Obesity Facts

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Research Article

How could different obesity scenarios alter the burden of type 2 diabetes and liver disease in Saudi Arabia?

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Short Title: Obesity policy and non-communicable diseases in Saudi Arabia

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Abstract

Introduction

Obesity is a major risk factor for type 2 diabetes (T2DM) and liver disease, and obesity-attributable liver disease is a common indication for liver transplant. Obesity prevalence in Saudi Arabia (SA) has increased in recent decades. SA has committed to the WHO 'halt obesity' target to shift prevalence to 2010 levels by 2025. We estimated the future benefits of reducing obesity in SA on incidence and costs of T2DM and liver disease under two policy scenarios: 1) SA meets the 'halt obesity' target; 2) population body mass index (BMI) is reduced by 1% annually from 2020 to 2040.

Methods

We developed a dynamic microsimulation of working-age people (20-59 years) in SA between 2010 and 2040. Model inputs included population demographic, disease and healthcare cost data, and relative risks of diseases associated with obesity. In our two policy scenarios, we manipulated population BMI and compared predicted disease incidence and associated healthcare costs to a baseline 'no change' scenario.

Results

Adults <35 years are expected to meet the 'halt obesity' target, but those ≥35 years are not. Obesity is set to decline for females, but to increase amongst males 35-59 years. If SA's working-age population achieved either scenario, >1.15 million combined cases of T2DM, liver disease and liver cancer could be avoided by 2040. Healthcare cost savings for the 'halt obesity' and 1% reduction scenarios are 46.7 and 32.8 billion USD, respectively.

Discussion/Conclusion

SA's younger working-age population is set to meet the 'halt obesity' target, but those aged 35-59 are off-track. Even a modest annual 1% BMI reduction could result in substantial future health and economic benefits. Our findings strongly support universal initiatives to reduce population-level obesity, with targeted initiatives for working-age people ≥35 years of age.

Keywords: Obesity, type 2 diabetes, liver disease, liver cancer, dynamic microsimulation modelling, non-communicable diseases

Introduction

In 2013, The World Health Organization (WHO) set an ambitious global target for countries to 'halt' obesity at 2010 levels by 2025, through measures such as fiscal policies to reduce consumption of sweetened beverages, supporting breastfeeding, and promoting healthier food in schools and other public institutions [1]. This target arose from a broader agreement to reduce by one-quarter the number of premature deaths from major non-communicable diseases (NCDs) – cardiovascular disease, diabetes and cancer – by 2025, for which obesity is a key risk factor [2]. A 2020 report from the World Obesity Federation is critical of global efforts towards the 'halt obesity' target [3]. Their projections suggest most countries have a less than 10% chance of meeting their goal, and they have put out a call to action to redress shortcomings in country responses to the obesity epidemic [3].

Developing a clearer understanding of the health and economic benefits of reaching the 2025 obesity target could renew political will for improved prevention and treatment in advance of the deadline. Beyond 2025, policy-makers could benefit from a snapshot of the longer-term future health of the population and the likely demands on the health system resulting from obesity. From a policy and planning perspective, it is useful for these snapshots to include the potential impact of particular policies on obesity, obesity-attributable diseases and associated healthcare costs [4].

Mathematical modelling is one approach for projecting future epidemiological and cost-related health outcomes in a population, which can be modified according to different policy scenarios [5]. Dynamic microsimulation models simulate the behaviour of hypothetical individuals over time [6], and are described by the Organisation for Economic Co-operation and Development (OECD) as the most appropriate method for risk factor and chronic disease modelling [7]. Key strengths include 1) large sample sizes of hypothetical individuals, replicating real, heterogeneous populations; 2) flexibility to account for the influence of pre-existing risk factors on an individual's disease status, which may progress and regress in line with a disease's natural history; 3) the ability to introduce hypothetical interventions to assess their potential influence on population-level outcomes; and 4) scope to estimate economic costs of diseases and potential cost savings associated with different policies [8-10]. Findings from microsimulation models are widely used to inform policy decisions, particularly in relation to budget allocation and interventions [8], a notable example being Minimum Unit Pricing in Scotland in 2018 [11].

