to determine the exposure levels of CMU (*n* 319), overweight/obesity (*n* 187) and dietary risk factors of NCD (*n* 37) in SSA (Fig. 1). In the online supplementary material, Supplemental Tables 2, 3 and 4, we provide the lists of these data sources. Data sources by sub-regions and countries can also be accessed on the Global Health Data Exchange (http://ghdx.healthdata.org/gbd-2015/data-input-sources).

For CMU, data were mainly obtained from demographic and health surveys, microdata of surveys, reproductive and health surveys, multiple indicator cluster surveys and living standards measurement surveys, scientific literature, FAO food balance sheets, and UNICEF and WHO databases. Data from the National Center for Health Statistics/WHO (the NCHS reference) were also used[2].

Multiple data sources, including FAO food balance sheets, household budget surveys, FFQ, and single as well as multiple diet recall surveys were used to estimate exposure levels of dietary risks for NCD. For *trans*-fatty acids, availability of packaged foods containing partially hydrogenated vegetable oil was used. Data of urinary Na and sugar-sweetened beverages were not adjusted to 8368 kJ/d (2000 kcal/d), unlike other dietary risk factors. For overweight/obesity, data were collated from surveys, longitudinal studies, published literature which provided both measured or self-reported height and weight, and

national or sub-national estimates of BMI, overweight and obesity[2].

Two modelling strategies were used to estimate the exposure levels for the risk factors: a spatiotemporal Gaussian process regression model (ST-GPR) and a Bayesian meta-regression model (DisMod-MR 2.1). These are mixed-effect models that borrow information across geographic location, age, sex and time. These approaches allow for the pooling of data from different sources and for adjustment of bias. Informative covariates are also able to be incorporated to assist in the predictions for locations in time where there was an absence of data. Adjustments were made including age–sex splitting, adding study-level covariates and bias correction for all risk factors[2,23,24].

ST-GPR is a modelling strategy that helps to estimate magnitude of health problems while using multiple and noisy data and helps to interpolate non-linear trends across time and geography without an assumption that the feature of data follows a definitive functional form. ST-GPR assumes a Gaussian process defined by mean and covariance functions[24,25]. DisMod-MR 2.1 is a computational engine designed to combine data using Bayesian statistical methods. It has a capacity to organize data at each geographic and analytical level. The analysis was performed at five hierarchies: global, super-region, region, country and sub-national (where applicable)[23,26,27].

For the dietary risks for NCD, first, ST-GPR was applied using the FAO data to model the availability of nutrients and foods. Then, DisMod-MR 2.1 was used to model the intake of each food group and nutrient and to account for study-level covariates (see online supplementary material, Supplemental Table 5). DisMod's ODE solver was utilized to generate a global age trend based on the diet recall data. This age trend was then applied to the FAO results to produce age-specific estimates of food and nutrient availability. Detailed methods are published elsewhere[2,28].

Relative risks

Relative risks of risk–disease pairs were obtained from meta-analyses of prospective observational studies or randomized controlled trials. For non-exclusive breast-feeding, a relative risk was determined using the associations with lower respiratory tract infection and diarrhoea. Discontinued breast-feeding was paired with diarrhoea only. The relative risks of wasting, stunting and underweight were adjusted using an algorithm that accounts for covariance between the three undernutrition indicators. Relative risks for Zn deficiency were estimated based on the results of clinical trials. The data sources for the relative risks have been described elsewhere[2].

For dietary data, relative risks were obtained from most recent meta-analyses of prospective observational studies, and if available, from randomized controlled trials. Metabolic mediators (BMI, total serum cholesterol, fasting plasma glucose and systolic blood pressure) were considered in the calculation (see online supplementary material, Supplemental Table 5). Due to scarce (inconclusive) evidence, for sugar-sweetened beverages and Na, relative risks were estimated using BMI and systolic blood pressure, respectively. The relative risk of change in BMI for each disease endpoint was obtained from meta-analyses, and if available, pooled analyses of prospective observational studies[2].

Attributable mortality and uncertainties

The proportion of mortality that could have been prevented if the exposure level of a risk factor had been sustained at the level associated with the lowest risk was calculated. The level of exposure that is associated with the lowest risk is called the theoretical minimum risk exposure level (TMREL). A 20 % uncertainty range below and above the TMREL was considered as an interval associated with the lowest risk and used in determining the burden of disease attributable to the risk factors (see online supplementary material, Supplemental Table 1).

To determine the mortality attributable to risk factors, first, the population attributable fraction (PAF) was determined using the following inputs: the exposure level for each dietary risk factor (P); the effect size (RR); the TMREL; and the total number of deaths from the specific disease. Joint PAF were calculated for wasting, underweight and stunting assuming independency. Additional details on methods of estimation can be found elsewhere[2].

The PAF was given as[2]

$$PAF_{joasgt} = \frac{\int_{x=l}^{u} RR_{joast}(x)P_{jasgt}(x)\mathrm{d}x - RR_{joasg}(TMREL_{jas})}{\int_{x=l}^{u} RR_{joasg}(x)P_{jasgt}(x)\mathrm{d}x}$$

for continuous risk factors, or as

$$PAF_{joasgt} = \frac{\sum_{x=l}^{u} RR_{joast}(x)P_{jasgt}(x) - RR_{joasg}(TMREL_{jas})}{\sum_{x=l}^{u} RR_{joas}(x)P_{jasgt}(x)}$$

for dichotomous or polychotomous risk factors, where:

PAF_{joasgt} is a population attributable fraction for a risk factor j, attributed to cause o for age group a, sex s, geography g and year t;

$RR_{joasg}(x)$ is the relative risk as a function of exposure level x for a risk factor j, attributed to cause o, age group a, sex s and geography g, with the lowest level of observed exposure being l and the highest being u;

$P_{jasgt}(x)$ is the distribution of exposure at x for age group a, sex s, geography g and year t; and

$TMREL_{jas}$ is the TMREL for risk factor j, age group a and sex s.

Then, the total attributable mortality was determined using the number of deaths and PAF[2], with the GBD 2015 mortality study used to obtain the number of deaths[2,21]:

$$Total\ attributable\ burden_{jasgt} = \sum_{o=1}^{w} Burden_{joasgt}\ PAF_{joasgt}$$

The overall proportion of disease burden attributable to aggregated dietary risk factors and CMU was computed using the following formula[2]:

$$PAF_{joasgt} = 1 - \prod_{k=1}^{K}\left[1 - PAF_{joasgt}\prod_{k=1}^{K}(1 - MF_{jio})\right]$$

where:

K is a set of risk factors for the aggregation;

PAF_{joasgt} is PAF for risk j for age group a, sex s, geography g and year t; and

MF_{jio} is the mediation factor for risk j mediated through i for cause o.

