Estimating the burden of disease attributable to a diet low in fruit and vegetables in South Africa for 2000, 2006 and 2012

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Background. Low intake of fruit and vegetables is associated with an increased risk of various non-communicable diseases, including major causes of death and disability such as cardiovascular disease, diabetes mellitus and cancers. Diets low in fruit and vegetables are prevalent in the South African (SA) population, and average intake is well below the internationally recommended threshold.
Objectives. To estimate the burden of disease attributable to a diet low in fruit and vegetables by sex and age group in SA for the years 2000, 2006 and 2012.
Methods. We followed World Health Organization and Global Burden of Disease Study comparative risk assessment methodology. Population attributable fractions – calculated from fruit and vegetable intake estimated from national and local surveys and relative risks for health outcomes based on the current literature – were applied to the burden estimates from the second South African National Burden of Disease Study (SANBD2). Outcome measures included deaths and disability-adjusted life years (DALYs) lost from ischaemic heart disease, stroke, type 2 diabetes, and five categories of cancers.
Results. Between 2000 and 2012, the average intake of fruit of the SA adult population (≥25 years) declined by 7%, from 48.5 g/d (95% uncertainty interval (UI) 46.6 - 50.5) to 45.2 g/d (95% UI 42.7 - 47.6). Vegetable intake declined by 25%, from 146.9 g/d (95% UI 142.3 - 151.8) to 110.5 g/d (95% UI 105.9 - 115.0). In 2012, these consumption patterns are estimated to have caused 26 423 deaths (95% UI 24 368 - 28 006), amounting to 5.0% (95% UI 4.6 - 5.3%) of all deaths in SA, and the loss of 514 823 (95% UI 473 508 - 544 803) healthy life years or 2.5% (95% UI 2.3 - 2.6%) of all DALYs. Cardiovascular disease comprised the largest proportion of the attributable burden, with 83% of deaths and 84% of DALYs. Age-standardised death rates were higher for males (145.1 deaths per 100 000; 95% UI 127.9 - 156.2) than for females (108.0 deaths per 100 000; 95% UI 96.2 - 118.1); in both sexes, rates were lower than those observed in 2000 (–9% and –12%, respectively).
Conclusion. Despite the overall reduction in standardised death rates observed since 2000, the absolute burden of disease attributable to inadequate intake of fruit and vegetables in SA remains of significant concern. Effective interventions supported by legislation and policy are needed to reverse the declining trends in consumption observed in most age categories and to curb the associated burden.

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The article in context

Evidence before this study. The first SA comparative risk assessment study estimated that the combined effect of low fruit and vegetable intake accounted for 3.2% of total deaths and 1.1% of all disability-adjusted life years (DALYs) in the year 2000. In both sexes, ischaemic heart disease accounted for the largest proportion of attributable DALYs (60.6% among males and 52.2% among females), followed by ischaemic stroke (17.8% and 32.7%, respectively). All types of cancer together accounted for the remaining 21.6% of attributable DALYs among males and 15.1% among females.
Added value of this study. Our study used updated methodology and information on prevalence of exposure and revised relative risks (RRs) to estimate separately the burden attributable to low fruit and low vegetable consumption for three time points: 2000, 2006 and 2012. We used current evidence from systematic reviews and meta-analyses to select the health outcomes and identify appropriate RR functions and improved estimates of fruit and vegetable consumption in the SA population as continuous distributions. We calculated the attributable burden using updated estimates of the total number of deaths and DALYs due to the selected health outcomes. The results indicate that between 2000 and 2012, the average intake of fruit and vegetables in the SA population aged ≥25 years decreased by 7% and 25%, respectively. The number of deaths attributable to low fruit consumption increased from 17 931 to 19 257 and the number of DALYs from 357 592 to 386 308. Deaths attributable to low vegetable consumption increased from 8 434 in 2000 to 9 584 in 2012, and DALYs from 164 200 to 182 049. In 2012, age-standardised attributable death rates were higher for males (145.1 deaths per 100 000;

95% UI 127.9 - 156.2) than for females (108.0/100 000; 95% UI 96.2 - 118.1), and in both sexes were lower than those observed in 2000 (−9% and −12%, respectively).

Implications of the available evidence. While the change in exposure distribution and some progress in age categories characterised by a high burden of cardiovascular disease have resulted in a decrease in age-standardised death rates attributable to a diet low in fruit and vegetables, the absolute burden remains high and the overall decreasing trend in consumption in the majority of the population is alarming. Effective interventions supported by legislation and policy are needed to reverse the declining trends in consumption observed in most age categories and to curb the associated burden.

Fruit and vegetables are essential components of a healthy diet, and insufficient intake is associated with poor health and an increased risk of various non-communicable diseases (NCDs), including major causes of death and disability such as cardiovascular disease (CVD), diabetes mellitus and cancer.[1-4] In 2017, an estimated 3.6 million deaths and 93 million disability-adjusted life years (DALYs) worldwide were attributable to inadequate fruit and vegetable consumption.[5] Diets low in fruit and vegetables ranked third and fifth, respectively, among all dietary risk factors per number of attributable deaths and DALYs at global level, and first and fourth in the southern sub-Saharan Africa region.[5]

There are several biologically plausible reasons why consumption of vegetables and fruit might delay or prevent the onset of NCDs. Fruit and vegetables are rich in nutrients, fibre and phytochemicals, including vitamins, flavonoids, carotenoids, antioxidants, minerals, and many other classes of compounds with proven biological activity.[1,6,7] Experimental studies have shown that many of these compounds exert a favourable influence on physiological mechanisms associated with NCD risk, such as cholesterol synthesis, hormone metabolism, platelet aggregation and blood pressure regulation. Dietary fibre and phytochemicals also have proven antioxidant, antibacterial, anti-inflammatory and antiviral effects, and the ability to stimulate the immune system.[2,6,8] Positive effects on gut microbiota have recently been hypothesised.[9]

