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Population-level impact of weight loss on predicted healthcare spending and the incidence of obesity-related outcomes in the Asia-Pacific region: a modelling study

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Abstract

Background The Asia-Pacific (APAC) region includes a significant proportion of the global population currently living with overweight and obesity. This modelling analysis was conducted to quantify the incidence of obesity-related comorbidities and change in obesity-related costs over 10 years with a hypothetical 10% weight loss in Australia, South Korea, Thailand, and India.

Methods An epidemiological-economic model was used to describe current prevalence and direct medical costs of ten obesity-related comorbidities, including type 2 diabetes and hypertension, in adults aged 20–69 years living with obesity, and estimate incidence and costs over 10 years. Incidence reduction and the associated savings by 2032 were then estimated for a 10% weight-loss scenario.

Results The total estimated medical costs for the ten obesity-related comorbidities in 2022 were 2.9, 7.5, 10.2, and 23.3 billion USD in Australia, South Korea, Thailand, and India, respectively. Costs increase to 6.9, 18.4, 23.5, and 44.3 billion USD in 2032, if insufficient action is taken. A 10% weight reduction would result in estimated savings of 0.3, 1.2, 2.2, and 3.0 billion USD in Australia, South Korea, Thailand, and India, respectively, in 2032, with cumulative savings over the 10-year period of 1.8, 7.0, 13.0, and 17.4 billion USD. Incidence of comorbidities were estimated to rise less in the weight-loss scenario.

Conclusions The financial, societal, and health benefits of a substantial but achievable 10% weight loss in adults living with obesity, and the consequences of insufficient action, are pronounced in the APAC region. To achieve sustained weight loss in the real world, policy actions for addressing barriers to obesity management are required.

Keywords Asia-Pacific, Healthcare cost, Obesity, Obesity comorbidity, Policy, Weight loss

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Background

The rising global rate of obesity represents a substantial and growing health, economic, and societal burden [1, 2]. According to the World Health Organization (WHO), worldwide obesity nearly tripled between 1975 and 2016 [1], and in 2022, the World Obesity Federation reported that 764 million adults were living with obesity [2]. The burden of related comorbidities, such as type 2 diabetes, coronary heart disease, sleep apnoea, hypertension and stroke, osteoarthritis, and dyslipidaemia, has also increased with obesity prevalence [3].

Global prevalence of obesity is expected to increase to over one billion individuals by 2030, far exceeding the WHO target of no increase between 2010 and 2025 [2]. As a result, other critical targets are similarly at risk, including the Sustainable Development Goals targets on non-communicable diseases, universal health coverage, and malnutrition, and the Triple Billion targets [2, 4].

The Asia-Pacific (APAC) region now includes the largest number of individuals living with overweight or obesity worldwide (body mass index [BMI] ≥25 and ≥30 kg/m^2, respectively) at approximately one billion individuals, which equates to two out of every five adults in the region [5]. Public health experts attribute this regional phenomenon to the increase in the availability of lower-cost high-calorie food, and more sedentary lifestyles due to rapid urbanization and a shift away from manufacturing-led employment [5]. This growing concern is compounded by the observed increased prevalence of obesity-related comorbidities at a much lower BMI in some Asian countries than is seen in Western countries [6]. The WHO BMI threshold of ≥30 kg/m^2 may therefore be substantially underestimating the true health burden of obesity, and further magnifies the need for clear estimates of its impact in a region of the world where obesity incidence is developing fastest.

The financial consequences of the worldwide increase in rates of obesity, and associated comorbidities, are increasing. By 2060, the total cost of obesity to the global economy is expected to be in excess of 18 trillion United States dollars (USD) [7]. In addition to the fiscal burden of obesity and obesity-related expenditures, excessive medical expenses carry a large opportunity cost, by reducing the availability of healthcare resources and limiting the ability of health systems and governments to respond to other urgent health crises.

For the APAC region, failure to respond to the economic burden of overweight and obesity and failure to adhere to targets will have extensive implications for healthcare systems, and considerable impacts on economic growth and productivity [4]. Obesity contributes to approximately 12% of the total current regional healthcare expenditure, with an associated cost to the economies of 166 billion USD a year [5].

Clinical studies have shown that in individuals living with obesity, achieving a 5–15% weight loss can help to prevent the development of future comorbidities, with some conditions needing a 10% reduction or more for substantial risk reduction [8, 9]. Practical guidelines and policy recommendations for obesity, along equitable access to obesity management (which can include lifestyle interventions based around diet and exercise, support programmes, and more specific treatment interventions), can therefore make a target weight loss of 10% more achievable for more individuals living with obesity. As such, understanding the potential societal benefit of a 10% weight loss at the population-level is now a relevant and timely exercise for the APAC region.

Our hypothetical analysis focuses on four countries from the APAC region: Australia, South Korea, Thailand, and India. These countries represent a diverse mix of health systems, biological variance, and epidemiology, social, cultural, and environmental determinants of health. The objectives of this analysis were to quantify the incidence of obesity-related comorbidities, and the change in obesity-related costs over 10 years with a 10% weight loss in 257 million individuals living with obesity across these four countries, in a systematic and consistent manner.