Using the Monte Carlo approach[29], the uncertainty of parameters for exposure, relative risk and attributable mortality was calculated with 1000 repeated draws. Uncertainty intervals (95 % UI) for the estimates were reported[2].

Results

Mortality related to child and maternal undernutrition, dietary risk factors and overweight/obesity in 2015

Table 1 provides the estimated number, crude rates and proportions of mortality accounted for by CMU, diet and overweight/obesity in SSA and its sub-regions in 2015. Deaths attributable to CMU totalled 826 204 (95 % UI 737 346, 923 789) or 10·3 % (95 % UI 9·1, 11·6 %) of all deaths in SSA. The proportion of mortality caused by CMNN diseases attributable to CMU was 17·7 % (95 % UI 15·7, 19·9 %). Except for Southern SSA where dietary factors of NCD contributed the highest number of deaths, in all other sub-regions CMU was responsible for the highest number of deaths. Overweight/obesity and dietary risk factors accounted for 266 768 (95 % UI 189 051, 353 096) or 3·3 % (95 % UI 2·4, 4·4 %) and 558 578 (95 % UI 453 433, 680 197) or 7·0 % (95 % UI 5·8, 8·3 %) of all-cause mortality, respectively. The relative contribution to NCD mortality attributable to overweight/obesity and dietary risk factors was 9·8 % (95 % UI 7·0, 12·8 %) and 20·5 % (95 % UI 17·3, 24·3 %), respectively. The age-standardized proportion of all-cause mortality attributable to CMU was higher in Western SSA compared with other sub-regions.

In 2015, the age-standardized proportion of all-cause mortality was significantly higher for dietary risks of NCD compared with overweight/obesity and CMU. Overall, the age-standardized proportion of deaths attributable to CMU, overweight/obesity and dietary risks was 12·2 % (95 % UI 10·2, 14·7 %), 3·8 % (95 % UI 3·4, 4·3 %) and 5·3 % (95 % UI 3·8, 7·0 %), respectively (Table 2). The highest age-standardized proportion of deaths attributable to CMU was found in Chad (7·8 %; 95 % UI 4·8, 11·8 %). On the other hand, the highest age-standardized proportion of deaths attributable to overweight/obesity and dietary risks of NCD was found in South Africa (11·6 %; 95 % UI 9·4, 13·7 %) and Cameroon (17·8 %; 95 % UI 15·0, 21·2 %), respectively. Botswana (0·7 %; 95 % UI 0·3, 1·4 %), Burundi (1·5 %; 95 % UI 0·6, 2·7 %) and Guinea-Bissau (6·7 %; 95 % UI 5·6, 7·9 %) had the lowest age-standardized proportion of mortality attributable to CMU, overweight/obesity and dietary risks of NCD, respectively (see online supplementary material, Supplemental Tables 6, 7 and 8).

The number, rate and proportion of deaths attributable to CMU, overweight/obesity and dietary risks of NCD by age are shown in Fig. 2 and the online supplementary material, Supplemental Fig. 1.

Childhood wasting and underweight were the most common CMU risks, accounting for 8·5 and 3·0 % of all deaths, respectively. Diets low in fruits (2·2 %), whole grains (1·7 %), vegetables (1·5 %), nuts and seeds (1·3 %) and high in Na (1·3 %) were found to be the most common dietary risk factors (Table 3).

Trend of mortality attributable to child and maternal undernutrition, dietary risk factors and overweight/obesity between 1990 and 2015

Table 3 depicts the trends of mortality attributable to CMU, overweight/obesity and dietary risks of NCD in SSA and sub-regions. The number of deaths attributable to CMU decreased substantially by 44·6 % in the past 25 years, falling from 1·49 million (1 490 671; 95 % UI 1 305 548, 1 667 532) in 1990 to 0·83 million (826 204; 95 % UI 737 346, 923 789) in 2015. In contrast, deaths attributable to overweight/obesity and dietary risks of NCD increased by 143·8 and 73·0 %, rising from 109 407 (95 % UI 71 767, 152 893) in 1990 to 266 768 (95 % UI 189 051, 353 096) in 2015 and from 322 932 (95 % UI 271 234, 387 047) to 558 578 (95 % UI 453 433, 680 197), respectively. Similar patterns were identified at sub-regional level. The age-standardized proportion of deaths related to by CMU decreased by 55·3 %, falling from 8·5 % (95 % UI 7·4, 9·5 %) in 1990 to 3·8 % (95 % UI 3·4, 4·3 %) in 2015. On the other hand, the age-standardized proportion of deaths attributable to overweight/obesity and dietary risks of NCD rose by 63·3 and 17·2 %, rising from 3·2 % (95 % UI 2·1, 4·6 %) and 10·4 % (95 % UI 8·7, 12·6 %) in 1990 to 5·3 % (95 % UI 3·8, 7·0 %) and 12·2 % (95 % UI 10·2, 14·7 %) in 2015, respectively. However, in the Southern SSA sub-region, the proportion of deaths attributable to overweight/obesity decreased by 10·3 %, falling from 14·9 % (95 % UI 12·6, 17·9 %) to 13·4 % (95 % UI 11·3, 15·9 %). The attributable mortality trend across the past 25 years is shown in Fig. 3 and the online supplementary material, Supplemental Fig. 2.

