Estimating the burden of disease attributable to low fruit and vegetable intake in South Africa in 2000

Michelle Schneider, Rosana Norman, Nelia Steyn, Debbie Bradshaw and the South African Comparative Risk Assessment Collaborating Group

Objectives. To estimate the burden of disease attributed to low fruit and vegetable intake by sex and age group in South Africa for the year 2000.

Design. The analysis follows the World Health Organization comparative risk assessment (CRA) methodology. Population-attributable fractions were calculated from South African prevalence data from dietary surveys and applied to the revised South African burden of disease estimates for 2000. A theoretical maximum distribution of 600 g per day for fruit and vegetable intake was chosen. Monte Carlo simulation-modelling techniques were used for uncertainty analysis.

Setting. South Africa.

Subjects. Adults ≥ 15 years.

Outcome measures. Mortality and disability-adjusted life years (DALYs), from ischaemic heart disease, ischaemic stroke, lung cancer, gastric cancer, colorectal cancer and oesophageal cancer.

Results. Low fruit and vegetable intake accounted for 3.2% of total deaths and 1.1% of the 16.2 million attributable DALYs. For both males and females the largest proportion of total years of healthy life lost attributed to low fruit and vegetable intake was for ischaemic heart disease (60.6% and 52.2%, respectively). Ischaemic stroke accounted for 17.8% of attributable DALYs for males and 32.7% for females. For the related cancers, the leading attributable DALYs for men and women were oesophageal cancer (9.8% and 7.0%, respectively) and lung cancer (7.8% and 4.7%, respectively).

Conclusions. A high intake of fruit and vegetables can make a significant contribution to decreasing mortality from certain diseases. The challenge lies in creating the environment that facilitates changes in dietary habits such as the increased intake of fruit and vegetables.

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Fruit and vegetables contain many nutrients such as vitamins, minerals and fibre which may, individually or in combination, be protective against cardiovascular diseases (CVDs) and certain cancers.[1] The World Health Organization (WHO)[2] recognises that there is convincing evidence of decreased risk of coronary heart disease, stroke, high blood pressure and obesity associated with an increased fruit and vegetable intake. Although definitive quantification of the protective effects against other conditions is still lacking, there is probable evidence of decreased risk for cancer of the oral cavity, oesophagus, stomach, colon and rectum, as well as probable evidence of decreased risk of type 2 diabetes mellitus with an increased intake of fruits and vegetables. Eating plenty of fruit and vegetables also reduces the occurrence of fractures, cataracts, age-related macular degeneration[3] and birth defects, and plays a role in response to infections.

Burden of Disease Research Unit, South African Medical Research Council, Tygerberg, Cape Town
Michelle Schneider, MSc
Rosana Norman, PhD
Debbie Bradshaw, DPhil (Oxon)

Chronic Diseases of Lifestyle Research Unit, South African Medical Research Council, Tygerberg, Cape Town
Nelia Steyn, PhD

Corresponding author: *M Schneider (michelle.schneider@mrc.ac.za)*

There are several mechanisms by which these protective effects are mediated. In the case of cancers, anti-oxidants, various micronutrients and other substances block and suppress the action of carcinogens and prevent oxidative DNA damage. In the case of atherosclerosis, deficiencies of folic acid and vitamins B_{12} and B_6 increase levels of homocysteine and generate free radicals, resulting in oxidative damage to endothelial cells, which in turn leads to aggregation of monocytes and platelets and vasoconstriction.[4,5] Another potential mechanism by which fruit and vegetables affect cardiovascular risk is an indirect link via the high potassium concentration of some fruit and vegetables, that serves to modulate blood pressure.[6]

Many fruit and vegetables are high in dietary fibre, which expedites the movement of waste products through the intestinal tract and also lowers blood cholesterol levels.[7] Vitamin A helps protect against infectious diseases. It helps maintain the lymphocyte pool and thus is involved in the T-cell-mediated response to infection.[8] Plants also produce unique compounds called 'phytochemicals' to protect themselves against viruses, bacteria and fungi. The exact mechanisms by which these promote human health are unclear.[7] The interactive and synergistic effects of nutrients in food cannot be discounted.[8]

Ideally, to protect against CVDs and certain cancers, the WHO recommends an intake of 400 g/day – the equivalent of 5 portions of fruit and vegetables per day of 80 g each.[2] This recommendation has been based on a dose-response effect which indicates an increased risk of disease at less than 200 g/day, yet little benefit above 400 g/day.[9] The intake of fruit and vegetables in South Africa is estimated to be similar to that in the UK, with an average per capita intake of about 200 g/day.[10] Although greater than that of India (120 - 140 g/day), the South African intake is considerably less than that of China (369 g/day) and Spain (600 g/day).[10]

Data from South African food balance sheets show that annual per capita fruit intake increased from 67.6 kg in 1962 to 80.2 kg by 2001, while vegetable intake remained more or less the same at 120 g/day.[11] Overall, this amounted to an increase in combined fruit and vegetable intake per capita per day from 185 g in 1962 to 220 g by 2001. Despite these increases, which are mainly due to improved access, fruit and vegetable intake in South Africa is extremely low.