Methods

This analysis was conducted in three stages, for which the detailed methodology can be found in Additional file 1. In brief, we:

Estimate the direct costs (cost of medical treatment) associated with obesity-related comorbidities in 2022

A simulation analysis was conducted to illustrate the impact of population-level weight loss across Australia, South Korea, Thailand, and India, using a common modelling framework. The schematic of this model is outlined in Fig. 1. Costs were predicted using current direct healthcare costs and therefore from the perspective of healthcare systems, with no discount or inflation rate applied. No specific priority populations were assessed, and costs were based on national averages (no regional differences assessed). An illustrative benchmark scenario of 10% weight loss was selected as a target in the modelling analysis, as it was determined to be a clinically feasible level of weight loss [10–12].

The epidemiological-economic model was constructed by adapting the predictive risk model from Khunti and colleagues to simulate the impact of weight reduction by 10% for adults 20–69 years old, with a BMI of 25–50 kg/m^2 (30–50 kg/m^2 for Australia), on the incidence and

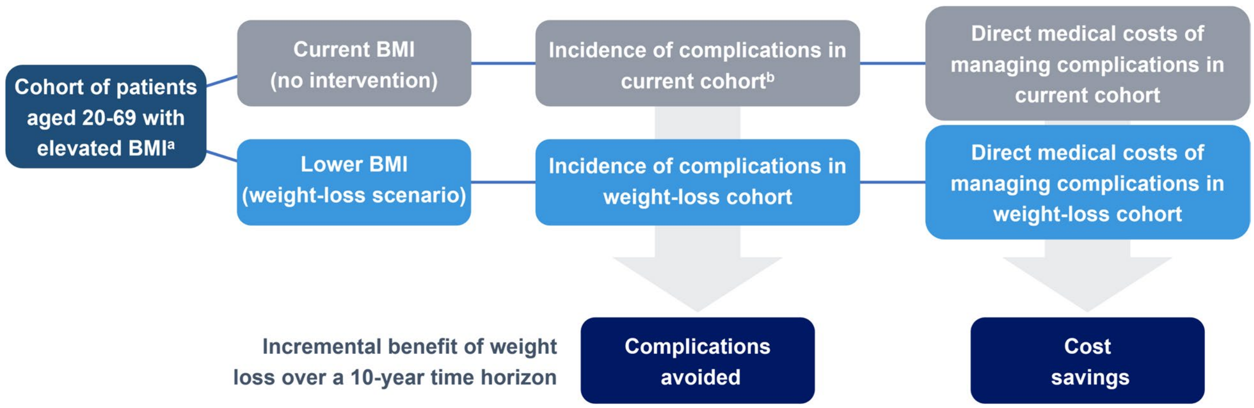

Fig. 1 Modelling approach. [a]Elevated BMI was ethnicity-adjusted to encompass a range of 30–50 kg/m^2 for Australia and 25–50 kg/m^2 for South Korea, Thailand, and India. [b]Due to limited data, only six of the ten complications were considered for India. BMI, body mass index

direct medical costs of ten obesity-related comorbidities: type 2 diabetes, hypertension, dyslipidaemia, heart failure, atrial fibrillation, unstable angina/myocardial infarction, hip/knee osteoarthritis, asthma, sleep apnoea, and chronic kidney disease [13, 14]. A summary of the adapted risk engine can be seen in Fig. S1. Country-specific prevalence estimates for these diseases and the average direct medical costs of treatment were obtained through a rapid scoping literature review, country databases, and expert opinion (parameters for the comorbidities are shown in Table S1). The rapid scoping review was carried out utilizing Google Scholar and PubMed and targeting peer-reviewed and grey literature from reputable sources, prioritizing open-access research literature from known academic and institutional publishers (see Table S2 for the inclusion/exclusion criteria for this review, and Table S3 for the studies reviewed). Owing to data inconsistencies and limitations, sleep apnoea, dyslipidaemia, atrial fibrillation and flutter, and unstable angina were omitted from the analysis for India.

Localise data/adjust base reading to reflect population of specific country accurately

Population-representative cohorts were then constructed to match the observed demographic distribution and prevalence of obesity and the relevant obesity-related comorbidities in each target country. The prevalence of comorbidity and the estimates of incident diagnoses used in the local models for this analysis were based on and scaled from a contemporary cohort from the United Kingdom (UK), derived from electronic primary care medical records (CPRD GOLD) [15], as reported in a study by Haase and colleagues [14]. To construct a population reflecting the age, sex or gender, and BMI distribution in the APAC country (Australia, South Korea, Thailand, or India), population demographics and obesity prevalence from existing literature were taken into account (captured from the rapid scoping review). For each age/sex or gender/BMI bin, values from the UK cohort were adjusted to match the corresponding numbers in the target population in the APAC country. This was achieved by scaling the prevalence of obesity-related comorbidities in the target population based on the prevalence of comorbidities in the contemporary UK cohort and scaling the 10-year incidence of these comorbidities accordingly including an adjustment for mortality.

Figure 2 demonstrates an example of the scaling from the UK cohort to an APAC country. Using that example, in the case of men aged 50–59 years with a BMI of 42 kg/m^2, there were 2530 individuals in the UK cohort and an assumed 4280 individuals in the target population, resulting in a scaling factor of 1.7. This scaling factor was then used to adjust the number of individuals with comorbidities in 2022. To calculate the number of cases in the UK cohort for the year 2032, the number of incident cases projected over a 10-year period by the UK risk engine for each obesity-related comorbidity was added to the number of cases in 2022. Estimates for 2032 were then adjusted post hoc for mortality (see Additional File 1 for details on calculated mortality adjustment), and the adjusted number of cases in the UK cohort for each specific age/gender/BMI bin was then scaled by the factor of 1.7 to obtain the projected number of cases for 2032 in the corresponding age/gender/BMI bin in the population of the APAC country.