Saudi Arabia (SA) is a co-signatory on the WHO 'halt obesity' pledge and is a pertinent case-study country for quantifying the potential benefits of different obesity policies. SA national estimates show that 24.1% of men and 33.5% of women were obese in 2013 [12], much higher than the 2016 global average of 11% for men and 15% for women [13]. SA has correspondingly high and increasing levels of type 2 diabetes (T2DM) [14], for which obesity increases the risk more than seven-fold [15]. Obesity is also implicated in the rising prevalence of non-alcoholic fatty liver disease (NAFLD), which affects more than 30% of the Middle East population [16] and could affect 48% of SA's population by 2030 [17]. A more serious NAFLD variant – non-alcoholic steatohepatitis (NASH) – is linked to advanced liver fibrosis, cirrhosis and liver cancer [18]. NASH has overtaken hepatitis C virus as the most common indication for liver transplants in SA [19]. The health and economic burden of T2DM, liver disease and liver cancer could be dramatically reduced with effective obesity policies and lifestyle interventions [20-22].

We used a well validated dynamic microsimulation model [22-27] to quantify the future health and economic benefits of two obesity policy scenarios compared to a baseline 'no change' scenario in SA from 2010 to 2040:

- Scenario 1: attainment of the 'halt obesity' target (i.e. no movement of individuals into the obese category between 2010 and 2025)
- Scenario 2: a reduction in population-level BMI by 1%, annually from the year 2020 to 2040

We estimated cumulative incidence avoided and direct healthcare costs avoided for obesity-attributable T2DM, liver disease and liver cancer between 2010 and 2040.

Materials and Methods

Dynamic microsimulation model

Our model included a hypothetical population of 100 million individuals, developed from the most recent SA age and sex population distribution available from the UN [28]. We implemented the model from 2010 to enable assessment of the 'halt obesity' scenario, which relates to the period 2010 to 2025. We modelled outcomes to 2040. Our model has been previously used to predict UK obesity trends and other NCDs [22, 25], and further adapted and implemented across 70 countries, including Saudi Arabia [24] and the wider Middle East [26]. The method has also previously been employed to quantify the impact of different policy scenarios on burden and direct healthcare costs of related diseases [29]. The full method is described elsewhere [21] and in the Online Supplementary Material.

Focused literature reviews to source model input data

We searched for prevalence estimates for different categories of BMI (our risk factor) by age and sex. Incidence, prevalence, and mortality estimates for T2DM, liver disease, and liver cancer (our disease outcomes) were also collected, as well as papers reporting relative risks linking BMI categories to our diseases. Our BMI categories were: healthy weight (BMI<25.00 kg/m^2), pre-obese (25.00-29.99 kg/m^2), and obese (≥30.00 kg/m^2), following WHO definitions [30]. We also searched for direct healthcare cost estimates for our focal diseases.

Inclusion/exclusion criteria

We included data for all adults in SA, but restricted our reporting to people of working age (20-59 years) given their greater influence on the economy. We excluded data older than 15 years to ensure our predictions were not unduly influenced by historical data no longer reflective of SA's population characteristics. We prioritized data firstly from SA, then the Middle East region, then Asia, and finally to other countries outside of Asia until we found suitable data sources.

Final data sources

Cross-sectional BMI data were drawn from multiple sources and years (see Table S1, Online Supplementary Material). Data on T2DM in SA were drawn from the 2017 Global Burden of Disease study [31], with relative risks drawn from a global study, reporting estimates for Asian males and females [32]. Liver disease data were drawn from the Global Burden of Disease study [31], which provides incidence and mortality estimates from 2016, for which 'Cirrhosis and other chronic liver diseases' was the most appropriate category and could be linked to the limited available relative risk data [33]. Liver cancer incidence was drawn from the 2014 Saudi Cancer Registry [34], and mortality data were from the 2018 registry [35]. Relative risks were drawn from a 2012 global meta-analysis, which included an estimate for Asian populations [36].