Table 1 The mortality associated with child and maternal undernutrition (CMU), overweight/obesity and dietary risks of non-communicable diseases (NCD) in sub-Saharan Africa by sex and sub-region, 2015

Sub-region/risk factor	Sex	Number	95 % UI	Crude rate (per 100 000)	95 % UI	Crude proportion (%), all-cause†	95 % UI	Crude proportion (%), CMNND or NCD‡	95 % UI
Central sub-Saharan Africa									
CMU	Males	60 921	44 674, 85 600	107	78, 150	11·5	8·0, 16·7	20·3	15·0, 27·4
	Females	51 993	38 745, 67 891	90	67, 118	10·3	7·5, 13·8	17·6	13·4, 22·2
	Both sexes	112 914	86 048, 147 814	98	75, 129	10·8	8·3, 14·4	18·9	15·1, 23·8
Dietary risks of NCD	Males	34 928	20 768, 53 734	61	36, 94	6·4	4·5, 8·6	19·6	15·3, 24·0
	Females	38 562	22 618, 59 551	67	39, 103	7·4	5·2, 9·8	20·4	16·1, 25·4
	Both sexes	73 490	45 379, 107 237	64	40, 93	7·0	4·9, 9·0	20·0	16·0, 24·7
Overweight/obesity	Males	11 601	4642, 22 671	20	8, 40	2·1	1·0, 3·8	6·5	3·2, 10·7
	Females	17 412	7962, 32 278	30	14, 56	3·3	1·9, 5·3	9·2	5·3, 13·9
	Both sexes	29 013	15 050, 51 043	25	13, 44	2·7	1·6, 4·2	7·9	4·9, 11·4
Eastern sub-Saharan Africa									
CMU	Males	149 789	131 170, 171 630	80	70, 92	9·6	8·0, 11·5	17·6	15·3, 20·3
	Females	133 530	114 345, 153 324	70	60, 81	9·7	8·0, 11·6	17·1	14·6, 19·6
	Both sexes	283 319	250 895, 320 673	75	67, 85	9·6	8·3, 11·2	17·4	15·3, 19·7
Dietary risks of NCD	Males	119 901	87 703, 164 985	64	47, 88	7·6	6·2, 9·5	21·6	18·0, 25·7
	Females	102 730	70 418, 146 151	54	37, 77	7·4	5·7, 9·6	19·7	15·8, 24·4
	Both sexes	222 631	171 455, 293 795	59	45, 78	7·5	6·1, 9·2	20·7	17·1, 25·0
Overweight/obesity	Males	30 374	14 290, 54 154	16	8, 29	1·9	0·9, 3·2	5·5	2·7, 8·9
	Females	46 043	25 932, 72 884	24	14, 38	3·3	2·0, 4·9	8·8	5·4, 12·7
	Both sexes	76 417	46 080, 111 311	20	12, 30	2·6	1·6, 3·7	7·1	4·6, 9·9
Southern sub-Saharan Africa									
CMU	Males	10 373	8848, 12 082	27	23, 32	2·4	2·0, 2·9	5·1	4·3, 5·9
	Females	9090	7750, 10 561	23	20, 27	2·3	1·9, 2·7	4·8	4·0, 5·6
	Both sexes	19 463	16 718, 22 467	25	22, 29	2·4	2·0, 2·7	4·9	4·2, 5·7
Dietary risks of NCD	Males	39 752	32 162, 48 409	104	84, 127	9·3	7·9, 11	24·2	20·7, 28·3
	Females	45 292	36 735, 55 600	115	93, 141	11·4	9·6, 13·7	24·3	20·7, 28·8
	Both sexes	85 044	70 412, 102 766	110	91, 133	10·3	8·7, 12·2	24·3	20·8, 28·5
Overweight/obesity	Males	23 800	15 959, 32 345	62	42, 85	5·6	3·8, 7·4	14·5	10·0, 19·2
	Females	44 089	34 540, 54 775	112	88, 139	11·1	9·0, 13·3	23·7	19·5, 27·9
	Both sexes	67 889	54 186, 81 717	88	70, 106	8·2	6·7, 9·8	19·4	15·8, 23·0
Western sub-Saharan Africa									
CMU	Males	218 342	181 853, 259 496	111	92, 132	12·8	10·3, 15·2	20·2	16·6, 23·7
	Females	192 166	160 756, 229 348	99	83, 118	13·1	10·7, 15·8	20·0	16·8, 23·7
	Both sexes	410 508	348 886, 476 136	105	89, 122	12·9	10·8, 15·1	20·1	17·0, 23·3
Dietary risks of NCD	Males	89 085	69 374, 116 474	45	35, 59	5·2	4·3, 6·3	18·2	15·3, 21·7
	Females	88 328	66 490, 121 954	46	34, 63	6·0	4·9, 7·5	19·7	16·0, 23·8
	Both sexes	177 413	140 988, 225 225	45	36, 58	5·6	4·6, 6·7	18·9	16·0, 22·4
Overweight/obesity	Males	38 131	20 308, 61 072	19	10, 31	2·2	1·2, 3·4	7·8	4·5, 11·7
	Females	55 319	33 901, 82 816	29	18, 43	3·7	2·5, 5·1	12·3	8·4, 16·4
	Both sexes	93 450	63 598, 130 648	24	16, 33	2·9	2·1, 3·9	10·0	7·0, 13·1
Sub-Saharan Africa									
CMU	Males	439 426	385 540, 496 385	92	80, 103	10·4	9·0, 11·8	18·0	15·7, 20·4
	Females	386 778	343 498, 438 507	81	72, 91	10·3	9·0, 11·8	17·4	15·3, 19·8
	Both sexes	826 204	737 346, 923 789	86	77, 96	10·3	9·1, 11·6	17·7	15·7, 19·9
Dietary risks of NCD	Males	283 666	228 502, 351 697	59	48, 73	6·7	5·6, 8·0	20·5	17·3, 24·2
	Females	274 912	215 903, 352 108	57	45, 73	7·3	6·0, 8·9	20·4	17·2, 24·7
	Both sexes	558 578	453 433, 680 197	58	47, 71	7·0	5·8, 8·3	20·5	17·3, 24·3
Overweight/obesity	Males	103 906	58 575, 158 084	22	12, 33	2·4	1·4, 3·6	7·5	4·4, 11·1
	Females	162 862	111 690, 219 247	34	23, 46	4·3	3·0, 5·7	12·1	8·5, 15·9
	Both sexes	266 768	189 051, 353 096	28	20, 37	3·3	2·4, 4·4	9·8	7·0, 12·8

UI, uncertainty interval; CMNND, communicable, maternal, neonatal and nutritional diseases.
†Proportions are for all causes of death.
‡Proportions are for specific categories of diseases (i.e. CMNND accounting for CMU; NCD accounting for dietary risks and overweight/obesity).