It has been estimated that globally 2.7 million (4.9%) deaths and 26.7 million (1.8%) disability-adjusted life years (DALYs) per year in 2000 were attributable to low fruit and vegetable intake.[6] In the global study,[6] low dietary intake of fruit and vegetables is estimated to cause about 31% of ischaemic heart disease, 19% of ischaemic stroke, 20% of oesophageal cancer and 19% of gastric cancer worldwide. Attributable fractions were lower for lung and colorectal cancers (12% and 2% respectively). The aim of this study was to estimate the overall burden of disease attributed to low fruit and vegetable intake, by sex and specific age groups in South Africa for 2000. This will serve to provide country-level data and facilitate comparative work.

Methods

Following the WHO comparative risk assessment (CRA) methodology,[6,12,13] the disease burden attributable to low fruit and vegetable intake was estimated by comparing the levels of fruit and vegetable intake observed in South Africa with a counterfactual distribution conferring the lowest possible risk. Fruit and vegetable intake was treated as a continuous variable, defined as the mean per capita dietary intake of fruit and vegetables measured in grams per day (g/day). The estimates excluded potatoes in order to be consistent with international recommendations.[14] Sweet potatoes are used interchangeably with potatoes in South Africa, and were also excluded. Pulses or dry legumes such as lentils and beans were not included. However, green legumes such as fresh peas or green beans were included.

Fruit and vegetable consumption is unusual in that there is an inverse risk factor-disease relationship. As fruit and vegetable intake is protective, a theoretical maximum distribution of intake, based on an upper consumption level that is protective, was used to calculate the population-attributable fractions (PAFs). It is not clear whether there is a threshold effect for fruit and vegetable consumption, although many studies[6] have presented a linear dose-response relationship. In the global CRA project[6] the counterfactual was chosen to be a constant level using a minimum risk approach. The highest mean daily intake of fruit and vegetables is found in Greece, and estimated to be about 700 - 800 g per person per day. This finding notwithstanding, the global study[6] found that dietary survey data for adults in any country rarely went above an intake of 500 g/day and never above 550 g/day, even in countries such as Italy and Israel which are known for their high fruit and vegetable intake. As in the global CRA, the theoretical minimum risk distribution was therefore set at 600 g/day in adults with a standard deviation (SD) of 50 g/day in an ideal scenario. Set intervals of fruit and vegetables of 80 g/day (equivalent to 1 serving) were used for the distributional transition, constituting a plausible and feasible change for individuals towards the selected counterfactual (theoretical maximum risk) level.[6]

With the exception of the National Food Consumption Survey on children,[15] there are no nationally representative dietary surveys in South Africa. However, a recent meta-analysis that pooled data from the available dietary surveys was re-analysed to determine the mean and SD of fruit and vegetable intake measured in g/day for adults older than 15 years by age groups.[16,17] Despite the actual intake data following a skewed distribution, fruit and vegetable consumption was assumed to follow a truncated normal distribution. Sensitivity analyses incorporating a skewness value observed in US populations have shown the truncated normal distribution to result in slightly conservative estimates of exposure to low intakes (T Vos, School of Population Health, University of Queensland, Brisbane – personal communication, 2006). Data were not available for the elderly; surveys only included adults up to the age of 65 years. We assumed that individuals aged 70 - 79 and 80+ years consumed the same amount of fruit and vegetables as those in the closest age group (60 - 69 years).

The choice of outcomes included in the analysis was determined by reviews of the literature and strong evidence of a risk factor-disease relationship suggesting a protective effect of fruit and vegetable consumption in preventing ischaemic heart disease, ischaemic stroke, lung, gastric, colorectal and oesophageal cancers.[6] Risk factor-disease relationships for each selected outcome were determined on the basis of a systematic literature review combined with meta-analysis.[6] There is also limited evidence for other protective health outcomes, including type 2 diabetes, chronic obstructive pulmonary disease, cataracts, cancers of the mouth and pharynx, and cancers that may have a hormonal aetiology, including ovarian, endometrial, thyroid and prostate cancers. These, however, were not included in the global CRA project[6] due to insufficient evidence at this stage.