The antioxidant effects have attracted substantial research attention, resulting in growing evidence of their ability to reduce oxidative stress and consequent DNA damage linked to cancer incidence.[10-12] It is generally agreed that synergies and complementarities among constituents are key elements underlying the observed health benefits of diets rich in fruit and vegetables, and intake of their active elements as purified nutritional supplements does not produce the same effects.[13-15] Indirect action mechanisms may also play a role in the beneficial effects of high fruit and vegetable intake, due to displacement of unhealthy foods high in saturated fats, *trans* fats, simple carbohydrates and sodium, and prevention of body weight gain.[2,16,17] Displacement mechanisms may be key to explaining the protective effects against type 2 diabetes.[4]

From an epidemiological perspective, the current bulk of evidence supports a causal association between adequate intake of fruit and vegetables and reduced risk of CVD and some types of cancer, and a protective effect against development of type 2 diabetes.[1,18,19] Numerous prospective studies have found evidence of a robust protective effect of fruit and vegetable intake against coronary heart disease and stroke.[20-23] Meta-analyses have estimated a pooled hazard ratio for overall cardiovascular mortality of 0.96 (95% confidence interval (CI) 0.92 - 0.99) for each additional serving of fruit and vegetables combined,[3] and an RR for stroke of 0.68 (95% CI 0.56 - 0.82) per 200 g/d increase in fruit consumption, and of 0.89 (95% CI 0.81 - 0.98) per 200 g/d increase in vegetable intake.[24]

Experimental data also show that increasing intake of fruit and vegetables reduces blood pressure, a major determinant of CVD, adding to the case for causality.[23] For cancers, a series of case-control studies carried out in the 1990s pointed to major effects on a large variety of cancers, but have not been confirmed by subsequent prospective cohort studies.[25,26] Epidemiological evidence currently supports the existence of a modest effect on the incidence of all cancers (RR 0.97; 95% CI 0.95 - 0.99 for each 200 g/d increment in fruit and vegetable intake),[2] but stronger protection against specific types of cancers, namely those of the lips and oral cavity,[26-28] larynx and pharynx,[26,28,29] trachea, bronchi and lungs[30] and oesophagus.[31] For diabetes, pooled estimates from meta-analysis of prospective cohort studies estimate an RR of 0.93 (95% CI 0.88 - 0.99) per 1 serving/d increment of fruit intake and 0.90 (95% CI 0.80 - 1.01) per 1 serving/d increment of vegetable intake.[4]

Some studies also suggest that increasing the consumption of fruit and vegetables – or at least of some specific categories of them – may lower the risk of certain eye diseases such as glaucoma and diabetic retinopathy;[32,33] osteoporosis;[34] asthma and chronic obstructive pulmonary disease;[35-37] rheumatoid arthritis;[38,39] chronic inflammatory bowel disease;[40] and cognitive decline, depressive disorders and other mental health conditions.[41-44] While the evidence of causality is still controversial, it is likely that at least some of these associations contribute to determining the inverse relationship between fruit and vegetable intake and all-cause mortality observed in multiple studies.[2,3]

In most populations, the mean intake of fruit and vegetables is lower than the levels suggested by international guidelines, which generally recommend consuming at least five servings (400 g) per day of fruit and/or vegetables.[5,45] Discrepancies between recommended and actual intake are higher in low- and middle-income compared with high-income countries, and may be partly explained by the relative unaffordability of fruit and vegetables in poorer regions.[46]

The sub-Saharan African region shows especially low fruit and vegetable consumption (ranking last across all World Health Organization (WHO) regions[5]), and SA is no exception. Analyses of SA food balance sheets indicate an average combined intake of fruit and vegetables per capita (including children) of 213 g/d in 2009, decreased from the 234 g/d estimated for 1999.[47] The first South African Comparative Risk Assessment Study (SACRA1) in 2000 quantified the contribution of this largely inadequate intake of fruit and vegetables for the year 2000, estimating that it accounted for 3.2% of total deaths and 1.1% of total DALYs.[48]

The present study aimed to update the SACRA1 estimates in the light of: (*i*) new evidence regarding the relationship between fruit and vegetable intake and risk of disease; (*ii*) improved estimates of intake in the SA population; and (*iii*) updated estimates of total deaths, years of life lost and DALYs sourced from the second South African National Burden of Disease Study (SANBD2).[49]

We report age- and sex-specific estimates of the burden of disease attributable to low fruit and low vegetable intake in SA for the years 2000, 2006 and 2012.

Methods

Overview

We used the comparative risk assessment methodology developed by the WHO and updated in the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD).[50,51] For each relevant cause of death and disability (health outcome) we calculated the fraction of disease burden attributable to low fruit and vegetable consumption (population attributable fraction, PAF) as the proportional reduction in the total burden that would be observed if the actual population intake (exposure) was shifted to a counterfactual scenario corresponding to the lowest risk (theoretical minimum risk exposure level (TMREL)). We calculated the outcome-specific attributable burden by multiplying the PAFs by the total burden due to that outcome (in terms of deaths and DALYs), and the overall burden as the sum of the outcome-specific burden.

In light of the current evidence that fruit and vegetable intake affect the risk of various diseases differently, we carried out the calculation for the two exposures separately.

Exposure

In the calculation of fruit intake, we included fresh, frozen, cooked, canned or dried fruits, and excluded fruit juices and salted or pickled fruits. For vegetables, we included fresh, frozen, cooked, canned or dried vegetables, and excluded legumes, salted or pickled vegetables, juices, nuts, seeds, and starchy vegetables such as potatoes or corn.

We used published results of a pooled analysis of multiple dietary databases obtained from surveys undertaken in SA between 1983 and 2000 to characterise the distribution of mean daily intake of fruit and vegetables for the year 2000.[52] We used microdata from the World Health Survey 2003 (WHS 2003) and from the South African National Health and Nutrition Examination Survey 2012 (SANHANES-1) to characterise the distribution for the years 2006 and 2012, respectively.[53,54]

From WHS 2003 and SANHANES-1 microdata we calculated individual intake from responses to the relevant items included in the survey questionnaires and estimated means and standard deviations (SDs) of the population distributions by sex and 10-year age groups with standard methods (weighted averages with robust standard error). We assumed an average weight of 80 g for a serving of fruit or vegetables.[55] As only combined estimates of fruit and vegetable intake were available from the 2000 meta-analysis, we obtained separate estimates by assuming that the ratio between fruit and vegetable intake observed in SANHANES-1 was also applicable for the year 2000.

