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Potential health and economic impact of achieving Kenya's overweight and obesity reduction target: a modelling study

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ABSTRACT

Introduction Kenya has adopted the WHO target of halting the rise of overweight, including obesity, by 2025. This paper assesses the potential impact of achieving the set target on health, healthcare cost and productivity.

Methods We used a proportional multistate life table model (*Kenya Obesity Model*) to simulate the 2019 population of Kenya over their lifetime. We compared a scenario in which body mass index (BMI) distributions stabilise in 2025 against one whose BMI distributions stabilise in 2044, and quantified changes in disease-specific health outcomes, healthcare costs and productivity. We searched the literature to identify the best estimates of the total and disease-specific healthcare costs in Kenya. We used the Human Capital Approach to estimate productivity gains.

Results If BMI distributions stabilised in 2025, an estimated 6.8 million health-adjusted life years (HALYs) (95% uncertainty interval (UI) 5.8–7.9 million) would be saved over the lifetime of the 2019 Kenyan population (135 HALYs per 1000 persons). A total of US$755 million in body mass-related healthcare costs could be saved by 2044 (US$15 per capita). For context, this equates to 16% of Kenya's annual healthcare expenditure. Over the lifetime, ~US$3 billion healthcare costs could be saved (US$62 per capita). By 2044, the total productivity gain resulting from a reduction in high BMI-related mortality and morbidity (combined) was ~US$5.8 billion (~US$237 per capita).

Conclusion Achieving Kenya's overweight and obesity reduction target could improve health outcomes and also yield substantial healthcare cost savings and productivity gains.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The rising burden of non-communicable diseases linked to high body mass causes a large social and economic burden.

⇒ While several international studies have estimated the health and economic impact of obesity and overweight, most of these studies focused on high-income countries.

WHAT THIS STUDY ADDS

⇒ Halting the rise of overweight and obesity not only improves health outcomes but also yields healthcare costs savings and productivity gains, which are about eight times higher than the direct healthcare cost savings realised.

⇒ By 2044, US$755 million in body mass-related healthcare costs could be saved and ~US$5.8 billion in productivity gain could be realised.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings support the case for government action to prevent further increases in overweight and obesity.

INTRODUCTION

Globally, the rising trend in mean body mass index (BMI)[1 2] has resulted in a substantial increase of the burden of non-communicable disease (NCD) attributable to high BMI.[3 4] This has created a double burden of disease in many low -income and middle -income countries (LMICs) that still battle with malnutrition and face a large burden of infectious disease.[3 5 6] In Kenya, high body mass is ranked seventh among the top 10 risk factors contributing to total disability-adjusted life years (DALYs) in 2019 for all ages combined.[5] Of the adult population in Kenya, 27% have overweight or obesity (~6.8 million people),[7] overweight defined as a BMI of 25.0–29.9 kg/m^2 and obesity as ≥30.0 kg/m^2.[8] This rising BMI-related burden of NCDs causes a huge social and economic burden in the country.

Overweight is considered a consequence of sustained energy imbalance that results from excessive energy intake (diet) and/or insufficient energy expenditure (physical activity).[9] In sub-Saharan Africa countries such as Kenya, a nutrition transition, complemented by increased sedentary lifestyles, has been considered as a driver for the obesity epidemic.[10 11] People eat progressively less locally produced indigenous foods rich in fibre and low in fat, and more of products high in saturated fats and sugar, and industrially processed foods which have become increasingly available.[12 13] Rapid urbanisation,

increased sedentary lifestyles and emergence of less energy-demanding jobs[12] have led to physical inactivity which is associated with an increased prevalence of overweight and obesity.[14 15]

Prioritisation of NCD prevention in Kenya is an aspiration.[16] The country has set out various national strategies for the prevention and control of NCDs and adopted the Global Action Plan target to halt the rise (0% increase) of overweight and obesity by 2025.[17–20] Although achieving the obesity reduction target is challenging, population-wide strategies that target the modifiable components of energy intake and energy expenditure may achieve great overall health impact.[21 22]

Several international studies (most conducted in high-income countries) have estimated the economic impact of obesity and overweight by either estimating the current or future cost of overweight and obesity[23–28] or by quantifying the potential healthcare cost savings that could be realised from reduction of overweight and obesity.[29–31] Various studies have estimated the impact of reduction of overweight and obesity on productivity,[32–37] capturing cost from a societal perspective that considers indirect costs.[38 39] Studies that estimated both direct and indirect costs of obesity found productivity-related costs higher than the direct healthcare costs.[40] So far, no research has been published on the assessment of the potential productivity gains and healthcare cost savings associated with prevention and control of overweight and obesity in adults in Kenya.

In this study, we use a proportional multistate life table model[41 42] to quantify the potential impact of achieving the Kenya national target of halting the rise (0% increase at all ages) of overweight and obesity by 2025. Quantifying these benefits may give impetus for government and development partners to prioritise the prevention of overweight and obesity.

METHODS

Study design

This study is an extension of previous work where we developed the *Kenya Obesity Model*,[41] an adaptation of the proportional multistate life table (pMSLT) model[42] developed by Veerman *et al*.[43] The pMSLT is a macrosimulation model with state-transition (Markov) property that simulates multiple age cohorts of the population into the future. The model allows for the inclusion of multiple diseases simultaneously while accounting for comorbidity.[42] We modelled a total of 37 diseases associated with high BMI (online supplemental SF table 1).[5 41 44] We explain the multistate life table modelling process in the online supplemental SF pages 3–5 and online supplemental SF figure 1.

Modelled scenario

In this assessment, the model was extended to model the difference between health and economic outcomes for a reference population with 'business as usual' where the current BMI levels and trend continue unabated for 25 years, and a comparator (an identical 'intervention' population) in which 'business as usual' is maintained until the rising trend is halted in the year 2025 (the target is to halt the rise by 2025).

BMI distribution and disease epidemiology

As described in our previous work,[41] current BMI levels are derived from the latest published national survey results (online supplemental SF table 2).[7 45] We derived the BMI trend from age-specific and sex-specific mean BMI data for Kenya from the NCD Risk Factor Collaboration (NCD-RisC) study from 1975 to 2016[2] (online supplemental SF pages 6 and 7, online supplemental SF figures 2 and 3). Our business-as-usual scenario (base case) assumes that the observed rising BMI trend continues up to 25 years into the future.