This method was chosen as a pragmatic option for producing local estimates consistent with population-level statistics in the absence of robust representative individual-level data that would be needed to populate models for each country. Risk modelling for the APAC countries was developed as an extension of the

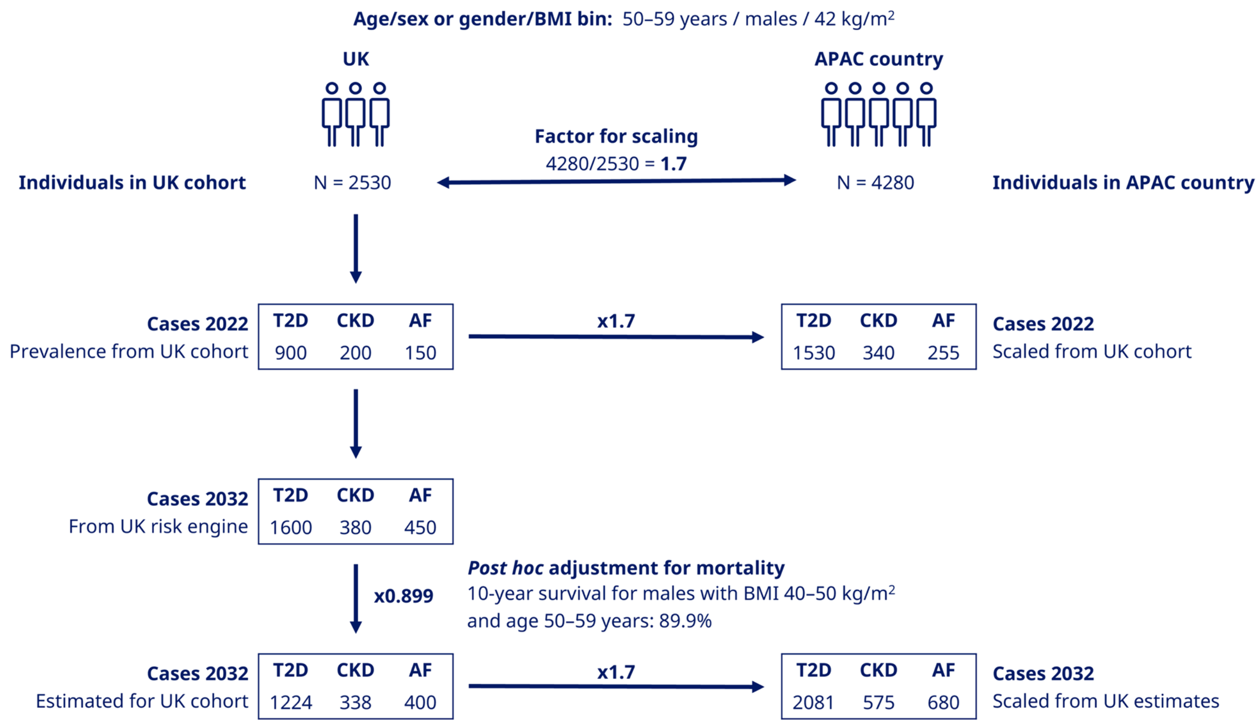

Fig. 2 Scaling from the UK cohort. AF, atrial fibrillation; APAC, Asia-Pacific; BMI, body mass index; CKD, chronic kidney disease; HF, heart failure; T2D, type 2 diabetes; UK, United Kingdom

weight-loss model described in the original publication from Khunti and colleagues [13, 14].

The risk engine was adapted to reflect the increased risk at lower BMI in Asian ethnicities, as the original risk engine did not consider ethnicity. The cohort that was used to derive the original risk engine with BMI ≥30 kg/m^2 (N = 418,774) was extended to individuals with BMI ≥25 kg/m^2 and ethnicity captured in the CPRD GOLD [15] database or HES (Hospital Episode Statistics) as either "White," "South Asian," or "East Asian" (N = 440,781). For the analysis, the individuals were assigned to two ethnicity categories: "White" or "Asian" (combination of "South Asian" and "East Asian"). A covariate for the ethnicity category and an interaction term between the ethnicity and BMI were added to the original model definition, and models for the ten obesity-related comorbidities were retrained with the extended cohort. Figure S2 demonstrates impact of Asian ethnicity on outcome risk in the refined model, ranging from more than a factor of three for the type 2 diabetes risk, a 50% risk increase for dyslipidaemia, and a lower risk in Asian people for developing atrial fibrillation.

Asian ethnicity was therefore included as a risk factor in the model for the South Korean, Thailand, and Indian populations, whereas the original parameters used by Khunti and colleagues [13] were used for the Australia model. The risk model was further Localised to each country using best-available existing disease prevalence and costing data as well as adjustment for the relevant country-level obesity thresholds. Owing to further emerging scientific evidence around a higher risk for type 2 diabetes and cardiovascular disease at lower BMIs in Asian people, along with published guidelines, lower BMI cut-off values were used in this analysis to define overweight and obesity in Asian populations [5, 16–20]. Therefore, based on the WHO classification of a BMI of ≥30 kg/m^2, the country model for Australia used a threshold of 30–50 kg/m^2 for obesity, while the South Korea, Thailand, and India models used 25–50 kg/m^2 [5, 16–21].

