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Background: Non-communicable diseases (NCDs) represent at least 30% of disability adjusted life years in South Africa. Many of the risks associated with NCDs are related to diet, tobacco and alcohol. In South Africa, diets are not diverse enough and often contain too much salt, while tobacco and alcohol consumption remain too high. Thus, NCD risks will continue to expand, unless those behaviours can be altered.

Objectives: In this research, we offer an estimate of the potential reduction in NCD incidence that would arise from an improvement in diet, combined with a reduction in both tobacco and alcohol consumption.

Methods: We apply the PRIME model, which simulates the effect of risk reduction on NCD incidence. The model inputs baseline data related to the population, risky consumption behaviour and NCD incidence. The model allows for counterfactual scenarios altering the risky consumption behaviour to yield revised NCD incidence.

Results: We find that reducing salt, tobacco and alcohol, along with improved fruit, vegetable and fiber consumption would yield a 10% reduction in NCDs, from the 2018 baseline. NCD incidence reductions arise primarily from ischemic heart disease (49%), cerebrovascular diseases (33%) and bronchus and lung disease (11%).

Conclusion: South Africa's NCD incidence is high, because of relatively poor behavioural choices, despite plans and policies meant to change that behaviour and reduce the incidence. South Africa should increase their efforts to reach NCD goals. If the government is able to reduce harmful behaviour, with respect to a number of the underlying consumption choices, NCD incidence will fall precipitously.

INTRODUCTION

Non-communicable diseases (NCDs) – cancer, type 2 diabetes mellitus, respiratory illnesses (such as chronic obstructive pulmonary disease) and mental health disorders – are an increasing global burden.[1] An estimated 41 million people could die prematurely from NCDs, which could cost more than USD47 trillion over the next few decades.[2] NCDs are disproportionately problematic in the less developed world, more than 75% of NCD-related deaths occur in low- and middle- income countries (LMICs), and these deaths are likely to become the biggest cause of death in the region [2,3-4].

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In South Africa, there is a quadruple burden of disease – communicable diseases, NCDs, maternal and child health, and injury-related disorders.[5-7] Furthermore, there is extensive inter-personal violence and, like many other countries in the region, there is evidence of increasing multimorbidity, which raises both the demand for and cost of health care, when health budgets are limited.[8-14] By 2010, NCDs already were amongst the top causes of death in the country, a large share of which were premature (before the age of 60).[15] Relatively recent estimates of NCD burdens in the country, suggest that they make up approximately 30% of disability-adjusted life years (DALYs) and nearly two-thirds of catastrophic health expenditure (CHE).[16]

NCDs are commonly associated with socio-environmental and behavioural factors, including tobacco and alcohol use, sedentary lifestyles and unhealthy diets, most of which have become more common in less developed countries.[5-6,17] In this study, we evaluate the potential health improvement that can be derived from reductions in NCD behavioural risk factors, such as excessive consumption of salt, smoking, alcohol, and insufficient intake of fiber, fruits, and vegetables in South Africa, analyzing data from 2018 through the lens of the Preventable Risk Integrated Model (PRIME). Although there is some recent evidence of a small reduction in NCD-related deaths, the burden remains high, partly due to associations with antiretroviral therapy, and, therefore continues to deserve attention.[18-19]

BACKGROUND AND POLICY CONTEXT

South Africa is amongst the most unequal countries in the world, with a Gini coefficient hovering around 0.69, while 83% of households without at least one employed member experience poverty, which contributes to NCD prevalence.[20-24] There are also inequities in education, malnutrition outcomes, access to food and energy similar to those related to ill-health.[25-32]

Although access to food and nutrition is unequal, there has been an increase in the consumption of sugar-sweetened beverages (SSB), packaged and fast foods.[33] Despite the inequality in the country, access to such food sources amongst the poor has increased, such that 40% of South Africans consume enough energy, but not enough nutritional quality.[34] For the most part, marketing, product placement and the increased availability of high-energy products has fuelled this increase in consumption.[35]

There is also evidence of high salt consumption in the country, which is related to both hypertension, an aging population and, ultimately, increased cardiovascular disease (CVD).[5-6,36] Premature mortality and long-term disability, which affect government health expenditure, labour productivity and the economy, are obvious problems associated with CVD.[37-38] CVD is also likely to have a significant impact on out-of-pocket (OOP) expenditures, which tend to be higher in lower income households, rural and underserved communities.[39-40] Health gains could be substantial, if a modest salt reduction can be achieved.[41-42]

