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Economic burden of excess weight among older adults in Singapore: a cross-sectional study

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ABSTRACT

Objectives To estimate the incremental per capita and aggregate direct and indirect costs of excess weight among older adults (aged 40–80) in Singapore.
Design Secondary data analysis of an existing cross-sectional survey
Setting Residential districts in South-West Singapore
Participants 5848 older adults (aged 40–80) from Singapore's three dominant ethnic groups
Primary and secondary outcome measures We used regression models to estimate per capita medical expenditures and absenteeism costs attributable to overweight and obesity based on WHO's body-mass index (BMI) classification. Per capita estimates were multiplied by prevalence to obtain aggregate costs.
Results The sample included 2467 Chinese, 2128 Indians and 1253 Malays. Indians and Malays are three to four times more likely to be obese (BMI≥30 kg/m^2) than Chinese. Among Chinese, compared with those who are normal weight, individuals who are overweight missed one additional workday per year more (p<0.05). Individuals in the obese category had S$720 per year greater medical expenditures (p<0.05) but missed workdays were not statistically different from those in the normal weight category. Among Indians, differences were not significant between normal and overweight categories. Indians in the obese category incurred an additional S$310 per year (p<0.10) more than those of normal weight. For Malays, no significant differences by BMI category were identified. Aggregate burden is estimated at S$261M (million) (95% CI: 57M to 465M) with 68% from medical expenditures. Chinese, Malays and Indians make up 79%, 12% and 9% of the population, respectively, but account for 76%, 19% and 4% of the costs of excess weight respectively.
Conclusion Excess weight imposes a substantial health and economic burden among older Singaporeans. Successful efforts to prevent and reduce obesity prevalence may generate both health and economic improvements.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The population-based sample is large and representative of Singaporeans aged 40–80 years old within each ethnicity, with prevalence data on obesity and demographics closely matching that from population-based surveys.
⇒ Key-dependent variable, body-mass index, was measured by trained professionals, which eliminates reporting bias.
⇒ Key independent variables of healthcare utilisation used to calculate medical expenditure and absenteeism were self-reported and may be prone to reporting and recall bias.

INTRODUCTION

The proportion of Singapore residents in the high risk body-mass index (BMI) category of >27.5 kg/m^2 increased to 20.7% in 2019–2020 from 18.7% in 2017, and has likely continued to increase due to lockdowns and other effects of the COVID-19 pandemic.[1] Rising rates of overweight and obesity are concerning due to the well-established relationship between excess weight and risks for non-communicable diseases (NCD), but also due to the financial strain that excess weight imposes on the health system and broader economy.

The WHO defines overweight as having BMI ranging between 25.0 and 29.9 kg/m^2 and obese as BMI values above 30 kg/m^2.[2] A growing body of research reveals the extent to which overweight and obesity are responsible for higher rates of medical expenditures faced by public and private sector payers. On a per capita basis, Finkelstein and colleagues showed that individuals with obesity incurred annual medical expenditures that were 37% higher than their normal weight counterparts.[3] Estimates from around the world suggest that, in the absence of overweight and obesity, annual medical expenditures would be between 2% and 9% lower.[4] These higher costs are partly borne by governments, but also passed along to private insurers, employers and individuals in the form of higher premiums, copayments and deductibles for medical services. Finkelstein and colleagues further reported increasing rates of absenteeism and presenteeism (reduced productivity while working) resulting from overweight and obesity, with the largest increases occurring for those with the highest BMI values.[5] Estimates suggest that, in aggregate, excess weight costs economies between 0.5% and 1.6% of gross domestic product (GDP).[4]