To populate our model, we used the following Kenya-specific data from the Global Burden of Disease (GBD) 2019 study: age-specific, sex-specific and cause-specific incidence, prevalence, and case fatality rates (online supplemental SF table 3), all-cause mortality and disability rates (online supplemental SF tables 4 and 5) and the 2019 population data (online supplemental SF table 6).[5 46] We used DisMod V.II software to enforce internal consistency in the epidemiological estimates and derive remission and case fatality parameters not provided in the GBD data (online supplemental SF pages 7 and 8, online supplemental SF figure 4).[47] We calculated disability weights using disease-specific prevalence and years lived with disability (YLDs) estimates from the 2019 GBD study (online supplemental SF page 30, online supplemental SF table 7).[5 41 48] Based on the latest evidence of diseases associated with high BMI, we modelled 37 diseases and used respective relative risk estimates by age and sex as reported in the GBD 2019 study (online supplemental SF table 8).[5 41 44]

Life table analysis

We modelled the entire 2019 population in Kenya (50.2 million, online supplemental SF table 6) over their lifetime with risks rising only from age 20 and no burden among children. This is in line with the available evidence which shows high BMI (>22.5 kg/m^2) is associated with NCDs that are commonly seen in adults (apart from asthma).[44] Figure 1 gives a schematic overview of this study. Halting the rise in BMI translates to fewer people who have overweight and obesity in Kenya since we model a closed cohort of the 2019 population, incorporating effects of population ageing but do not incorporate new birth cohorts or immigration. This impacts on incident cases of the modelled diseases. For each age-sex group, the proportional changes in incidence after a change in BMI were calculated using the potential impact fraction (see also online supplemental SF pages 4 and 5),[49] using 22.5 kg/m^2 as our optimal BMI level (theoretical minimum risk exposure level).[41] Changes in incidence

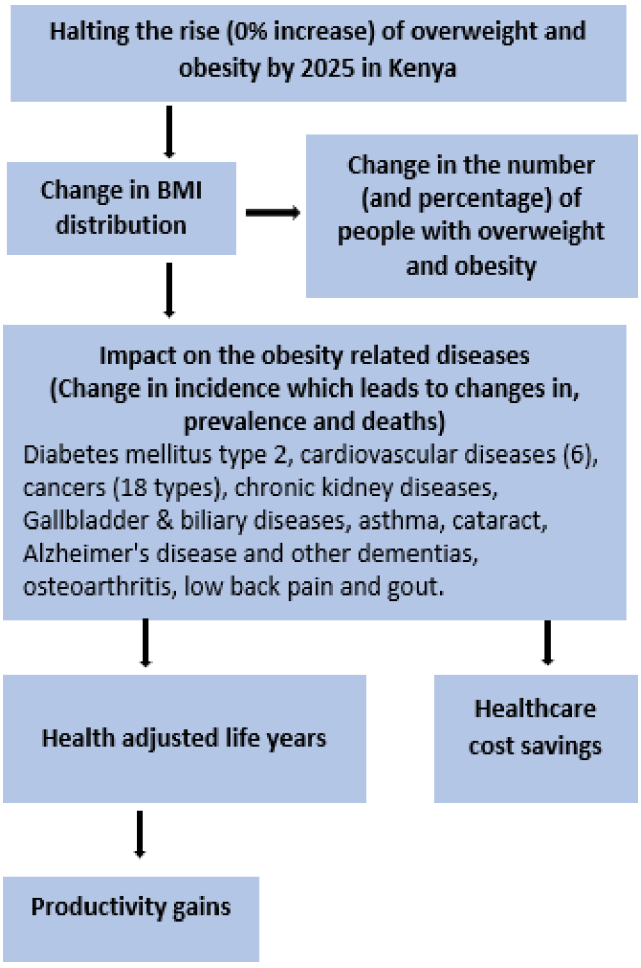

Figure 1 Schematic overview of the study. BMI, body mass index.

resulted in changes in prevalence, and ultimately disease-specific mortality followed. Changes in disease-related quality of life at every age were calculated using disease-specific disability weights.[5 48] The new disease-specific mortality and morbidity rates and cost offsets are fed into a life table. The changes in the morbidity and mortality are summarised as health-adjusted life years (HALYs) and life expectancy (HALE), and the change in health expenditure is assessed. Finally, the changes in the HALYs affect productivity. In this study, we took a societal perspective that allows for the assessment of indirect effects on the wider economy that are valued by the rest of the society, not the effects of inability to work on the well-being of the individual which may be incorporated in the measurement of quality of life.[38 39]

In the section below, we describe how we extended the *Kenya Obesity Model*[41] to incorporate healthcare costs and productivity outcomes.

Healthcare cost data and estimating healthcare savings

Disease-specific costs in Kenya

We identified estimates of disease-specific costs from five published studies.[50–53] We present the cost estimates in table 1 alongside additional notes on how we calculated the annual cost per incident or prevalent case of the disease. Two studies reported only point/mean estimates for disease costs.[50 53] One study defined uncertainty boundaries by applying an arbitrary ±15% value to the central value[52] and one study provided the mean, median and SD.[51] Therefore, we assumed the SE of the mean to be 20% of the published point estimates of costs for each disease. The ±20% is often used in the literature to estimate the lower and upper limits of costs. In addition, for best alignment with the total healthcare costs estimate for Kenya, we used only the disease costs estimates from public facilities (not private hospitals) reported in the published studies. Using Kenyan data on the percentage of people who had some sickness reported but did not seek healthcare and percentage of the population requiring admission who did not get admitted, we adjusted the disease costs to account for the percentage of people with disease who are likely to seek medical care in Kenya and hence incur healthcare costs. The estimates of these two percentages were taken from the 2013 Kenya Household Health Expenditure survey report.[54]

Total healthcare costs

We used latest estimates from the 2020 WHO Global Health Expenditure Database that estimated the total healthcare costs for Kenya as US$4.5 billion for the year 2018.[55] Although we did not use cost estimates from the 2013 Household Health Expenditure survey, the survey report provided data on health-seeking behaviour, use of healthcare services and the corresponding health expenditures (by age groups and sex), out-of-pocket health spending and health insurance coverage.[54] In terms of utilisation of healthcare services by health facility type/ownership, the survey results[54] corresponded well to the characteristics of the health system in Kenya as documented in the Kenya National Health Accounts.[56] The health accounts indicate that government contributes to 42.8% of healthcare financing scheme followed by household out-of-pocket (26.1%), donors (17.9%) and voluntary healthcare payment systems at 13.2%.[56] The country's current health expenditure is 4.59% of the gross domestic product and 11% of the country's total budget.[55] To apportion the total healthcare costs across specific age groups and sex, we used proportional cost distribution informed by the age-specific annual per capita health spending and sex-specific spending on healthcare published in the 2013 Kenya Household Health Expenditure and Utilisation Survey (table 2).[54] To derive the yearly costs of all other diseases per person, we subtracted the age-specific and sex-specific costs of all modelled diseases from the total health expenditure in the respective sex and age groups (table 2). Overall healthcare costs for all other health conditions are included because as preventive interventions prolong life, additional health expenditure is expected in those added years of life.[57 58]

The change in high-BMI-related NCDs healthcare expenditure was based on the predicted reduction in

Table 1 Per capita annual disease costs in US$ derived from identified primary studies*