The literature on tobacco consumption and health effects in South Africa captures tobacco attributable deaths, as well as race-based differences in mortality rates and economic costs

associated with tobacco related diseases.[43-46] Although in most countries smoking prevalence has declined, smoking prevalence in South Africa increased from 19% in 2017 to 24% in 2021.[47] Tobacco consumption is mainly driven by male adults, with a smoking prevalence of 39% in 2021. The increasing trend in smoking prevalence is potentially fuelled by increasing illicit cigarette trade. Between 2017 and 2021, illicit trade rose from 35% to 54%.[48-49] The illicit cigarette market not only endangers individual health – due to potentially poor cigarette quality – but also constrains the government budget, due to tobacco tax losses. An illicit market share of 54% means that the South African government could double its tobacco tax revenues, if smokers could be convinced to consume legal tobacco products. Tobacco is responsible for approximately 10% of deaths, while the costs of premature death, morbidity and health care are estimated at near 1% of GDP, although larger cost estimates also exist.[43,46,50]

South Africans are also known to drink too much, following both binge and other risky drinking patterns. Of particular concern is annual per capita alcohol consumption, which is around 9.5 litres.[51-52] Furthermore, South Africa's 4 (out of 5) in its patterns-of-drinking-score is one of only nine countries scoring that high globally.[53] While illicit alcohol trade has not yet reached illicit cigarette trade levels, it is responsible for a substantial loss to South Africa's budget. Illicit alcohol trade constituted 22% of the total market in 2020 producing a fiscal deficit of R11.3 billion.[54]

The United Nations High-Level NCD Meeting focused its attention on the potential LMIC health system impacts arising from an increasing NCD burden, while the World Health Organization (WHO) has focused some attention on best buys, or cost effective, feasible and inexpensive interventions that offer large improvements in public health.[55-56] Given that public health spending has not generally met the 15% government budget share proposed in the Abuja Declaration in Africa, and that both health insurance and access to health care is incomplete, many costs are likely to be covered by OOP expenditures.[57-61] OOP costs are associated with poor health outcomes for, especially the poor, many of whom are elderly and have chronic conditions.[62-64] Thus, there is a need to manage costs, if not at the national level, then at least at the individual level, via prevention.

The government has responded to the NCD threat via its NCD plan, which includes multiple stakeholders and focuses on reducing prevalence, and, therefore, burden.[65-66] Amongst the government's goals and targets:[32,65]

1. 25% reduction in relative premature mortality (<60 years) from NCDs by 2020
2. Reduce alcohol and tobacco consumption by 20% by 2020
3. Salt intake reduction to <5 g per day by 2020
4. 10% reduction in rate of obesity and/or overweight by 2020
5. 20% Reduction in the prevalence raised blood pressure by 2020
6. 10% increase in physical activity prevalence
7. Cervical cancer screening for every woman: three screens per lifetime or every five years for those with an STD, or according to policy for HIV-positive women
8. 30% increase in the share of those able to control their hypertension, diabetes and asthma by 2020
9. 30% increase in screening for mental disorders by 2030

NCD policies are meant to drive behavioural change and, eventually reduce NCDs; such policies were generally based on community and public participation, although such participation does not appear to have affected implementation or made much impact on NCDs.[67-68] In support of the NCD plan, the government has enacted a series of reforms meant to reduce tobacco consumption, advertising associated with unhealthy foods, and the consumption of certain ingredients or components in unhealthy foods, such as fatty acids, salt and sugar.[69] By 2021, 8 policies were designed to affect smoking, a further 7 for alcohol, 8 for unhealthy diets and 5 on inactivity.[68] Thus, NCD policies are in place, but only tobacco control has been, at least partially effective, most likely contributing to the small reduction reported in NCD deaths.[18, 68] South Africa is not unique in that way, NCDs are increasing most everywhere, especially in LMICs.[53,71-73] Some of the problems relate to limited physical activity, partly due to a lack of either green or safe spaces, especially in urban informal settlements, deters many outdoor activities.[74]

To some degree, the country's endeavours were supported by international developments, such as the UN endorsement of the declaration for controlling and preventing NCDs, while NCD reduction targets were internationally developed soon after. [56,73] Despite being able to use international agreements in support of NCD policy, many regulations were not easily implemented, as industry pushed back against regulations.[75] Furthermore, only 13 (6 unhealthy diets, 3 tobacco control and 4 physical activity) of the identified programs has been implemented by 2021.[66-87] The government has also been moving, in fits and starts, towards its version of universal health coverage, via a national health insurance scheme, to improve universal health coverage.[88-89]

In summary, the current governmental approach seems to be rather ineffective to curb behavioural risks and a consequent reduction of NCDs. If the South African government aims to reach its NCD goals and improve the health care system, it needs to follow another harm-based approach. Additional measures do not necessarily require costly interventions but could also be built upon consumer education and awareness-raising. If consumers would be more conscious about their lifestyles, they would potentially consume less harmful, i.e. with a healthier diet, lower alcohol consumption and reduced-risk tobacco products instead of smoking.