Singapore is a city-state with a population exceeding 5.5 million. It enjoys a high standard of living and has health outcomes that are among the best in the world, despite spending roughly 5% of GDP on healthcare.[6] Singapore has an island network of outpatient polyclinics and private medical practitioner's clinics that provide primary medical treatments, preventive healthcare and health education. Eighty per cent of primary healthcare services are offered by over 1800 private medical clinics, whereas the remaining are delivered by 23 government polyclinics.[7] By contrast to primary healthcare, public hospitals provide 80% of hospital care.[8] Payment for services is a combination of out-of-pocket spending, health savings accounts (called MediSave), high deductible health plans (termed MediShield Life) and subsidies for low-income patients (termed MediFund). Yet, an ageing population and rising rates of overweight and obesity are threatening these outcomes.[1 6] Although the rising prevalence of obesity and NCDs has been well documented, to date no study has quantified the economic burden of excess weight. That is the focus of this effort. Using a unique data set comprising of samples of Singaporean Chinese, Indians and Malays aged 40 years or older that includes data on both measured height and weight and self-reported data on medical utilisation and absenteeism, this study aims to provide information on the per capita and total incremental costs of excess weight in Singapore.

METHODS

Data

Study population and data collection

The Singapore Epidemiology of Eye Diseases (SEED) cohort is a multiethnic longitudinal population-based study that evaluates the incidence, prevalence, risk factors and novel biomarkers of age-related eye diseases for Singaporean adults of Malay, Indian and Chinese descent. The SEED cohort is based on an age-stratified random sampling strategy of individuals between the ages of 40 and 80 years from 15 residential districts in the South-Western part of Singapore. This area was chosen based on the Singapore Population Census 2000, where the residents in this area were representative of the Singapore population in terms of age, housing and socioeconomic status. Detailed descriptions of data collections and other assessments have been published earlier.[9] The data for the current study are taken from three of the SEED substudies—the Singapore Chinese Eye Study 2 (SCES-2), Singapore Indian Eye Study 2 (SINDI-2) and the Singapore Malay Eye Study 3 (SIMES-3). Collection of the data used in this study occurred between 2011 and 2017. During this period, measured height and weight and self-reported medical history for select risk factors for NCDs (ever been diagnosed with diabetes, hypertension and high cholesterol) were collected. A questionnaire was also fielded that included a healthcare utilisation (inpatient admissions, outpatient visits and emergency department (ED) visits) and productivity loss component. A total of 2661 Chinese, 2200 Indian and 1327 Malay participants completed these assessments.

Obesity classification

For the primary analysis, we adopted WHO's classification of BMI for the general population: 18.5–24.9 kg/m^2 (normal weight category), 25.0–29.9 kg/m^2 (overweight category) and ≥30 kg/m^2 (obese category).[2] In subsequent guidelines, WHO also published a revised BMI classification for Asian populations: 18.5–22.9 kg/m^2 (normal weight category), 23.0–24.9 kg/m^2 (overweight category), 25.0–29.9 kg/m^2 (obese I category) and ≥30 kg/m^2 (obese II category).[10] This revision was to address the fact that some Asian populations face higher risk of obesity-related comorbidities at lower BMI values. However, as the evidence did not indicate a clear BMI cutpoint for all Asian subtypes for overweight and obesity, and to be consistent with the preponderance of published studies, we used general population BMI classifications in the primary analysis but presented results using the Asian cut-offs in a secondary analysis.

Healthcare expenditure

We examined healthcare expenditures from a health system perspective which includes both public and private services. Costs of providing these services were proxied by non-subsidised[i] bill sizes from the public sector, which are set to reflect true costs. The participants were asked about their utilisation of healthcare services, including outpatient visits, visits to the ED and counts and lengths of inpatient stays. A recall period of 1 month was employed for outpatient visits, including hospital outpatient clinic or physician's office visits, whereas 6 months was used for hospitalisations and visits to the ED. We annualised healthcare services utilisation by multiplying by 12 for outpatient, and two for inpatients and ED visits. Given the self-reported nature of the data, to limit the impact of outliers on the estimates, we windsorised utilisation of each type of healthcare services at the 99th percentile. Healthcare expenditure was subsequently calculated as the product of the frequency of utilisations and non-subsidised unit costs, which were obtained from publicly available sources (online supplemental appendix table 1).

[i]Publicly funded hospitals in Singapore provide substantial subsidies based on means-testing of patients' household income level.

