Estimating the changing burden of disease attributable to alcohol use in South Africa for 2000, 2006 and 2012

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Background. Alcohol use was one of the leading contributors to South Africa (SA)'s disease burden in 2000, accounting for 7% of deaths and disability-adjusted life years (DALYs) in the first South African Comparative Risk Assessment Study (SACRA1). Since then, patterns of alcohol use have changed, as has the epidemiological evidence pertaining to the role of alcohol as a risk factor for infectious diseases, most notably HIV/AIDS and tuberculosis (TB).
Objectives. To estimate the burden of disease attributable to alcohol use by sex and age group in SA in 2000, 2006 and 2012.
Methods. The analysis follows the World Health Organization (WHO)'s comparative risk assessment methodology. Population attributable fractions (PAFs) were calculated from modelled exposure estimated from a systematic assessment and synthesis of 17 nationally representative surveys and relative risks based on the global review by the International Model of Alcohol Harms and Policies. PAFs were applied to the burden of disease estimates from the revised second South African National Burden of Disease Study (SANBD2) to calculate the alcohol-attributable burden for deaths and DALYs for 2000, 2006 and 2012. We quantified the uncertainty by observing the posterior distribution of the estimated prevalence of drinkers and mean use among adult drinkers (≥15 years old) in a Bayesian model. We assumed no uncertainty in the outcome measures.
Results. The alcohol-attributable disease burden decreased from 2000 to 2012 after peaking in 2006, owing to shifts in the disease burden, particularly infectious disease and injuries, and changes in drinking patterns. In 2012, alcohol-attributable harm accounted for an estimated 7.1% (95% uncertainty interval (UI) 6.6 - 7.6) of all deaths and 5.6% (95% UI 5.3 - 6.0) of all DALYs. Attributable deaths were split three ways fairly evenly across major disease categories: infectious diseases (36.4%), non-communicable diseases (32.4%) and injuries (31.2%). Top rankings for alcohol-attributable DALYs for specific causes were TB (22.6%), HIV/AIDS (16.0%), road traffic injuries (15.9%), interpersonal violence (12.8%), cardiovascular disease (11.1%), cancer and cirrhosis (both 4%). Alcohol remains an important contributor to the overall disease burden, ranking fifth in terms of deaths and DALYs.
Conclusion. Although reducing overall alcohol use will decrease the burden of disease at a societal level, alcohol harm reduction strategies in SA should prioritise evidence-based interventions to change drinking patterns. Frequent heavy episodic (i.e. binge) drinking accounts for the unusually large share of injuries and infectious diseases in the alcohol-attributable burden of disease profile. Interventions should focus on the distal causes of heavy drinking by focusing on strategies recommended by the WHO's SAFER initiative.

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The article in context

Evidence before this study. The first South African Comparative Risk Assessment Study (SACRA1) established alcohol as one of the leading contributors to the national burden of disease in 2000, accounting for 7% of deaths and DALYs. However, the study omitted the burden arising from several important diseases, most notably HIV/AIDS and tuberculosis (TB).
Added value of this study. The study provides updated information on the burden of disease from alcohol for 2006 and 2012 and improves on the previous estimates for 2000 by applying updated RR functions for a wider range of alcohol-related health outcomes, including HIV/AIDS and TB. For injuries, the risk function assigns increasing risk with higher levels of use and takes into account the pattern of drinking. The study also considers a wider range of data sources for exposure levels and applies a more systematic approach to estimate

alcohol use prevalence and drinking patterns. The study identifies frequent heavy episodic (i.e. binge) drinking as the main contributor to the unusually large share of injuries and infectious diseases in the alcohol-attributable burden of disease profile.

Implications of the available evidence. The prominence of infectious diseases such as HIV/AIDS and TB alongside injuries in SA's alcohol-attributable disease burden highlights the need to apply evidence-based interventions to change drinking patterns. Careful consideration should be given to legislation and/or interventions that target the disease pathways to groups most affected by these diseases, including upstream prevention and health promotion strategies that address known socioeconomic risk factors of alcohol use such as violence and poverty. Within the health service, priority should be accorded to the integration of evidence-based substance use services. Screening, brief intervention and referral to treatment (SBIRT) has shown potential to reduce alcohol use among several populations in SA. The country's inability to reduce alcohol harm successfully is therefore not due to any uncertainty as to which strategies will reduce harm, but rather to the lack of political will to implement the necessary regulatory changes to wean the alcohol industry from its dependence on the current pattern of excessive alcohol use.

Alcohol use is one of the leading contributors to the burden of disease globally. In 2016, alcohol use accounted for an estimated 5.3% of deaths globally – ~3 million – and 5.0% of DALYs.[1] This placed alcohol as the seventh leading risk factor for premature death and disability globally, accounting for 1.6% (95% uncertainty interval (UI) 1.4 - 2.0) of the disease burden among females and 6.0% (95% UI 5.4 - 6.7) among males. In the age group 15 - 49 years, alcohol use was the leading risk factor in 2016. Infectious diseases such as TB, alcohol use disorders and, for men in particular, injuries were the major causes of death and disability. Beyond 50 years of age, cancers and cardiovascular diseases accounted for a greater share of the alcohol-attributable burden.[2]

In SA, with its relatively young population and high incidence of injuries,[3] alcohol contributes even more substantially to the disease burden. SACRA1 in 2000 placed alcohol as the third leading contributor to the disease burden, accounting for 36 840 deaths (7.1% of total deaths) and 7.0% of DALYs.[4] These initial estimates omitted the contribution of alcohol as a risk factor for infectious diseases such as HIV/AIDS and TB, both significant contributors to SA's overall disease burden.[5] For these diseases, alcohol misuse compromises adherence to therapy and the course of the disease. Additionally, in the case of HIV/AIDS, alcohol use increases risk-taking behaviour and unsafe sex that contribute to its spread. More recent comparative risk assessment (CRA) studies have included the alcohol-attributable burden for these two important diseases.[1,6-10] With the inclusion of TB, the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) estimated 45 900 alcohol-attributable deaths in SA in 2006, decreasing to 36 500 deaths in 2016.[8] These estimates were broadly consistent with a regional study that included HIV/AIDS and TB and estimated 46 154 alcohol-attributable deaths in SA in 2004.[10] However, in these studies, country-level estimates were derived from global models that borrow information across age, time and geographical locations to predict local exposure based on large sets of covariates (such as socioeconomic, demographic, health system access, climate and food consumption indicators) uniformly available across countries and regions.[11] This global approach may result in local specificities being overlooked.

Drinking behaviour is determined by a complex array of influences associated with health and social harms: the characteristics of the individual drinker, the sociocultural environment where alcohol is consumed, and structural factors that influence alcohol sales regulations in different jurisdictions.[12] Yet, for any health condition, alcohol use risk is particularly affected by two mechanisms: the overall volume of alcohol consumed by the individual, and the pattern of drinking – i.e. the frequency and number of drinks consumed during each drinking event. Heavy episodic drinking (HED) is considered the most harmful drinking pattern, as it greatly increases the risk for a range of acute conditions arising from infectious diseases and, most notably, injuries.

The World Health Organization (WHO) estimated the prevalence of current drinkers of alcohol in SA at 31% of the adult population in 2018.[13] SA's drinking pattern is characterised by very high levels of HED, with 59% of current drinkers reporting HED in the previous 30 days.[13] Drinking, and HED in particular, are significantly more common among men.[14,15] Consequently injuries account for a far greater share of the alcohol-related disease burden in SA than elsewhere. Studies have ascribed 63% and 46% of SA's alcohol-related DALYs in 2000[4] and 2004[10] respectively, to injuries, compared with the 2005 global average of 37%.[7] However, several repeated national surveys, such as the South Africa Demographic and Health Survey (SADHS),[16] the South African HIV/AIDS, Behavioural Risks, Sero-status, and Mass Media Impact Survey (SABSSM)[17] and the National Income Dynamics Study (NIDS),[18] have observed a change in the drinking profile – both the proportion of drinkers and the amount that they drink – that influences estimates for the alcohol-attributable disease burden. A recent study to estimate the burden across different socioeconomic groups used SA survey data to describe drinking patterns. This study provided a considerably higher overall estimate of 62 300 (95% UI 27 000 - 103 000) alcohol-attributable adult deaths.[14] Furthermore, as yet no study has used the empirically derived and, for selected conditions, expert-adjusted SANBD2[5] to calculate the current alcohol-attributable burden instead of the GBD estimates for SA.