METHODS and DATA

We evaluate the potential health improvement that can be derived from reductions in NCD behavioural risk factors, such as excessive consumption of salt, smoking, alcohol, and insufficient intake of fiber, fruits, and vegetables in South Africa, analyzing data from 2018 through the lens of the Preventable Risk Integrated Model (PRIME).[90] The Preventable Risk Integrated Model (PRIME), an Oxford-developed tool is a publicly accessible scenario modeling tool designed to assess the impact of changes in non-communicable disease (NCD) risk factors on morbidity and mortality. The tool compares real-world baseline data with hypothetical scenarios derived from extensive meta-analyses (counterfactual scenario) or policy prescriptions. The comparison arises from simulating the number of incidences that could be prevented from a change in unhealthy consumption activities.

The simulations are underscored by relative risks derived from the existing literature for each disease, age group, and gender. Using the relative risks, population attributable fractions (PAFs) are calculated in the model, determining the percentage of disease cases potentially preventable under alternative risk factor scenarios. The model compares actual data with an improved hypothetical scenario to estimate the number of avertable incidences. By categorizing complex data into distinct groups and applying PAFs to the incidence count in each, PRIME estimates the impact of modifying risk factors on total morbidity.[90]

PRIME needs three sets of input data for a given year: age and gender distribution of the population, NCD incidence rates for each disease (ICD-10) by age and gender, and risk factor behaviour by age and gender. Below, we describe how the data is developed for the model.

Unhealthy consumption goods

To estimate the average consumption of salt and fiber (and standard deviations to capture the distribution) per gender and age group, data from the Global Dietary Database (GDD) 2018 is used.[91] However, salt intake is underreported in the data, because the metadata only includes added salt used during cooking, whereas the salt added to industrialized products is not considered.[92-93] Therefore, we calculate the total salt consumption knowing that, on average, 55% of salt intake in South Africa is from processed food, to counter underestimation.[93]

Vegetables – not including starches, such as potatoes – and fruit intake are calculated from the South African Demographic and Health Survey (SADHS) from 2016. Because the GDD data is aggregated, some information, such as *the percent consuming <1 fruit/vegetable portions daily*, cannot be calculated.[94-95] The SADHS dataset provides only the number of fruit and vegetable types consumed daily, without specifying the amounts. To address this gap, we utilize the GDD to calculate the average quantity consumed, the standard deviation, and the percentage of individuals consuming less than one portion daily. With the insights from the GDD data, we can determine the average daily consumption of fruits and vegetables in grams. This process involves dividing the total consumption by the number of types to estimate the average intake per fruit or vegetable type. We then use these estimates to calculate the daily fruit and vegetable intake for each respondent. This newly derived variable enables us to generate the necessary inputs for the PRIME.

Further, the share of current, former, and never smokers, as well as daily alcohol consumption, is also obtained from the SADHS. Regarding current smoking behaviour, we account for both daily and weekly smokers. For alcohol consumption, we consider the number of drinks per day, with the understanding that a standard drink contains 12g of alcohol.[96] These calculated values represent the baseline scenario in the PRIME model.

Although the counterfactual scenarios can be modified in PRIME, we use the policy prescriptions from WHO recommendations for consumption of these goods.[95] Thus, it is assumed that mean South African population consumption behaviour is shifted, but the spread of consumption remains unchanged, such that standard deviations in the counterfactual match the baseline scenario.[97]
For risk reduction in smoking, we follow a different approach. While quitting smoking always remains the best solution for health, convincing all smokers to quit smoking immediately is

deemed unrealistic. Additionally, the PRIME model does not allow for a reduction in consumption levels for smoking, unlike for other risk factors, which limits the potential counterfactual scenarios to a reduction in the number of current smokers. To overcome both limitations we consequently follow a more pragmatic approach, wherein we allow a certain share of smokers to switch to less harmful alternatives or quit smoking.

Less harmful alternatives include nicotine containing products that heat instead of burn nicotine, such as e-cigarettes and heat-not-burn products. Given their recent market introduction, epidemiologic research is still needed to determine whether less harmful alternatives reduce the disease risk associated with smoking and, if so, how substantial this difference is. However, due to the robust toxicological evidence for alternative tobacco products and their increasing attractiveness to consumers, we are obliged to include these nicotine products in the model. To avoid overestimating their health benefits, we assume a rather conservative risk reduction level of 50% based on toxicological studies and expert opinions.[98-104] These studies were commissioned by governmental authorities or research institutes applying different methodologies. Most researchers estimate either cancer potencies or biomarkers and make assumptions in terms of health risks based on the difference in these compounds.