Work productivity loss

We measured work productivity losses in terms of the number of workdays missed due to health-related reasons (absenteeism) only. Using a modified version of the Work Productivity and Activity Impairment questionnaire,[11] a validated instrument commonly used to assess employee productivity loss related to health. Participants were asked to recall the number of days of work missed in the past 3 months due to their health problems. Similar to healthcare utilisation, the number of missed days were annualised and windsorised at the 99th percentile.

The cost of workdays lost was valued at participants' daily wage rate, which was based on self-reported monthly employment income ranges. We used midpoint coding for monthly income ranges, and set a threshold of SGD13 000 monthly income for those earning over SGD11 000 a month. Missing responses were replaced with gender-specific and age-specific average monthly wages obtained from MOM Labour Statistic 2019.[12] Daily wage rates were derived by assuming 20 workdays in a month (excluding approximately 12 public holidays in Singapore and assuming 2 weeks of vacation).

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

Statistical analysis

Per capita burden prediction

We used regression analysis to quantify the incremental cost attributable to overweight and obesity relative to individuals with normal weight. For healthcare expenditures and absenteeism costs, as is commonly done, we applied a two-part regression model.[13] The first part is a logistic regression for the probability of having any medical utilisation or having any absenteeism days. The second part uses a generalised linear model with a log link function and a gamma error distribution for the cost amount conditional on non-zero utilisation or absenteeism days. For regressions of absenteeism days, we applied a negative binomial model. In each regression, the key independent variable is WHO BMI category, with normal weight as the omitted reference group. Regressions also controlled for age, gender, marital status (married and not married), education level (no formal education, primary education, secondary education, postsecondary education and others) and housing type (1–2 room Housing Development Board (HDB) flat,[ii] 3–4 room HDB flat, 5-room HDB/executive condominium, private housing and others).

Regressions were run separately for each ethnic group. We calculated per capita cost attributable to excess weight by subtracting average predicted costs for individuals in each excess weight category (overweight and obese) with the dichotomous excess weight variable set to one from average predicted costs for these individuals with the excess weight variable set to zero (ie, counterfactual predicted expenditures for these individuals if they were normal weight). We then averaged this difference across individuals in each BMI category to obtain the incremental costs attributable to overweight and obesity, respectively.

Aggregate burden prediction

We estimated aggregate health expenditures by multiplying the per capita incremental healthcare cost estimates by the number of people in Singapore of each ethnic group, aged 40–80 years old who are estimated to be overweight and obese. For the sum of health expenditure and absenteeism costs, we follow a similar approach but conservatively assume that those not in the workforce have zero absenteeism cost (this assumes that they are not working for reasons other than their weight). Furthermore, for the total pooled aggregate estimation of all ethnic groups, we used weighted regression to obtain per capita burden for all ethnic groups, before multiplying this burden with the number of individuals in overweight and obese categories (online supplemental Method for more details). All costs are reported in 2019 Singapore dollars (S$). All analysis was done on STATA V.15.1.

RESULTS

Descriptive statistics

Table 1 presents sample characteristics of participants from the SCES-2, SINDI-2 and SiMES-3 samples. Of primary interest, Indians and Malays have significantly higher proportions of individuals in the overweight and obese categories, compared with Chinese. Indians and Malays are 3–4 times more likely to be obese, compared with Chinese, with 6.1% of Chinese 18.9% of Indians and 25.3% of Malays to be obese. Similarly, more than 40% of Indians and Malays are in the overweight category, as compared with 29.2% of Chinese. Using the Asian BMI cut-offs, Chinese still have the highest proportion of normal weight (online supplemental appendix table 2). Furthermore, among those with BMI 18.5–24.9 kg/m^2, about two-thirds of Chinese are considered normal weight based on the Asian BMI cut-offs. However, only about half of Indians and Malays are considered normal weight under the Asian BMI cut-offs.

Table 2 presents the average medical expenditures associated with each BMI category. Several points are worth noting. First, not surprisingly, total medical expenditures are mainly driven by inpatient expenditures (>70%) across all ethnic groups and BMI categories. Second, as hypothesised, Chinese in the obesity category have much greater average inpatient and total expenditures than Chinese in normal weight or even overweight categories. Yet the same cannot be said for Indians and Malays. This is largely driven by the fact that Indians and Malays in the normal weight (and overweight) category have costs that

[ii]HDB flats are subsidised public housing.