We estimate the burden of disease attributable to alcohol use in SA using: (*i*) the empirically derived SANBD2 estimates; (*ii*) all major diseases and conditions affected by alcohol use; and (*iii*) a synthesis of SA survey data on drinking prevalence and alcohol use patterns to model alcohol exposure between 1998 and 2015. This will facilitate comparative analysis with the South African Medical Research Council (SAMRC)'s first NBD CRA study that estimated the alcohol-attributable burden of disease for 2000, and the SA estimates from other CRA studies.

Methods

Study design

We assessed the alcohol-attributable burden of disease – alcohol-attributable deaths and DALYs, a composite measure comprising years of life lost due to premature mortality and years lived with a disability – in SA by sex and 10-year age groups (15 - 24, 35 - 44, 45 - 54, 55 - 64, ≥65) for 2000, 2006 and 2012. The study is based on the original WHO CRA methodology[19] refined through several iterations, the most recent of which is available at the International Model of Alcohol Harms and Policies (interMAHP) open-access alcohol harms estimator and policy scenario modeller.[20] Estimates were

modelled using a population attributable fraction (PAF) method with a counterfactual theoretical minimum risk exposure defined as lifetime abstinence.

Burden of disease metrics

We categorised the various conditions causally linked to alcohol use according to the SANBD2 classification, which aggregated ICD-10 codes into 140 locally relevant causes and cause categories that reflect local disease patterns. Burden of disease metrics for each of these broad cause categories are based on published mortality trends[5] and provide the denominator on which to base the alcohol-attributable burden (Table 1). In comparison with SANBD2, the GBD study uses a wider range of disease categories, with the most recently published mortality and morbidity estimates describing 249 causes of death and 315 diseases, respectively.[21,22] However, for alcohol, the GBD categories align neatly with the SANBD2 subset. We included additional conditions not included in the GBD alcohol estimates, viz. HIV/AIDS and pancreatitis.

There is emerging evidence of a causal link between HIV/AIDS and alcohol use, and its inclusion is consistent with the WHO position.[23] Experimental research has demonstrated an increased risk of unsafe sex following alcohol use.[24,25] This makes it less likely that the strong association between alcohol use and both HIV/AIDS infection and sexually transmitted diseases (STDs)[26,27] is attributable to a common third cause such as risky behaviour. There is also a clear causal effect of alcohol use on HIV/AIDS patients' adherence to antiretroviral treatment,[28-30] as well as the course of HIV/AIDS among patients who are not yet on antiretroviral therapy.[29,31-35] A considerable proportion of acute pancreatitis is alcohol induced, estimated at one-third of all cases in the USA, and repeated episodes can lead to chronic pancreatitis.[36-38]

We were unable to include three additional alcohol-related conditions identified in interMAHP that could not be disaggregated from the NBD broad causes, viz. degeneration of the nervous system due to alcohol (ICD-10 code G31.2), alcohol-induced pseudo-Cushing syndrome (E24.4) and alcoholic gastritis (K29.2).

Table 1. Disease outcomes related to alcohol consumption

Health outcomes	ICD-10 codes
Infectious diseases	
HIV/AIDS	B20 - B24.9, Z21
Lower respiratory infections	J09 - J15.8, J16 - J16.9, J20 - J21.9
Tuberculosis	A15 - A19.9
Injuries	
Interpersonal violence	X85 - Y09
Self-inflicted injuries	X60 - X84
Road traffic injuries	V01 - V04, V06, V09 - V80, V82 - V85, V87, V89
Drowning	V90, V92, W65 - W70, W73, W74
Falls	W00 - W19
Fires	X00 - X19
Poisoning	X40 - X49, Y67
Other unintentional injuries	V05, V81, V86, V88, V91, V93 - V98, W20 - W46.2, W49 - W62, W64 - W70, W75, W77 - W81, W83 - W94, W97, W99, X20 - X39, X50 - X54, X57 - X58, Y35 - Y84, Y87.0 - Y87.1, Y88 - Y88.3, Y89.0 - Y89.1
Cancers (neoplasms)	
Breast cancer	C50, D05
Colon and rectum cancer	C18 - C21, D01.0 - D01.4
Larynx cancer	C32, D02.0
Liver cancer	C22, D01.5
Oesophageal cancer	C15
Oral cavity, nose and pharynx cancer	C00 - C05; C08 - C10; C12 - C14, D00.0
Pancreatic cancer	C25, D01.7
Cardiovascular diseases	
Alcoholic cardiomyopathy	I42.6
Atrial fibrillation and cardiac arrhythmia	I47 - I49
Haemorrhagic stroke	I60 - I61.9, I62.0 - I62.03, I67.0 - I67.1, I68.1 - I68.2, I69.0 - I69.298
Hypertensive heart disease	I11 - I11.9
Ischaemic heart disease	I20 - I25
Ischaemic stroke	I63 - I63.9, I65 - I66.9, I67.2 - I67.3, I67.5 - I67.6, I69.3 - I69.398
Neuropsychiatric conditions	
Alcohol use disorders	F10 - F10.99, G31.2, G72.1, P04.3, Q86.0, R78.0, X45 - X45.9
Epilepsy	G40 - G41.9
Other chronic diseases	
Cirrhosis and liver disease	K70, K74
Diabetes mellitus	E11, E13, E14
Pancreatitis	K85 - K86

Alcohol exposure

We sourced data on alcohol use at individual level from 17 surveys conducted in SA between 1998 and 2016 on nationally representative samples of the population aged ≥15 years (Table 2). A summary measure of the overall risk of bias, the risk of bias score, was assigned to each survey by using the Burden of Disease Review Manager risk assessment tool, developed by the Burden of Disease Unit at the SAMRC to systematically assess the methodological quality of observational epidemiological studies.[39] The risk of bias score – which takes into account both external (sample representativeness and response rates) and internal validity of the study (appropriateness of definitions and measurement methods) – ranges from 1 to 20, with lower scores indicating a higher risk of bias.

We pre-processed individual data to calculate, for each survey, sex and age group, raw estimates of the prevalence of current and former drinking and HED, and the distribution of individuals across alcohol use classes. Aggregated results were combined with data on alcohol production, sales, imports and exports as inputs of a Bayesian model to generate yearly estimates of the prevalence of drinkers in the population and the parameters that characterise consumption among drinkers. These methods are summarised in the appendix (https://www.samedical.org/file/1885) and described in detail elsewhere.[54]

Relative risk measures

Two conditions listed in Table 1 were fully attributable to alcohol use, viz. alcohol use disorders and alcoholic cardiomyopathy. To calculate the burden due to alcoholic cardiomyopathy, we apportioned a fraction of the total cardiomyopathy burden from SANBD2. The fraction was calculated by applying the PAF for alcoholic cardiomyopathy for the southern sub-Saharan Africa region for 2015 across all ages and time periods for both mortality and morbidity.[55]

Conditions that were partially attributable to alcohol use included cancers, infectious diseases, acute adverse effects, cardiovascular diseases, other chronic diseases and neuropsychiatric conditions. Relative risks (RRs) for the partially attributable conditions with reference to the counterfactual minimum risk of no alcohol use were obtained from three sources.[1,56,57] PAFs for each condition were calculated by applying RRs for different levels of daily use to current HEDs and drinkers who did not binge. HED was defined as self-reported use, in the previous 30 days, of ≥60 g of alcohol on a single occasion for men, equivalent to ≥5 standard drinks, and of ≥48 g of alcohol on a single occasion for women, equivalent to ≥4 standard drinks. Following the interMAHP approach, in the calculation of the burden for conditions where RRs differ for HED, we included as 'HED by default' individuals whose average daily use exceeded the HED cut-off. For some conditions, RRs different from 1 also applied to former drinkers, who had not consumed alcohol in the past 12 months.