Separately by sex, we fitted a linear meta-regression model with the logarithm of the mean daily intake as the outcome, and year, age category and their interaction as predictors. We used the estimated coefficients to generate age- and sex-specific estimates of the mean daily intake for the years 2000, 2006 and 2012. We used a weighted estimator to fit the model, with weights represented by the inverse variance of the input estimates. We applied the same procedure to estimate the SD of the intake distribution.

In both the WHS 2003 and SANHANES-1 microdata we found that, in agreement with the results of studies in various populations,[56-58] the positively skewed distributions of fruit and vegetable intake were adequately represented by a Weibull distribution. We used the method of moments to calculate for each sex, age group and year the shape and scale parameters of the intake distribution from their estimated mean and SD.

Theoretical minimum risk exposure level. Based on the results of pooled analyses of multiple studies carried out by the GBD group,[5] we assumed that for all health outcomes the minimum risk is observed for mean intakes of 250 g/d of fruit and 360 g/d of vegetables, with no further benefit for higher consumptions. We assumed a uniform uncertainty distribution with limits ±20% of these thresholds.

Health outcomes and RRs

We included in our analyses the following conditions: ischaemic heart disease (ICD-10 codes I20 - I25); ischaemic stroke (I63); haemorrhagic stroke (I60 - I62); lip and oral cavity cancer (C00 - C08); pharynx cancer (C09 - C13); tracheal, bronchus and lung cancer (C33 - C34); larynx cancer (C32); oesophageal cancer (C15); and type 2 diabetes (E10 - E14). We sourced the RR functions from the GBD 2017 study.[5] As the SANBD does not distinguish between nasopharynx and other pharynx cancers, for which GBD 2017 provides slightly different RR functions, we conservatively applied the lowest RR to all pharynx cancers. We assumed no protective effect below the age of 25 years. The RRs for each 100 g/day decrease in fruit and vegetable intake and their 95% CIs are shown in Table S5 in the appendix (https://www.samedical.org/file/1839).

Population attributable fractions

For each outcome *o* and year *y*, and separately for fruit and vegetables, we calculated the PAF as:

$$PAF = \frac{\int_{x=0}^{imax} RR_o(x) \cdot P_y(x) \cdot dx - RR_o(TMREL)}{\int_{x=0}^{imax} RR_o(x) \cdot P_y(x) \cdot dx}$$

where $RR_o(x)$ is the RR function for outcome o; $P_y(x)$ is the distribution of the average daily intake of fruit or vegetables in year y; and $imax$ is the upper limit of the daily intake (assumed at 2 500 g/d).

To calculate the total burden of disease attributable to the combined effect of low fruit and vegetable intake, we also estimated the PAFs for the overall effect. Assuming no correlation between fruit and vegetable intake, we calculated the overall PAF_o for each outcome o as:

$$PAF_o^{TOT} = 1 - (1 - PAF_o^{FRUIT}) \cdot (1 - PAF_o^{VEG})$$

Uncertainty estimates

We used Monte Carlo simulation to present uncertainty ranges around point estimates of the PAFs, reflecting the level of uncertainty in the exposure, the RR functions and the TMREL.

Separately for each year, sex, age group and health outcome, we drew 2 000 random samples from the distributions of the parameters of the exposure distribution, the RR functions and the TMREL, and repeated the calculation of the PAF. We used the mean of the distribution of the replicates as the point estimate of the PAF, and the 2.5th and 97.5th percentiles as the bounds of the 95% uncertainty interval (UI).

In drawing the samples, we assumed a normal distribution for the scale and shape parameter of the Weibull distribution (with mean and SD given by the point estimates and their standard error), a uniform distribution for the TMREL, and a log-normal distribution for the RRs in Table S5.

Attributable burden

We calculated the burden attributable to low fruit and vegetable intake by multiplying the PAFs by the number of deaths[49] and DALYs extrapolated using the ratio of non-fatal burden (years lived with disability) to fatal burden (years of life lost) from the GBD estimates for SA[50] due to each condition by year, sex and age category. To calculate age-standardised rates, we used the mid-year population estimates provided by the Centre for Actuarial Research at the University of Cape Town,[59] and the WHO standard population.[60]

Table 1. Disease burden attributable to a diet low in fruit in males, females and persons aged ≥25 years in South Africa for 2000, 2006 and 2012