Due to limited cost data availability for Saudi Arabia, for all diseases, we used cost data from the United Kingdom [37, 38], converted to US dollars (2010 value) using a purchasing power parity approach [39] (Table S2, Online Supplementary Material).

Implementing policy scenarios

The simulated population was exposed to three scenarios: 1) no additional policy (baseline); 2) obesity halted at 2010 levels: no-one in the population could move from the healthy-weight or pre-obese groups into the obese group between 2010 and 2025; 3) an annual 1% reduction in population-level BMI was implemented from the year 2020 until 2040.

Microsimulation outputs

Microsimulation outputs were generated for ~100 million hypothetical individuals representing the entire SA population. Here, we report only results for the working age (20-59 years) population, representing ~60 million trials.

Results

Confidence limits (+/-) for all results refer to Monte Carlo error of trials in the microsimulation.

Estimated obesity prevalence under current trends (baseline scenario 2020-2040):

Obesity prevalence estimates for the period 2020-2040 are presented in Table S3 (Online Supplementary Material) by five-year age groups and sex. Our model suggests strong sex and generational effects on obesity. This modeling approach estimated that 33.7% of all working-age males (20-59 years) were obese in 2020, with a maximum obesity prevalence of 34.8% is predicted in 2030 and declining to 33.3% in 2040. Trends for the youngest males (20-34 years) are optimistic, showing a steady decline from 19.8% in 2020 to 15.5% in 2040. Obesity trends for 35-59 years-old males are more concerning, predicted to increase from 43.7% in 2020 to 56.3% in 2040 in the 35-44 age group, and from 45.5% to 59.9% in the 45-54 age group. Obesity amongst the oldest males (55-59 years) is expected to increase from 38.9% to 46.4%.

For working-age females, although declines in obesity prevalence are predicted, the prevalence is still high: 34.5% in 2020 to 27.7% in 2040. The magnitude of decline varies considerably by age group, as does the starting prevalence. Females <35 years of age have the lowest starting and finishing prevalence: 20.0% in 2020 to 10.7% in 2040. In contrast, nearly 50% of females 35-54 years were estimated to be obese in 2020, dropping to 40% by 2040. Females

55-60 years have the highest starting obesity prevalence (54.3% in 2020) and the smallest reduction over time (50.2% in 2040).

Estimated cumulative incidence avoided for T2DM, liver disease and liver cancer (2010-2040), by obesity policy scenario relative to baseline

Cumulative incidence avoided, for each disease, for each year of the microsimulation are shown in Figure 1, for both scenarios compared to baseline. T2DM was predicted to show the greatest reduction of all diseases between 2010 and 2040, at 994,453 [± 2,569] for scenario 1 (halt obesity) and 1,019,715 [± 2,560] for scenario 2 (1% BMI reduction). For liver disease, 156,095 [± 1,165] cases could be avoided in scenario 1, and 147,041 [± 1,170] in scenario 2, by 2040. Reductions for liver cancer were predicted as 324 [± 172] and 534 [± 171] for scenarios 1 and 2, respectively, by 2040. In total, this represents a reduction of 1,150,871 [± 2,826] disease cases in scenario 1, and 1,167,290 [± 2,820] cases in scenario 2 (see Table S4 [Online Supplementary Material] for full results by scenario, sex and age-group).

In both scenarios, the majority of incidence avoided was in males (~68-73% of cases avoided). By age, the greatest reductions were seen in adults aged 35-49 (~51-63% of cases avoided).