Disease modelled	Incident or prevalent case per year	Cost type/notes	Percentage of patients	Point estimates of cost per incident or prevalent case per year	Year of costing	Source of data/ primary study	Country of the primary study
	Incident cost	Diagnosis		4.23			
		Mild asthma (management (mgt)/treatment (rx))	0.95	67.93			
		Severe asthma (mgt/rx)	0.05	146.74			
Asthma	Prevalent cost	Weighted average used as prevalent cost		71.87	2017	Subramanian *et al*[50]	Kenya
		Breast cancer (clinical breast examination)(screening)		3.90			
		Diagnosis		401.00			
	Incident cost	Total cost used as incident cost		404.90			
		Breast cancer treatment			2017	Subramanian *et al*[50]	Kenya
		Stage I	0.07	1340.38			
		Stage II	0.35	1340.38			
		Stage III (curative approach)	0.19	1542.58			
		Stage III (palliative approach) and stage IV	0.40	675.35			
Breast cancer	Prevalent cost	Weighted average used as prevalent cost		1126.19	2017	Subramanian *et al*[50]	Kenya
		CKD (dialysis)	0.70	5338.00			
		CKD (transplant)	0.30	9237.00			
CKD†	Prevalent cost	Weighted average used as prevalent cost		6507.70	2017	Subramanian *et al*[50]	Kenya
CLL	Prevalent cost	Average cost of treatment		1164.20			
CML		Average cost of treatment		686.00			
ALL							
AML		We used total number of prevalent CLL and CML cases in Kenya from GBD to calculate a weighted average cost which was applied as the prevalent cost for ALL, AML and other leukaemia					
Other leukaemia	Prevalent cost			1027.85	2016	Atieno *et al*[53]	Kenya
Multiple myeloma	Prevalent cost	Average cost of treatment		1473.10			
Colon and rectum cancer	Prevalent cost	Average cost of treatment		1742.10	2016	Atieno *et al*[53]	Kenya
		Diabetes—random blood sugar (screening)		4.95			
		Diagnosis		41.95			
	Incident cost	Total cost used as incident cost		46.90			
		Insulin only (mgt/rx)	0.32	186.40			
		Oral medication only (mgt/rx)	0.25	88.61			
		Both insulin and oral medication (mgt/rx)	0.43	234.44			
Diabetes mellitus type 2	Prevalent cost	Weighted average used as prevalent cost		182.61	2017	Subramanian *et al*[50]	Kenya
Gallbladder and biliary tract cancer	Prevalent cost	Average cost of treatment		407.90	2016	Atieno *et al*[53]	Kenya

Continued

Table 1 Continued

Disease modelled	Incident or prevalent case per year	Cost type/notes	Percentage of patients	Point estimates of cost per incident or prevalent case per year	Year of costing	Source of data/ primary study	Country of the primary study
		Annual treatment cost for hypertension					
		Treatment—1 drug	0.20	25.64			
		Treatment—2 drug	0.35	67.25			
		Treatment—3 drug	0.25	81.20			
		Treatment—4 drug	0.10	110.33			
		Treatment—resistant	0.10	159.36			
Hypertensive heart disease	Prevalent cost	Weighted average used as prevalent cost		75.93	2017	Subramanian *et al*[50]	Kenya
Intracerebral haemorrhage	Prevalent cost	Used the cost of prevalent haemorrhagic stroke		1406.30	2013–2017	Aminde *et al*[51]	Cameroon
Subarachnoid haemorrhage	Prevalent cost	Used the cost of prevalent haemorrhagic stroke		1406.30	2013–2017	Aminde *et al*[51]	Cameroon
		Acute myocardial infarction	0.2F, 0.35M	1995.65			
		Angina	0.35	1,236.81			
		Heart failure (secondary to hypertension)	0.10	1026.07			
	Incident cost	Weighted average calculated using the given event distribution as cited by authors		1633.10	2017	Subramanian *et al*[50]	Kenya
IHD‡	Prevalent cost	All CHD states (chronic annual cost for secondary prevention)		300.00	2012	Gazianio *et al*[52]	South Africa
Ischaemic stroke	Incident cost	Stroke cost per inpatient or outpatient episode		1873.93	2017	Subramanian *et al*[50]	Kenya
	Prevalent cost	Stroke (chronic annual cost for secondary prevention)		900.00	2012	Gazianio *et al*[52]	South Africa
Kidney cancer	Prevalent cost	Average cost of treatment for renal carcinoma		671.40			
Liver cancer	Prevalent cost	Average cost of treatment for liver cancer		1303.40			
Oesophageal cancer	Prevalent cost	Average cost of treatment		866.80			
Ovarian cancer	Prevalent cost	Average cost of treatment		2217.00			
Pancreatic cancer	Prevalent cost	Average cost of treatment		1244.00			
Thyroid cancer	Prevalent cost	Average cost of treatment for follicular thyroid carcinoma		1342.70			
Uterine cancer	Prevalent cost	Average cost of treatment for endometrial carcinoma		1624.40	2016	Atieno *et al*[53]	Kenya

*All disease costs in the identified studies were hospital based (with some being tertiary hospitals)
†Only estimated CKD cases on dialysis and transplant were costed in our model. Of the 9.1% global CKD prevalence, dialysis accounted for 0.041% (0.037 to 0.044), and kidney transplantation for 0.011% (0.010 to 0.012).[65]
‡We considered the acute presentations of IHD as acute myocardial infarction, angina and heart failure (secondary to hypertension).[50] To determine the number of people diagnosed with IHD that had experienced each of the above events (ie, myocardial infarction, angina and heart failure (secondary to hypertension)), we used proportions identified in a study by Subramanian and colleagues[71] based on previous research.[72 73]
ALL, acute lymphoid leukaemia; AML, acute myeloid leukaemia; CKD, chronic kidney disease; CLL, chronic lymphoid leukaemia; CML, chronic myeloid leukaemia; GBD, Global Burden of Disease; IHD, ischaemic heart disease.

Table 2 2019 healthcare costs in US$

	2019 total healthcare costs in US$				2019 costs of all other diseases not included in the model	
	Costs in US$		Costs per person in US$		Costs per person in US$	
Age group	Male	Female	Male	Female	Male	Female
0–4	211 311 453	297 171 638	65	94	61	89
5–14	100 841 169	141 815 008	16	23	10	16
15–24	120 840 100	169 939 915	22	31	15	22
25–34	130 257 586	183 183 919	34	46	22	31
35–44	171 101 963	240 624 205	63	86	39	61
45–54	262 208 203	368 748 782	153	218	101	169
55–64	404 422 822	568 748 122	401	557	290	465
65+	578 064 332	812 943 744	846	985	622	802
Total	**1 979 047 628**	**2 783 175 333**				

Total healthcare costs for Kenya were derived from the 2020 WHO Global Health Expenditure Database that published 2018 costs.[55] We inflated the reported 2018 total healthcare costs to 2019 (our model base year) based on Kenya consumer price indices.[61] To convert the reported US dollars (US$) to Kenya shillings, the reader to use the world Bank's official 2019 exchange rate of 102.[74]

disease mortality and morbidity following achievement of the target. Cost data are often skewed and higher costs concentrated among a small group of 'high-cost' patients.[59] However, at the population level modelled in this study, we assumed that at the aggregate level, the cost data averages will be approximately normally distributed—in line with the central limit theorem.[60] Therefore, we modelled healthcare costs as normally distributed assuming the SE of the mean to be 20% of the point estimates. We extracted the costs in US$ as published in the primary studies and then inflated all cost estimates to 2019 (our model base year) based on Kenya consumer price indices.[61]

Estimating productivity gains

We estimated productivity outcomes for the 2019 working population in Kenya (20 years up to retirement age of 65 years) over their lifetime. We used the Human Capital Approach[39] to estimate productivity gains resulting from a reduction in high BMI-related (1) mortality, (2) mortality and morbidity (combined), and (3) morbidity. First, to estimate productivity gains resulting from a reduction in high BMI-related mortality, we use the methodology previously used in Nomaguchi *et al*.[32] Productivity gains are estimated from the age of premature death until the age of traditional retirement in Kenya (65 years). In Equation 1, we describe how we quantified productivity changes. People obtain additional life years (LYs) due to halting the rise of overweight and obesity with the potential to earn higher income as follows:

$$pM = \sum_{i=1}^{n} \left(L'x - Lx\right) iWA, \quad (1)$$

where pM is productivity changes due to reduced high BMI-related mortality, $(L'x\text{-}Lx)i$ is the difference in years lived between employed population post 'intervention,' that is, after halting the rise in overweight and obesity ($L'x$) and the employed population pre 'intervention' (Lx), and WA is the average annual wage rate in the working population in Kenya (US$655.05).[62] In the model, we apply an adjustment for the percentage of the 2019 working population that is employed in Kenya (58.4%).[62] Due to limitations in the data availability on sex-age-specific average wage rate in Kenya, we apply one estimate across all age groups and sex. While this limits factual accuracy, it is recommended for promotion of equity in economic assessments.[39]