For application within the model, assuming that 50% of smokers switch to alternatives and these alternatives pose 50% of the health risk compared to smoking products, is equivalent to assuming that 25% of smokers have the same relative risks as ex-smokers and 25% remain in their current smoking status.

Population and Incidences

Population data by age and gender is obtained from the World Bank for 2018 in South Africa.[105] However, since the World Bank data aggregates from the age of 80, we have taken the distribution of 80–84-year-olds among 80+ year olds from the 2011 census, applying it to the World Bank data, assuming the distribution has not changed between 2011 and 2018.[106]

The incidences per disease by age group and gender are obtained from the Global Burden of Disease for 2018.[107] Due to the difference in longevity of cancer diseases (ICD codes C00-C14: Lip, oral cavity and pharynx cancer, C16: Stomach cancer, C25: Pancreas cancer, C18-20: Colorectum cancer, C50: Breast cancer, C64: Kidney cancer, C22: Liver cancer, C53: Cervix cancer, C34: Bronchus and lung), the incidence is calculated using the following formula:

$Total\ I_{cancer,n=10} = I_{cancer} + (Total\ I_{cancer,n-1} * SR_{cancer}), with\ n > 1$, with

Total $I_{cancer,n=10}$ represents the incidence per each cancer for year 10.
Total $I_{cancer,n-1}$ represents the incidence per each cancer from the previous year.
I_{cancer} represents the number of new incidences per year for each cancer.
SR_{cancer} denotes the yearly survival rate, derived from the survival rate per cancer after 10 years.
n is the year for which the incidence is being calculated.[90]

This formula calculates the 10-year incidence of diseases, based on acute and chronic incidences.[108] Chronic diseases, such as cancer, are typically evaluated over a 10-year

period. This is because only considering new cases within a given year could potentially underestimate the incidence of these diseases due to their longevity.[109] The formula assumes a consistent decline in the survival rate over those 10 years, presuming that after 10 years, individuals are no longer affected by cancer.

RESULTS

Modelling data

As noted earlier, PRIME requires inputs by age and gender for a variety of (potentially unhealthy) consumption goods, which we captured from the GDD, SADHS and Census.[91,94,106] Table 1 reports simple averages for the Baseline for males and females, which were averaged across all age groups (not weighted by population), as well as the counterfactual values, which are based on both WHO recommendations and our tobacco risk reduction methods described above. The data suggests that too many South Africans do not eat any fruit or vegetables, although average consumption of fruit and vegetables is in line with recommendations. Furthermore, South Africans consume too much salt and alcohol, but not enough fiber, while too many South Africans continue to smoke. Thus, the differences between baseline and counterfactual consumption are large, in many cases.

Table 1. Baseline and Counterfactual Model Values

	Males		Females	
Risk Factors	Baseline	Counterfactual	Baseline	Counterfactual
Fruit (grams/day)	134.88	200	151.33	200
Pct with < 1 fruit per day	92.39	0	93.69	0
Vegetable (grams/day)	281.47	200	238.06	200
Pct with <1 vegetable per day	50.51	0	35.21	0
Fiber (grams/day)	21.70	25	20.87	25
Salt (grams/day)	8.75	5	7.99	5
Pct low alcohol consumers	0.61	99	0.90	99
Alcohol (grams/day)	22.97	12	13.44	12
Never smoked	0.55	0.55	0.91	0.91
Former smoker	0.11	0.17	0.02	0.03
Current smoker	0.34	0.29	0.06	0.05

Note: Averages in grams/day (for fruit and vegetables) are calculated only for those that consume at least one per day, while the alcohol average is only for those consuming alcohol.

Baseline and counterfactual incidence

We begin by describing the baseline population disease incidence; see Figure 1. It shows higher incidence of disease for women, which is primarily due to them making up a larger share of the relatively older population, due to lower life expectancy for men, as well as representing all or nearly all cases of cervical and breast diseases (which represents approximately 15% of incidence). Total incidence in the data is 840 908, just over 355 000 for men and 485 000 for women, while the most common incidences are diabetes (20%),

Ischaemic heart diseases (12%), chronic obstructive pulmonary disease (8%), breast disease (8%), cervical disease (7%), bronchus and lung disease (5%) and colorectum disease (5%). As we describe below, the counterfactual incidence suggests that male health benefits relatively more from the healthier consumption and behaviour choices underpinning the counterfactual scenario in the PRIME model.