	Males				Females				Persons			
Disease outcome	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***
2000												
Haemorrhagic stroke	34	2 862	40	60 857	30	3 570	36	74 695	32	64 32	37	135 552
Ischaemic stroke	28	1 730	34	31 310	23	2 320	28	40 631	25	4 051	31	71 941
Ischaemic heart disease	16	1 988	18	38 177	14	1 626	16	30 532	15	3 614	17	68 709
Diabetes mellitus	14	630	15	16 163	13	929	15	24 107	13	1 559	15	40 270
Oesophageal cancer	25	832	25	14 497	25	516	25	9 614	25	1 348	25	24 111
Trachea, bronchi and lung cancers	14	553	14	9 833	14	216	14	4 006	14	769	14	13 839
Mouth cancer	8	59	8	1 203	8	28	8	567	8	87	8	1 770
Larynx cancer	8	43	8	818	8	7	8	142	8	50	8	960
Oropharynx, nasopharynx and other pharynx cancers	8	16	8	312	8	6	8	127	8	22	8	439
Total attributable burden	-	**8 713**	-	**173 171**	-	**9 218**	-	**184 421**	-	**17 931**	-	**357 591**
(95% UI)		(7 753 - 9 634)		(154 962 - 190 313)		(7 993 - 10 180)		(162 004 - 201 531)		(16 276 - 19 246)		(326 506 - 380 777)
% of total burden	-	**3.3**	-	**1.8**	-	**3.9**	-	**2.0**	-	**3.6**	-	**2.0**
(95% UI)		(2.9 - 3.6)		(1.6 - 2.0)		(3.4 - 4.3)		(1.7 - 2.1)		(3.2 - 3.8)		(1.7 - 2.1)
2006												
Haemorrhagic stroke	34	3 055	39	63 386	30	4 017	36	83 756	32	7 072	37	147 141
Ischaemic stroke	28	1 879	34	33 573	23	2 688	29	47 209	25	4 567	30	80 783
Ischaemic heart disease	16	2 323	18	44 514	14	1 882	16	35 652	15	4 205	17	80 166
Diabetes mellitus	14	861	16	21 815	13	1 286	15	34 336	13	2 147	15	56 151
Oesophageal cancer	25	692	25	11 883	25	457	25	7 836	25	1 148	25	19 718
Trachea, bronchi and lung cancers	14	548	14	9 497	14	257	14	4 578	14	805	14	14 075
Mouth cancer	8	61	8	1 245	8	26	8	520	8	87	8	1765
Larynx cancer	8	35	8	631	8	7	8	136	8	42	8	760
Oropharynx, nasopharynx and other pharynx cancers	8	20	8	400	8	7	8	129	8	27	8	536
Total attributable burden	-	**9 473**	-	**186 944**	-	**10 628**	-	**214 151**	-	**20 101**	-	**401 095**
(95% UI)		(8 368 - 10 451)		(166 163 - 206 253)		(9 294 - 11 761)		(189 175 - 234 901)		(18 241 - 21 552)		(365 290 - 426 199)
% of total burden	-	**2.8**	-	**1.5**	-	**3.2**	-	**1.7**	-	**3.0**	-	**1.6**
(95% UI)		(2.4 - 3.0)		(1.4 - 1.7)		(2.8 - 3.5)		(1.5 - 1.8)		(2.7 - 3.2)		(1.4 - 1.7)
2012												
Haemorrhagic stroke	33	2 844	38	56 171	29	3 633	34	72 130	31	6 478	36	128 301
Ischaemic stroke	28	1 872	33	32 422	22	2 604	27	44 683	24	4 476	29	77 105
Diabetes mellitus	14	991	16	27 120	12	1 393	16	45 432	13	2 384	15	72 552
Ischaemic heart disease	16	2 124	18	41 010	14	1 638	17	30 531	15	3 762	17	71 541

Continued ...

Table 1. (continued) Disease burden attributable to a diet low in fruit in males, females and persons aged ≥25 years in South Africa for 2000, 2006 and 2012

	Males			Females			Persons			
Disease outcome	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***
Oesophageal cancer	26	649	10 763	25	423	7 187	26	1 072	25	17 950
Trachea, bronchi and lung cancers	14	635	10 672	14	287	4 999	14	922	14	15 671
Mouth cancer	8	56	1 124	8	29	570	8	85	8	1 694
Larynx cancer	8	41	748	8	8	149	8	48	8	898
Oropharynx, nasopharynx and other pharynx cancers	8	22	439	8	7	156	8	30	8	595
Total attributable burden	-	**9 235**	**180 469**	-	**10 022**	**205 839**	-	**19 258**	-	**386 308**
(95% UI)		(8 062 - 9 972)	(158 316 - 195 791)		(8 628 - 11 162)	(178 495 - 227 765)		(17 301 - 20 569)		(349 529 - 410 216)
% of total burden	-	**3.3**	**1.8**	-	**4.0**	**2.0**	-	**3.6**	-	**1.9**
(95% UI)		(2.9 - 3.6)	(1.6 - 1.9)		(3.4 - 4.4)	(1.7 - 2.2)		(3.3 - 3.9)		(1.7 - 2.0)

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

We used R Statistical Software v. 3.6 (R Core Team, Austria) to conduct the analyses.[61] Further methodological details are available in the appendix.

Results

Fruit and vegetable intake

In the SA population aged ≥25 years, both fruit and vegetable consumption declined between 2000 and 2012 (Fig. 1). Fruit intake decreased by 7%, from 48.5 g/d (95% UI 46.6 - 50.5) to 45.2 g/d (95% UI 42.7 - 47.6) in 2012. Vegetable consumption decreased by 25%, from 146.9 g/d (95% UI 142.3 - 151.8) to 110.5 g/d (95% UI 105.9 - 115.0).

The declining trend was present in all age groups and more pronounced among those aged ≥75 years. An increasing trend was only observed for fruit consumption among males aged 64 - 74 years and females aged 45 - 54 (Table S6 and Fig. S2 in the appendix: https://www.samedical.org/file/1839).

Assuming independence between the population distributions of fruit and vegetable intake, in 2012, <7% of adults aged ≥25 years had an average combined daily intake of fruit and vegetables greater than the generally recommended value of 5 servings (400 g).

Attributable burden

Tables 1 and 2 show PAFs and number of deaths and DALYs attributable to diets low in fruit and vegetables, respectively. Among women, the total number of deaths attributable to low fruit intake increased from 9 218 (95% UI 7 993 - 10 180) in 2000 to 10 628 (95% UI 9 294 - 11 761) in 2006, and then declined to 10 022 (95% UI 8 628 - 11 162) in 2012. Among men, the number increased from 8 713 in 2000 (95% UI 7 753 - 9 634) to 9 235 (95% UI 8 062 - 9 972) in 2012.

Estimates of DALYs followed a similar pattern in both sexes, with an increase between 2000 and 2006 followed by a decrease in 2012. Overall, the number of DALYs increased from 357 592 (95% UI 326 506 - 380 777) to 386 308 (95% UI 349 529 - 410 216). In both sexes the burden attributable to low vegetable intake increased between 2000 and 2006 and declined thereafter. In 2012, the attributable deaths numbered 4 685 (95% UI 3 772 - 5 526) for males and 4 899 (95% UI 3 895 - 5 859) for females, and attributable DALYs were 90 165 (95% UI 73 388 - 106 069) for males and 91 884 (95% UI 75 342 - 107 593) for females. In 2012, the combined effect of low fruit and vegetable intake was responsible for 26 423 (95% UI 24 368 - 28 006) deaths and 514 823 (95% UI 473 508 - 544 803) DALYs, increasing from the 24 155 (95% UI 22 229 - 25 523) deaths and 471 119 (95% UI 438 780 - 494 654) DALYs estimated for the year 2000.