Most conditions presented monotonic relationships with the volume of alcohol consumed, i.e. an increase in total alcohol consumed was associated with a higher risk of disease. Exceptions included ischaemic heart disease, ischaemic stroke and diabetes. More complex relationships have been observed for these conditions, with beneficial effects among some individuals who drink moderately and avoid HED. These benefits are reversed with heavy drinking or occasional HED. For acute adverse effects, blood alcohol concentration at the time of the injury event increased risk. For these conditions, the RR included a step function for HED. In addition, some health conditions had different RR functions by gender and age group. For example, the RR of diabetes is higher among males compared with females, while the RR of drowning is the same for males and females. The complete range of risk functions for each condition, as well as the original sources from which they are derived, are available in Table S1 in the appendix (https://www.samedical.org/file/1885) as well as at the online dashboard https://sacra2.shinyapps.io/alcohol/

Population attributable fractions

We used the exposure estimates and the RR functions described above to calculate the proportion of burden due to each disease attributable to alcohol use (PAF) with the formula:[58]

$$PAF = \frac{P_{FD}[RR_{FD} - 1] + P_{CD}\int_{0.03}^{150} C(x)[RR_{CD}(x) - 1]dx}{1 + P_{FD}[RR_{FD} - 1] + P_{CD}\int_{0.03}^{150} C(x)[RR_{CD}(x) - 1]dx}$$

Table 2. Data sources for alcohol exposure in South Africa

Survey	Data collection*	Sample size†	Current use	Past use	HED	Quant	Risk of bias score
World Health Survey[40]	2003	351	Yes	Yes	No	Yes	13 (low)
South Africa Demographic and Health Survey[16,41,42]	1998	13 786	Yes	Yes	No	Yes	13 (low)
	2003	8 089	Yes	Yes	No	Yes	15 (low)
	2016	10 336	Yes	Yes	No	Yes	15 (low)
National Income Dynamics Study[18,43-45]	2008	15 502	Yes	Yes	No	Yes	13 (low)
	2010 - 2011	16 636	Yes	Yes	No	Yes	10 (low)
	2012	18 651	Yes	Yes	No	Yes	10 (moderate)
	2014 - 2015	22 723	Yes	Yes	No	Yes	10 (moderate)
South African Social Attitudes Survey[46-49]	2003	4 955	Yes	No	No	No	10 (moderate)
	2004	5 596	Yes	No	No	No	10 (moderate)
	2010	3 056	Yes	Yes	No	No	10 (moderate)
	2014	3 073	Yes	No	Yes	No	10 (moderate)
South African National Health and Nutrition Examination Survey[50]	2012	4 980	Yes	No	Yes	Yes	14 (low)
South African National HIV Prevalence, Incidence, Behaviour and Communication Survey[17,51-53]	2002	7 060	Yes	No	No	No	12 (moderate)
	2005	16 116	Yes	Yes	Yes	Yes	12 (moderate)
	2008	13 097	Yes	Yes	Yes	Yes	12 (moderate)
	2012	26 316	Yes	Yes	Yes	Yes	12 (moderate)

HED = heavy episodic drinking; Quant = average/typical quantity of alcohol consumed.
*Year(s) of data collection.
†Number of adult individuals (≥15 years) with non-missing data on alcohol use.

where P_{FD} is the proportion of former drinkers; P_{CD} is the proportion of current drinkers; RR_{FD} is the RR for former drinkers; $RR_{CD}(x)$ is the RR for current drinkers as a function of the average daily alcohol use x in grams; and $C(x)$ is the density function that describes the distribution of average daily use among drinkers. The integral is extended from 0.03 g/day (corresponding to 1 drink per year, which is the minimum quantity that defines a current drinker) and 150 g/day.[59]

For conditions for which the RR function differs for HED, we used the modified formula:[58]

$$PAF = \frac{P_{FD}[RR_{FD}-1] + A\int_{0.03}^{c} C(x)[RR_{CD}(x)-1]dx + B\int_{0.03}^{c} C(x)[RR_{HED}(x)-1]dx + P_{CD}\cdot\int_{c}^{150} C(x)[RR_{HED}(x)-1]dx}{1 + P_{FD}[RR_{FD}-1] + A\int_{0.03}^{c} C(x)[RR_{CD}(x)-1]dx + B\int_{0.03}^{c} C(x)[RR_{HED}(x)-1]dx + P_{CD}\cdot\int_{c}^{150} C(x)[RR_{HED}(x)-1]dx}$$

where

$$A = P_{CD}\cdot\frac{P_{CD}-P_{HED}}{P_{CD}-P_{BAT}} \quad ; \quad B = P_{CD}\cdot\frac{P_{HED}-P_{BAT}}{P_{CD}-P_{BAT}} \quad ; \quad P_{BAT} = P_{CD}\int_{c}^{150} C(x)dx$$

and $RR_{HED}(x)$ is the RR for HED, and P_{BAT} the proportion of drinkers with use above the gender-specific HED threshold c.

Uncertainty estimates

We calculated the uncertainty in the exposure by taking 1 000 draws from the posterior distribution of the prevalence of current drinkers and the parameter of the distribution of average use among drinkers recovered from the Bayesian model. For the proportion of former drinking and HED, we took 1 000 draws from a normal distribution with means and standard deviations corresponding to the point estimates and their standard error. We accounted for the uncertainty in the RR functions by taking 1 000 samples from the distribution of their coefficients. We then used the draws to repeat the estimation of the PAFs. The 2.5th and 97.5th percentiles of the calculated results were used as a measure of uncertainty. Further details on the implementation and estimation of the models are available in the appendix (https://www.samedical.org/file/1885).

Results

The estimated age- and sex-specific trends in the prevalence of male and female drinkers and the quantity of alcohol consumed by drinkers in grams of pure ethanol per day in the adult population (≥15 years) between 1998 and 2016 are shown in Figs 1 and 2. In 1998, the overall prevalence of drinking among males and females (Fig. 1, last panel, solid blue line) was ~37%, decreasing to 34% in 2007 and increasing to 36% in 2016. In all years, drinking prevalence was highest among males: 57% in 1998 (females 19%), 50% in 2007 (females 19%) and 54% in 2016 (females 20%). Fig. 1 shows the prevalence of current drinkers among six age groups, and among the whole population aged ≥15 (last panel). The prevalence of current drinking increased from 1998 to 2016 in younger age groups among males (15 - 24 years) and females (15 - 34 years), and decreased consistently among older females (≥35 years). Average use decreased from 42 g/day in 1998 to 35 g/day in 2016 (Fig. 2, last panel, solid blue line). The main decrease in alcohol use occurred from 1998 to 2008, after which use decreased at a slower rate. As expected, average use was consistently higher among males than females: 52 g/day in 1998 (females 33 g/day), and 43 g/day in 2016 (females 27 g/day). Among males, average daily use increased in the younger 15 - 24-year age group from 2007, decreased consistently in the 25 - 44-year age group and remained more constant, declining slightly, for older ages (≥45 years). Among females, average use increased in younger age groups (15 - 34 years) and decreased in older age groups (≥35 years) from the mid-2000s.

The number and proportion of deaths and DALYs attributable to alcohol in the years 2000, 2006 and 2012 are shown in Figs 3 and 4 and Table 3.

The total number of deaths attributable to alcohol increased from 42 657 in 2000 to 45 913 in 2006, before decreasing to 37 366 in 2012. These estimates took into account a few deaths averted owing to beneficial effects of low consumption levels in some strata, e.g. reduced diabetes mortality among women. More than 1.28 million DALYs were attributable to alcohol in 2000, compared with 1.41 million in 2006 and 1.16 million in 2012. In 2012, TB (22.6%), HIV/AIDS (16.0%), road injuries (15.9%), interpersonal violence (12.8%), cardiovascular disease (11.1%) and cancer and cirrhosis (both 4%) ranked as the leading contributors to alcohol-attributable DALYs (Table 3).

The 2006 peaks for deaths and DALYs corresponded with temporary increases in infectious diseases and injuries. Most non-communicable disease (NCD) categories – cancers, cardiovascular diseases, neuropsychiatric conditions and other chronic conditions – declined consistently from 2000 to 2012, but DALYs from effects of prenatal exposure to alcohol increased over the study period.