Second, to estimate productivity gains resulting from a reduction in high BMI-related mortality and morbidity (combined), we use estimated HALYs gained by the working population in Kenya (age 20–65). We used the disability weight as a proxy for work-ability. Disability weights indicate the average loss of quality of life due to disease.[48] In Equation 2, people obtain additional HALYs due to halting the rise of overweight and obesity with the potential to earn higher income as follows:

$$pM = \sum_{i=1}^{n} \left(Lw'x - Lwx\right) iWA, \quad (2)$$

where pM is productivity changes due to reduced high BMI-related mortality and morbidity (combined), $(Lw'x\text{-}Lwx)i$ is the difference in health-adjusted years lived between employed population post 'intervention,' that is, after halting the rise in overweight and obesity ($Lw'x$) and the employed population pre 'intervention' (Lwx), and WA is the average annual wage rate in the working population in Kenya. Third, we estimate productivity gains resulting from a reduction in high BMI-related morbidity. We use the same equation as above but in place of $Lw'x\text{-}Lwx$ (difference in health-adjusted years lived) by the working population in Kenya, we use

the high BMI-related morbidity calculated as the difference between HALYs gained and added years lived by employed populations, that is, ((*Lw'x-Lwx*)-(*L'x-Lx*)).

In our main analysis, we applied a 3% discount rate for health and economic (productivity and healthcare costs) outcomes as recommended in Drummond *et al*.[39]

Uncertainty analyses

The simultaneous and combined effect of the uncertainty in model inputs on our outcomes was quantified using Ersatz software.[63] We performed a Monte Carlo simulation with bootstrapping (2000 iterations) while incorporating probabilistic uncertainty from model inputs (BMI, relative risks, costs). For all outputs, the 95% uncertainty intervals (UIs) were calculated. These are 2.5 and 97.5 percentiles capturing sampling error with input data.

Sensitivity analyses

In one-way sensitivity analyses, we examined the implications of alternative discount rates (0% and 5%).

We used Microsoft Excel for Microsoft V.365 and two software add-ins: the EpiGearXL V.5.0 add-in for calculation of the potential impact fraction.[63] We used the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist to guide our reporting.[64] Ethics approval was not required for this analysis.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting or dissemination plans of our research. However, this study was carried out as part of a larger stakeholder engaged modelling study that has ethical approval from the Griffith University Human Research Ethics Committee (GU Ref No: 2019/707) and the Kenyatta National Hospital/University of Nairobi Ethics & Research Committee (P81/02/2021).

RESULTS

In this paper, although we modelled the 2019 population in Kenya over their lifetime, as appropriate, we present results for various policy relevant periods, that is, year 2030, over the first 25 years (year 2044), and lifetime estimates.

Health outcomes

To illustrate the modelled scenarios, figure 2 presents a graph for two age groups (20–24 and 45–49 years) showing the business as usual for base case (trend going up for 25 years into the future) and the intervention case (trend stable from the year 2025).

Figure 3 shows the changes in incidence, prevalence and mortality results for the modelled diseases over the first 25 years by disease group. By disease group, up to the year 2044, the leading contributors of the health gains were musculoskeletal diseases (537 052 new cases avoided; 95% UI 444 361–639 460), T2DM (466 030; 95% UI 360 103–597 378) and cardiovascular diseases (301 729; 95% UI 248 559–367 949). In the year 2044, the largest proportional reduction in disease prevalent cases would be seen in type 2 diabetes followed by musculoskeletal diseases and cardiovascular diseases. The cumulative numbers of new cases averted by 2044 (incidence), in 2044 (prevalence) and corresponding proportional changes are presented in online supplemental SF tables 9 and 10). By 2044, deaths averted would be highest for cardiovascular diseases, type 2 diabetes and cancers (figure 3, online supplemental SF table 11).

The change in health outcomes translates to approximately 7756 HALYs (95% UI 6978–8608) saved by the year 2030 and 449 276 HALYs (95% UI 398 202–5 06 152) by the year 2044. Over the lifetime of the 2019 Kenyan population, approximately 6.8 million HALYs (95% UI 5.8–7.9 million) (135 HALYs per 1000 persons) or 4.8 million LYs (95% UI 3.8–6.1 million) could be saved. For these time periods, greater gains would be seen in females than males for both HALYs and LYs (table 3).

Healthcare cost savings

Halting the rise of overweight and obesity could save US$755 million in overweight and obesity-related healthcare costs by 2044 (table 3). By 2044, cardiovascular diseases contributed the most to the healthcare cost savings (figure 4). Over the lifetime of the 2019 population, the reduction in the healthcare costs (savings) is estimated at US$3096 million (US$62 per capita).

Productivity gains

By the year 2044, the total productivity gains resulting from a reduction in high BMI-related morbidity in the 2019 working-age population aged 20–65 years was estimated to be US$4883 million (95% UI 4277–5594) (table 3). Productivity gains resulting from high BMI-related mortality were US$1507 million (95% UI 1209–1865), while gains from high BMI-related mortality and morbidity (combined) were US$5773 million (95% UI 5012–6650), ~US$237 per capita.

Sensitivity analyses

Compared with the base case scenario (3% discount rate), applying a 5% discount reduced the lifetime HALYs gained by ~42% (table 4). When no discounting was applied, the HALYs gained were 4.5 times greater than those reported in base case (3% discounting). This relatively large impact is because the health gains materialise over time in future. Applying a 5% discount reduced the healthcare cost savings by about 59% when compared with the base case scenario of 3% discount rate. When no discounting was applied the savings were 1.5 times greater than when 3% discount was applied. In comparison to HALYs, the impact of discounting on healthcare cost savings was modest. Into the future, the cost savings