The relative risk (RR) estimates associated with an 80 g/d increase in fruit and vegetable intake, adjusted for potential

Table I. Selected health outcomes and relative risks (95% confidence intervals) associated with increased fruit and vegetable intake* by age group

	Age groups (years)		
Outcomes (ICD-10)[18]	15 - 69	70 - 79	80+
Ischaemic heart disease	0.90	0.93	0.95
(I20-I25)	(0.82 - 0.99)	(0.85 - 1.01)	(0.87 - 1.03)
Ischaemic stroke	0.94	0.95	0.97
(I63)	(0.89 - 0.99)	(0.91 - 1.00)	(0.92 - 1.02)
Lung cancer	0.96	0.97	0.98
(C33-C34)	(0.93 - 0.99)	(0.91 - 1.02)	(0.92 - 1.03)
Gastric cancer	0.94	0.95	0.97
(C16)	(0.86 - 1.03)	(0.87 - 1.04)	(0.89 - 1.06)
Colorectal cancer	0.99	0.99	1.00
(C18, C20)	(0.97 - 1.02)	(0.97 - 1.02)	(0.97 - 1.02)
Oesophageal cancer	0.94	0.95	0.97
(C15)	(0.88 - 1.01)	(0.89 - 1.02)	(0.91 - 1.04)

Source: Adapted from Lock *et al.*, 2004.[6]
*Unit of change in risk is change per 80 g/d increase in fruit and vegetable intake.

confounders (including smoking, body mass index and physical activity) are shown in Table I. The same RR applied for individuals aged 15 - 69 years; however, for many diseases the RR decreases with increasing age due to the increasing background mortality from other causes. The RRs were adjusted to take account of age attenuation. The excess risk was reduced by a quarter for ages 70 - 79 years and by a half for the age group 80+ years. It was assumed that there was no protective effect below the age of 15 years. It was also assumed that there was no difference in RR across sub-populations.[6]

Customised MS Excel spreadsheets based on templates used in the Clinical Trials Research Unit at the University of Auckland (S Vander Hoorn – personal communication, 2006) as well as in Australian studies (T Vos – personal communication, 2006) were used to calculate the PAFs using a discrete version of the general potential impact fraction (see below), taking into account continuous risk factor-disease exposures compared with a theoretical maximum distribution (conferring the lowest possible risk) on a categorical scale). The PAF was calculated as:

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

where n = the number of exposure categories; P_i = the proportion of the South African population in exposure category i; RR_i = the relative risk for exposure category i; and P'_i = the proportion of population in exposure category i in the counterfactual distribution.

The PAFs were then applied to revised South African burden of disease estimates for 2000:[19] number of deaths, years of life lost (YLL) to premature mortality, years of life lived with disability (YLD) and DALYs for the relevant disease and injury categories to calculate attributable burden.

Decreased fruit and vegetable consumption is associated with increased risk of ischaemic stroke, with insufficient evidence for an association with haemorrhagic stroke. The South African burden of disease endpoint, however, is 'total stroke', rather than stroke subtypes. Total stroke deaths and DALYs were therefore adjusted by the age-specific proportions of ischaemic fatal and non-fatal strokes for the AFR-E region using the method of Lawes and colleagues.[20] (AFR-E refers to a WHO mortality stratum sub-region; African regions with high child and adult mortality rates, including South Africa.) These proportions correspond to the limited data available on relative burden of the sub-types in South Africa.[21]

Monte Carlo simulation-modelling techniques were used to present uncertainty ranges around point estimates that reflect all the main sources of uncertainty in the calculations. The @ RISK software version 4.5 for Excel[22] was used, which allows multiple recalculations of a spreadsheet, each time choosing a value from distributions defined for input variables. The probability distributions around the input variables were based on standard errors of the prevalence specifying a normal distribution. For the RR input variables we specified a normal distribution with the natural logarithm of the RR estimates as the entered means of the distribution and the standard errors derived from the published 95% confidence intervals (CIs).[6] For each of the output variables (namely attributable burden as a percentage of total burden in South Africa, 2000), 95% uncertainty intervals were calculated bounded by the 2.5th and 97.5th percentiles of the 2000 iteration values generated.