Table 2 The burden of mortality associated with child and maternal undernutrition (CMU), overweight/obesity and dietary risks of non-communicable diseases (NCD) in sub-Saharan Africa between 1990 and 2015

	Number						Age-standardized rate (per 100 000)				Age-standardized proportion (%), all-cause†						Age-standardized proportion (%), CMNND or NCD‡					
Sub-region/Risk factor	1990	95% UI	2015	95% UI	Change (%)	95% UI	1990	95% UI	2015	95% UI	1990	95% UI	2015	95% UI	Change (%)	95% UI	1990	95% UI	2015	95% UI	Change (%)	95% UI
Central sub-Saharan Africa																						
CMU	152 378	123 661, 190 511	112 914	86 048, 147 814	−26	−45, −1	144	118, 179	60	45, 80	7·5	5·9, 9·8	3·9*	2·9, 5·6	−48·4	−63·5, −28·3	15·9	12·8, 19·6	9·8*	7·2, 12·8	−38·6	−55·5, −17·6
Dietary risks of NCD	37 715	25 752, 53 853	73 490	45 379, 107 237	95	25, 203	206	141, 292	194	121, 276	10·7	8·1, 13·6	12·4	9·1, 15·7	16·0	3·6, 27·8	22·9	18·8, 27·9	22·7	18·5, 28·1	−0·8	−6·4, 4·6
Overweight/ obesity	13 683	7705, 21 628	29 013	15 050, 51 043	112	30, 259	67	38, 105	68	37, 116	3·5	2·1, 5·0	4·3	2·6, 6·5	24·7	1·0, 63·8	7·5	4·5, 10·8	8·0	5·0, 11·6	6·7	−11·9, 36·7
Eastern sub-Saharan Africa																						
CMU	605 387	529 428, 684 327	283 319	250 895, 320 673	−53	−60, −45	169	149, 190	52	46, 59	8·1	7·1, 9·2	3·7*	3·2, 4·3	−54·1	−61·3, −45·6	16·7	14·6, 19·0	9·3*	8·2, 10·6	−44·7	−52·9, −35·3
Dietary risks of NCD	135 083	111 972, 166 003	222 631	171 455, 293 795	65	31, 103	213	176, 265	173	132, 226	10·2	8·5, 12·5	12·4	10·2, 15·1	21·2	10·8, 31·2	23·6	19·7, 28·7	23·5	19·4, 28·7	−0·4	−6·7, 5·5
Overweight/ obesity	32 585	18 538, 49 585	76 417	46 080, 111 311	135	83, 201	46	26, 72	54	33, 80	2·2	1·2, 3·4	3·9	2·4, 5·5	74·9	50·2, 107·6	5·1	2·9, 7·9	7·4	4·7, 10·5	43·9	25·3, 70·2
Southern sub-Saharan Africa																						
CMU	52 501	49 300, 55 991	19 463	16 718, 22 467	−63	−68, −57	61	58, 65	20	17, 23	4·2	3·9, 4·5	1·3*	1·1, 1·5	−68·2	−73·0, −63·1	14·9	13·4, 16·2	3·5*	3·0, 4·0	−76·8	−80·5, −72·8
Dietary risks of NCD	50 079	42 299, 59 924	85 044	70 412, 102 766	70	51, 94	219	184, 263	204	169, 246	14·9	12·6, 17·9	13·4	11·3, 15·9	−10·3	−14·9, −4·9	24·2	20·6, 28·7	24·8	21·1, 29·3	2·4	−0·2, 6·1
Overweight/ obesity	35 031	27 735, 42 711	67 889	54 186, 81 717	94	68, 124	146	114, 180	157	124, 190	9·9	7·8, 12·1	10·4	8·3, 12·4	4·2	−4·4, 13·5	16·1	12·7, 19·7	19·2	15·5, 23·0	19·0	10·9, 27·2
Western sub-Saharan Africa																						
CMU	680 406	577 609, 777 762	410 508	348 886, 476 136	−40	−49, −28	170	145, 195	57	49, 66	10·3	8·5, 12·2	4·5*	3·7, 5·4	−56·2	−65·2, −45·2	20·3	17·0, 23·6	10·3*	8·5, 12·2	−49·4	−58·5, −37·9
Dietary risks of NCD	100 056	78 235, 127 200	177 413	140 988, 225 225	77	39, 128	151	119, 191	144	115, 183	9·2	7·6, 11·0	11·4	9·6, 13·7	24·9	16·8, 33·9	21·2	17·9, 25·2	23·0	19·4, 27·2	8·4	4·5, 12·5
Overweight/ obesity	28 107	15 240, 44 439	93 450	63 598, 130 648	232	136, 390	34	18, 55	64	42, 89	2·1	1·1, 3·3	5·0*	3·5, 6·7	141·1	92·5, 228·4	4·8	2·6, 7·5	10·1	7·0, 13·5	109·2	70·2, 180
Sub-Saharan Africa																						
CMU	1490 671	1305 548, 1 667 532	826 204	737 346, 923 789	−45	−51, −37	156	138, 174	53	47, 59	8·5	7·4, 9·5	3·8*	3·4, 4·3	−55·2	−61·1, −49·2	18·2	15·9, 20·3	9·3*	8·2, 10·6	−48·8	−55·2, −41·8
Dietary risks of NCD	322 932	271 234, 387 047	558 578	453 433, 680 197	73	52, 97	191	158, 231	169	138, 208	10·4	8·7, 12·6	12·2	10·2, 14·7	17·2	11·9, 22·5	22·8	19·2, 27·2	23·3	19·6, 28·0	2·5	−1·0, 5·6
Overweight/ obesity	109 407	71 767, 152 893	266 768	189 051, 353 096	144	108, 195	59	39, 83	73	51, 97	3·2	2·1, 4·6	5·3	3·8, 7·0	63·3	47·9, 83·5	7·1	4·6, 10·0	10·1	7·2, 13·4	42·9	30·3, 60·1

UI, uncertainty interval; CMNND, communicable, maternal, neonatal and nutritional diseases.
*Significantly increased or decreased based on 95% UI.
†Proportions are for all causes of death.
‡Proportions are for specific category of diseases (i.e. CMNND accounting for CMU; NCD accounting for dietary risks and high- overweight/obesity).