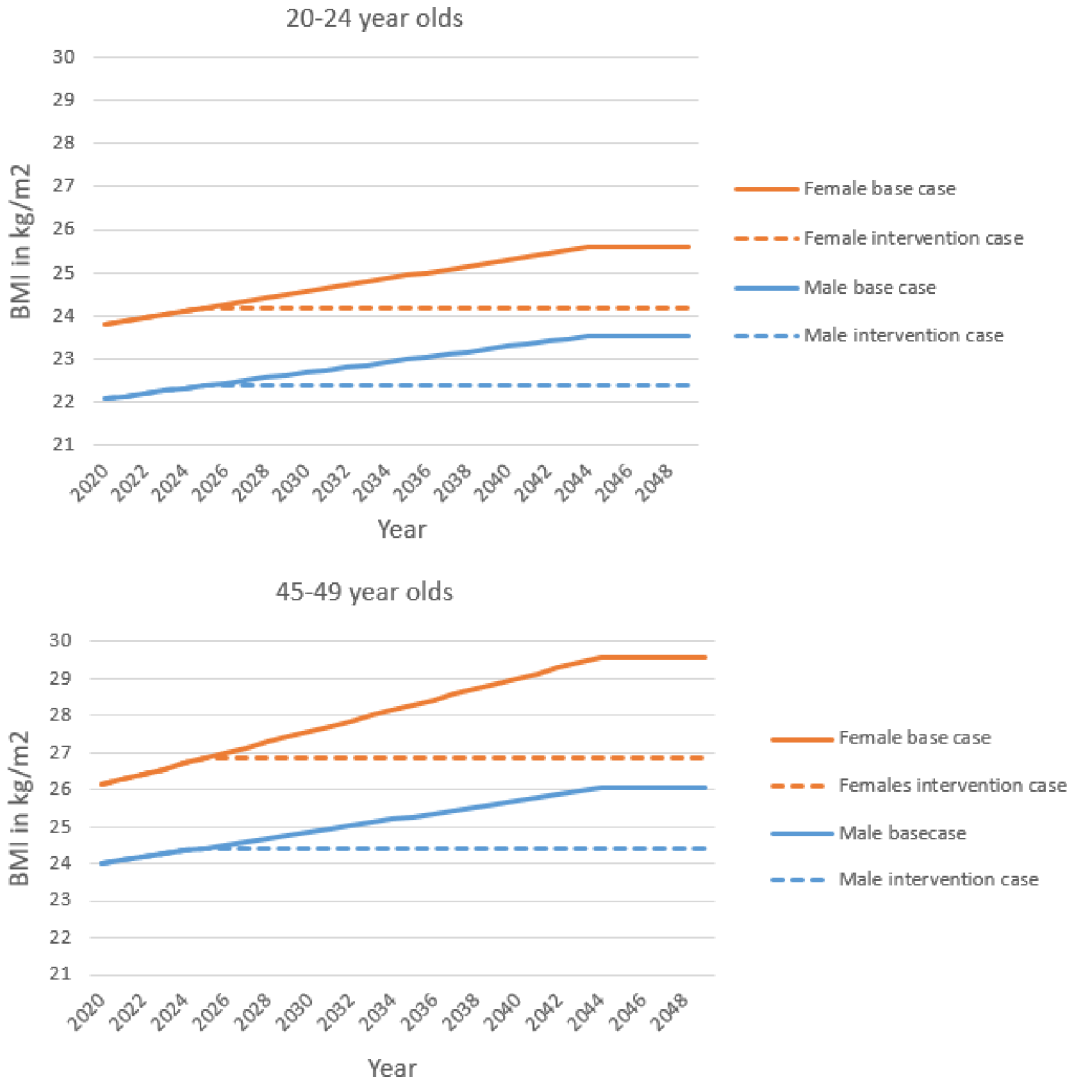

Figure 2 BMI trend for base case versus intervention scenario. Base case (trend going up for 25 years into the future) and the intervention case (trend stable from the year 2025). BMI, body mass index; kg, kilograms; m^2, metres squared.

are outweighed by additional healthcare costs as more people are alive resulting from prevented mortality from high BMI-related diseases. See online supplemental SF figure 5 for healthcare cost savings over different time periods with varying discount rates. Across all productivity gain estimates, no discounting increased the estimates by about 80% while a 5% discount rate resulted to a 30% reduction in all three productivity gain estimates (figure 5).

DISCUSSION

Our results show that halting the rise of overweight and obesity in the year 2025 may save 6.8 million HALYs (95% UI 5.8–7.9 million) over the lifetime of the 2019 Kenyan population (135 HALYs per 1000 persons). By the year 2044, 449 276 HALYs (95% UI 398 202–506 152) may be saved (9 HALYs per 1000 persons) with the leading contributors to the health gains (new cases avoided) being musculoskeletal diseases, followed by T2DM and cardiovascular diseases. The health impact is slow to eventuate. This is because BMI influences incidence, decreasing prevalence in years/decades after, with mortality modelled as a function of prevalence. Therefore, the added years of life can be decades into the future. The potential health gains are consistent with our previous study where we estimated the avoidable disease burden if exposure to high BMI was eliminated in Kenya.[41] However, the results are different in magnitude because in this study we assess a different scenario (ie, achieving target—halting the rise of overweight and obesity in the year 2025). Both studies showed greater health gains would be seen in females than males. This is largely due to the baseline distribution of overweight and obesity where a greater percentage of women have overweight or obesity in Kenya.[7 45]

We found that a total of US$755 million in high BMI-related healthcare costs could be saved by 2044. (For context, this translates to 16% of Kenya's annual healthcare expenditure or 1% of gross domestic product.) By 2044, the gains in productivity from high BMI-related