Table 1 Descriptive summary of the sample

Sample characteristic	Chinese n=2467	Indian n=2128	Malay n=1253
Men (%)	49.3	49.2	45.9
Mean age (SD)	59.3 (8.9)	59.4 (9.0)	60.2 (9.0)
BMI categories			
Normal (%): 18.5–24.9 kg/m^2	64.7	40.1	33.9
Overweight (%): 25.0–29.9 kg/m^2	29.2	40.9	40.8
Obese (%): ≥ 30 kg/m^2	6.1	18.9	25.3
Education			
No formal education (%)	10.0	7.8	10.4
Primary education (%)	29.9	30.0	39.7
Secondary education (%)	36.8	38.3	40.1
Postsecondary education (%)	23.3	23.9	9.9
Housing			
1–2 room HDB flat (%)	2.1	3.8	13.3
3–4 room HDB flat (%)	55.3	59.5	65.3
5 room/executive HDB flat (%)	28.6	28.0	17.7
Other (%)	14.0	8.7	3.8
Marital status			
Single (%)	21.3	22.2	30.8
Married (%)	78.7	77.8	69.2
Currently employed (%)	54.4	55.0	41.3
Monthly income from work			
Less than S$999 (%)	11.8	12.0	14.7
S$1000–$1999 (%)	30.2	34.6	37.8
S$2000–$2999 (%)	16.1	18.8	19.1
S$3000–$3999 (%)	9.3	12.4	12.6
S$4000–$4999 (%)	5.6	5.0	5.4
S$5000–$6999 (%)	5.2	5.4	4.1
S$7000–$8999 (%)	3.7	2.7	1.4
S$9000–$10 999 (%)	2.5	2.1	0.0
Over S$11 000 (%)	3.7	2.9	0.0
Do not know (%)	0.8	0.1	0.2
Refused (%)	11.3	4.0	4.8

BMI, body-mass index; HDB, Housing Development Board.

Table 2 Summary of per capita outpatient, ED, inpatient expenditures and absenteeism days and absenteeism costs among employed individuals by BMI strata and ethnic groups (S$)

	Chinese n=2467	Indian n=2128	Malay n=1253
	Mean (SD)	Mean (SD)	Mean (SD)
Outpatient expenditure (S$)			
Normal	221 (378)	255 (423)	272 (372)
Overweight	247 (385)	246 (402)	304 (421)
Obese	221 (369)	261 (416)	285 (369)
ED expenditure (S$)			
Normal	5 (35)	5 (35)	13 (55)
Overweight	7 (42)	4 (31)	10 (48)
Obese	12 (52)	6 (38)	7 (41)
Inpatient expenditure (S$)			
Normal	487 (2135)	846 (2905)	1129 (3637)
Overweight	464 (2257)	799 (2840)	1099 (3543)
Obese	1028 (3398)	739 (2710)	1368 (3685)
Total medical expenditure (S$)			
Normal	701 (2189)	1113 (2985)	1428 (3717)
Overweight	721 (2337)	1054 (2900)	1420 (3663)
Obese	1278 (3502)	1009 (2768)	1645 (3771)
	Chinese n=1341	**Indian n=1168**	**Malay n=518**
	Mean (SD)	Mean (SD)	Mean (SD)
Annualised absenteeism days			
Normal	1.5 (7.0)	3.3 (11.6)	3.1 (10.1)
Overweight	2.4 (9.3)	3.5 (12.1)	4.1 (12.3)
Obese	2.8 (11.8)	4.7 (13.7)	4.0 (11.6)
Absenteeism cost (S$)			
Normal	255 (1306)	387 (1355)	380 (1242)
Overweight	490 (2485)	439 (1507)	607 (2074)
Obese	654 (3668)	749 (2833)	871 (3931)

Normal, 18.5–24.9 kg/m^2; overweight, 25.0–29.9 kg/m^2; obese, ≥30.0 kg/m^2.
BMI, body-mass index; ED, emergency department.

are roughly 1.5 and two times higher, respectively, than those for Chinese in the same BMI category. Higher costs for the normal weight category suggest lower incremental costs for those in higher BMI categories.