The proportional distribution of attributable deaths across health outcomes is shown in Fig. 2. The burden attributable to a diet low in fruit was mostly due to stroke and ischaemic heart disease in both sexes and with modest variations across years. The fraction of attributable burden due to diabetes was larger, increasing over time among females but decreasing among males. In all years, the burden attributable to a diet low in vegetables was predominantly due to ischaemic heart disease among males and to stroke among females. In 2012, CVD accounted for 83% of the deaths attributable to the combined effect of low fruit and vegetable intake, and 84% of DALYs.

Age-standardised attributable rates are shown in Figs 3 and 4. Between 2000 and 2012, age-standardised death rates attributable to low fruit intake decreased by 9% in males and by 15% in females. Age-standardised death rates attributable to low vegetable intake decreased more in men (−10%) than in women (−5%). Age-standardised DALY rates due to low fruit intake decreased by a similar amount (−13%) in both sexes, while age-standardised DALY rates due to low vegetable intake decreased more in men (−13%) than in women (−6%).

Age patterns

The age distributions of the number of deaths attributable to the combined effect of low fruit and vegetable intake were largely different by sex (Fig. 5). Among men, attributable deaths peaked in the 55 - 64-year age group and declined afterwards, while among females the number of deaths grew almost linearly with age. Attributable DALYs showed an age pattern more similar across sexes, albeit more pronounced among males, with a peak between the ages of 45 and 64 years,

Table 2. Disease burden attributable to a diet low in vegetables in South African adults aged ≥25 years by sex for 2000, 2006 and 2012

	Males				Females				Persons			
Disease outcome	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***	**AF, %**	**Deaths, *n***	**AF, %**	**DALYs, *n***
2000												
Haemorrhagic stroke	15	1 274	21	27 494	12	1 367	14	29 181	13	2 641	16	56 676
Ischaemic heart disease	19	2 416	18	45 581	15	1 726	17	31 937	17	4 142	19	77 519
Ischaemic stroke	13	772	16	14 202	9	883	11	15 804	10	1 654	13	30 006
Total attributable burden	-	**4 462**	-	**87 278**	-	**3 976**	-	**76 922**	-	**8 438**	-	**164 201**
(95% UI)		(3 601 - 5 262)		(70 570 - 102 290)		(3 168 - 4 758)		(62 681 - 90 437)		(7 231 - 9 565)		(141 428 - 184 132)
% of total burden	-	**1.7**	-	**0.9**	-	**1.7**	-	**0.8**	-	**1.7**	-	**0.9**
(95% UI)		(1.4 - 2.0)		(0.7 - 1.1)		(1.3 - 2.0)		(0.7 - 1.0)		(1.4 - 1.9)		(0.7 - 1.0)
2006												
Haemorrhagic stroke	20	2 874	22	29 367	19	2 480	16	36 440	20	4 549	17	65 808
Ischaemic heart disease	15	1 389	18	54 526	22	2 913	19	41 569	25	6 850	20	96 096
Ischaemic stroke	12	851	16	15 577	15	1 744	12	20 546	17	3 093	14	36 124
Total attributable burden	-	**5 114**	-	**99 472**	-	**5 076**	-	**98 556**	-	**10 190**	-	**198 028**
(95% UI)		(4 104 - 6 088)		(80 028 - 117 632)		(4 094 - 6 607)		(81 106 - 115 589)		(8 752 - 11 521)		(170 551 - 222 245)
% of total burden	-	**1.5**	-	**0.8**	-	**1.5**	-	**0.8**	-	**1.5**	-	**0.8**
(95% UI)		(1.2 - 1.8)		(0.7 - 1.0)		(1.2 - 1.9)		(0.6 - 0.9)		(1.3 - 1.7)		(0.7 - 0.9)
2012												
Haemorrhagic stroke	20	2 578	22	25 752	13	1715	22	33 217	14	3 105	21	58 969
Ischaemic heart disease	15	1 275	17	49 579	1	2220	26	38 070	18	5 094	25	87 649
Ischaemic stroke	12	831	15	14 834	10	1140	19	20 595	11	1 992	18	35 430
Total attributable burden	-	**4 685**	-	**90 165**	-	**4 899**	-	**91 883**	-	**9 584**	-	**182 049**
(95% UI)		(3 772 - 5 526)		(73 388 - 106 069)		(3 895 - 5 859)		(75 342 - 107 593)		(8 174 - 10 864)		(156 462 - 204 159)
% of total burden	-	**1.7**	-	**0.9**	-	**1.9**	-	**0.9**	-	**1.8**	-	**0.9**
(95% UI)		(1.4 - 2.2)		(0.7 - 1.2)		(1.5 - 2.3)		(0.7 - 1.0)		(1.5 - 2.1)		(0.8 - 1.0)

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

and lower values at younger and older ages (Fig. 6). Separate distributions for fruit and vegetables are shown in Figs S3 - S6 in the appendix (https://www.samedical.org/file/1839).

Discussion

In this study, we calculated the distribution of fruit and vegetable intake in the SA adult population between 2000 and 2012. In 2012, the mean combined intake (155.7 g/d) was far below the recommended amount of 400 g/d,[5,45] and 20% lower than the estimated value for the year 2000 (195.4 g/d), with most of the decrease attributable to low intake of vegetables.

While our national estimates cannot be directly compared with estimates referring to specific subpopulations, results from multiple local studies are in clear agreement with our finding that consumption of fruit and vegetables in the SA population is extremely low. Among these studies is the Prospective Urban and Rural Epidemiology (PURE) study in rural and urban communities in North West, Eastern Cape and Western Cape provinces,[62,63] the Cardiovascular Risk in Black South Africans (CRIBSA) study,[64] and the study by Pretorius *et al.*[65] on hospital patients.