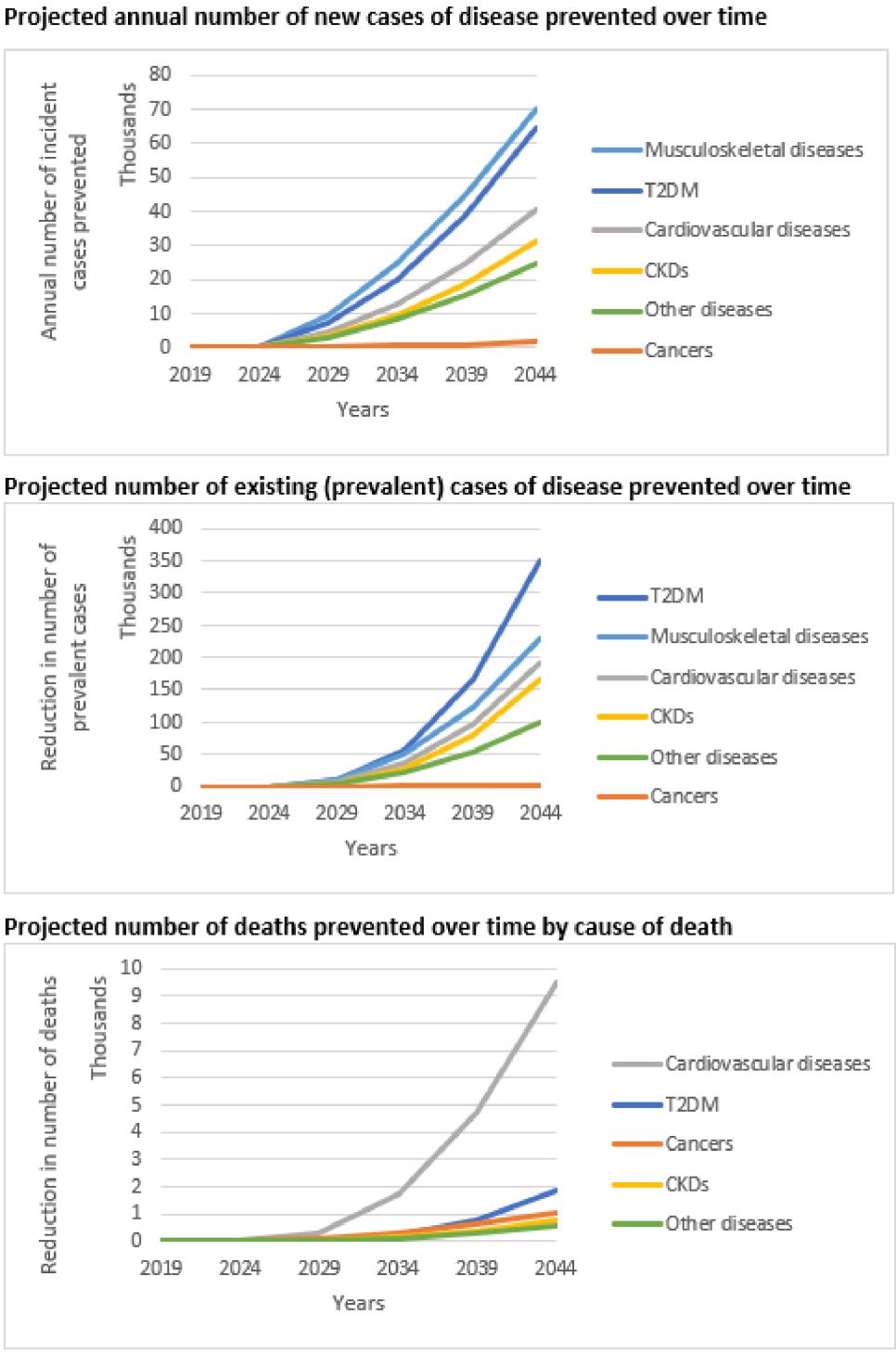

Figure 3 Changes in modelled diseases over the first 25 years. Cardiovascular diseases: atrial fibrillation and flutter, hypertensive heart disease, ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage; musculoskeletal diseases: gout, low back pain, osteoarthritis (hip and knee); cancers: 18 cancers (breast (female), colon and rectum, gallbladder and biliary tract, kidney, leukaemia (five types), liver (three types), multiple myeloma, oesophageal, ovarian, pancreatic, thyroid, uterine); other diseases: Alzheimer's disease and other dementias, asthma, cataract, gallbladder and biliary diseases (SF online supplemental SF tables 9–11). CKDs, chronic kidney diseases; T2DM, type 2 diabetes mellitus;

mortality and morbidity (combined) (~US$5.8 billion) were about eight times higher than the direct healthcare cost savings realised in the same period of time.

Our findings are in line with previous studies that have explored the economic impact of overweight and obesity.[23–29 33 35 37] However, no study is directly comparable. This is particularly because studies use different methodologies to estimate direct and indirect costs.[37] Total population size and population size by age groups vary across countries. Additionally, the prevalence of

Table 3 Effects of the achievement of the national target (halt the rise of overweight and obesity by 2025 in Kenya)

Variable	Female, mean (95% UI)	Male, mean (95% UI)	Total, mean (95% UI)
HALYs gained over the lifetime of the 2019 population	4 769 376	1 995 590	6 764 966
	(3 884 260–5 867 936)	(1 678 158–2 337 407)	(5 819 478–7 911 381)
LYs gained over the lifetime of the 2019 population	3 517 443	1 306 714	4 824 156
	(2 597 441– 4 790 994)	(1 037 816–1 600 505)	(3 824 980– 6 149 268)
HALYs gained over different time periods			
By 2030	5134	2622	7756
	(4425– 5879)	(2269–2996)	(6978–8608)
By 2044	300 991	148 285	449 276
	(254 362–352 204)	(127 121 –170 805)	(398 202–506 152)
Deaths avoided over different time periods*			
By 2030	884	380	1265
	(62–1217)	(303–467)	(983–1607)
By 2044	46 292	19 843	66 135
	(34 099–62 317)	(15 699–24 144)	(52 764–83 073)
Healthcare cost savings over the lifetime of the 2019 population (in million US$)	1672	1424	3096
	(464–2777)	(1057–1834)	(1753–4292)
Healthcare cost savings by the year 2044 (in million US$)	480	275	755
	(384–594)	(226–333)	(636–894)
Cumulative productivity gains by year 2044 (in million US$)			
Productivity gains (morbidity)	3162	1721	4883
	(2651–3782)	(1416–2057)	(4277–5594)
Productivity gains (mortality)	983	524	1507
	(722–1304)	(395–667)	(1209–1865)
Productivity gains (mortality and morbidity)	3742	2031	5773
	(3104–4537)	(1659–2431)	(5012–6650)

We modelled the entire 2019 population in Kenya with risks rising only from age 20 and no burden among children. Productivity gains estimates: gains resulting from a reduction in high BMI-related morbidity, mortality and related mortality and morbidity (combined). A 3% discount rate was applied for health and economic outcomes.
*This is the overall mortality number from life table where we count both the reduction in mortality from BMI-related diseases and the increase in mortality due to other causes.
BMI, body mass index; HALYs, health-adjusted life years; LYs, life years; UI, uncertainty interval; US$, US dollars.

overweight and obesity is country-specific, and studies assess different interventions which have different impacts on overweight and obesity prevalence. Time periods for these assessments vary between studies. Moreover, studies may differ in whether they apply future BMI trends in their assessments or not.

A South African study estimated that the total cost of overweight and obesity for the year 2020 was ZAR33 194 million (~US$1826 million) which represented 15.4% of government health expenditure and was equivalent to 0.67% of the country's gross domestic product.[23] A recent study on Brazil estimated that annually, US$654 million direct healthcare costs related to NCDs were attributable to overweight and obesity.[27] Studies that have assessed the impact on productivity are from high-income countries where authors have assessed the impact of BMI reducing interventions. For example, in a New Zealand study, the total healthcare costs attributable to overweight and obesity amounted to NZ$686 million (~US$425 million), 4.4% of New Zealand's total healthcare expenditure in 2006 and substantial costs of lost productivity were reported.[34] The obesity and overweight-related costs were largest for type 2 diabetes (38%), followed by hypertension (27%).[34] In an Australian study, 20% tax on sugar-sweetened beverages was found to reduce the number of people with obesity which translated into substantial reductions in healthcare costs and productivity gains in both the paid and unpaid sectors of the economy.[32] In these two studies,[32 34] the productivity changes are estimated using both the Human Capital Approach and Friction Cost Approach.[39] In our study, we used the Human Capital Approach as it better reflects our societal