Infectious diseases accounted for the greatest share of the total alcohol-attributable burden in 2012 for both deaths (36.4%) and DALYs (40.4%) (Figs 3C and 4C). TB was the single largest contributor overall, consistently accounting for between 7 000 and 8 000 deaths across the study period, although the HIV/AIDS burden surpassed TB in 2006, when it exceeded 10 000 deaths, compared with 5 322 deaths in 2000 and 5 487 in 2012 (Fig. 3A - C). NCDs were the second leading contributor to alcohol-attributable deaths (32.4% of deaths), but just 23.4% of DALYs in 2012. Cardiovascular diseases accounted for approximately half of the alcohol-attributable NCD burden. Injuries accounted for 31.2% of total alcohol-attributable deaths and 36.1% of DALYs in 2012. Road traffic injuries and interpersonal violence were the major contributors to the injury burden, accounting for 5 146 and 4 225 deaths respectively in 2012, while self-inflicted injuries (i.e. suicide) ranked third at 1 395 deaths (Table 3).

There was considerable variation in the alcohol-attributable burden defined by age and sex (Figs 5 and 6). Both infectious diseases and injuries were concentrated in younger age groups, whereas NCDs, particularly cardiovascular diseases and cancers, were concentrated in older age groups. Beneficial effects from moderate drinking accrued exclusively to women in the older age groups in reducing mortality and morbidity risks for diabetes and ischaemic stroke. Overall, there were just over 4 male deaths for every female death in 2000, increasing to nearly 5 in 2012. This ratio was consistent across infectious diseases and most NCDs. For injuries, male deaths far exceeded female deaths, by a factor of 11 in 2000 and up to 12 in 2006. For cardiovascular diseases, males also experienced significantly higher mortality, which increased over the study period (45% higher than females in 2000, increasing to 72% by 2012).

Overall, alcohol remains an important contributor to the disease burden, ranking fifth among the 18 risk factors included in the second SACRA in terms of both overall mortality and DALYs for SA in 2012. Alcohol accounted for 7.1% of all deaths (95% UI 6.6 - 7.6) and 5.6% of all DALYs (95% UI 5.3 - 6.0) in 2012 (Table 3). The alcohol-attributable burden was particularly marked for men, accounting for 11.1% of deaths (95% UI 10.2 - 12.1) and 9.5% of DALYs (95% UI 8.8 - 10.2). In the case of women, alcohol accounted for 2.6% of deaths (95% UI 2.3 - 3.0) and 1.9% of DALYs (95% UI 1.7 - 2.1).

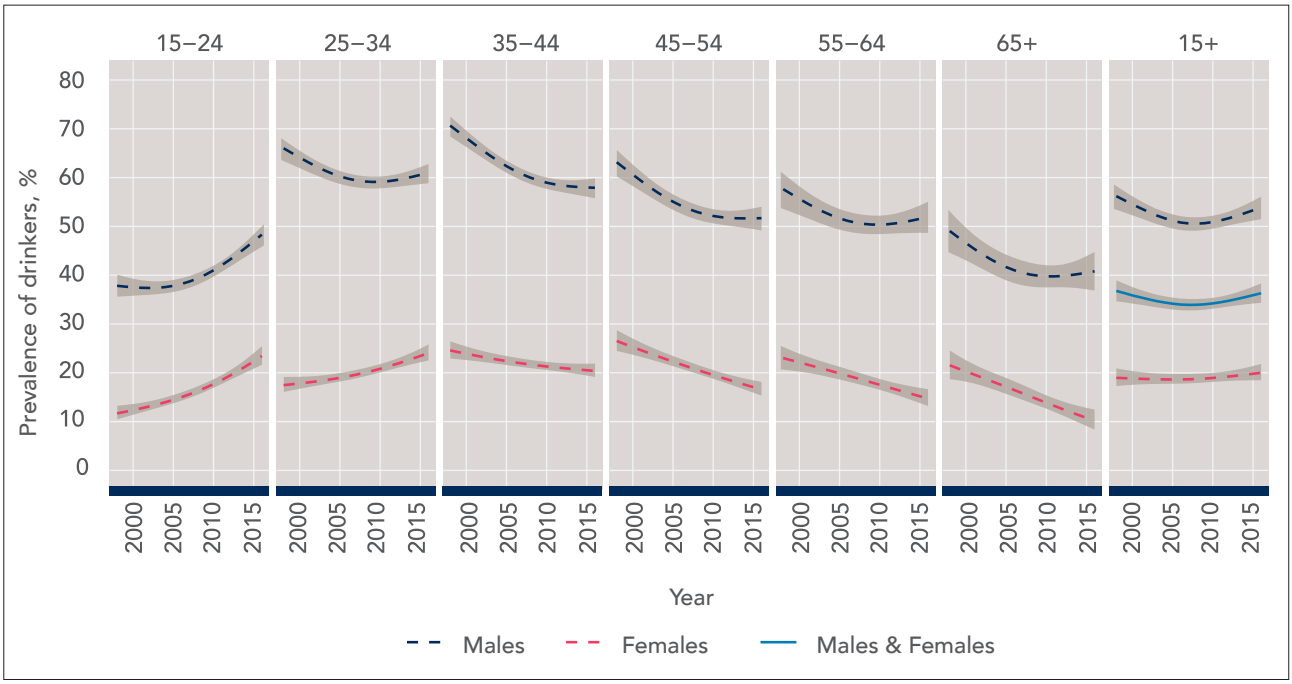

Fig. 1. Prevalence of current drinking in South Africa among males and females by age group for 1998 - 2016.

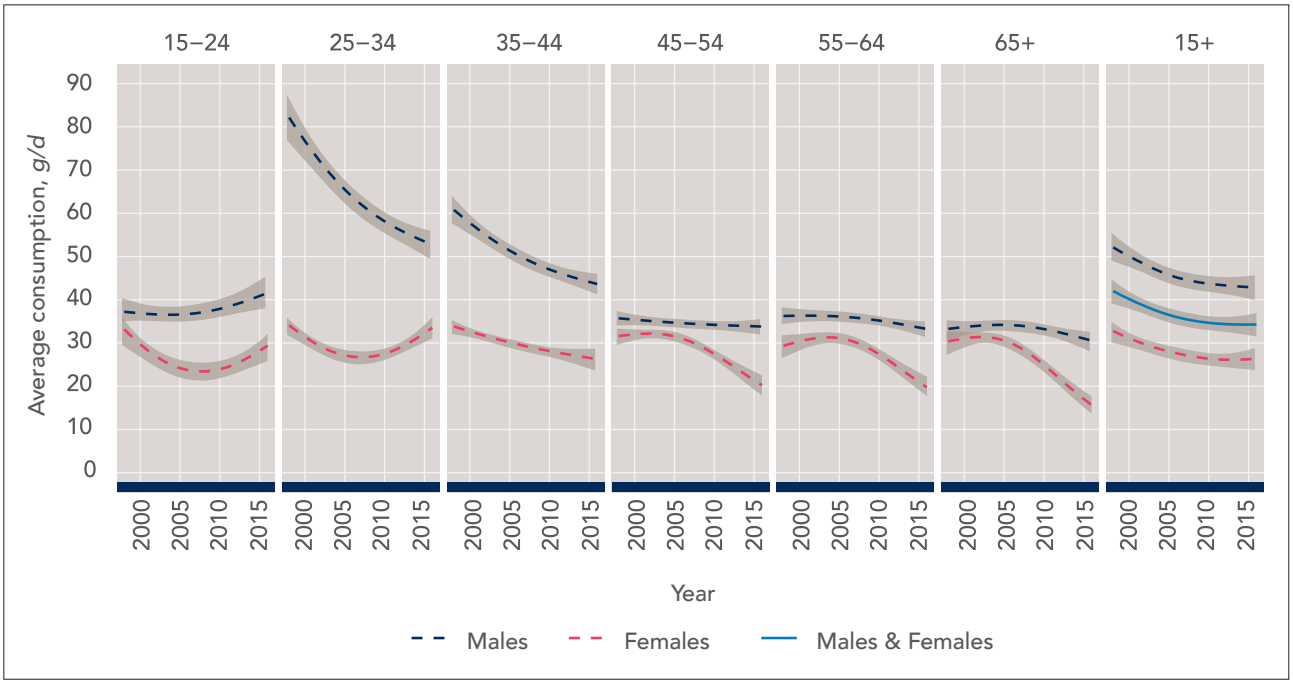

Fig. 2. Average daily alcohol use in South Africa among males and females by age group for 1998 - 2016.