The PURE study in North West included a cohort of 1 154 black African men and women aged 30 - 70 years.[62] Large differences were observed between rural and urban areas. In 2012, the median intake of vegetables was 39.4 g/d among rural men and 87.8 g/d among urban men. Among women, the median intake was 58.1 g/d in rural areas and 105.5 g/d in urban areas. Regarding fruit, rural men consumed a median of 56.1 g/d v. 65 g/d consumed by urban men. Women consumed 58.6 g/d in rural areas and 164.3 g/d in urban areas. Considering a 63%/47% split between urban and rural populations as per 2012 World Bank estimates, and assimilating the black African subgroup (80.7% of the population) to the whole SA population, the PURE data give an approximate overall consumption of 183 g/d, which compares reasonably well with our finding for the same year.[66,67]

Okop *et al.*[63] analysed data collected within the scope of the PURE study in two economically disadvantaged communities, an urban township (Langa) near the Cape Town metropolis and a rural community (Mount Frere)

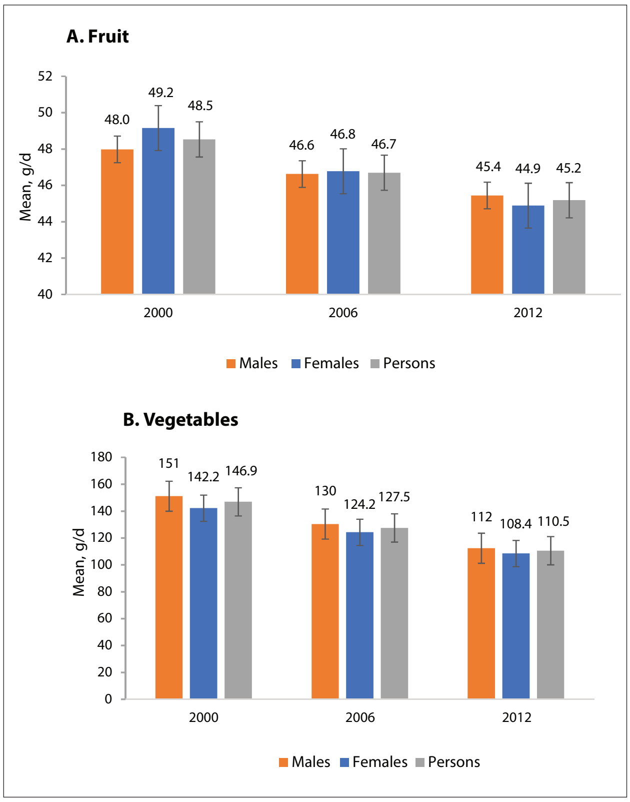

Fig. 1. Mean intake of (A) fruit and (B) vegetables in South African adults aged ≥25 years, by sex for 2000, 2006 and 2012.

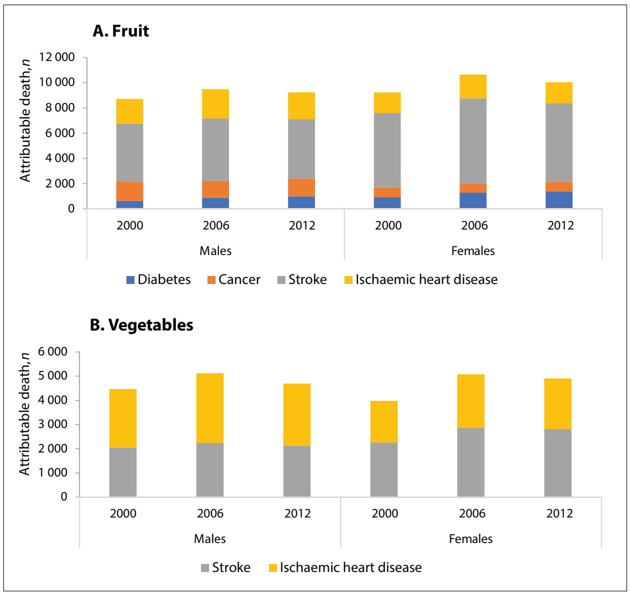

Fig. 2. Deaths attributable to low (A) fruit and (B) vegetable intake in South African adults aged ≥25 years by health outcome and sex for 2000, 2006 and 2012.

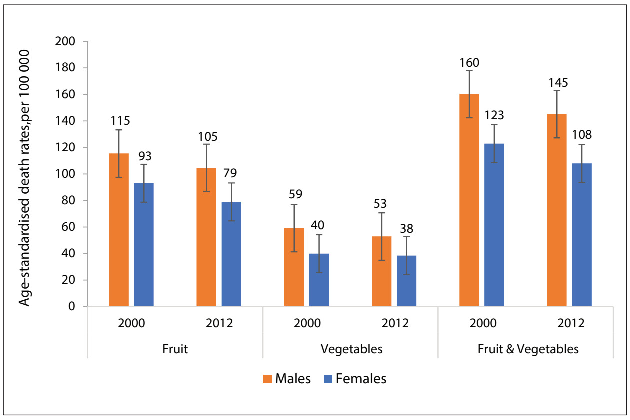

Fig. 3. Age-standardised death rates attributable to low fruit and vegetable intake in South African adults aged ≥25 years by sex for 2000 and 2012.

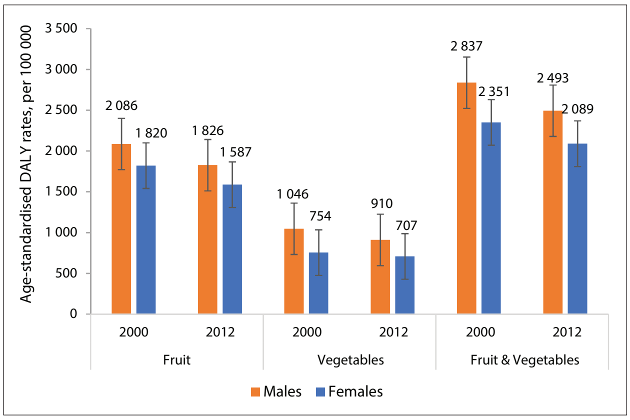

Fig. 4. Age-standardised DALY rates attributable to low fruit and vegetable intake in South African adults aged ≥25 years by sex for 2000 and 2012. (DALY = disability-adjusted life year.)

in Eastern Cape. They found that a higher proportion of participants in the urban township compared with their rural counterparts had purchased fruit (93% v. 51%) and vegetables (62% v. 56%) either daily or weekly. Only 37.8% of the participants consumed at least two portions of commonly available fruits and vegetables daily, with no differences between the two communities.