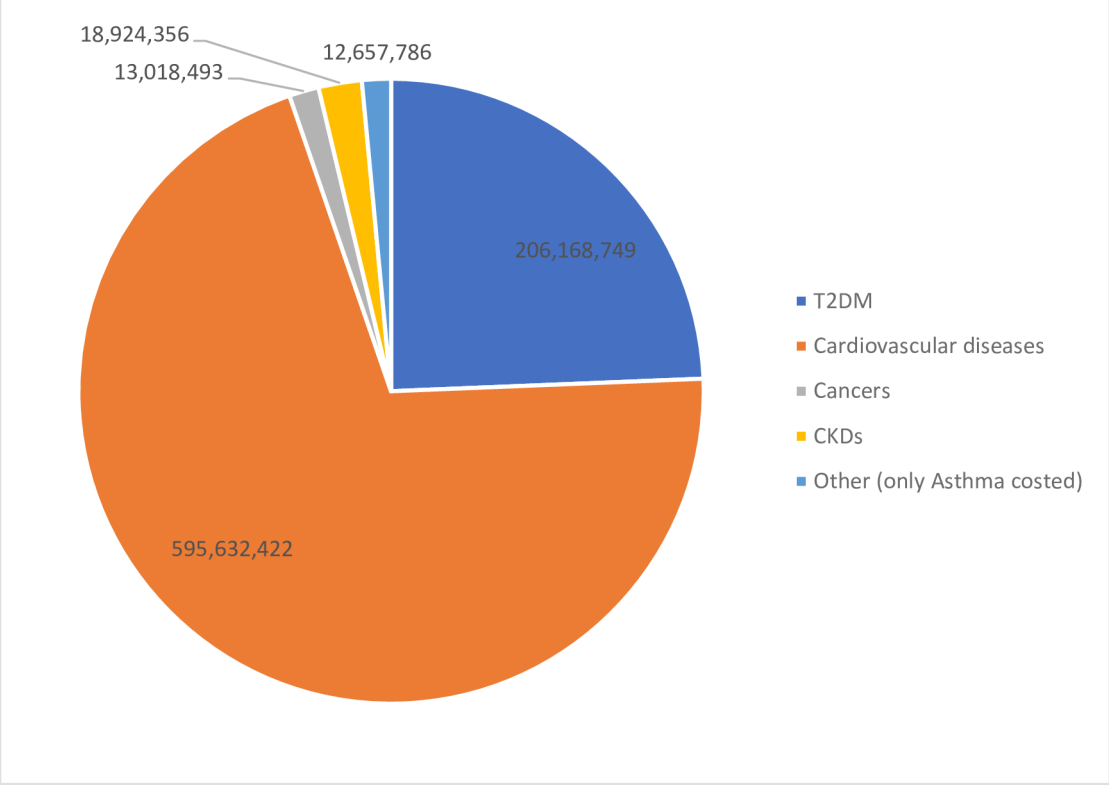

Figure 4 Healthcare cost savings by disease groups. We did not identify any literature with costs for low back pain, osteoarthritis hip, osteoarthritis knee, gout, Alzheimer's disease and other dementias, cataract, gallbladder and biliary diseases and atrial fibrillation and flutter (AFF). We considered that costs for AFF may already be included under the other cardiac related conditions costed. Cardiovascular diseases: atrial fibrillation and flutter, hypertensive heart disease, ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage; cancers: 18 cancers (breast (female), colon and rectum, gallbladder and biliary tract, kidney, leukaemia (five types), liver (three types), multiple myeloma, oesophageal, ovarian, pancreatic, thyroid, uterine). CKDs, chronic kidney diseases; T2DM, type 2 diabetes mellitus;.

Table 4 Effects of the achievement of the national target with different discount rates applied

Modelled scenarios	0% discount rate	3% discount rate (base case)	5% discount rate
	Total, mean	Total, mean	Total, mean
Variable	(95% UI)	(95% UI)	(95% UI)
HALYs gained over the lifetime of the 2019 population	30 513 170 (25 976 578–36 240 896)	6 764 966 (5 819 478–7 911 381)	2 853 103 (2 452 791–3 311 707)
HALYs gained by 2030	10 259 (9204–11 348)	7756 (6978–8608)	6477 (5817–7185)
HALYs gained by 2044	812 755 (718 261–915 870)	449 276 (398 202–506 152)	308 062 (272 307– 347 585)
Healthcare cost savings over the lifetime of the 2019 population (in million US$)	4857 (–2027 to 10 321)	3096 (1753–4292)	1830 (1283–2361)
Healthcare cost savings by the year 2044 (in million US$)	1340 (1133–1581)	755 (636–894)	522 (442–612)

Total represents values for both male and female. National target scenario modelled was halting the rise of overweight and obesity by 2025 in Kenya. We modelled the entire 2019 population in Kenya with risks rising only from age 20 and no burden among children. Diseases not costed: low back pain, osteoarthritis hip, osteoarthritis knee, gout, Alzheimer's disease and other dementias, cataract, gallbladder and biliary diseases and AFF.
AFF, atrial fibrillation and flutter; BMI, body mass index; HALYs, health-adjusted life years; LYs, life years; UI, uncertainty interval; US$, US dollars.

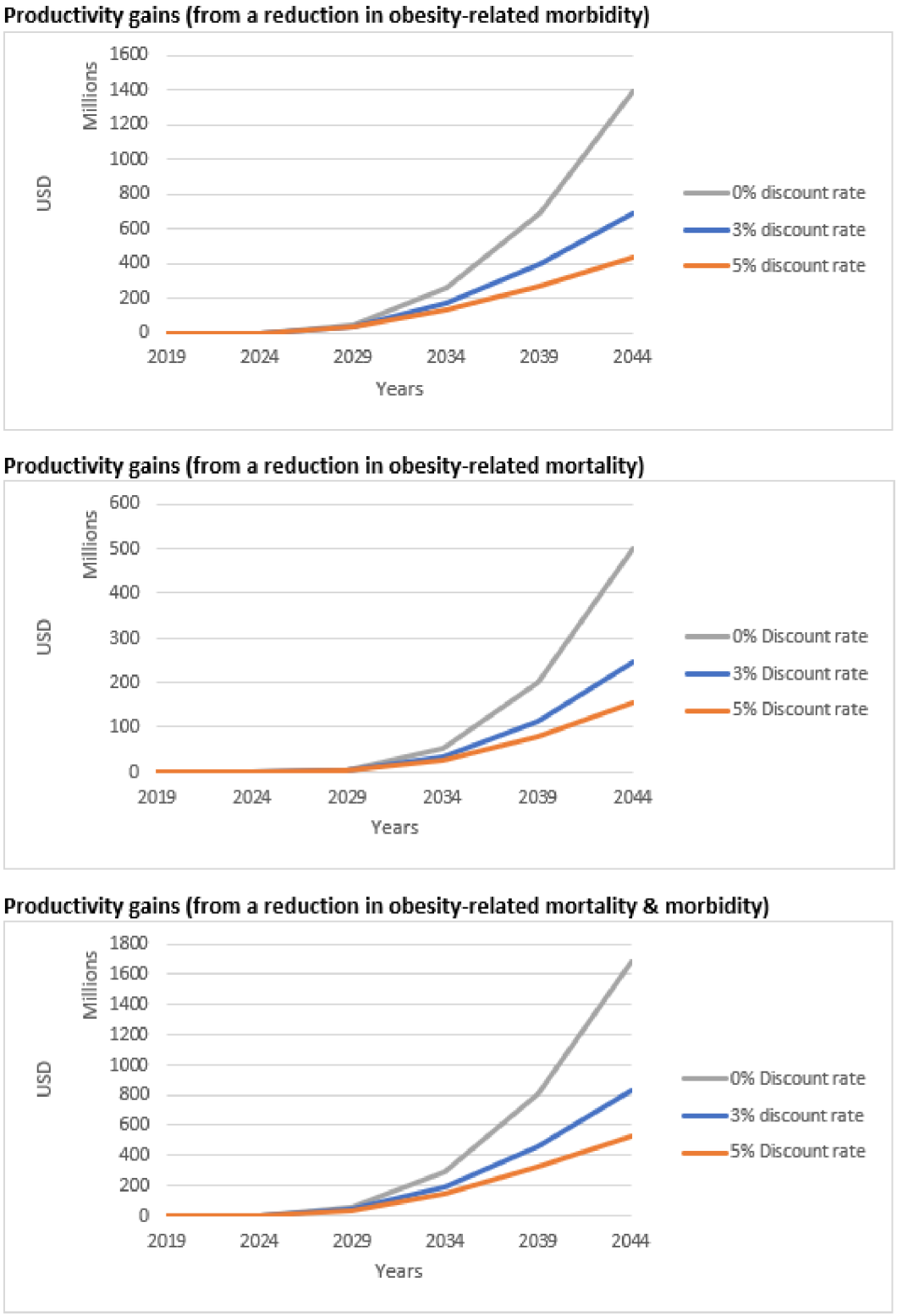

Figure 5 Productivity gains over different time periods with different discount rates applied. USD, US dollars. *3% discount rate reflects the main analysis (base case) scenario reported in main manuscript. Due to the difference in magnitude of the estimates, the scale on the Y axis differ across the three panels.

perspective where we estimate changes in productivity using the gross earnings of those in employment.[39] In another Australian study, the authors found that the productivity gains associated with a 10% tax on unhealthy foods (an obesity prevention policy) over the period from 2003 to 2030 accounted for almost twice the value of the estimated savings to the healthcare system.[36] Our findings also showed that productivity gains were greater than healthcare cost savings with potential productivity gains resulting from a reduction in high BMI-related mortality

and morbidity (combined) being 7.6 times higher than the direct healthcare costs savings by the year 2044. In sum, our findings corroborate previous work and show that reduction of overweight and obesity would yield substantial healthcare cost savings and productivity gains in not only high-income countries but also in LMICs.