The extended risk engine also incorporated BMI, weight change, age, gender, ethnicity, smoking status, and medical history (including baseline diagnoses of type 2 diabetes, hypertension, dyslipidaemia, and cardiovascular events) to estimate the risk of developing the ten obesity-related comorbidities. These risk estimates were then aggregated to provide insights at the population level, enabling the estimation of incident cases for a specific country. The risk engine then provided the number of expected incident cases for each comorbidity over the next 10 years. These estimates were then multiplied by the yearly treatment costs to determine the projected additional treatment costs a decade from now.

For additional details on additional considerations for the modelling, including heterogeneity and addressing uncertainty, see Additional file 1.

Estimate total economic impact

Nominal cost savings from population-level weight loss were projected over 10 years. The 2032 costs were estimated for the 2022 population living with obesity, adjusted for mortality, based on the rate of additional comorbidities diagnosed in the aging population and the corresponding treatment costs in two hypothetical scenarios:

1. That all individuals keep their current weight
2. That a population-level weight loss of 10% was achieved across the cohort

The difference in the present valued cost estimates from these two scenarios provides an estimate of the cost savings from weight loss. Cost savings in 2032 were predicted for the full populations for each country, and for population-representative cohorts of 100,000 individuals in each country; cumulative costs over the 10-year period were also estimated.

A sensitivity analysis was conducted to characterize uncertainty in the model by varying treatment costs from 50 to 150% of the actual costs for each outcome for the population-representative cohorts of 100,000 individuals. Additionally, the changes in the 10-year risk for the obesity-related comorbidities based on stable weight, 5%, 10%, and 15% weight loss were also assessed to further characterize the model. Further details and results for these analyses can be found in Additional file 1 (in the simulation model methodology, and Figures S3 and S4). A CHEERS checklist for this study can be found in Additional file 2 [22].

Results

Baseline demographics

Baseline demographics for individuals included in the simulation analysis can be found in Table 1. There were some notable differences across the four countries; for example, more individuals in Australia were in higher BMI groups than the other three countries. However, prevalence of comorbidities was similar with the following exceptions: hypertension was more common in Australia (30.9% compared with 20.0–24.0%); type 2 diabetes was more common in India (15.9%) and South Korea (15.3%) than in Australia (10.7%) and Thailand (7.3%).

2022 costs and 2032 costs in the non-intervention scenario

Table 2 reports the aggregated direct medical costs for treating all ten obesity-related comorbidities in the model for 2022 and 2032, by country. Based on the simulation model, the total direct costs in 2022 were 2.9 billion USD in Australia, 7.5 billion USD in South Korea, 10.2 billion USD in Thailand, and 23.3 billon USD in India. In a scenario where no intervention is undertaken to avoid the projected increases in obesity-related comorbidities, these direct costs are estimated to increase to 6.9 billion USD in Australia, 18.4 billion USD in South Korea, 23.5 billion USD in Thailand, and 44.3 billion USD in India in 2032. Costs for each disease by country are reported in Tables S4–7.

Costs per individual are projected to increase from 2022 to 2032 from 558 to 1410 USD in Australia, from 545 to 1397 USD in South Korea, from 685 to 1649 USD in Thailand, and from 104 to 207 USD in India (with India only having costs estimated for six out of the ten comorbidities) (Table 2).

The number of individuals with type 2 diabetes, one of the most prominent comorbidities for obesity (in Asian populations in particular) [16, 17], is estimated to approximately double between 2022 and 2032 (Tables S4–7). Between 2022 and 2032, the model predicts an increase in type 2 diabetes cases from 0.6 to 1.1 million in Australia, 2.1 to 4.3 million in South Korea, 1.1 to 3.8 million in Thailand, and 35.4 to 69.3 million cases in India. Costs for type 2 diabetes are estimated to rise accordingly from 2022 to 2032, with estimated increases of 0.6 to 1.2 billion USD in Australia, 1.5 to 3.1 billion USD in South Korea, 1.7 to 5.9 billion USD in Thailand, and 3.8 billion to 7.4 billion USD in India (Tables S4–7). As at the population level, costs are predicted to rise for obesity-related comorbidities in the population-representative cohorts of 100,000 individuals in each country.

Cost savings in 2032 and cumulative cost savings in the 10% weight-loss scenario

Our model estimated that in 2032, a 10% weight loss could result in savings of 0.3 billion USD in Australia, 1.2 billion USD in South Korea, 2.2 billion USD in Thailand, and 3.0 billion USD in India, compared with the costs estimated in a no-intervention scenario (Fig. 3; Tables S4–7). In this 10% weight-loss scenario, cumulative savings from 2022 to 2032 were estimated to be 1.8 billion USD in Australia, 7.0 billion USD in South Korea, 13.0 billion USD in Thailand, and 17.4 billion USD in India (Tables S4–7). As in the no-intervention scenario, costs savings were similar in the 10% weight-loss scenario for the population-representative cohorts of 100,000

Table 1 Baseline demographics of patients living with obesity for the simulation model