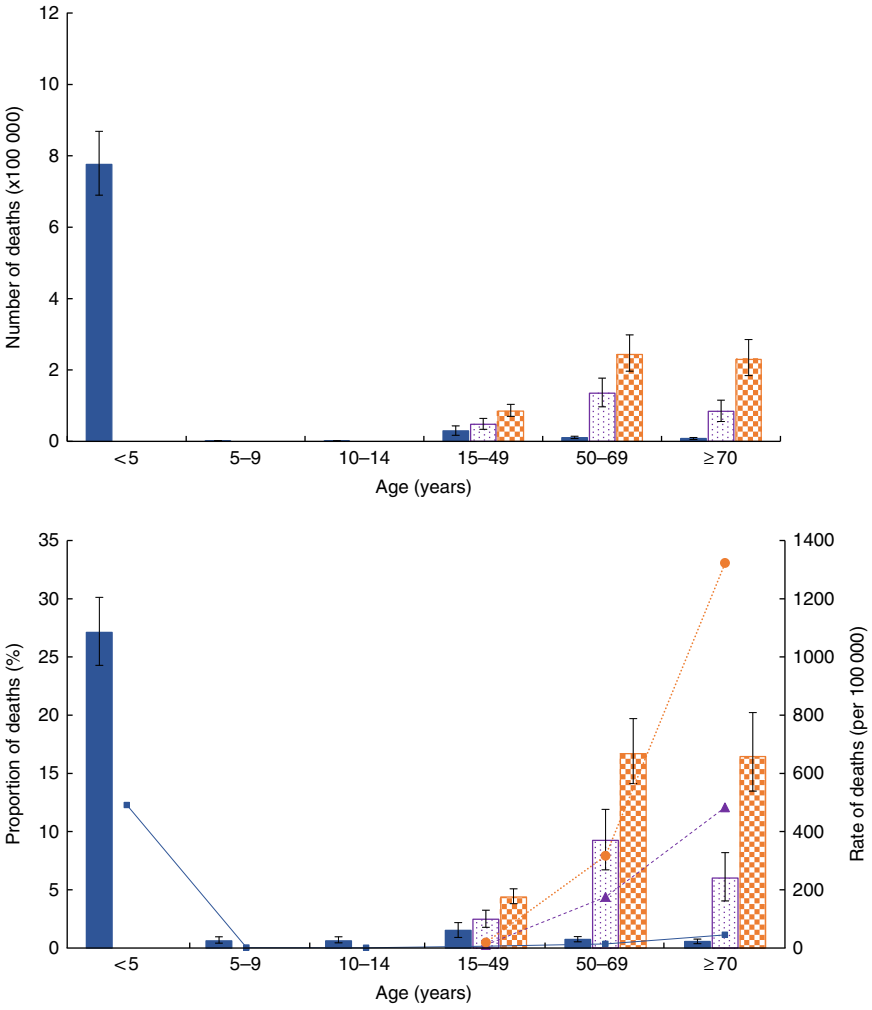

Fig. 2 (colour online) Number, proportion (of all-cause) and rate of deaths associated with child and maternal undernutrition (CMU), overweight/obesity and dietary risks of non-communicable diseases (NCD) in sub-Saharan Africa by age in 2015: ■, CMU number/proportion; —■—, CMU rate; ⊡, overweight/obesity number/proportion; --▲--, overweight/obesity rate; ⊠, dietary risks of NCD number/proportion; ···●···, dietary risks of NCD rate. Numbers and proportions are mean values with their 95 % uncertainty intervals represented by vertical bars

Countries and sub-regions show different levels of increase or decrease in mortality attributable to each of the risk factors. The age-standardized proportion of deaths attributable to CMU fell by more than half in most of the countries. The highest reduction (~80 % or above) was found in Botswana, South Africa and Cape Verde. The age-standardized proportion of deaths attributable to overweight/obesity rose in all SSA sub-regions. The highest increase (140·7 %) was recorded in Western SSA, rising from 2·1 % (95 % UI 1·1, 3·3 %) in 1990 to 5·0 % (95 % UI 3·5, 6·7 %) in 2015. Countries like Burkina Faso (377·2 %), Liberia (270·8 %) and Chad (254·4 %) recorded the highest increases in the age-standardized proportion of deaths attributable to overweight/obesity in the last 25 years. Except for all the Southern SSA countries, Burundi and Comoros (Eastern SSA counties), all other nations recorded increases in diet-related deaths. Burkina Faso (64·7 %) and Liberia (48·7 %) had the highest increase in the age-standardized proportion of deaths attributable to dietary risks of NCD (Table 2 and online supplementary material, Supplemental Tables 6, 7 and 8).

SSA achieved a significant reduction in the age-standardized proportion of deaths related to childhood undernutrition, discontinued breast-feeding and vitamin A deficiency. On the other hand, an increase of the proportion of deaths related to all components of dietary risks of NCD was recorded (Table 3).

The age-standardized proportion of deaths caused by CMNN diseases related to CMU fell significantly in all sub-regions of SSA. On the other hand, the proportion of NCD deaths attributable to dietary risk factors and overweight/obesity either increased or remained relatively stable (Table 2).

Discussion

In the present study we found that the mortality burden attributable to CMU, overweight/obesity and dietary risks

Table 3 The number, rate, proportion and percentage change of deaths associated with child and maternal undernutrition (CMU), dietary risks of non-communicable diseases (NCD)and overweight/obesity in sub-Saharan Africa between 1990 and 2015