Discussion

Alcohol has continued to impose a considerable health burden in SA since SACRA1 was conducted in 2000, despite drinkers comprising just under one-third (31%) of the adult population (≥15 years) in 2015 (55% among males, 20% among females). In 2012, infectious diseases (including HIV/AIDS and TB) and injuries accounted for the greatest share of the burden among males, both accounting for just over one-third of deaths (36.8% and 35.0%, respectively) and DALYs (39.3% and 39.7%, respectively). Among females, infectious disease and NCDs were the leading contributors to the alcohol-attributable disease burden, accounting for 34.7% and 51.7% of deaths and 45.8% and 35.7% of DALYs, respectively.

Comparing three time points, our study showed that the burden was greater in 2006 than it was in 2000 and 2012. This can be ascribed to the greater overall disease burden in this period, particularly for HIV/AIDS and injuries, rather than an increase in alcohol use, which had declined from 1998 in almost all age groups. The decrease in the burden for these two important conditions also accounts for 2012 recording the lowest overall alcohol-attributable burden. These findings reflect temporal changes in both the national drinking pattern and the total burden of disease. Both HIV/AIDS and injuries

Table 3. Burden attributable to alcohol use in adults (≥15 years) by sex in South Africa for 2000, 2006 and 2012

	Males			Females			Persons		
Health outcome	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***
2000									
Acute adverse effects									
Interpersonal violence	26.6	5 847	202 586	8.7	324	11 570	24.0	6 172	214 156
Self-inflicted injuries	26.5	1 099	342 79	8.6	101	3 323	22.5	1 201	37 602
Road traffic injuries	39.7	4 126	154 661	14.4	521	20 975	33.2	4 647	175 636
Drowning	26.9	116	3 830	8.5	7	270	23.9	123	4 100
Falls	26.2	135	6 183	7.9	12	1 505	22.0	148	7 688
Fires, heat and hot substances	27.2	390	15 368	8.6	90	3 551	19.3	480	18 918
Poisonings	27.0	59	1 964	8.9	15	495	19.1	74	2 460
Other unintentional injuries	27.4	274	12 020	8.5	14	1 351	24.8	287	13 370
Cancers (neoplasms)									
Breast cancer	-	-	-	6.4	163	3 904	6.2	163	3 904
Colorectal cancer	23.0	270	4 860	3.7	45	830	13.0	315	5 690
Larynx cancer	28.9	157	3 122	10.3	9	196	26.3	166	3 318
Liver cancer	21.9	349	6 813	14.3	137	2 519	19.1	486	9 332
Oesophageal cancer	28.0	930	17 076	9.7	203	3 905	20.9	1 133	20 981
Oral cavity, nose and pharynx cancer	49.2	465	9 803	19.8	87	1 841	39.9	551	11 644
Pancreas cancer	5.0	34	627	1.8	11	199	3.4	45	826
Cardiovascular diseases									
Alcoholic cardiomyopathy	100	125	2 396	100	16	302	100	141	2 698
Atrial fibrillation and cardiac arrhythmia	10.0	22	825	2.9	10	309	5.6	32	1 134
Haemorrhagic stroke	17.2	1 464	29 112	12.7	1 523	28 412	14.6	2 987	57 524
Hypertensive heart disease	17.0	1 034	18 265	4.8	508	8 613	9.3	1 542	26 878
Ischaemic heart disease	14.6	1 854	44 609	5.9	688	11 211	10.4	2 542	55 821
Ischaemic stroke	2.0	125	2 430	4.5	449	7 288	3.6	574	9 725
Infectious diseases									
Lower respiratory infections	9.4	799	17 062	2.3	167	3 183	6.2	966	20 246
HIV/AIDS	7.8	4 187	157 052	1.8	1 135	45 399	4.5	5 322	202 451
Tuberculosis	43.9	6 774	209 178	14.1	1 040	33 798	34.3	7 814	242 976
Neuropsychiatric conditions									
Alcohol use disorders	100	469	19 440	100	144	7 471	100	613	26 911
Epilepsy	30.1	750	22 342	8.3	120	3 770	22.1	870	26 112

Continued ...

Table 3. (continued) Burden attributable to alcohol use in adults (≥15 years) by sex in South Africa for 2000, 2006 and 2012

	Males			Females			Persons		
Health outcome	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***
Other chronic diseases									
Cirrhosis and liver disease	71.0	2 179	49 746	54.3	883	21 477	65.2	3062	71 223
Diabetes mellitus	4.1	193	4 599	–3.1	–233	–6 054	–0.3	–40	–1 455
Pancreatitis	49.9	223	7 597	18.7	19	756	44.1	242	8 353
Total attributable burden	-	**34 450**	**1 057 871**	-	**8 207**	**222 367**	-	**42 657**	**1 280 187**
(95% UI)		(30 701 - 38 174)	(935 048 - 1 174 205)		(7 208 - 9 410)	(201 511 - 246 643)		(38 689 - 46 578)	(1 152 640 - 1 396 923)
% of total burden	-	**12.9**	**10.9**	-	**3.4**	**2.4**	-	**8.4**	**6.7**
(95% UI)		(11.5 - 14.3)	(9.7 - 12.1)		(3.0 - 3.9)	(2.1 - 2.6)		(7.7 - 9.2)	(6.0 - 7.3)
2006									
Acute adverse effects									
Interpersonal violence	26.5	5 120	179 807	8.2	268	9 824	23.9	5 388	189 631
Self-inflicted injuries	26.4	1 384	44 853	8.4	100	3 586	23.1	1 484	48 439
Road traffic injuries	39.6	5 025	182 058	13.5	558	21 449	33.2	5 583	203 507
Drowning	25.8	203	6 742	7.8	9	339	23.4	213	7 080
Falls	24.9	133	7 780	6.2	9	1 206	21.1	142	8 986
Fires, heat and hot substances	25.9	316	11 718	7.8	57	2 214	19.1	373	13 932
Poisonings	27.0	66	2 138	8.1	11	373	20.4	77	2 511
Other unintentional injuries	26.7	258	9 366	7.5	14	1 023	23.6	272	10 388
Cancers (neoplasms)									
Breast cancer	-	-	-	5.4	169	4 201	5.3	169	4 201
Colorectal cancer	21.2	311	5 481	3.1	47	888	12	358	6 369
Larynx cancer	26.8	117	2 179	8.5	7	145	23.9	124	2 324
Liver cancer	20.0	275	5 364	12.5	109	2 004	17.1	384	7 369
Oesophageal cancer	26.3	716	12 863	7.8	141	2 558	18.9	857	15 421
Oral cavity, nose and pharynx cancer	47.3	483	10 176	16.4	69	1 467	38.3	552	11 643
Pancreas cancer	4.6	34	590	1.5	12	199	3.0	46	788
Cardiovascular diseases									
Alcoholic cardiomyopathy	100	139	2 684	100	20	416	100	159	3 100
Atrial fibrillation and cardiac arrhythmia	9.8	23	1 226	2.3	9	298	5.1	32	1 524
Haemorrhagic stroke	16.1	1 472	28 216	10.7	1 428	27 330	12.9	2 900	55 546
Hypertensive heart disease	16.1	1 002	16 979	3.7	449	7 741	7.9	1 450	24 721
Ischaemic heart disease	12.5	1 848	46 323	4.7	617	10 360	8.8	2 465	56 684
Ischaemic stroke	1.6	108	2 159	4.6	533	8 761	3.5	641	10 925

Continued ...