	Total				Men				Women			
	Australia	**South Korea**	**Thailand**	**India**	**Australia**	**South Korea**	**Thailand**	**India**	**Australia**	**South Korea**	**Thailand**	**India**
Total population, N[a]	25,697,298	51,625,561	67,228,562	1,393,409,033	12,737,005	25,738,197	32,832,687	723,973,437	12,960,293	25,887,364	34,395,875	669,435,596
Population living with obesity, *N* (% of total)	5,178,153 (20.2%)	13,835,510 (26.8%)	14,866,687 (22.1%)	223,247,243 (16.0%)	2,691,590 (21.1%)	8,920,875 (34.7%)	5,819,474 (17.7%)	103,922,525 (14.4%)	2,486,563 (19.2%)	4,914,635 (19.0%)	9,047,213 (26.3%)	119,324,718 (17.9%)
Sex distribution[b]												
Male	52.0%	64.5%	39.1%	46.6%	-	-	-	-	-	-	-	-
Female	48.0%	35.5%	60.9%	53.4%	-	-	-	-	-	-	-	-
Age distribution, years[b]												
Age 20–29	14.3%	16.2%	13.9%	17.1%	14.9%	18.9%	16.3%	19.3%	13.7%	11.3%	12.4%	15.2%
Age 30–39	19.8%	16.3%	20.8%	27.4%	19.5%	18.8%	21.5%	28.4%	20.0%	11.6%	20.3%	26.5%
Age 40–49	21.7%	22.9%	26.7%	25.3%	21.9%	22.0%	26.0%	24.2%	21.5%	24.6%	27.2%	26.2%
Age 50–59	23.3%	24.2%	24.3%	18.8%	23.3%	23.2%	22.7%	17.8%	23.3%	26.1%	25.3%	19.7%
Age 60–69	20.8%	20.4%	14.3%	11.4%	20.3%	17.2%	13.5%	10.2%	21.4%	26.3%	14.9%	12.4%
BMI categories, kg/m^2[c]												
BMI 25–29.9	0.0%	83.3%	70.7%	72.2%	0.0%	84.2%	74.2%	76.7%	0.0%	81.6%	68.4%	68.3%
BMI 30–34.9	62.0%	14.3%	18.3%	17.5%	65.8%	13.7%	17.9%	16.5%	57.9%	15.2%	18.6%	18.3%
BMI 35–39.9	24.8%	1.5%	6.7%	6.2%	23.8%	1.3%	5.1%	4.4%	25.8%	1.9%	7.7%	7.8%
BMI 40–50	13.2%	1.0%	4.3%	4.2%	10.4%	0.8%	2.8%	2.5%	16.3%	1.3%	5.3%	5.6%
Comorbidity prevalence[d]												
Type 2 diabetes	10.7%	15.3%	7.3%	15.9%	11.5%	16.1%	9.4%	15.3%	9.8%	13.9%	5.9%	16.3%
Asthma	20.7%	18.8%	19.0%	19.8%	20.2%	19.5%	19.9%	20.7%	21.3%	17.4%	18.4%	19.0%
Sleep apnoea	2.9%	1.1%	1.1%	1.2%	4.3%	1.4%	1.8%	1.7%	1.3%	0.5%	0.6%	0.7%
Hip/knee osteoarthritis	4.0%	2.4%	2.2%	2.0%	3.5%	1.9%	1.9%	1.6%	4.5%	3.2%	2.5%	2.3%
Hypertension	30.9%	24.0%	20.0%	20.5%	34.5%	24.3%	22.9%	21.8%	27.0%	23.4%	18.1%	19.3%
Dyslipidaemia	24.1%	23.7%	16.6%	19.3%	28.3%	24.8%	21.1%	21.5%	19.7%	21.6%	13.7%	17.4%
Heart failure	0.9%	0.6%	0.5%	0.5%	1.2%	0.8%	0.7%	0.7%	0.5%	0.5%	0.3%	0.4%

Table 1 (continued)

	Total				Men				Women			
	Australia	**South Korea**	**Thailand**	**India**	**Australia**	**South Korea**	**Thailand**	**India**	**Australia**	**South Korea**	**Thailand**	**India**
Chronic kidney disease	3.3%	2.7%	2.3%	2.3%	3.0%	2.4%	2.1%	2.1%	3.6%	3.4%	2.4%	2.5%
Atrial fibrillation and flutter	1.8%	1.2%	0.9%	0.9%	2.5%	1.4%	1.4%	1.2%	1.0%	0.8%	0.6%	0.5%
Unstable angina/MI	2.4%	2.3%	1.5%	1.5%	3.6%	2.8%	2.5%	2.3%	1.1%	1.2%	0.8%	0.9%

BMI body mass index, *MI* myocardial infarction

[a] Population included in the model at time of analysis

[b] Data sourced from the Australian Bureau of Statistics, KOSIS Statistics Korea, Thailand National Statistical Office, and the United Nations Department of Economic and Social Affairs

[c] Data from literature (see Tables S8–11 for further details and sources)

[d] Prevalence for local cohort with BMI 25/30 to 50 kg/m^2 and age 20–69 scaled from United Kingdom data

Table 2 Direct medical costs in 2022 and in 10 years (no-intervention scenario)

Country	Obese population	2022			2032	
		Direct medical costs[POPN] (USD)	Cost per person (USD)	Proportion of GDP (%)	Direct medical costs[POPN] (USD)	Cost per person (USD)
Australia[a]	5.2 million	2.9 billion	558	0.21%	6.9 billion	1410
South Korea[a]	13.8 million	7.5 billion	545	0.46%	18.4 billion	1397
Thailand[a]	14.9 million	10.2 billion	685	2.1%	23.5 billion	1649
India[b]	223 million	23.3 billion	104	0.86%	44.3 billion	207

GDP gross domestic product, *POPN* population, *USD* United States dollars

[a] Costs estimated for Australia, South Korea, and Thailand factor the direct medical costs of ten obesity-related comorbidities—diabetes, hypertension, dyslipidaemia, heart failure, atrial fibrillation, unstable angina/myocardial infarction, hip/knee osteoarthritis, asthma, sleep apnoea, and chronic kidney disease

[b] Costs estimated for India only factors in six out of the ten obesity-related comorbidities factored in this model. Sleep apnoea, dyslipidaemia, atrial fibrillation and flutter, and unstable angina are excluded owing to data inconsistencies/limitations

individuals in each country as estimated at the population level (Tables S4–7).