Estimated direct healthcare costs avoided for T2DM, liver disease and liver cancer (2010-2040), by obesity policy scenario

Cumulative healthcare costs avoided for each disease, through each year of the microsimulation, are shown in Figure 2, for both scenarios compared to baseline. Figure S1 (Online Supplementary Material) shows the schematic of risk factor model and microsimulation model. Costs avoided are cumulative from 2010. The greatest savings were predicted for T2DM, at 31,606,477,828 [± 32,682,902] USD for scenario 1 (halt obesity), and 22,245,802,810 [± 33,149,239] USD for scenario 2 (1% BMI reduction), by 2040. Costs avoided for liver disease were 15,124,470,064 [± 56,156,104] USD and 10,557,215,034 [± 56,655,461] USD for scenarios 1 and 2, respectively. Costs avoided for liver cancer were 7,805,755 [± 4,037,343] and 11,462,574 [± 4,028,680] respectively. In total, costs avoided for the three diseases were predicted to be 46,738,753,648 [± 65,099,771] USD for scenario 1, and 32,814,480,419 [± 65,764,303] USD for scenario 2 (see Table S5 [Online Supplementary Material] for full results by scenario, sex and age group).

Discussion/Conclusion

Future trends in obesity prevalence

Our results show a mixed picture of future obesity trends if there is no change in current policy, with large variation by age and sex. The 40.5% 'halt obesity' target for women [1] is set to be reached overall, but not by women 35-59 years who will remain considerably off-target. Whilst it is encouraging that obesity amongst working-age women is set to decline over time, for women 35-59 years, prevalence starts high and remains high in 2040. Men overall are not set to meet the 'halt obesity' target of 27.2% [3], though men <35 years may reach it. Men 35-59 years are further away from the 2025 target than women, with increasing obesity predicted over time. Almost 60% of men 45-54 years could be obese by 2040.

One other study has modelled SA obesity trends in relation to the halt obesity target [3]. The World Obesity Federation (WOF) report estimates that neither males nor females are on track to meet the target. The study authors used ordinary least squares (OLS) regression to derive 2025 obesity estimates of 40.0% for adult males and 49.1% for adult females in 2025. Our results are more optimistic for women overall, and more pessimistic for men, though our estimates overlap for women 35-54 years of age. There are several reasons why our results differ, including our focus on the working-age population (rather than all adults), and methodological differences (e.g. the use of a dynamic microsimulation with the flexibility to move between granular states versus a deterministic approach). Another key difference is that we excluded BMI data sources older than 15 years, and the WOF report included data from the 1980s, which could affect the gradient. Our results complement the WOF report findings because they provide additional information about obesity by age group, highlighting which segments of the population are off track.

Quantifying future benefits of achieving obesity scenarios

Our findings suggest that reducing obesity would be particularly beneficial for preventing T2DM, for which around a million cases would be avoided for both scenarios. The management of T2DM is extremely costly, and the achievement of either scenario represents T2DM cost savings of over 22.2 billion USD. For liver disease, each scenario could avoid around 150,000 cases by 2040 – amounting to savings of over 10.5 billion USD. Liver cancer, despite being the least common of the diseases evaluated, would also lead to substantial cost savings of around 7.8 to 11.5 million

USD. We are not aware of other studies quantifying the potential benefits of meeting the 'halt obesity' target, or other policy scenarios (such as achieving an annual 1% reduction in BMI).

Implications for SA policy

The need for targeted weight reduction interventions

Our results strongly suggest the need for targeted weight reduction interventions, particularly for people 35 years and older. For women in this age group, obesity trends are decreasing, but not rapidly, so interventions that hasten the reduction would be worthwhile. For men, of concern is the increasing obesity trend predicted for those 35 years and older. Interventions will be needed to address the factors underlying this increase. A number of effective obesity prevention and treatment interventions exist, which can have meaningful individual- and population-level impacts [20-22].