In 2009, the CRIBSA study[64] was undertaken in the same areas where the 1990 Black Risk Factor (BRISK) study[68,69] was carried out to determine the prevalence of NCDs and lifestyle risk factors associated with them. The study took place in black African townships in Cape Town. Observed mean intakes were 224 g/d in males and 232 g/d in females, an increase from the 1990 estimates (68 g/d and 193 g/d for males and females, respectively), but still well below the recommendations.

Finally, Pretorius *et al.*[65] studied 50 patients with heart failure at a major Soweto hospital through a quantified food frequency questionnaire. They found that men had a median fruit and vegetable intake of 250 g/d and women a median intake of 225 g/d. Vegetable intake was particularly low, at <80 g/d in both sexes. This would certainly help to explain the low intakes of vitamin C and folate that were prevalent in this adult group.

Data from the Food and Agriculture Organization on per capita consumption of fruit and vegetables also support our findings. Estimates for the year 2014 indicate an average consumption for SA of 81.1 g/d for vegetables and 41.3 g/d for fruit, and a combined per capita consumption of 122.4 g/d;[70] this compares reasonably well with the 155.7 g/d in the present study. However, it should be remembered that this does not include home-grown vegetables, which are consumed in fair quantities in some provinces, and that it also includes children and adults aged <25 years.[71] Data from the National Food Consumption Survey[72] indicated that 17% of households grew crops and 10% picked wild indigenous leafy vegetables.[73]

These low levels of fruit and vegetable consumption are part of a broader shift towards more 'westernised' diets compared with the traditional rural diet, which is usually high in leafy green vegetables,

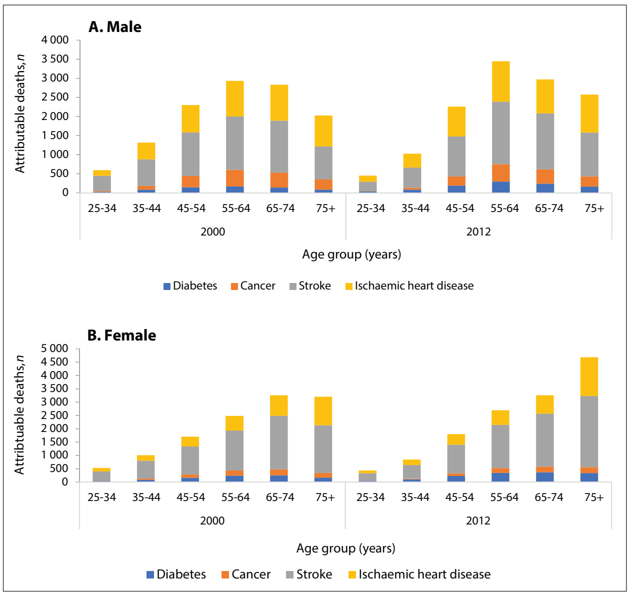

Fig. 5. Deaths attributable to low fruit and vegetable intake combined in South African adults aged ≥25 years for (A) males and (B) females by health outcome and age group.

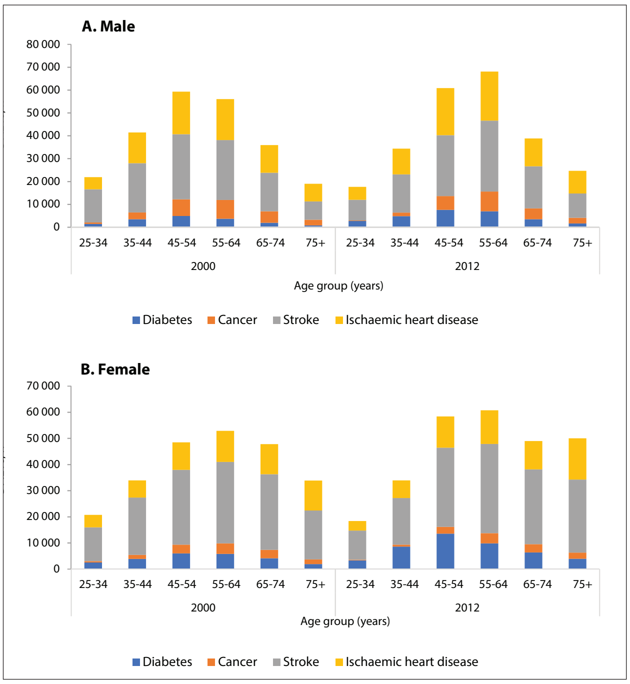

Fig. 6. DALYs attributable to low fruit and vegetable intake combined in South African adults aged ≥25 years for (A) males and (B) females by health outcome and age group. (DALY = disability-adjusted life year.)

low in fat and legumes, and low in processed foods, added sugar and salt. This was evident among the participants in the PURE study, whose average consumption of added sugar, sugar-sweetened beverages, candy and chocolate was far higher than the WHO recommendations of 50 g/d.[74] Their salt intake was also high owing to the high consumption of salt and salty products.