Using type 2 diabetes again as an example, in the 10% weight-loss scenario, the number of individuals with type 2 diabetes is only estimated to rise from 0.6 to 1.0 million in Australia, 2.1 to 3.6 million in South Korea, 1.1 to 3.0 million in Thailand, and 35.4 to 59.1 million cases in India. This represents a 27.3% reduction in Australia, a 31.7% reduction in South Korea, a 29.0% reduction in Thailand, and a 30.1% reduction in India in the estimated increase in the 10-year incidence of type 2 diabetes. Cost savings across the countries for type 2 diabetes in the 10% weight-loss scenario were estimated at 0.2 billion USD in Australia, 0.5 billion USD in South Korea, 1.2 billion USD in Thailand, and 1.1 billion USD in India in 2032, with cumulative savings over the 10 years 1.0 billion USD in Australia, 2.9 billion USD in South Korea, 7.3 billion USD in Thailand, and 6.4 billion USD in India (Tables S4–7).

Discussion

Direct medical costs of obesity and its related comorbidities are increasing at an alarming rate in the APAC region, aggravated by the fact that some of the key comorbidities, such as type 2 diabetes, occur at lower BMI in this region. Our modelling analysis identified substantial potential cost savings that could be achieved through weight loss and demonstrated the economic implications of insufficient action on obesity. The economic benefits of a reduction in the prevalence of obesity in the region are profound. The simulation analysis indicated that achieving a population-level weight loss of 10% in each of these four APAC countries could reduce the predicted incidence in obesity-related comorbidities. A reduction in the incidence of type 2 diabetes by between 27.1 and 31.7% (depending on country), for example, would be expected to render substantial cost savings over the next 10 years compared with a no-intervention scenario. This is in addition to the health and well-being benefits for those individuals who have otherwise developed type 2 diabetes or other obesity-related comorbidities.

The economic burden of obesity is well established, despite varied methodologies in demonstrating this burden worldwide [23]. There is considerable variation in available data and comparisons between the relatively few studies of obesity in the APAC region. Comparative analysis or regional analysis is therefore challenging due to differences in methodology and terminology. Using Australia as an example, in one study, an estimated 8.6 billion USD of total societal costs were related to obesity in 2011–2012 (3.8 billion USD direct costs and 4.8 billion USD indirect costs) [24], whereas another study for the same period showed a much higher total cost estimate of 41.7 billion USD. The latter was influenced by the inclusion of a range of other costs attributable to both overweight and obesity, such as long-term care expenses and social support (direct cost estimate 10.8 billion USD and indirect costs 30.9 billion USD) [25].

Trends reported in our simulation modelling are broadly comparable with other modelling analyses [13, 14, 26–28]. A cost-of-illness analysis assessing current and future costs of obesity and overweight in 8 countries, including Australia, India, and Thailand, took a more conservative weight loss target of 5% compared to our study, included indirect costs (which we omitted), and projected costs up to 2060. It also related all costs or savings to the gross domestic product (GDP) of the country in question, and did not focus on or model the clinical burden of obesity. As such, direct comparison with our study is limited, however it did demonstrate and conclude that there are substantial economic burdens associated with obesity that will increase without intervention (from 0.8–2.4% GDP in 2019 to 2.4–4.9% GDP in 2060, depending on country), and that there is a need for advocacy and policy action to address this situation, which

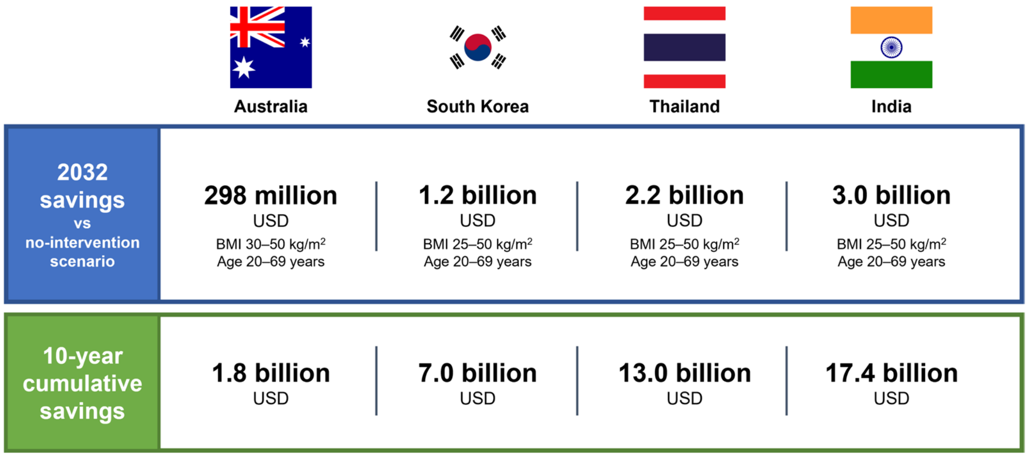

Fig. 3 Estimated direct medical cost savings of 10% weight loss in each country in 2032. BMI, body mass index; USD, United States dollars

aligns with the results and conclusions reported in this analysis [26]. To compare against recorded costs instead of modelling data, using a study of one of the Asian countries we investigated for comparison with our modelling, an analysis of the socioeconomic costs of morbid obesity in South Korea showed a 1.47 times increase in those costs between 2009 and 2013 (from 492 billion South Korean won [KRW]) to 726.2 billion KRW). These cost increases over 4 years follow a similar trend in the increases we report in direct costs for this country in our analysis, which more than doubled over 10 years. This study defined morbid obesity as ≥30 kg/mg^2, lower than the typical threshold for morbid obesity of ≥35 kg/m^2, and aligning with our study of using a lower threshold for Asian populations [28].