	Unstandardized (2015)								Age-standardized (1990 and 2015)									
									Rate (per 100 000)				Proportion (%), all-cause†					
Risk factor	Number	95 % UI	Rate (per 100 000)	95 % UI	Proportion (%), all-cause†	95 % UI	Proportion (%), CMNND or CND‡	95 % UI	1990	95 % UI	2015	95 % UI	1990	95 % UI	2015	95 % UI	Change (%)	95 % UI
CMU	**826 204**	**737 346, 923 789**	**86**	**77, 96**	**10·3**	**9·1, 11·6**	**17·7**	**15·7, 19·9**	**156**	**138, 174**	**53**	**47, 59**	**8·5**	**7·4, 9·5**	**3·8***	**3·4, 4·3**	**– 55·2**	**– 61·1, – 49·2**
Childhood undernutrition	**730 679**	**647 336, 823 453**	**76**	**67, 86**	**9·1**	**8·0, 10·4**	**15·7**	**13·8, 17·7**	**135**	**117, 152**	**41**	**36, 46**	**7·4**	**6·3, 8·4**	**2·9***	**2·5, 3·4**	**– 60·0**	**– 66·0, – 53·6**
Childhood stunting	136 455	62 418, 236 262	14	7, 25	1·7	0·8, 2·9	2·9	1·4, 5·1	32	17, 53	8	3, 13	1·8	0·9, 2·9	0·6*	0·3, 0·9	– 69·1	– 79·7, – 58·3
Childhood underweight	243 432	194 332, 304 245	25	20, 32	3·0	2·4, 3·8	5·2	4·2, 6·5	53	41, 70	14	11, 17	2·9	2·2, 3·8	1·0*	0·8, 1·2	– 66·2	– 74·5, – 54·2
Childhood wasting	679 606	572 543, 776 337	71	60, 81	8·5	7·1, 9·8	14·6	12·2, 16·7	118	97, 141	38	32, 43	6·4	5·2, 7·8	2·7*	2·3, 3·2	– 57·4	– 65·2, – 48·2
Suboptimal breast-feeding	**198 263**	**131 082, 275 781**	**21**	**14, 29**	**2·5**	**1·6, 3·5**	**4·3**	**2·8, 6·0**	**28**	**19, 38**	**11**	**7, 15**	**1·5**	**1·0, 2·1**	**0·8**	**0·5, 1·1**	**– 48·5**	**– 59·0, – 35·9**
Non-exclusive breast-feeding	181 045	115 278, 255 182	19	12, 27	2·3	1·5, 3·2	3·9	2·5, 5·5	25	16, 34	10	6, 14	1·3	0·9, 1·9	0·7	0·5, 1·0	– 47·2	– 58·1, – 34·1
Discontinued breast-feeding	21 899	7028, 42 927	2	1, 4	0·3	0·1, 0·5	0·5	0·2, 0·9	4	1, 8	1	0, 2	0·2	0·1, 0·4	0·1	0·0, 0·2	– 58	– 69·2, – 43·0
Vitamin A deficiency	**47 350**	**27 913, 69 775**	**5**	**3, 7**	**0·6**	**0·3, 0·9**	**1·0**	**0·6, 1·5**	**19**	**11, 30**	**3**	**2, 4**	**1·0**	**0·6, 1·6**	**0·2***	**0·1, 0·3**	**– 81·3**	**– 87·3, – 73·4**
Zn deficiency	**33 626**	**1951, 74 941**	**4**	**0, 8**	**0·4**	**0·0, 0·9**	**0·7**	**0·0, 1·6**	**7**	**0, 15**	**2**	**0, 4**	**0·4**	**0·0, 0·9**	**0·1**	**0·0, 0·3**	**– 62·8**	**– 72·7, – 48·1**
Fe deficiency	**62 060**	**44 679, 84 503**	**6**	**5, 9**	**0·8**	**0·6, 1·0**	**1·3**	**1·0, 1·8**	**16**	**12, 20**	**10**	**8, 14**	**0·9**	**0·6, 1·1**	**0·7**	**0·6, 1·0**	**– 12·4**	**– 23·6, 4·0**
Dietary risks	**558 578**	**453 433, 680 197**	**58**	**47, 71**	**7·0**	**5·8, 8·3**	**20·5**	**17·3, 24·3**	**191**	**158, 231**	**169**	**138, 208**	**10·4**	**8·7, 12·6**	**12·2**	**10·2, 14·7**	**17·2**	**11·9, 22·5**
Diet low in fruits	173 675	113 390, 242 591	18	12, 25	2·2	1·5, 2·9	6·4	4·3, 8·6	57	39, 78	49	32, 69	3·1	2·1, 4·2	3·5	2·4, 4·9	13·5	7·2, 20·0
Diet low in whole grains	133 971	85 649, 191 670	14	9, 20	1·7	1·1, 2·4	4·9	3·2, 7·0	43	27, 61	37	24, 54	2·3	1·5, 3·3	2·7	1·7, 3·9	16·1	10·1, 21·8
Diet low in vegetables	123 544	67 075, 190 913	13	7, 20	1·5	0·8, 2·4	4·5	2·5, 6·9	43	23, 66	36	20, 56	2·3	1·3, 3·6	2·6	1·4, 4·0	13·1	6·4, 18·7
Diet low in nuts and seeds	102 661	64 118, 147 118	11	7, 15	1·3	0·8, 1·8	3·8	2·4, 5·2	34	22, 49	32	20, 45	1·9	1·2, 2·6	2·3	1·4, 3·2	21·9	15·9, 28·3
Diet high in Na	101 044	25 201, 238 911	11	3, 25	1·3	0·3, 3·0	3·7	0·9, 8·8	35	9, 89	31	8, 77	1·9	0·5, 4·8	2·2	0·6, 5·5	16·4	4·3, 43·7
Diet low in seafood *n*-3 fatty acids	72 605	31 205, 118 470	8	3, 12	0·9	0·4, 1·5	2·7	1·2, 4·3	25	11, 40	22	9, 36	1·3	0·6, 2·1	1·6	0·7, 2·6	17·6	10·0, 24·5
Diet high in processed meat	33 854	14 548, 54 713	4	2, 6	0·4	0·2, 0·7	1·2	0·6, 2·0	10	4, 16	10	4, 16	0·6	0·2, 0·9	0·7	0·3, 1·1	29·0	20·1, 47·8
Diet high in *trans*-fatty acids	16 679	5192, 35 015	2	1, 4	0·2	0·1, 0·4	0·6	0·2, 1·3	5	2, 11	5	1, 10	0·3	0·1, 0·6	0·3	0·1, 0·7	15·0	5·2, 23·5
Diet low in PUFA	14 411	5864, 23 613	2	1, 2	0·2	0·1, 0·3	0·5	0·2, 0·9	5	2, 8	4	2, 7	0·3	0·1, 0·4	0·3	0·1, 0·5	10·3	– 10·7, 35·2
Diet suboptimal in Ca	8126	5324, 11 367	1	1, 1	0·1	0·1, 0·1	0·3	0·2, 0·4	2	2, 3	2	2, 3	0·1	0·1, 0·2	0·2	0·1, 0·2	32·8	23·7, 42·0
Diet high in sugar-sweetened beverages	2939	2059, 4102	0	0, 0	0·0	0·0, 0·1	0·1	0·1, 0·2	1	0, 1	1	0, 1	0·0	0·0, 0·1	0·1	0·0, 0·1	37·1	23·2, 52·3
Diet low in fibre	4537	1414, 9404	0	0, 1	0·1	0·0, 0·1	0·2	0·1, 0·4	2	1, 3	1	0, 3	0·1	0·0, 0·2	0·1	0·0, 0·2	17·4	5·8, 29·0
Diet low in milk	5729	1986, 9624	1	0, 1	0·1	0·0, 0·1	0·2	0·1, 0·4	2	1, 3	2	1, 3	0·1	0·0, 0·2	0·1	0·0, 0·2	33·9	25·0, 43·0
Diet high in red meat	1734	474, 3116	0	0, 0	0·0	0·0, 0·0	0·1	0·0, 0·1	0	0, 1	0	0, 1	0·0	0·0, 0·0	0·0	0·0, 0·1	46·8	29·7, 63·8
Overweight/obesity	**266 768**	**189 051, 353 096**	**28**	**20, 37**	**3·3**	**2·4, 4·4**	**9·8**	**7·0, 12·8**	**59**	**39, 83**	**73**	**51, 97**	**3·2**	**2·1, 4·6**	**5·3**	**3·8, 7·0**	**63·3**	**47·9, 83·5**