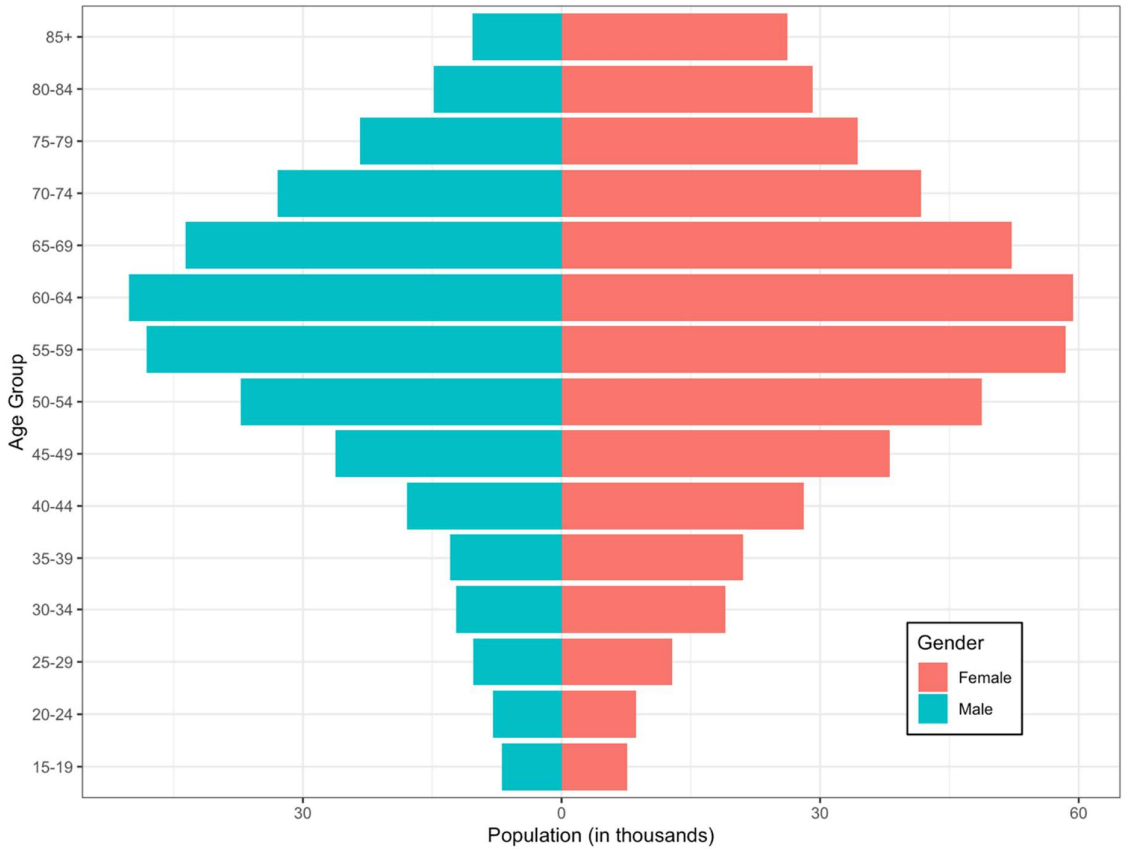

Figure 1. South Africa Baseline Incidence Pyramid (PRIME)

Avertable Incidence

As noted above, there are extensive differences between current South African consumption of salt, fruit, vegetables, fiber, alcohol and tobacco, relative to the recommendations. Inappropriate consumption of those goods has been linked to disease; thus, a revision in consumption towards something more appropriate has the potential to reduce disease. The difference in incidence between the baseline and the counterfactual is presented in Figure 2. We refer to this as avertible incidence, as it arises from reductions in risky consumption behaviour.