Results

Mean intakes of fruit and vegetables by age and sex are shown in Table II. The mean intake for males in the 30 - 44-year age group was noticeably lower. The population-weighted mean per capita intake of fruit and vegetables over all ages

Table II. Mean and standard deviation (SD) of dietary intake of fruit and vegetables (g/day) (excluding potatoes)

	Age group (years)					
	15 - 29	30 - 44	45 - 59	60 - 69*	70 - 79*	80+*
Males						
Mean	260	186	251	248	248	248
SD	380	283	285	447	447	447
Females						
Mean	230	218	234	223	223	223
SD	267	279	286	281	281	281

Source: Steyn *et al.*, 2003.[17]
*Data only provided for 60+-year-olds.

was 235 g/d for males and 226 g/d for females, just under 3 servings per day. Based on these mean levels, it was estimated that about 80% of adults 15 years and older eat less than the recommended 5 fruits and vegetables (400 g/d) each day. Hence about 11.1 million males and 12.5 million females over 15 years of age were affected by low fruit and vegetable intake in South Africa in 2000.

The PAFs for the related health outcomes varied by age and sex (Table III). In 2000 a similar number of deaths were attributable to low fruit and vegetable intake in males (8 673 deaths) and females (8 037 deaths). Uncertainty analysis showed that in total between 10 232 and 21 467 deaths were attributable to low fruit and vegetable intake. The burden attributable to low fruit and vegetable intake accounted for 176 918 DALYs (95% uncertainty interval 123 964 - 215 119). Since many of the deaths occurred in middle and old age, the proportion of total DALYs (1.1%) was lower than for total deaths (3.2%).

For both males and females the largest proportion of total YLL attributed to low fruit and vegetable intake was for ischaemic heart disease, accounting for 60.6% and 52.2% respectively (Fig. 1). Ischaemic stroke accounted for 17.8% of attributable DALYs for males and 32.7% for females. The leading selected cancers were oesophageal cancer accounting for 9.8% and 7.0% of attributable DALYs in males and females, respectively, and lung cancer accounting for 7.8% and 4.7% of all DALYs attributable to low fruit and vegetable intake in males and females, respectively.

Discussion

When examining the results of this study, various additional uncertainties need to be acknowledged. These include the use of the collective term 'fruit and vegetables', which comprises a very heterogeneous group; the various components and combinations of these may have different effects. Furthermore, there are many uncertainties with regard to the mechanisms of the protective effects of fruit and vegetable intake on health. There is also marked heterogeneity in the best available evidence on the effects of fruit and vegetable consumption on risk of ischaemic heart disease.[6]