Table 2 also reveals similar results for absenteeism. There is an increasing trend in days missed from work (and costs) as a function of higher BMI categories among Chinese respondents. This also holds for Indians and Malays but, as with medical expenditures, Indians and Malays in the normal and overweight categories incur more absenteeism days than Chinese in the same BMI categories, which again suggests lower incremental costs for being in the obese category.

Attributable cost of excess weight

Table 3 presents the incremental burden attributable to excess weight based on the regression results that control for observable differences that may be correlated with both excess weight and measures of health expenditures

Table 3 Incremental per capita medical expenditures and productivity losses due to excess weight (regression-controlled)

	Medical expenditure, S$ (95% CI)	Absenteeism days (95% CI)*	Absenteeism cost, S$ (95% CI)*
Chinese			
Normal (ref)	–	–	–
Overweight	57 (–143 to 256)	1.0† (0.0 to 1.9)	147 (–29 to 324)
Obese	720† (96 to 1345)	1.6 (–1.1 to 4.2)	315 (–277 to 906)
Number of observations	2427	1335	1335
Indian			
Normal (ref)	–	–	–
Overweight	13 (–254 to 280)	0.4 (–1.0 to 1.8)	19 (–141 to 178)
Obese	18 (–328 to 364)	2.1 (–0.5 to 4.6)	310‡ (–46 to 653)
Number of observations	2107	1166	1166
Malay			
Normal (ref)	–	–	–
Overweight	104 (–372 to 580)	0.8 (–1.3 to 2.8)	127 (–240 to 494)
Obese	325 (–198 to 848)	0.7 (–1.6 to 3.0)	96 (–243 to 435)
Number of observations	1225	515	515

Reference category is normal, 18.5–24.9 kg/m^2; overweight, 25.0–29.9 kg/m^2; obese, ≥30.0 kg/m^2.
*Among employed workers only.
†P < 0.05.
‡P < 0.10.
§P < 0.01.

and absenteeism. Coefficient estimates are generally in the hypothesised direction for all ethnic groups and BMI categories with individuals with overweight and obesity incurring higher healthcare expenditure and wage loss. Specifically, among Chinese, individuals with overweight missed more workdays (1 day per year, p<0.05) and incurred higher annual absenteeism cost (S$176, p<0.10). For Chinese in the obese category, the incremental medical cost was S$720 per year for medical expenditure (p<0.05), while additional miss workdays and absenteeism costs were not statistically significant. Among Indians, we only found significant incremental cost for absenteeism costs among those in the obese category. Indians in the obese category incurred an additional S$310 per year (p<0.10). Similarly, whereas Malays with overweight and obesity showed positive incremental costs as compared with those who are normal weight, the results were not statistically different.

Incremental burden predictions using the Asian BMI cut-offs are reported in online supplemental appendix table 3. Results show similar trends of higher medical expenditure, absenteeism days and costs among Chinese for higher BMI categories. For Indians and Malays, there are no statistically significant differences in medical expenditures or absenteeism across BMI categories.

Aggregate burden prediction

Table 4 combines the per capita estimates with prevalence data to produce aggregate estimates of the costs of obesity among Singapore residents aged 40—80 years old. Predicted total medical cost of excess weight is estimated to be S$178 million, representing 1.6% of total healthcare expenditures in the city-state (S$11 300 million in 2019). Total medical and absenteeism cost is estimated at S$261 million, with individuals in the obese category accounting for 60% of this total. By ethnicity, Chinese are responsible for 76% of total costs of excess weight, followed by 4% for Indians and 19% for Malays.

Applying Asian cutpoints generates even larger predicted costs of excess weight at S$306 million (online supplemental appendix table 4). The majority of the burden is driven by individuals in the obese II category (BMI≥30 kg/m^2), who account for 55.4% of the total cost. Chinese account for 69% of the total cost, followed by 31% for Malays. Due to the high cost of Indians in the normal weight category, there appear to be no additional costs resulting from excess weight.