UI, uncertainty interval; CMNND, communicable, maternal, neonatal and nutritional diseases.
The sum of numbers, rates and percentages in rows exceeds the total because of overlap between various risk factors. 0 % represents very low proportion.
Bold font indicates level 2 or level 3 categories of the risk factors.
*Significantly increased or decreased based on 95 % UI.
†Proportions are for all causes of death.
‡Proportions are for specific category of diseases (i.e. CMNND accounting for CMU; NCD accounting for dietary risks and overweight/obesity).

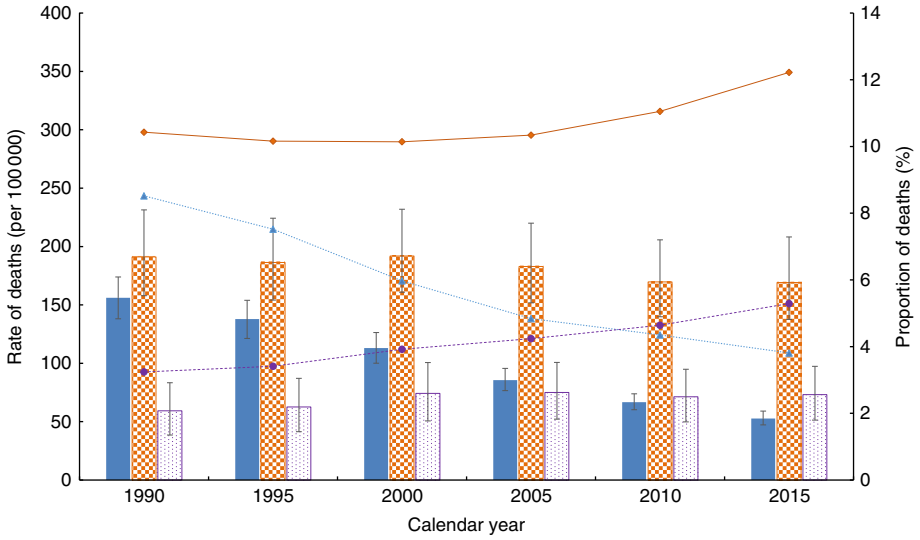

Fig. 3 (colour online) Age-standardized rate and proportion of deaths (all-cause) associated with child and maternal undernutrition (CMU), overweight/obesity and dietary risks of non-communicable diseases (NCD) in sub-Saharan countries between 1990 and 2015: ■, CMU rate; ···▲···, CMU proportion; ▨, overweight/obesity rate; - -●- -, overweight/obesity proportion; ▨, dietary risks of NCD rate; —◆—, dietary risks of NCD proportion. Rates are mean values with their 95 % uncertainty intervals represented by vertical bars

of NCD in SSA is high, indicating that the burden of diseases in the region is related to complex behavioural and metabolic risk factors. The relative contribution of dietary risks of NCD to all-cause deaths was significantly higher compared with overweight/obesity and CMU. Deaths attributable to CMU have decreased significantly in the past 25 years and similar patterns were found at sub-regional level. Each of the SSA countries has shown different levels of increase or decrease in mortality attributable to the CMU, overweight/obesity and dietary risk factors of NCD. To the best our knowledge, our study is the first of its kind to investigate the number (proportion) and trend of mortality attributable to a double burden of malnutrition (i.e. mortality attributable to CMU (eight risk factors), overweight/obesity and dietary risks of NCD (fourteen risk factors)) in the SSA, SSA sub-regions and countries. In addition, our results provide additional insights by strengthening the body of evidence on the existence of a double burden of nutrition-related diseases, which has not been given full attention by stakeholders. The findings could inform and highlight to governments and stakeholders in SSA countries the need to design and implement appropriate interventions to tackle this unprecedented phenomenon.

The paradox

Our findings show the coexistence of a significant burden of mortality attributable to CMU, overweight/obesity and dietary risk factors in SSA. In 2015, CMU and dietary risks of NCD were the second (behind unsafe sex) and third most important behavioural risk factors for mortality[30]. Overweight/obesity was also the second most important metabolic risk of mortality in SSA (behind systolic blood pressure)[2,30]. In line with our findings, studies highlighted that the burden of NCD attributable to dietary risks is substantially high in addition to the already existing burden of undernutrition[8]. Furthermore, evidence also shows that the prevalence of obesity in Africa is high and increasing[5, 11]. The coexistence of a high burden of both under- and overnutrition in SSA is also reflected at country level. For instance, in rural Nigeria, the prevalence of overweight (BMI = 0–29·9 kg/m^2)/obesity (BMI ≥ 30·0 kg/m^2) in adults and elderly people and of underweight (weight-for-age *Z*-score < −2) in school-aged children was found to be 30·0[31] and 70·5 %[32], respectively. Zeba *et al.*[33] reported that 23·5 % of adults in Burkina Faso had at least one CVD risk factor and one nutritional deficiency. In addition to socio-economic and technological developments, urbanization[34] and an increase in per capita income[35], the minimal policy responses to the growing burden of NCD could explain the high burden of diet-related diseases in SSA[36]. Increases in agricultural production and changes in trade policies (by increasing the availability and accessibility of processed foods) were also found to be drivers of the problem[37]. Given the multi-faceted factors of nutrition-related burden of diseases in SSA, multisectoral collaboration at the macro and micro levels is a key to addressing the problem effectively.

Another important finding of the present study is the paradoxical trend in mortality attributable to CMU, overweight/obesity and dietary risks of NCD over the past 25 years. The mortality related to overweight/obesity and dietary risks of NCD has increased significantly, despite the deaths attributable to CMU still remaining substantially high. This finding mirrors studies that have shown the substantial contribution of both infectious diseases and NCD to the current burden in SSA – highlighting the

non-classical epidemiological transition[38]. The burden of CMNN diseases has also persisted despite the emerging burden of NCD[39]. In line with other studies[8], our findings suggest that SSA is undergoing a nutrition transition. However, the coexistence of a significant burden of disease associated with both over- and undernutrition shows that the transition is atypical[8]. Many hypotheses have been postulated to explain this pattern. A study by Popkin and Gordon-Larsen[40] explained that such a change is associated with a faster increase of diet- and obesity-related NCD compared with the socio-economic developments that SSA countries have achieved.