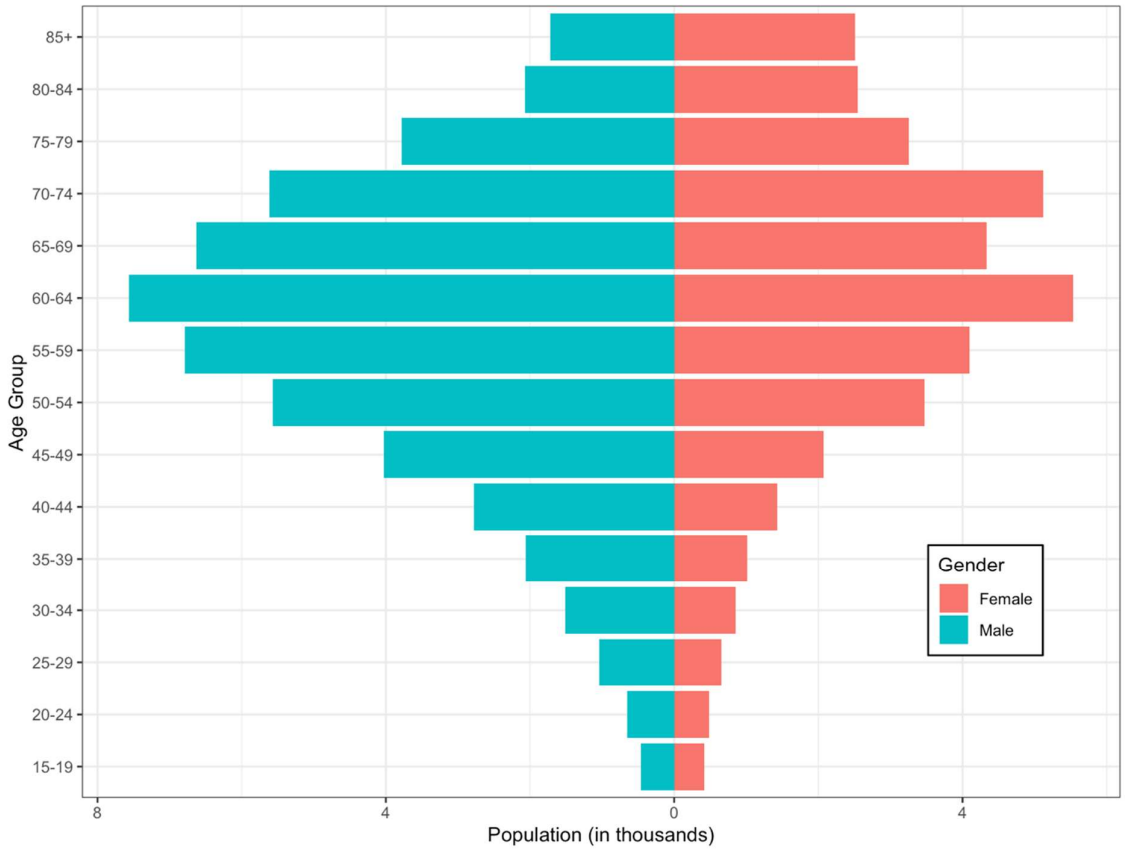

Figure 2. Avertible Incidence Arising from the Counterfactual Scenario (PRIME)

We further dissect Figure 2. Specifically, we present avertable incidence – by disease category – in Figure 3, which also offers insight into the consumption changes needed to make a difference. The total reduction in incidence arising from consumption modifications is close to 80 000; with baseline incidence near 840 900, that represents a decrease near 9.5% from baseline. The reduced incidence falls primarily within ischemic heart disease (49%), cerebrovascular diseases (33%) and bronchus and lung disease (11%).

Under our counterfactual scenario, and the relatively poor consumption of fruits and vegetables in the baseline data, the model finds that 49% of the reduction can be attributed to improved fruit and vegetable intake across a wider swathe of the population, while 21% can be attributed to a reduction in salt intake, 14% to reduction in smoking and smoking risk, and 14% from improvements in fiber consumption.

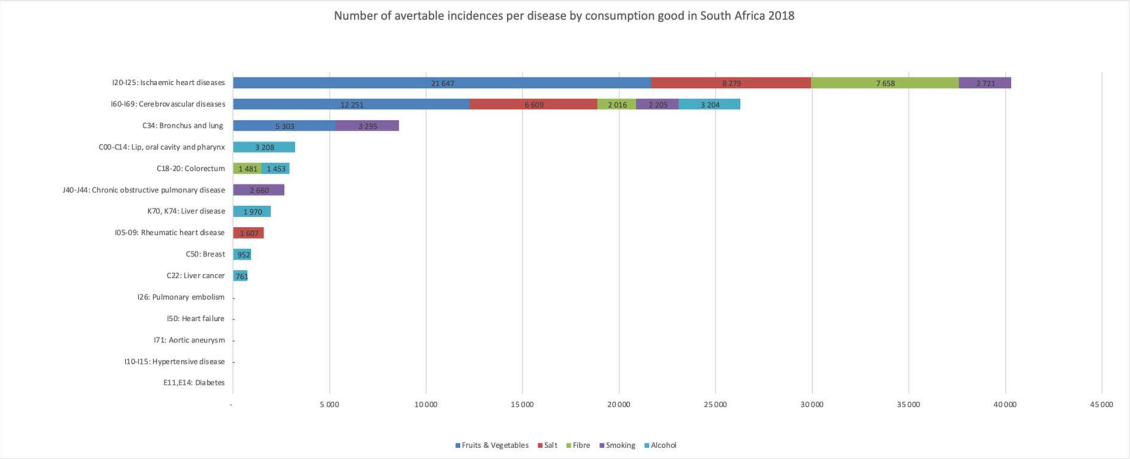

Figure 3. Avertable incidence by disease and risk factor (PRIME)

Given that women suffered the most disease, while, arguably, men were the worst consumption culprits, we briefly consider the improvements by gender; see Figure 4. The reduction in incidence is dominated by the difference in behaviours by gender; thus, overall, the reduction in incidence is larger for men. For example, the reduction in incidence for smoking risk reduction 2.7 times larger for men than women. For alcohol, the reduction is 12 times larger for men, while for salt, it is 1.3 times. Thus, there are 44 500 fewer cases for men and approximately 34 700 fewer cases for women, in the counterfactual.