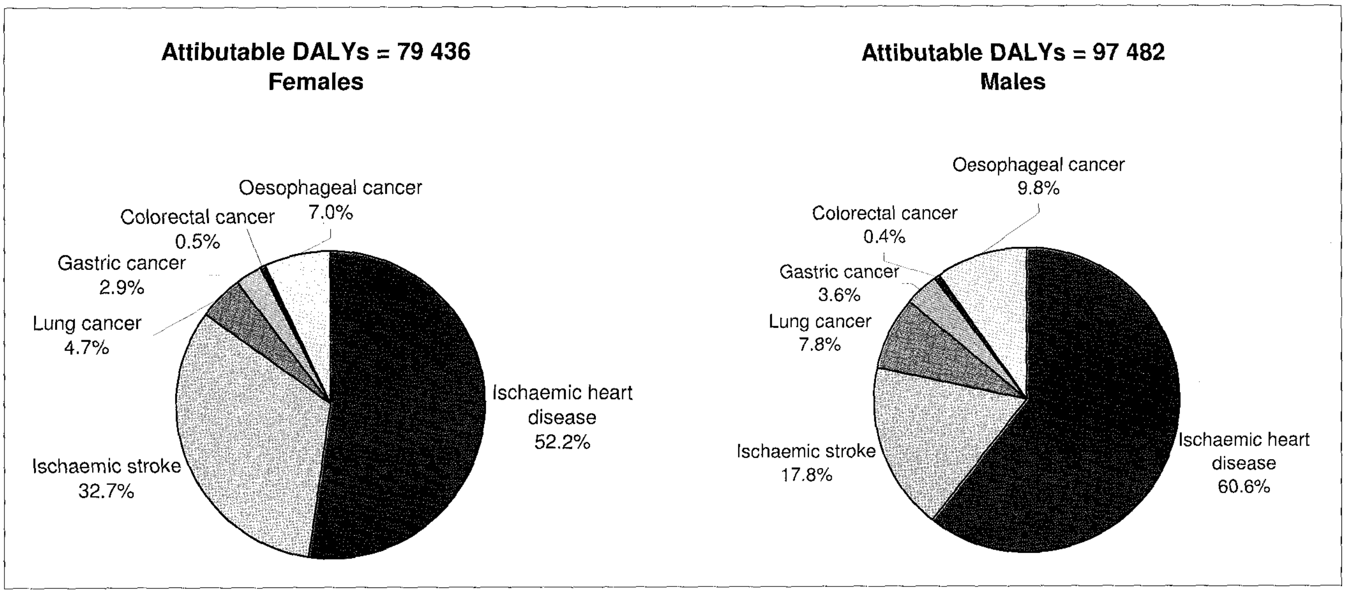

Fig. 1. Burden attributable to low fruit and vegetable intake in males and females, South Africa, 2000.

Table III. Population-attributable fractions (PAFs) and burden attributable to low fruit and vegetable intake, South Africa, 2000

Health outcome	Males PAF (%)	Males Deaths	Males DALYs	Females PAF (%)	Females Deaths	Females DALYs	Persons PAF (%)	Persons Deaths	Persons DALYs
Ischaemic heart disease	35.1	5 390	59 081	33.9	4 678	41 434	34.6	10 068	100 515
Ischaemic stroke	20.9	1 505	17 369	23.3	2 336	26 013	22.2	3 841	43 382
Lung cancer	15.2	667	7 609	15.8	330	3 743	15.4	996	11 352
Gastric cancer	23.6	298	3 533	23.7	204	2 310	23.6	502	5 843
Colorectal cancer	3.1	30	362	3.2	35	405	3.1	64	767
Oesophageal cancer	23.7	784	9 528	24.2	454	5 531	23.9	1 238	15 059
Total burden		**8 673**	**97 482**		**8 037**	**79 436**		**16 709**	**176 918**
95% uncertainty range		5 602 - 10 986	65 737 - 119 592		4 452 - 10 631	56 077 - 96 243		10 232 - 21 467	123 964 - 215 119
% of total burden		**3.2%**	**1.2%**		**3.3%**	**1.0%**		**3.2%**	**1.1%**
95% uncertainty range		2.0 - 4.0%	0.8 - 1.4%		1.8 - 4.3%	0.7 - 1.2%		2.0 - 4.1%	0.8 - 1.3%

PAF = population-attributable fraction; DALYs = disability-adjusted life years.

Available dietary data[16] for South Africa suggest that the average intake of fruit and vegetables of just under 3 servings a day is considerably less than the recommended 5 servings a day. The present study shows that a low fruit and vegetable intake makes a significant contribution to the number of deaths and DALYs from ischaemic heart disease and ischaemic stroke, accounting for 35% and 22% respectively, as well as oesphageal and gastric cancer (both 24%). Apart from human loss and suffering, the deaths and DALYs attributable to the low intake of fruit and vegetables have great cost implications for the health services. This is particularly regrettable since a large proportion of these costs are believed to be preventable.

Low fruit and vegetable intake ranked 11th on the list of 17 selected risk factors in the current CRA study for South Africa in 2000, accounting for 1.1% of the 16.2 million DALYs. In terms of the proportion of deaths or DALYs, both were lower in South Africa than globally, at 3.2% versus 4.9% of deaths and 1.1% versus 1.8% of DALYs.[6] It is interesting to note that the South African PAFs were between 1% and 5% higher than the global study for all selected health outcomes. The lower attributable proportion is a consequence of competing causes and age structure. In both studies, the estimate of the attributable burden must be considered to be a conservative quantification of the role of fruit and vegetables. Limited data on associations has restricted the analysis to 5 health outcomes with strong evidence. Contribution to other conditions, including infections, was not assessed in this study.

This study has several other limitations. The lack of nationally representative dietary data for adults has made it necessary to make use of a pooled estimate of small studies[17] that have been weighted to represent the population profile of the country. These studies were undertaken between 1983 and 2000, spanning a period during which there was a slight increase in the intake. Furthermore, there are indications that eating patterns vary within the country. For example, fruit and vegetable intake is higher in urban areas compared with rural areas (168 g/d versus 137 g/d), most probably because of greater access to and availability of fruit and vegetables in the urban areas.[16] Two studies[23,24] have found very low intake of fruit and vegetables among black South Africans living in rural areas of Limpopo, with an average 132 - 134 g/d per capita. A study among black African urban residents of Cape Town[25] found similarly low levels of consumption, viz. 139 g/d or less than 2 portions per day. One of the few studies undertaken among white adults[26] showed a far higher fruit and vegetable intake of 391 g/d.