Include working-age people ≥35 years as a target group in SA's obesity strategy

SA's 2019 obesity strategy explicitly refers to the commitment to reduce key NCDs by one-quarter by 2025 [40]. The strategy is being delivered through a framework that combines a life-course approach with a socio-ecological outlook to recognize the multi-factorial nature of obesity. However, the target groups for obesity monitoring do not explicitly include middle- or older-aged people; and instead, focus mostly on those engaged with antenatal services. This omission could work against the overarching life-course approach upon which the strategy is based. Our data show that people 35-59 years of age are at high risk of developing obesity and obesity-attributable diseases, many of whom would not be captured by antenatal services. Targeted interventions to these groups, and the use of general population surveys to monitor obesity and obesity-related diseases will be paramount to achieving NCD targets, preventing harm and reducing healthcare costs attributable to obesity.

Saudi Vision 2030

SA is planning to restructure the country's vital service sectors through ambitious Saudi Vision 2030 objectives. The Health Sector Transformation Program is one of the eight themes that Saudi Vision 2030 covers [41] and aims to facilitate access to healthcare services, improve the quality and efficiency of health services, and promote prevention of health risks [41, 42]. Community-based health programs, healthy food and eating behavior promotion, and multilevel health education initiatives are expected to be a vital part of this program. In particular, one of the current initiative strategic pillars focuses on reducing the prevalence of risk factors (including obesity and diabetes) for NCDs. This vision is supported through various reform initiatives, which include but are not limited to health sector reform, the introduction of a modern care model (i.e., change in the design of care delivery), private sector participation and investment, and e-health initiatives to improve access to care and care management; and is further supported by the new agreements signed with multinational pharmaceutical companies to commence medicine manufacturing within SA and reinforcing medical research [43]. A recent Gulf Cooperation Council report mentions that the SA's health investment will increase to 66.67 billion USD (cumulative) by 2030 [44]. These healthcare reforms provide promise to address the current public health challenges in SA, notably to support reducing obesity prevalence in the Kingdom [45].

Strengths, limitations & future work

We have developed a novel SA microsimulation study designed to inform policy decisions to promote health in SA. Our study provides timely obesity estimates in the lead up to the 2025 'halt obesity' deadline. Our findings highlight the urgency of addressing obesity, particularly amongst middle-to-older age working people. We demonstrate that a relatively small 1% annual reduction in BMI could bring substantial health and economic benefits. Though we indicate optimistic projections for younger groups, changing environmental factors, such as COVID-19 restrictions that can affect physical activity and diet, will need monitoring across age groups [46, 47].

Our study was limited by the availability of data, and we used data from outside of SA for certain microsimulation modules. We identified a need for more up-to-date, national and regionally representative data on obesity incidence and prevalence, as well as specific liver diseases such as NAFLD, which are on the rise in SA [19]. More frequent, high-quality data will enable more detailed modelling of the associations between obesity and NCDs in SA, and more accurate projections of the economic and health burden from NCDs. We also restricted our reporting to people of working age, who have the greatest economic influence, but this meant we could not see the true extent of obesity's influence on slower progressing diseases such as NAFLD/NASH-related cirrhosis and liver cancer, more commonly seen in older age [48, 49].

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Statement of Ethics
Our study used open-access secondary data and did not require ethical approval.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

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Data Availability Statement
The data supporting the findings of this study are taken from publicly available sources (as mentioned in the Methods section and Online Supplementary Material). Further enquiries can be directed to the corresponding author.

Author Contributions
SA conceived the study, with support from LW. JS wrote the manuscript, with redrafts supported by LW, LR and TC. JG, JC-G and HI conducted literature reviews and sourced data for the microsimulation. TC, LR and LW adapted the model and ran the microsimulation. JS, TC and LW interpreted the data. SA, NB, NA, KA and HI reviewed and substantially revised the manuscript content. All authors reviewed and approved the final version of the manuscript.