Table 3. (continued) Burden attributable to alcohol use in adults (≥15 years) by sex in South Africa for 2000, 2006 and 2012

	Males			Females			Persons		
Health outcome	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***
Infectious diseases									
Lower respiratory infections	8.9	841	17 568	2.0	168	3 286	5.6	1 009	20 853
HIV/AIDS	7.1	7 742	269 631	1.8	2382	90 674	4.2	10 124	360 305
Tuberculosis	42.2	6 223	192 645	12.8	900	32 160	32.7	7 123	224 805
Neuropsychiatric conditions									
Alcohol use disorders	100	245	19 492	100	92	3 969	100	337	23 461
Epilepsy	28.7	739	21 758	7.8	122	3 990	20.8	861	25 748
Other chronic diseases									
Cirrhosis and liver disease	69.7	1 798	42 011	50.8	826	21 191	62.4	2 624	63 202
Diabetes mellitus	3.7	236	5 417	–2.9	–299	–8 070	–0.4	–63	–2 653
Pancreatitis	47.1	201	6 709	16.3	27	1 102	38.6	228	7 811
Total attributable burden	-	**37 061**	**1 154 004**	-	**8 851**	**254 683**	-	**45 913**	**1 408 715**
(95% UI)		(33 846 - 40 908)	(1 059 290 - 1 259 397)		(7 733 - 10 202)	(227 746 - 282 049)		(42 334 - 49 941)	(1 306 490 - 1 519 802)
% of total burden	-	**10.8**	**9.4**	-	**2.7**	**2.0**	-	**6.8**	**5.6**
(95% UI)		(9.9 - 11.9)	(8.6 - 10.3)		(2.3 - 3.1)	(1.8 - 2.2)		(6.2 - 7.4)	(5.2 - 6.0)
2012									
Acute adverse effects									
Interpersonal violence	25.9	4 012	140 713	7.9	212	8 003	23.3	4 225	148 716
Self-inflicted injuries	25.8	1 302	42 849	9.0	92	3 417	22.9	1 395	46 266
Road traffic injuries	38.1	4 638	163 922	13.0	508	20 601	32.0	5 146	184 523
Drowning	24.5	205	6 852	7.0	9	328	22.2	214	7 180
Falls	22.6	113	10 255	5.1	7	1 592	18.8	120	11 848
Fires, heat and hot substances	23.9	237	8 859	6.8	36	1 556	17.9	273	10 415
Poisonings	25.8	58	1 886	8.0	8	293	20.3	66	2 179
Other unintentional injuries	25.4	212	7 324	6.8	12	934	22.1	225	8 259
Cancers (neoplasms)									
Breast cancer	-	-	-	4.3	165	4 155	4.2	165	4 155
Colorectal cancer	21.1	394	6 984	2.5	41	835	12.5	434	7 819
Larynx cancer	25.8	130	2 429	7.3	6	146	23.0	136	2 575
Liver cancer	19.7	283	5 417	12.6	106	2 082	17.1	389	7 499
Oesophageal cancer	25.2	634	10 977	6.2	103	1 915	17.6	738	12 892
Oral cavity, nose and pharynx cancer	45.8	440	9 165	13.3	61	1 385	35.2	501	10 550
Pancreas cancer	4.4	38	644	1.3	12	204	2.8	50	848

Continued ...

Table 3. (continued) Burden attributable to alcohol use in adults (≥15 years) by sex in South Africa for 2000, 2006 and 2012

	Males			Females			Persons		
Health outcome	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***	**AF, %**	**Deaths, *n***	**DALYs, *n***
Cardiovascular diseases									
Alcoholic cardiomyopathy	100	117	2 245	100	16	315	100	133	2 560
Atrial fibrillation and cardiac arrhythmia	9.3	26	1 565	1.7	7	276	4.6	33	1 841
Haemorrhagic stroke	15.4	1 334	24 428	8.6	1 079	20 496	11.4	2 413	44 923
Hypertensive heart disease	15.0	975	15 961	2.4	297	5 296	6.8	1 272	21 256
Ischaemic heart disease	11.8	1 558	40 258	4.1	481	8 275	8.2	2 039	48 532
Ischaemic stroke	1.2	80	1 635	4.2	492	7 949	3.1	572	9 569
Infectious diseases									
Lower respiratory infections	8.4	838	17 791	1.6	149	3 275	5.1	987	21 066
HIV/AIDS	6.1	4 241	139 525	1.8	1 245	46 556	4.0	5 487	186 081
Tuberculosis	41.0	6 240	221 479	11.7	891	40 928	31.2	7 132	262 407
Neuropsychiatric conditions									
Alcohol use disorders	100	259	17 754	100	107	6 731	100	367	24 485
Epilepsy	26.9	638	19 399	7.2	86	3 230	20.3	724	22 629
Other chronic diseases									
Cirrhosis and liver disease	68.1	1 366	30 773	47.6	590	15 616	60.2	1 957	46 389
Diabetes mellitus	3.6	266	6 592	–2.3	–265	–9 306	0.0	2	–2 714
Pancreatitis	44.7	148	5 253	14.6	22	1 183	35.2	171	6 435
Total attributable burden	-	**30 785**	**963 111**	-	**6 581**	**198 264**	-	**37 366**	**1 161 413**
(95% UI)		(28 312 - 33 525)	(895 117 - 1 036 975)		(5 723 - 7 585)	(181 817 - 215 933)		(34 759 - 40 390)	(1 090 064 - 1 238 304)
% of total burden	-	**11.1**	**9.5**	-	**2.6**	**1.9**	-	**7.1**	**5.6**
(95% UI)		(10.2 - 12.1)	(8.8 - 10.2)		(2.3 - 3.0)	(1.7 - 2.1)		(6.6 - 7.6)	(5.3 - 6.0)

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

peaked during the study period, whereas there were long-term decreases in most other conditions.

The findings improve on previous SACRA estimates by applying updated RR functions for a wider range of alcohol-related health outcomes, including several conditions that contribute substantially to the SA disease burden, such as HIV/AIDS and TB. The study also considers a wider range of data sources for exposure levels and applies a more systematic approach to estimate alcohol use prevalence and drinking patterns. The effect of these methodological changes is evident in comparing the 2000 findings with those of SACRA1 – also for 2000. The estimated numbers of deaths and DALYs in 2000 are higher in SACRA2 compared with SACRA1 (deaths 42 657 v. 36 840 and DALYs 1.33 million v. 1.13 million). This is attributed to the inclusion of two infectious disease conditions (HIV/AIDS and TB) that are accounted for in SACRA2, but not in SACRA1. If these two conditions are excluded in SACRA2, then the estimates are considerably lower (29 521 deaths and 0.89 million DALYs). As the estimated alcohol-attributable NCD burden is broadly comparable between the two studies, this discrepancy can be ascribed to the considerably greater injury burden in SACRA1 – an estimated 22 869 deaths in 2000 v. 13 132 in SACRA2 for the same time period.

We consider that SACRA1 overestimated the alcohol-attributable injury burden, owing to the manner in which PAFs for alcohol were applied to the physical injury mortality and disability burden. For each injury category (road traffic, homicide, etc.), the PAFs were derived from the percentage of alcohol-positive injury fatalities from a 2001 national injury surveillance study.[60] Specifically, the proportion of fatalities with blood alcohol concentrations >0.05 g/100 mL, the legal limit for driving, was used to derive the PAFs for each injury category.[4] However, we know that alcohol cannot be considered the sole cause for an injury fatality even above a certain high-risk threshold, which is the implication of assigning the PAF in this manner. The risk function utilised in the present study better captures this complexity by assigning increasing risk with higher levels of use and also considers the pattern of drinking.