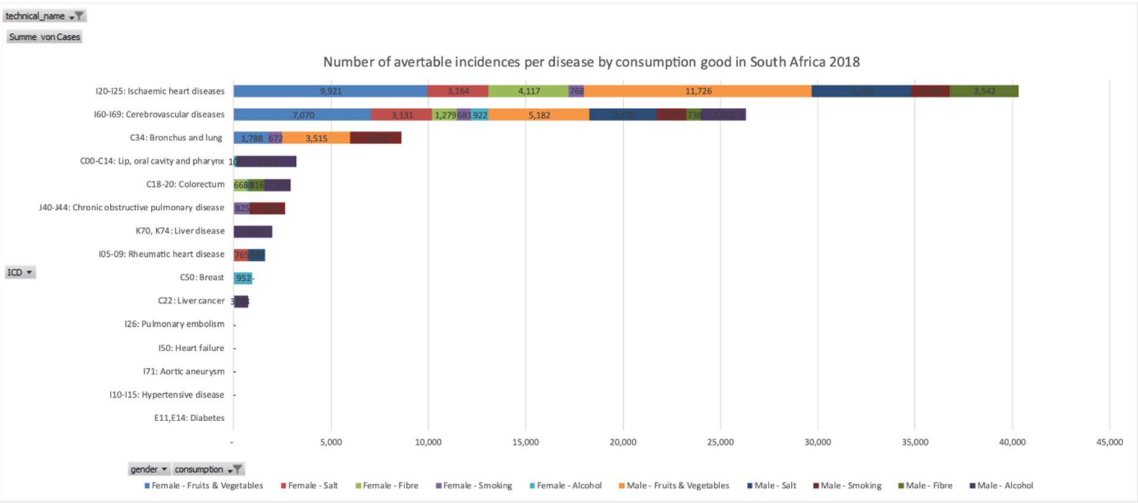

Figure 4. Avertable incidence by disease, risk factor and gender (PRIME)

Finally, we briefly offer insight into the sensitivity of our findings to assumptions related to tobacco consumption. Our initial assumption is based on a 50% risk reduction factor and 50% of smokers switching to less harmful alternatives; see Figure 5, which leads to 10 881 fewer incidences. Doubling the risk reduction factor to 100% – indirectly implying half of all smokers would quit all nicotine products – leads to double the incidence reduction: 21 762 fewer incidences. Relative to the counterfactual avertible incidences, close to 80 000, the overall reduction in incidences would rise to 11% of the baseline, compared to the initially calculated

9.5%. Thus, further progress with regards to smoking cessation would pay substantial dividends.