From the epigenetic point of view, studies also indicate that those who have exposure to diets with low energy and poor micronutrient contents in their early life are more likely to develop chronic diseases when they are challenged with high-energy foods and a sedentary life[41–43], resulting in an 'NCD epidemic'. Evidence shows that this could happen as a result of genetic susceptibility to NCD via fetal programming[44,45] and thrifty growth[46,47].

Global development agendas and initiatives have also impacted the current trend. For instance, the World Food Summit and the Millennium Development Goals largely ignored NCD and their risk factors. However, NCD were identified as a major health challenge for the Sustainable Development Goals, which have the objective of reducing premature mortality due to NCD by one-third[48]. As a result, countries should identify effective policy options and responses to prevent and control the increasing burden of NCD and the risk factors in SSA[49]. In this regard, despite the fact that a number of SSA countries have already formulated NCD policy frameworks, existing challenges, including limited implementation capacity, competing public health problems and the lack of effective and feasible means to integrate policies into the existing health-care system, have precluded the translation of these frameworks into practice[50]. The governments of SSA countries should recognize the importance of reorienting public health strategies and health-care services to provide the ability to address both child and maternal health problems and NCD.

Dietary risks of non-communicable diseases

Mortality either increased or remained the same for specific components of dietary risks of NCD over the past 25 years. Diets low in fruit, vegetables, whole grains, seeds and nuts, and high in Na were the most important dietary risk factors. In SSA and low-income countries, consumption of fruits and vegetables is very low[51,52]. In Ethiopia, Mozambique and South Africa, for instance, consumption of the recommended level of fruit and vegetables was reported to be very minimal[53–55]. It is also found that 3·2 % of total deaths in South Africa are associated with low intake of fruits and vegetables[56]. In low-income countries, low consumption of fruits and vegetables is highly correlated with affordability[52]. In addition, a recent analysis of the Global Dietary Database showed that consumption of whole grains, nuts and seeds in SSA has decreased in the past two decades[51]. Na intake was also found to be high in some of the SSA countries. For instance, 81·0 % of the adult population in SSA consumes more than the WHO recommendation level (2 g/d)[57].

Recognizing malnutrition as a major global health, economic and sustainable development challenge, the UN aims to improve overall nutrition through the Decade of Action on Nutrition (2016–2025)[58]. This programme addresses all forms of malnutrition, from stunting, wasting and micronutrient deficiencies to overweight, obesity and nutrition-related NCD. The programme gives a unique opportunity for SSA countries and stakeholders to scale up their interventions against the double burden of malnutrition. As part of these interventions, actions to increase knowledge and awareness of communities on diet and nutrition should be supported. Effective strategies to promote healthy dietary habits should be designed using the experiences of other countries[59]. Promoting nutrition-sensitive agriculture and value chain supply should be part of the strategies. Improving access to and use of appropriate information and communication technologies could also help in disseminating messages related to dietary behaviour and body weight, as well as in monitoring the effectiveness of interventions[60,61]. Evidence also shows that electronic and mobile health (e- & mHealth) interventions are effective in promoting healthy diet-related behaviours in developing countries[62].

Regional variation

The burden levels of CMU, overweight/obesity and dietary risk factors vary across sub-regions and countries. The highest age-standardized proportion of deaths attributable to CMU was found in Chad. In 2012, UNICEF reported that the proportion of children with acute malnutrition (wasting) in Chad was significantly higher than the WHO's emergency threshold (15 %)[63]. On the other hand, the highest age-standardized proportion of deaths attributable to overweight/obesity and dietary risks of NCD was found in South Africa (11·6 %) and Cameroon (17·8 %), respectively. In line with this, studies in these countries reported a high prevalence of overweight, obesity and NCD in the adult population, showing that the countries are at latter stages of nutritional transition[64,65]. International trade institutions such as an increasing number of processed food companies, and urbanization and consequent increase in the consumption of poor-quality diet, play a significant role in the burden of NCD[64,66,67]. SSA countries should develop and implement a strong and sustainable health information system to tackle the growing burden of NCD and their risk factors. Countries should also devise multisectoral interventions, including tailored and integrated agricultural, nutrition and public health policies, to overcome the

nutrition-related burden of diseases. Countries and international organizations should recognize the effect of globalization on diet-related NCD burden[37] and develop strategies to prevent and mitigate the impact.

Limitations

Although the GBD 2015 study used robust methods to estimate the burden of disease related to risk factors, limitations are inevitable. These limitations are discussed in detail elsewhere[1,2,28]; however, some of the most important limitations specific to the present study are discussed as follows. First, the relative risks were obtained from meta-regression analysis and used across the countries. Despite this, different risk factors could have different levels of effects across population subgroups. Second, availability of limited data in the region, particularly on dietary risk factors, could affect the estimates by over- or underestimating the burden. Third, because the urban and rural settings are substantially different environments in SSA countries, the estimates might not be applicable to these population subgroups separately. Fourth, nutritional risk factors were measured using different approaches. For instance, Zn deficiency was measured using a proxy exposure. Exposure to Zn deficiency (as an average total absorbed Zn) was determined based on the ratio of Zn to phytate in foods. Lastly, publication bias could affect the results, compromising the comparability of burden of diseases related to risk factors. For instance, more published data are available on childhood undernutrition than diet-related NCD in SSA[2].

Conclusion

In summary, whereas mortality attributable to undernutrition is declining significantly, the burden related to overnutrition is increasing. We found that the burden of mortality attributable to both under- and overnutrition in SSA is high, which highlights the presence of a double burden of malnutrition. SSA countries are in an important time of challenges and opportunities to overcome nutrition-related (both under- and overnutrition) burden of disease before the impact worsens. Evidence-based interventions and programmes should be designed to tackle this phenomenon in SSA. Tailored public health and nutritional policies should be designed to address the paradox. Multisectoral collaboration at different levels of the region is a key to further reduce the burden of diseases associated with undernutrition and to tackle the oncoming burden of overnutrition. Further prospective investigations, including biomarker and genetic studies, should be conducted to understand the specific factors of the complex feature of this unprecedented nutrition transition in the SSA countries.

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Supplementary material

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