Our estimates are broadly consistent with other studies that have estimated the alcohol-attributable burden using modelled estimates derived from indicators that were not country specific. For example, the 2018 CRA for the GBD study, which included

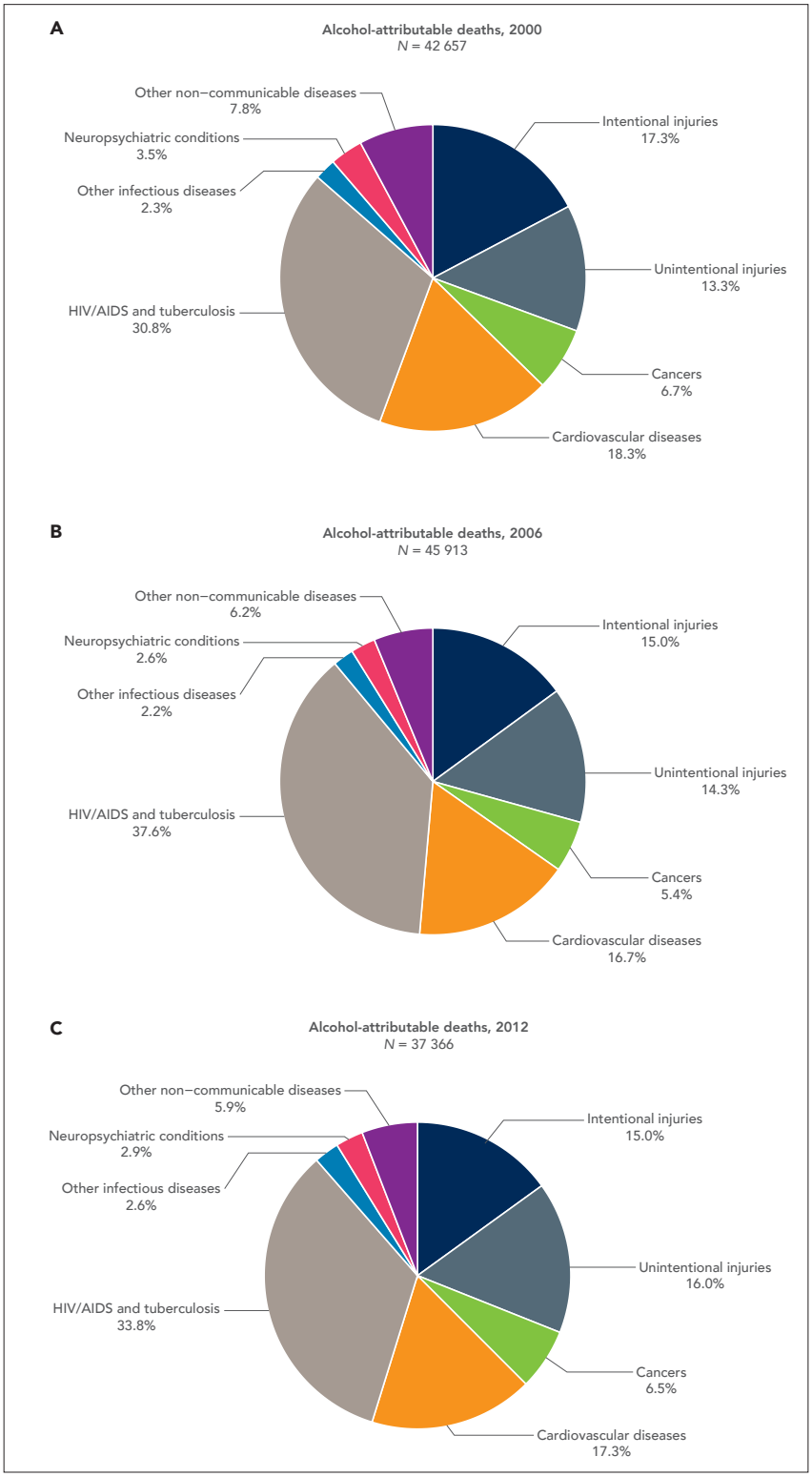

Fig. 3. Alcohol-attributable deaths for adults (≥15 years) in South Africa for 2000, 2006 and 2012.

the burden attributable to TB but not HIV/AIDS, estimated 45 900 alcohol-attributable deaths in SA in 2006, decreasing to 36 500 deaths in 2016.[2] An earlier regional study that included both HIV/AIDS and TB had estimated 46 154 alcohol-attributable deaths in SA in 2004.[10] The 2018 iteration of the GBD also included HIV/AIDS alongside TB and estimated 45 000 deaths in 2005, decreasing to 40 000 in 2010 and 37 000 in 2016.[2] The only notable exception was a study exploring comparative risk including TB and HIV/AIDS across SA's socioeconomic strata using individual and aggregate data from SA, which estimated 62 300 deaths from alcohol-attributable causes in 2015.[14] However, this study accounted for potential interaction effects between alcohol use and socioeconomic status for the risk of HIV/AIDS infection, leading to much higher estimates for HIV/AIDS deaths in the lower socioeconomic strata.

The major limitation of this study is that the burden measures are nearly 10 years out of date. While this could influence the applicability of some of the findings, we note that the prevalence data extend to 2016 and do not show any great variation. We also note that SA is unlikely to experience an equivalent epidemiological transition to that which occurred between 2000 and 2012, which was greatly influenced by the HIV pandemic. For this reason, we believe the findings are still broadly applicable.

We also note the exclusion of two categories included in interMAHP, which we were unable to separate from the SANBD2 coding, viz. degeneration of the nervous system due to alcohol and alcohol-induced pseudo-Cushing syndrome. These categories present an opportunity for future CRA revisions, but are considered relatively minor contributors to the overall disease burden and are unlikely to affect the results materially. We excluded alcoholic gastritis because the exact levels for the differential effects of different alcohol use patterns were inadequately defined for application to the available data (low levels of alcohol use were considered protective and high use harmful).[61-64]

The theoretical minimum risk of lifetime abstinence is consistent with the method applied by interMAHP.[58] We note that the GBD has recently applied an exposure level that minimises the burden for any given cause related to alcohol,[2] but this method is not yet universally accepted.[65] Even if it were applied to the SA estimates it would not affect the alcohol-attributable disease burden significantly, as diseases with beneficial effects of low consumption account for a small share of the overall burden. A more important limitation of this and other burden of disease studies is the omission of fetal alcohol syndrome. This is a condition that is entirely attributable to alcohol use but unusual in that the burden is transferred to the child rather than the mother who drinks during pregnancy. SA's rate for fetal alcohol syndrome[66] is among the world's highest, and its omission underweights the detrimental effects of alcohol at the population level.

With the inclusion of HIV/AIDS and TB, infectious diseases have surpassed injuries