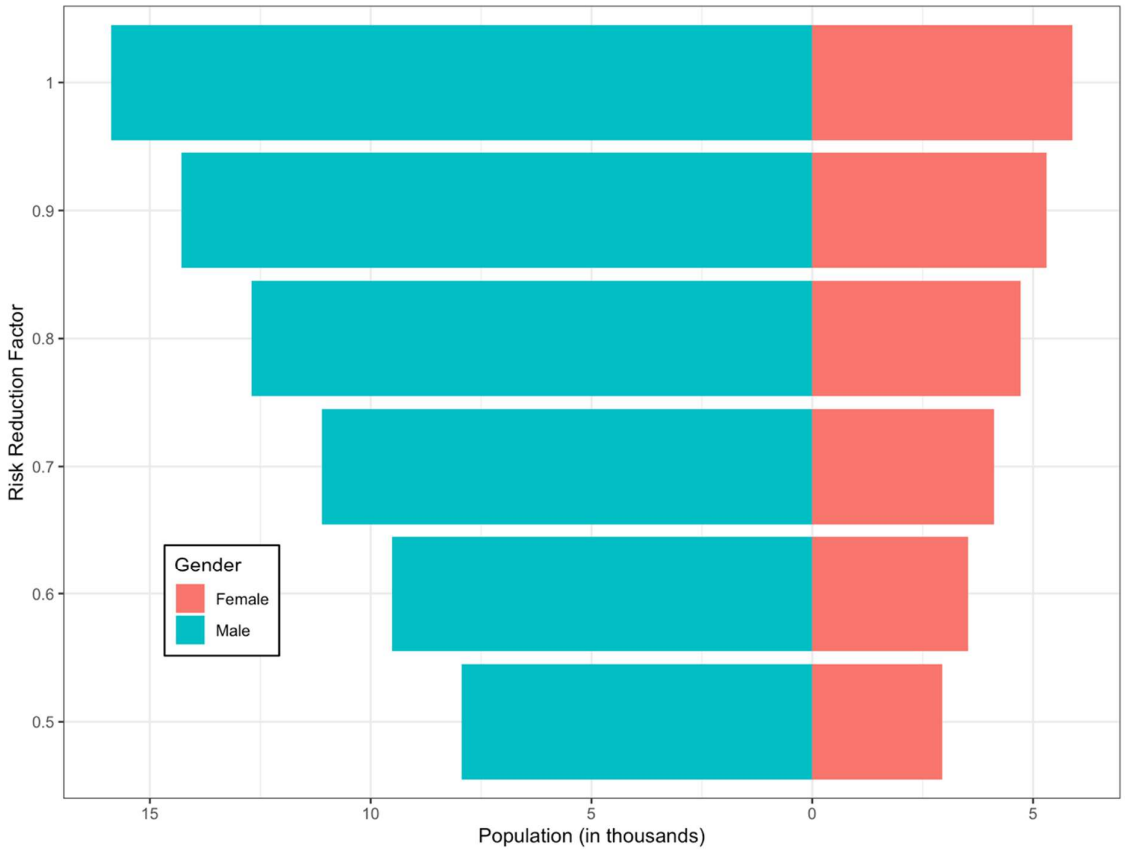

Figure 5 Sensitivity of Incidence to Tobacco Risk Reduction Assumption (PRIME)

CONCLUSION

South Africa is known for its quadruple burden of disease, which includes issues related to communicable diseases, NCDs, maternal and child health, as well as injury-related problems.[5-7] NCDs have been known to be a large problem amongst LMICs, while NCDs were already amongst the top causes of death in South Africa in 2010; more recent estimates suggest that they make up a large share of the DALYs.[2, 15-16] The government's NCD plan is a response to the threat that NCDs pose on the health of the populace, and, by extension, the healthcare system.[32,65-66] Similarly, the government has a variety of policies in place to regulate sugar, salt, tobacco and alcohol, although not all such policies had been fully implemented by 2021.[68-70]

Despite those plans and policies, the initial baseline for our model, in South Africa, suggests a populace consuming too much alcohol and salt, smoking too much, and not consuming enough fruit, vegetables or including enough fiber in their diets, which is similar to what the literature has found.[5,6,36,51-53] The model we have applied – the PRIME model – is used to examine the likely impact of reduced NCD risk consumption activities, such as a reduction in tobacco, alcohol and salt or an increase in fruits, vegetables and fiber.[90] The reductions

that we assume are in-line with WHO recommendations, and match the government's NCD plans.

Our baseline data suggests that NCD incidences are higher for women than for men, primarily due to cervical and breast diseases, despite the fact that NCD behaviours are riskier for men than for women. After applying our counterfactual scenario, we find an approximate 10% reduction in NCD incidence. However, due to the fact that NCD risky behaviour was initially higher for men, they would need to reduce the risks associated with their behaviour by more than would women; thus, we find that NCD incidence falls by more for men than women.

This significant reduction in NCD incidence from less harmful consumption requires a political understanding of the potential that South Africa could achieve. An appropriate policy approach that incentivizes South Africans to reduce unhealthy consumption is crucial to improve public health. This approach does not necessarily require costly interventions. While a change in dietary lifestyle primarily depends on income growth and is difficult to influence through policy, restricting alcohol consumption and smoking are comparatively low-hanging fruits. Both product markets contain a significant illicit share. Policymakers could do more to control the illicit market and/or promote less harmful alternatives, such as e-cigarettes, heat-not-burn products or low-alcohol beverages. Incentivizing less harmful alternatives implies lower taxation compared to their more harmful counterparts. Such that, consumers could eventually consume these less harmful alternatives, rather than purchasing questionable quality illicit products. Doing so would improve individual health, reduce NCDs and mitigate part of South Africa's tax losses from illicit trade.

Key findings:

1. *10% of NCD incidences could be prevented if South Africa's government would be able to convince adults to consume less harmful.*
2. *While a healthier diet often depends on income growth and is difficult to be influenced by authorities, information- and education-raising campaigns could empower South Africa's citizens to consume more consciously.*
3. *In comparison to complex dietary influencing measures, alcohol and tobacco are regulatory low-hanging fruits. The government could enforce illicit market restrictions and promote less harmful alternatives with lower tax rates.*
4. *Both approaches could improve public health thereby reducing NCD cases and compensating for South Africa's tax losses.*

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