In addition to dietary differences, there are also substantial differences in disease and mortality patterns in CVDs and cancers for SA sub-populations. For example, age-standardised ischaemic heart disease mortality per 100 000 population in 2000 was 129 for South African persons.[19] The figures for whites, black Africans, coloureds and Indians were 247, 75, 184 and 414 per 100 000, respectively. Stroke age-standardised mortality rate was 154 for black Africans, 80 for whites, 151 for coloureds and 127 for Asians. The corresponding rate for the South African population was 125 per 100 000.[19] The causes of these conditions are multi-factorial so it would be ideal to assess the contribution of low fruit and vegetable intake by population group. Unfortunately, nationally representative data on fruit and vegetable intake by population group are not yet available in South Africa.

Regardless of any shortcomings of this study, overall the results support the finding that a high intake of fruit and vegetables can make a significant contribution to decreasing mortality from certain diseases. The more difficult part, however, is persuading people to change their behaviour, to eat more fruit and vegetables and to eat a greater variety thereof. A multi-sectoral approach that includes public sector and private enterprise initiatives is needed. Interventions aimed at changing diet include: educating individuals, undertaking community interventions, modifying the food supply, changing the environment, and introducing economic policies.[1] Environmental and policy strategies should address both supply and demand of fruit and vegetables.

In terms of supply, fruit and vegetable production can provide employment and income to unskilled people thus helping to alleviate poverty. It is well suited to small-scale production units, such as those for individual households, and community and school vegetable gardens.[27] However, sustainability of these types of projects is dependent on partnerships between government, non-governmental organisations and industry.[27]

South African studies[8] show that the primary constraints to eating fruit and vegetables are affordability, availability and taste preferences. Fresh fruit and vegetables are not necessarily the most economical, in terms of either preparation time or cost. They are also not necessarily the easiest choice, especially for the poor. Take, for example, the storage of fresh fruit and vegetables, which last longer if refrigerated. The 2001 Census[28] found that only 40% of households have refrigerators, with lower proportions in rural areas and among the poor. As non-communicable diseases are emerging at an accelerated rate in poor countries and among poorer subpopulations in richer countries, the priority should be interventions aimed at the poor.[27]

In addition, cognisance of the nutrition transition is important when considering interventions.[27] Most middle-income countries are in the 'westernised, mass consumption'[27] stage in the nutrition transition. The emphasis for recommendations in these countries is to encourage the replacement of unhealthy food with fruit and vegetables, rather than adding fruit and vegetables to the diet.[27] This may involve going up against the politically powerful, well-funded food industry.[1]

Numerous interventions to promote fruit and vegetable consumption in children and/or their parents have been tested over the past 2 decades. Some of the most successful of these have been delivered in the school setting; including Squire's Quest,[29] TEENS,[30] Gimme-5[31] and CATCH.[32] The majority of these interventions have included changes in school meals or tuck shops/cafeterias, a curriculum taught by trained teachers, and some parental involvement. They have all shown that fruit and vegetable consumption can be significantly improved by active intervention.

To date, no South African interventions have specifically been aimed at improving fruit and vegetable consumption, despite the fact that the National Department of Health's Nutrition Directorate promotes the dietary guideline of 'Eat plenty of vegetables and fruits'. Recently, however, the Medical Research Council has launched an intervention similar to those mentioned above in the Western Cape; this will be evaluated to assess whether such a programme can be implemented in a developing country like South Africa with the same degree of success as those largely restricted to the USA and UK.

Conclusion and recommendations

On average, South Africans eat well below the recommended 5 servings of fruit and vegetables per day. In the context of the current burden of disease attributable to low intake and the health transition that is underway, this needs to be addressed on a population level.

Environmental changes are more effective in changing behaviour and increasing the demand for fruit and vegetables than changing individual knowledge and attitudes.[27] Nevertheless, it is also important to raise awareness of the value of eating fresh fruit and vegetables among individuals. The National Department of Health has recently implemented a new strategy for nutrition education which is predicated on the food-based dietary guidelines as part of the Integrated Nutrition Programme.[33] The 11 guidelines are being widely promulgated as part of nutrition intervention programmes aimed at developing healthy lifestyles. One of the guidelines is: 'Eat plenty of vegetables and fruits every day'. Implementation of the programme needs to include a specific focus on interventions to achieve this, and the impact of such efforts needs to be monitored.

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