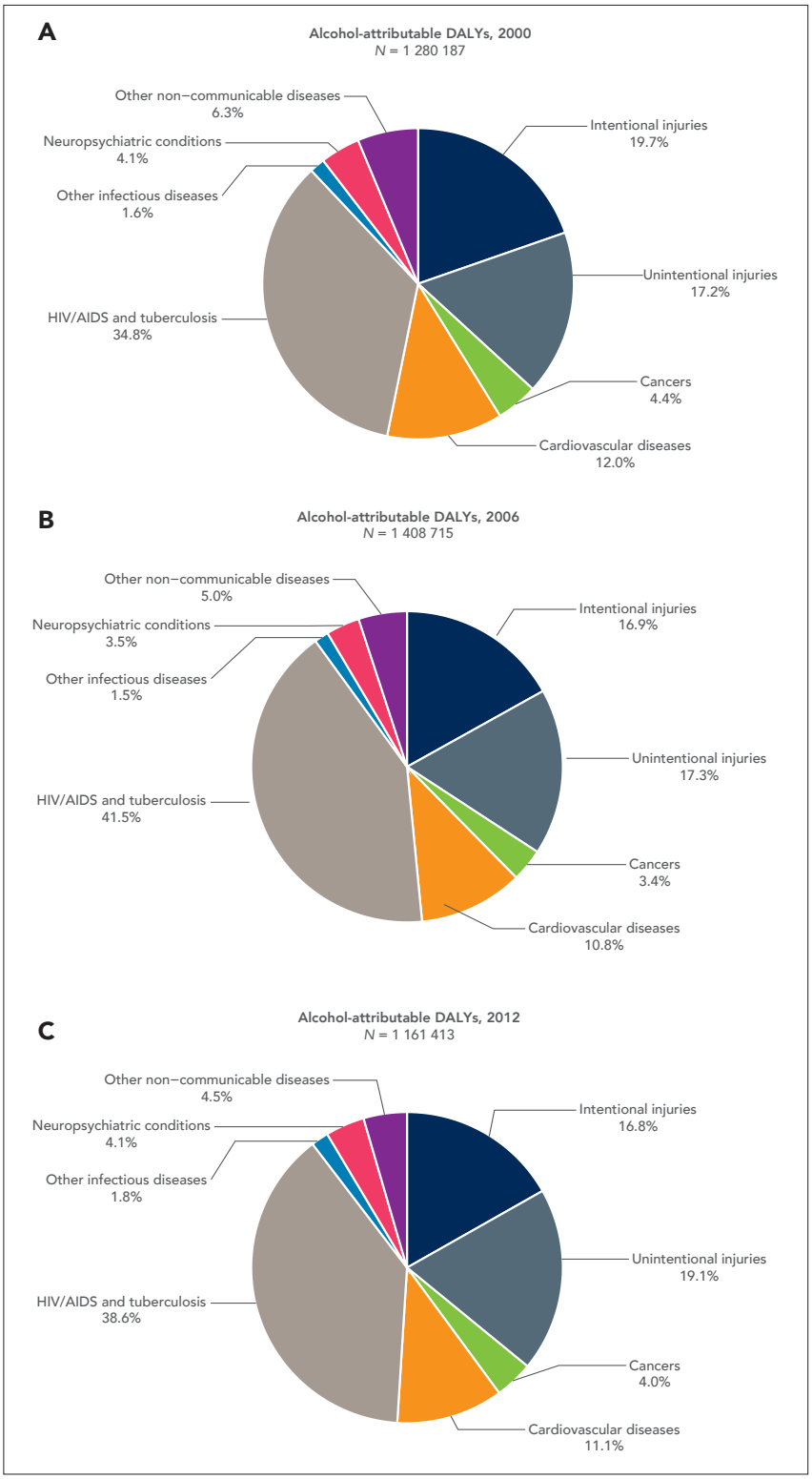

Fig. 4. Alcohol-attributable DALYs for adults (≥15 years) in South Africa for 2000, 2006 and 2012. (DALY = disability-adjusted life year.)

in accounting for the largest share of SA's alcohol-attributable burden (overall, but not for males). However, among the risk factors for injuries, alcohol remains the largest contributor to the burden of injuries in SA as it does globally.[13] Notwithstanding the long-term deleterious effects of alcohol on a range of chronic conditions, it is the acute effects of heavy drinking that contribute overwhelmingly to the burden by increasing risky behaviour, violence and unsafe sex.

At the same time, the pattern of drinking that underlies this burden drives the bulk of alcohol sales in SA – heavy drinkers and HED account for >80% of total alcohol sales[67] – which represent a considerable share of the profits for SA's powerful alcohol industry. Previous attempts to advance the adoption of evidence-based strategies in accordance with the WHO's global strategy to reduce alcohol harm have been met with intensive lobbying efforts by the industry to subvert implementation. For example, the Control of Marketing of Alcoholic Beverages Bill, which restricts advertising/marketing of alcoholic beverages (except at point of sale), sponsorship, and promotion of alcoholic beverages, was first placed before Cabinet in 2013 and is ensnared in covert internal processes.[68] In addition, the National Draft Liquor Bill (gazetted in 2015) and Western Cape Alcohol Harms Reduction Policy (drafted in 2016) and the 2016 Liquor Products Amendment Bill are all in stasis.[69]

Conclusion

The interventions that underpin successful harm reduction are based on an expanding global evidence base from successful implementation across multiple settings. The SAMRC has advised the government of the application of many of these interventions previously, most recently in 2020 as part of a public health collective of scientists, researchers, government stakeholders, civil society and private citizens in response to the National Strategic Plan to Combat Gender-Based Violence.[70] Interventions should focus on the distal causes of heavy drinking by focusing on strategies recommended by the WHO's SAFER initiative.[71] This initiative outlines five high-impact strategies: (*i*) strengthen restrictions on alcohol availability; (*ii*) advance and enforce drunk driving countermeasures; (*iii*) facilitate access to SBIRT; (*iv*) enforce bans or comprehensive restrictions on alcohol advertising, sponsorship, and promotion; and (*v*) raise prices on alcohol through excise taxes and pricing policies.

Moreover, the present study has highlighted the prominence of infectious diseases such as HIV/AIDS and TB in SA's alcohol-attributable disease burden, and careful consideration should be given to legislation and/or interventions that target these disease pathways and to the population groups most affected by these diseases. This should include upstream prevention and health promotion strategies that address known

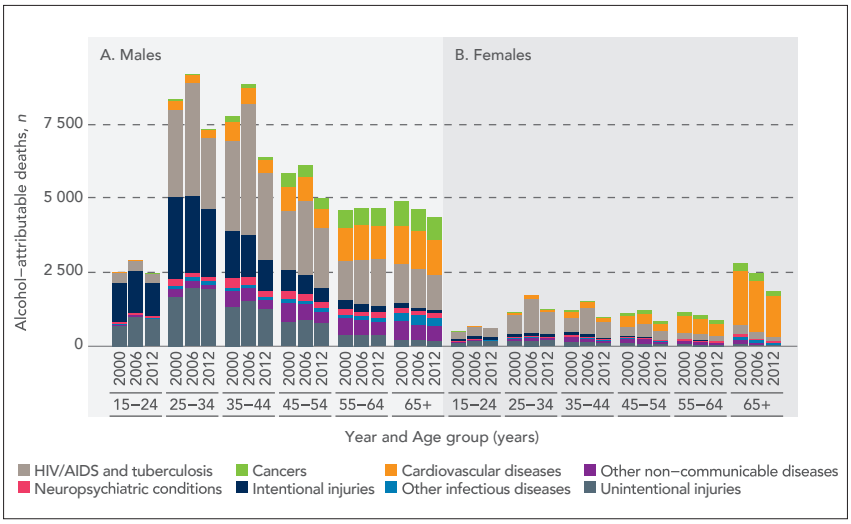

Fig. 5. Alcohol-attributable adult deaths by age and sex in South Africa for 2000, 2006 and 2012.

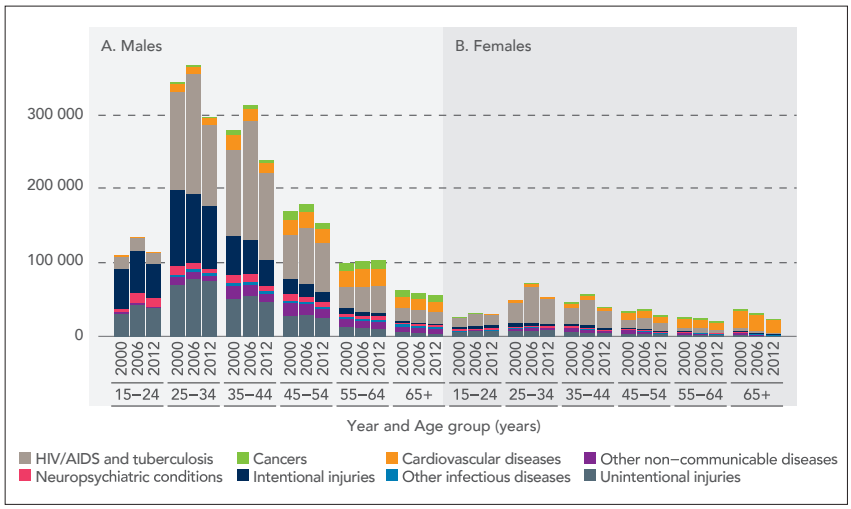

Fig. 6. Alcohol-attributable adult DALYs by age and sex in South Africa for 2000, 2006 and 2012. (DALY = disability-adjusted life year.)

socioeconomic risk factors of alcohol use such as violence and poverty.[72] Within the health service, priority should be accorded to the integration of evidence-based substance use services. SBIRT has shown potential to reduce alcohol use among several populations in SA affected by HIV/AIDS and TB.[73-75]

SA's inability to reduce alcohol harm successfully is therefore not due to any uncertainty as to which strategies will reduce harm, but rather to the lack of political will to implement the necessary regulatory changes to wean the alcohol industry from its dependence on the current pattern of excessive alcohol use. The tools developed for the current study have a wider use beyond providing a platform for the inclusion of additional outcome and exposure data to provide revised estimates. These could consider the impact of different alcohol use, not only on the disease burden but also on alcohol sales. This will be an important tool to assist policymakers in navigating the competing demands of public health and livelihoods.

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

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Conflicts of interest. None.

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