Our analysis scales from the UK cohort used in the retrospective UK primary care analyses from Khunti and colleagues and Haase and colleagues, from which the risk model we have used was derived, but it was designed to replicate local population-level characteristics [13, 14]. While our simulated findings by design differ from the original analyses, despite using the same cohort risk model, we similarly found risk reductions in obesity-related comorbidities with weight loss in our analysis. This is consistent with the diversity in these four key countries in APAC and highlights the importance of countering escalating obesity-related costs in the region [1, 5]. Predicted reductions in the incidence of comorbidities with the reported model are also similar to those identified in previous studies, including a study of the associations of weight loss with obesity-related comorbidities in a large integrated health system in the USA [29].

The economic burden identified in this analysis is substantial. However, it is likely that the true burden of obesity is being underestimated for several reasons. Firstly, the model makes no assumptions about future healthcare price inflation (whether or not nominal incomes will increase at the same rate). Secondly, the scope of modeled diseases (comorbidities) considered was limited to ten in the case of Australia, South Korea, and Thailand, and six in the case of India, due to data and modelling limitations. Moreover, increasingly important comorbidities such as mental health conditions were not included. Thirdly, for pragmatic reasons, the model covers only the direct medical costs of treatment and does not include productivity losses or other societal costs, as these are challenging to capture across countries, but contribute significantly to the full economic burden of obesity. Finally, the model provided estimates based on current prevalence of obesity, whereas as previously noted, the reality is that population prevalence of obesity is increasing, especially in the APAC region [1, 5].

A 10% weight-loss target was used in this analysis as the intervention scenario for the population-representative cohorts. Any hypothetical weight-loss target is challenging, especially when both policy change that may influence lifestyle interventions and the options for obesity management are rapidly changing. In this respect, it is important to recognize that lifestyle changes alone currently result in an average weight loss of 3–5%, an outcome that is impacted by genetic predisposition and physiological mechanisms that lead to weight loss recidivism [30]. However, the illustrative target of 10% should be achievable through effective management of obesity in combination with lifestyle interventions, thus supporting it as a target for this simulation analysis.

In terms of limitations of this study, differences in methodology and scope of the sources for the model mean that the reported estimates of the direct population-level costs of obesity vary widely, both across and within countries over time. Here, we have used a lower BMI cut-off for obesity for South Korea, Thailand, and India based on recommendations for Asian populations [16, 17], but each of these countries has a non-negligible population who are not of Asian ancestry, and similarly Australia has a non-negligible population who are of Asian ancestry. There is also a risk that by using a BMI cut-off of 25 kg/m^2 for South Korea, Thailand, and India, the incidence of obesity-related comorbidities may be overestimated in these countries. Indeed, the use of a BMI-driven model for Asian populations may not be ideal, and measures of obesity that either use or incorporate waist circumference would better represent these populations. However, in the absence of robust data for these countries on waist circumference at the population level, BMI has been used as an established alternative.

The analysis only provides a snapshot of the costs and potential direct medical cost savings of obesity—indirect costs may represent a similar burden or even greater burden than direct costs. We also did not investigate the cost burdens and potential savings by subgroup based on sex or gender, as this analysis was performed at the population level. We used a risk model based on UK data for constructing the populations for the modelling analysis, scaled in each case to match relevant macro-level characteristics of the four countries we have focused on. While this is not optimal, given the lack of local data available at the detail required for this modelling, this was a pragmatic approach to generating Localised results for the purposes of discussion and to provide much-needed impetus to generate local data that may fill the gap in future.

The simulated data reported here use populations of people living with obesity in 2022 to estimate direct medical cost savings of obesity and disease burden in a future population (adjusted for mortality), based on reduced costs in obesity-related comorbidities. The model is not able to consider increases in healthcare costs in the 10-year period of the model, which are likely but are difficult to predict. It also does not include elevation of obesity levels during that time period, and only models based on the current populations of individuals living with obesity in 2022. The assumption of uniform weight loss of 10% across each population also needs to be considered when extrapolating to the real world.

This hypothetical model estimates the clinical and economic benefits over a period of 10 years after a 10% weight loss. In reality, it should be acknowledged that population-level assumptions of weight loss are challenging. This magnitude of weight loss requires effort to achieve and sustain. Effect sizes and resulting outcomes are both likely to be affected by disparities in healthcare access, utilization and cost across and within countries, between rural and urban areas, or by socioeconomic status. This will in turn impact actual patterns of healthcare costs and cost savings.

Ultimately, the financial implications of continued insufficient action on obesity place an extensive burden on healthcare systems and global economies. This is particularly relevant in the APAC region, where there is a substantial and growing economic burden of obesity rooted in poorly developed policy, a lack of investment in effective strategies for management, and inadequate disease frameworks and coordination amongst public and private stakeholders. Our analysis shows that these epidemiological and economic consequences can be mitigated, but suggests that the lack of availability and consistency of comparable high-quality data on obesity across countries within a region, and between regions, may limit our collective understanding.