Strengths and limitations of our study

We used an established proportional multistate life table model (*Kenya Obesity Model*)[41–43] to assess the potential impact of achieving global and national target of halting the rise (0% increase) of overweight and obesity by 2025. A detailed report on the strengths and limitations of the *Kenya Obesity Model* is provided in our previous work.[41] We include a summary of this in online supplemental SF section 4.

There were specific strengths and limitations related to the healthcare costs and productivity modelling. A major strength is that we capture costs from a societal perspective by including productivity in our impact assessment. When compared against the health sector perspective, a societal perspective provides a more comprehensive estimate of cost savings related to reduction of overweight and obesity. Further, we estimate productivity gains resulting from a reduction in high BMI-related mortality, related mortality and morbidity (combined), and related morbidity.

Cost estimates were drawn from Kenyan studies[50 53] for all costed diseases apart from four cardiovascular diseases where estimates were drawn from Cameroon and South Africa.[51 52] This ensured that cost data were specific to Kenya and similar settings. A limitation is that all disease costs were hospital based (with some being tertiary hospitals) which reflect cost of treatment for advanced disease cases on referral, hence costs may be high. The case definitions used by GBD are broader where prevalent numbers, for instance, may include people not aware they have the condition. One study included some estimates based on recommended care in treatment guidelines.[50] Recommended care may differ from actual care given to patients. We took several measures to reflect plausible cost estimates. This included using published costs estimates from public facilities as opposed to private facilities and adjusting the disease costs to account for the percentage of people unwell who did not seek care hence did not incur healthcare costs. Also, we costed only CKD cases on dialysis and transplant in our model. No costs were attributed to the vast majority of cases in earlier disease stages (1, 2 and 3), which confer little to no functional health loss[65] and hence may not have formed part of the hospital-based CKD costs reported in the Kenya studies. We did not identify any literature with costs for low back pain, osteoarthritis hip, osteoarthritis knee, gout, Alzheimer's disease and other dementias, cataract, gallbladder and biliary diseases and atrial fibrillation and flutter (AFF). The exclusion of the costs of these diseases leads to underestimation of the cost savings reported in this study particularly for the musculoskeletal diseases that were the leading contributors of the potential health gains for new cases avoided. Our work highlights the need for costing studies in Kenya and similar settings.

Comorbidity increases disease-specific costs.[51 66] This means that though the envelope total healthcare costs for Kenya was captured in the model, the disease-specific costs for both modelled and non-modelled diseases may be higher. However, this is unlikely since our cost data was sourced from primary costing studies that determined the average annual disease costs established from study samples, likely capturing those with comorbidity and those without. Studies on disease costs with comorbidity present and data on number of people with comorbidity in the population would offer additional insights in the cost of NCDs. On balance, our study is likely to have underestimated healthcare cost savings resulting from the prevention of high BMI.

Regarding the employed population, the Kenya economic survey computes the average annual wage rate considering *people employed* as comprising of wage employees, self-employed and unpaid family workers and informal sector.[62] This covers a broad scope of those from 16 years of age who can legally engage in paid work to those beyond 65 years of age in some sectors. In our case, for the productivity-related outputs we modelled the 2019 working population in Kenya aged 20–65 years. This may mean that some additional gains in productivity could be realised from prevented obesity-related diseases for those older than 65 who are still productive. Although our model did not incorporate projected trends in the percentage of people employed in Kenya, we assessed the available data and established a similar percentage of people employed (58%) in 2013 report and computation from the 2021 economic survey report.[54 62] We also did not model projected trends for income levels due to changes in trends seen in available data that showed increases in annual wage rate between 2016 and 2019 (~5% annual increase) and a 4% reduction in the year 2020.[62] If the increasing trend in annual wage rate before COVID resumes, our current findings are an underestimation of the potential productivity gains that could result from halting the rise of overweight and obesity in Kenya.

Meaning of the study/implication for policy makers

To our knowledge, this is the first study to assess the potential productivity gains and healthcare cost savings associated with prevention and control of overweight and obesity in adults in Kenya. Data from future national surveys in Kenya will inform the progress made so far towards achieving the national target of halting the rise (0% increase at all ages) of overweight and obesity by 2025. Quantifying these benefits at this stage may give impetus for government and development partners to prioritise the prevention of overweight and obesity. Our findings are important to development partners, governments and stakeholders across multiple sectors as we show

that prevention of overweight and obesity is a means of increasing economic productivity. In Kenya, the healthcare cost savings realised from the reduction of overweight and obesity would also directly benefit households. This is because household out-of-pocket payments currently contribute to approximately 28% of current health expenditure funds in the country.[56] The findings also may provide evidence that could help generate increased demand by civil societies and the general public for government policies and interventions that reduce the prevalence of obesity. In Kenya, most of the government NCD policy actions are still at the development stage.[67] These include policy options that address the obesogenic environment, that is, the surroundings, opportunities or conditions of life whose influences promote obesity in individuals or populations.[68] For example, creation of avenues for increased physical activity such as urban planning that allows for active transport, fiscal and regulatory interventions that ensure provision of healthy and nutritious foods to all in the population, creation of healthy settings, health and nutritional education specifically targeted to the factors that influence BMI in the country. Stakeholders engaged in our larger obesity study identified and ranked a total of 24 broad strategies for the prevention of overweight and obesity in Kenya that may inform future policies in Kenya and similar settings.[69]

Future research

Subject to data availability, future modelling studies could estimate the potential impact of attainment of the national obesity reduction target on healthcare costs and productivity for each of the 47 counties in Kenya and by socioeconomic factors such as education level, wealth quintiles, urban versus rural residence. Assessment of cost-effectiveness of interventions that reduce the prevalence of overweight and obesity is also key. For instance, in our recent work, we assessed the potential impact of four selected food policy interventions for the prevention and control of overweight and obesity in Kenya.[70] Two specific policy interventions (a 20% tax on sugar sweetened beverages and mandatory kilojoule menu labelling) were assessed for cost-effectiveness and found dominant (health promoting and cost saving) offering potential policy options towards reduction of overweight and obesity. Such research supports evidence-based selection and priority setting for preventive strategies and intersectoral actions in efforts to achieve the set obesity reduction target.

CONCLUSION

Achieving the set overweight and obesity reduction target could improve health outcomes and also yield healthcare cost savings and productivity gains. Our estimates add to available evidence that may motivate for the prioritisation of the prevention of overweight and obesity in Kenya and similar settings that are battling with the rapid rise in mean BMI and related NCDs, alongside persisting communicable disease burden.

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Contributors MNW conceived the study, developed the study protocol under the supervision of JLV and LNA. MNW did the modelling analysis and wrote the first version of the manuscript. LNA and JLV contributed to analysis, interpretation of findings and reviewed successive versions of the manuscript. All authors critically reviewed the manuscript and approved the final version for publication. MNW is the guarantor of this study.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

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