The factors that are driving these dietary changes are complex and only partially known, but aspects of accessibility and affordability of the different categories of foods are probably playing an important role, and may contribute to an explanation of the counterintuitive finding from the PURE study of a higher consumption of fruit and vegetables among urban rather than rural participants.[75] The analyses by Okop *et al.*[63] of the data from the Eastern and Western Cape legs of the PURE study – conducted among participants with very low average household monthly income, with only 2.6% of households earning ≥ZAR5 000 (USD357.1) – offer some support in this regard. Controlling for age and gender, the analysis showed that those with monthly expenditure of ≥ZAR1 000 (USD71.4) on groceries compared with those who spent less, and those who travelled with a personal vehicle to purchase groceries compared with those who took public transport, were respectively 1.6 times (95% CI 1.05 - 2.44) and 2.1 times (95% CI 1.06 - 4.09) more likely to consume at least two portions of fruit and vegetables daily. In contrast, education level, attitude towards fruit and vegetables and owning a refrigerator had no significant association with daily intake of either.[63]

A few studies have also been conducted with the specific objective of understanding why people have such a low intake of fruit and vegetables. Peltzer and Phaswana-Mafuya[76] conducted a national study on fruit and vegetable consumption in SA adults aged >50 years (*N*=3 840). In multivariate analyses, daily tobacco use, low education and classification as black African or coloured according to Statistics South Africa's population group categorisation[77] were associated with inadequate fruit and vegetable intake. A qualitative study comprising focus groups was undertaken with consumers in Mitchell's Plain in the Cape Town metropolitan area.[78] Numerous barriers to fruit and vegetable consumption were identified, including affordability, negative effects of consumption, and perishability. The authors of the Heart of Soweto study identified a series of factors contributing to the low intake of fruit and vegetables of adults in Soweto,[79] including overall changes in dietary patterns, food insecurity, socioeconomic circumstances, perceptions of obesity and overweight, and awareness of healthy food choices.

As the current literature indicates, at approximately ≥250 g/d and ≥360 g/d consumption of fruit and vegetables, for which the lowest burden of disease is obtained, the level of consumption estimated in our study is associated with a remarkable excess burden. In 2012, we estimated that 3.6% of deaths could have been avoided by increasing fruit consumption to optimal levels, and 1.8% of deaths by increasing vegetable consumption to optimal levels.

It is worth noting that despite the generally decreasing trends in fruit and vegetable consumption, between 2000 and 2012 we observed an appreciable decrease in age-standardised attributable death and DALY rates. This apparent contradiction results from a combination of factors, including: (*i*) the fact that if the overall mean intake of fruit and vegetables decreased in the whole population, this was not always the case in the different age groups – in particular, mean fruit intake increased among males aged 65 - 74 years and females aged 45 - 54, both age groups characterised by a high absolute burden for CVD; (*ii*) the decrease in mean intake was accompanied by a change in the shape of the distribution, making the relationship between average consumption and attributable fractions far from linear or strictly monotonic; and (*iii*) the total burden due to various health outcomes varied significantly between 2002 and 2012, both overall and within each age category. Notably, the standardised rates of CVD (groups of diseases that account for >80% of the burden attributable to diet low in fruit and vegetables) decreased over this period in both sexes.[80]

The total attributable burden, however, was higher in 2012 compared with the previous decade, both in terms of deaths and DALYs.

Study strengths and limitations

Compared with SACRA1, the present study provides improved estimates of the burden of disease for the year 2000 and includes two further time points. Improvements include: (*i*) the use of current evidence from systematic reviews and meta-analyses to select the health outcomes and identify appropriate RR functions; (*ii*) updated estimates of fruit and vegetable consumption in the SA population as continuous distributions for the calculation of the attributable fractions; and (*iii*) updated estimates of total number of deaths and DALYs due to the selected health outcomes.

However, many limitations need to be acknowledged. First, the exposure estimates are based on a limited amount of data collected with inconsistent methods. Even though we believe that our modelling approach contributed to improving the quality of the estimates compared with the use of raw data, the results include large uncertainty and possibly bias. Second, the mechanisms underlying the effects of fruit and vegetable consumption on health are only partially known, and the best available evidence regarding the RR functions for various diseases is still characterised by marked uncertainty. Third, in the calculation of the attributable burden, we were unable to quantify the level of uncertainty on the total number of deaths and DALYs attributable to the various health outcomes, with the plausible effect of an underestimation of the width of the UIs reported for the attributable burden. Moreover, our study does not consider the joint effects of low fruit and vegetable intake with other risk factors (such as diets high in saturated fats, physical inactivity, and high blood pressure) that share a common causal pathway in the development of cardiovascular disease and type 2 diabetes. Such an analysis would assist in identifying which risk factors have the larger impacts on these health outcomes.

Conclusion and recommendations

While the reduction in the total burden for CVD and, to a lesser extent, some progress in fruit and vegetable intake in a few age categories have resulted in a decrease in age-standardised attributable death rates, the absolute attributable burden remains high and the overall decreasing trend in average consumption in the majority of the population is alarming.

Effective interventions supported by legislation and policy are needed to reverse the declining consumption trends and to curb the associated burden. Educational and environmental interventions targeting children and adolescents in school are among those that are more directly and immediately implementable. A first recommendation is to introduce more nutrition education on food and vegetable intake in the school curriculum from grades R to 12, to provide at least children and adolescents with this important dietary information. The South African food-based dietary guidelines[81] were first developed almost two decades ago for this purpose, but still do not appear to have been included in the school curriculum. A second recommendation is to ensure that the school environment is a healthy one and that sugar-sweetened beverages and unhealthy foods are not for sale. The Department of Basic Education should introduce and enforce such a policy in co-operation with the National Department of Health, together with a concerted effort to improve the number of school vegetable gardens.

As dietary patterns are driven by complex interactions between a wide set of social and economic processes, creating sustained changes requires that targeted interventions such as those suggested are accompanied by more upstream interventions to remove structural barriers to the increased consumption of fruit and vegetables. Some progress has been made in recent years, with legislation aimed at introducing positive changes in the food environment (such as increased taxation of sugary drinks[82] and compulsory reduction of salt content in some categories of foods[83]), but more needs to be done to ensure greater availability and affordability of fruit and vegetables across the different population strata.

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Author contributions. Conceived and designed the study: JDJ, RP, DB, VPvW, AC. Analysed the data: AC, NA. Prepared data for analysis: AC. Interrogated and interpreted results: all. Drafted manuscript: AC. Critical review of manuscript for important intellectual content: all. Senior authors: DB, VPvW, RP. Agreed to final version: all.

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Conflicts of interest. None.

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