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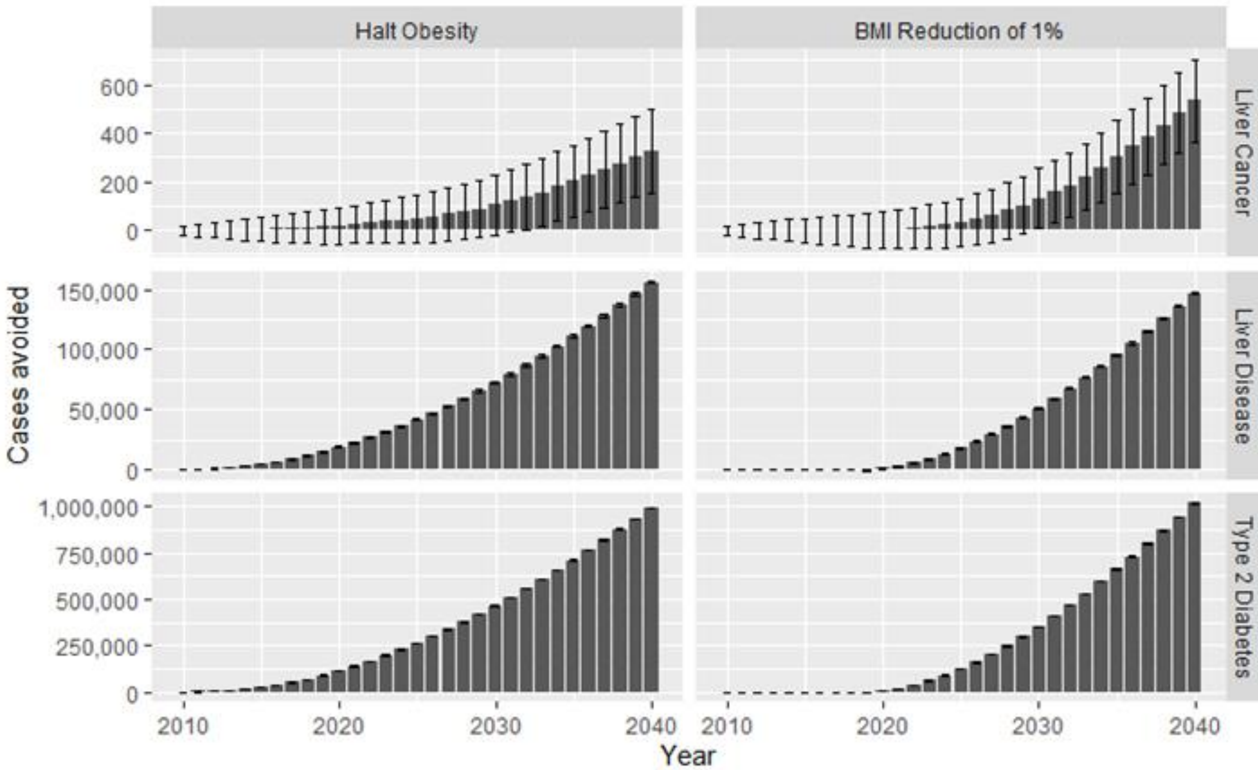
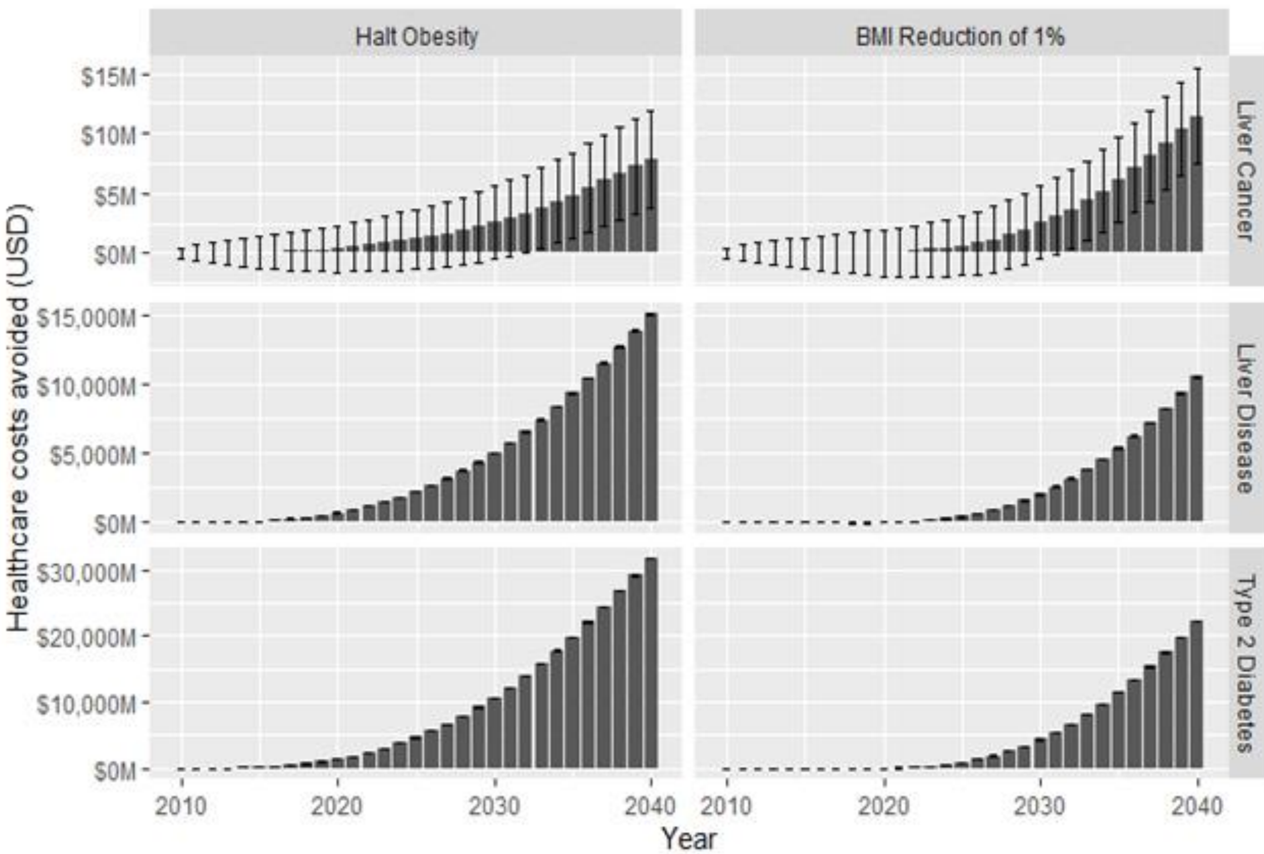
Fig. 1. Cumulative incidence avoided for type 2 diabetes, liver disease and liver cancer, for each obesity policy scenario compared to baseline, amongst people 20-59 years, 2010-2040.

Fig. 2. Cumulative direct healthcare costs avoided (USD) for type 2 diabetes, liver disease and liver cancer, for each obesity policy scenario compared to baseline amongst people 20-59 years, 2010-2040.



Halt Obesity
BMI Reduction of 1%
Liver Cancer
Liver Disease
Type 2 Diabetes
Cases avoided
600
400
200
0
150,000
100,000
50,000
0
1,000,000
750,000
500,000
250,000
0
2010
2020
2030
2040
Year



Halt Obesity
BMI Reduction of 1%
Liver Cancer
Liver Disease
Type 2 Diabetes
Healthcare costs avoided (USD)
$15M
$10M
$5M
$0M
$15,000M
$10,000M
$5,000M
$0M
$30,000M
$20,000M
$10,000M
$0M
2010
2020
2030
2040
Year