Conclusions

The burden of obesity, in terms of direct medical costs for healthcare systems, is extremely high in the APAC region, and if this health economic crisis is not made a priority, there will be severe ramifications on the healthcare system capacity costs over the next 10 years. This simulation modelling demonstrates that 10% weight loss in adults living with obesity in Australia, South Korea, Thailand, and India can result in substantial benefits in terms of reducing incidence of obesity-related comorbidities and the healthcare costs associated with those conditions. To achieve this, significant, transformative healthcare reform and corresponding resource commitments are needed to move towards this aspiration. However, this analysis demonstrates that the consequences of insufficient action will be substantial and costly, from both a public health and an economic aspect.

Abbreviations

APAC Asia-Pacific
BMI Body mass index
GDP Gross domestic product
MI Myocardial infarction
POPN Population
UK United Kingdom
USD United States dollars
WHO World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44263-024-00094-x.

Additional file 1 includes: Simulation model methodology—further details for the modelling analysis. Table S1: Cost sources for modelling analysis—details of individual costs and sources for each comorbidity by country. Table S2: Inclusion/exclusion criteria for rapid scoping literature review. Table S3: Studies reviewed as part of the rapid scoping literature review—details of each reference, study period, direct and indirect costs by country. Table S4: Direct medical cost savings of obesity per obesity-related comorbidity for adults aged 20–69 years old, BMI 30–50 kg/m^2, over 10 years for Australia. Table S5: Direct medical cost savings of obesity per obesity-related comorbidity for adults aged 20–69 years old, BMI 25–50 kg/m^2, over 10 years for South Korea. Table S6: Direct medical cost savings of obesity per obesity-related comorbidity for aged 20–69 years old, BMI 25–50 kg/m^2, over 10 years for Thailand. Table S7: Direct medical cost savings of obesity per obesity-related co-morbidity for adults aged 20–69 years old, BMI 25–50 kg/m^2, over 10 years for India. Table S8: Baseline demographics and data source for patients living with obesity for the simulation model in Australia. Table S9: Baseline demographics and data source for patients living with obesity for the simulation model in South Korea. Table S10: Baseline demographics and data source for patients living with obesity for the simulation model in Thailand. Table S11: Baseline demographics and data source for patients living with obesity for the simulation model in India. Figure S1. Summary of adapted risk engine, based on Khunti et al. Figure S2: Impact of Asian ethnicity on outcome risk in the refined model. Figure S3. Sensitivity analysis: Tornado plots for varied yearly treatment cost from 50% to 150% of the actual costs in the cohorts of 100,000 individuals and 10% weight loss.

Additional file 2 – CHEERS checklist [22].

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Authors' contributions
JY, VS, WA, TB, JRB, JGUR, RK, GK, KK, SYL, VM, and BO were all involved in the conceptualisation of this study. JY, VS, KK, and JP curated the data, and JY, VS, and JP conducted the formal analysis. JRB and JGUR were involved in the funding acquisition for this study. JY conducted the investigation and developed the study methodology with VS, JRB, and JGUR. WA, JRB, and JGUR coordinated the study administration. SK, SYL, and JP supervised the study. JRB, JGUR, SYL, and JP validated the study. VS and SK developed the visualization of the data and methodology for the manuscript. JY and BO were involved in the development of the first draft of the manuscript, and all authors contributed to the development of the final manuscript through review, editorial input, data interpretation, and final approval.

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Availability of data and materials
All data generated are available in the main text or Additional File 1. Web interfaces including the aggregated local populations for the four countries and the values used in this analysis are available here: https://github.com/VolkerSchnecke/Value_of_weight_loss_APAC. These also contain the code used to calculate costs and savings.

Declarations

Ethics approval and consent to participate
Ethics approval was not required as this modelling study used publicly available population-level data. No identifiable data were accessed and no interactions with participants were involved.

Consent for publication
Not applicable.

Competing interests
JY is the President of the Singapore chapter of the Professional Society for Health Economics and Outcomes Research (ISPOR) and reports funding from Novo Nordisk PHARMA GULF FZE for congress attendance. VS is an employee of Novo Nordisk A/S, Denmark. JRB and JGUR are employees of Novo Nordisk PHARMA GULF FZE. SK reports honoraria from Boehringer Ingelheim and Sanofi. GK reports payment for serving on advisory boards and honoraria or travel support received from Abbott, AstraZeneca, Boehringer Ingelheim, Eli Lilly, Novartis, Novo Nordisk, and Reed Exhibitions. KK reports clinical trial contracts from Alvogen Korea, Amgen, Boehringer Ingelheim, Eli Lilly, and Novo Nordisk PHARMA, consulting fees for Novo Nordisk PHARMA Korea, and honoraria for Alvogen Korea, Chong Kun Dang, and Novo Nordisk PHARMA Korea. VM reports acting as consultant and speaker and having received research or educational grants from Abbott, Alembic Pharmaceuticals Ltd., AstraZeneca, Boehringer Ingelheim, Biocon, Dr. Reddy's Laboratories, Emcure Pharmaceuticals Ltd., IPCA Laboratories Ltd., Johnson & Johnson, LifeScan, Lilly, MSD, Novartis, Novo Nordisk, Roche Diabetes Care India Pvt. Ltd, Sanofi-Aventis, SunPharma, USV Private Limited, and Zydus Healthcare Ltd. JP reports honoraria from INova and Novo Nordisk. BO reports a clinical study grant, consulting fees and honoraria from Novo Nordisk PHARMA Malaysia. The remaining authors declare no competing interests.

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