To better understand this finding, we compared the prevalence of three obesity-related diseases available in the data across the BMI categories: diabetes, hypertension and high cholesterol. Results are shown in online supplemental appendix table 5. Among Chinese, prevalence of these conditions increases for each successive BMI category. For example, diabetes prevalence is 9.7% among Chinese in the 18.5–23.0 BMI category but increases to 29.3% among those with BMI≥30 kg/m^2. For Indians and Malays, the trend is similar but prevalence is much higher for those in the lowest BMI category. For diabetes, compared with 9.7% for Chinese, prevalence

Table 4 Aggregate medical expenditures and productivity losses attributable to excess weight

	Number of residents	Medical expenditure, S$ million (95% CI)	Absenteeism cost, S$ million (95% CI)*	Combined cost, S$ million (95% CI)†
Chinese				
Overweight	443 828	23 (–68 to 115)	47 (–9 to 103)	60 (–52 to 172)
Obese	92 336	66** (8 to 124)	20 (–17 to 56)	80** (5 to 155)
Excess weight	536 164	88 (–25 to 201)	66* (–2 to 135)	139* (0 to 278)
Indian				
Overweight	68 354	1 (–18 to 19)	1 (–7 to 9)	2 (–18 to 23)
Obese	31 626	1 (–10 to 12)	6* (–1 to 13)	6 (–8 to 20)
Excess weight	99 980	2 (–23 to 26)	7 (–5 to 19)	8 (–20 to 37)
Malay				
Overweight	90 002	8 (–35 to 50)	9 (–16 to 34)	12 (–36 to 60)
Obese	55 833	18 (–11 to 48)	3 (–9 to 16)	23 (–10 to 57)
Excess weight	145 836	26 (–37 to 88)	12 (–20 to 45)	35 (–34 to 105)
Total‡				
Overweight	602 184	40 (–89 to 170)	72* (–2 to 147)	94 (–61 to 248)
Obese	179 796	111*** (32 to 190)	37* (–2 to 77)	138*** (39 to 236)
Excess weight	781 980	178** (8 to 349)	115** (23 to 207)	261** (57 to 465)

Reference category is normal, 18.5–24.9 kg/m^2; overweight, 25.0–29.9 kg/m^2; obese, 30.0+ kg/m^2.
*Among employed workers only.
†Absenteeism cost is assigned as 0 for non-working individuals; *p<0.10, **p<0.05, ***p<0.01.
‡Weighted by population proportion.

is 33.0% for Indians and 23.8% for Malays. Results for hypertension and high cholesterol are also much lower among Chinese in the normal weight (and overweight) category compared with Indians and Malays.

DISCUSSION

This paper quantifies the medical expenditures and absenteeism cost of excess weight among Singaporeans aged 40–80 years. Predicted total medical expenditures attributable to overweight and obesity is estimated to be S$178 million. This estimate represents 1.6% of total healthcare expenditure (S$11 300 million in 2019). This figure is on the low end of published estimates, which range between 2.9% and 9.7% of total healthcare spending.[14] Including absenteeism increases our estimates to S$261 million. Whereas total cost of excess weight is highest among Chinese (S$88 million), Malays' burden is disproportionate. Chinese, Malays and Indians make up 79%, 12% and 9% of the population, respectively, but account for 76%, 19% and 4% of the costs of excess weight, respectively. This partially reflects the disproportionately higher rates of overweight and obesity among Malays, the majority of whom are lower income.

Our estimates are also likely to be conservative given that they only examine residents aged between 40 and 80 years old and ignore other potential costs of excess weight, such as presenteeism, early retirement and premature mortality. We also assumed zero absenteeism costs among those who were not employed. However, some individuals may leave employment prematurely due to their poor health resulting from excess weight. These individuals would incur total work disruption rather than zero absenteeism days and costs as assumed.

Our primary estimates are also lower than those based on Asian cutpoints. This curious finding partly results from higher prevalence of obesity-related comorbidities among Indians and Malays in the high normal BMI category which drives up medical expenditures and absenteeism for this BMI category. This in turn reduces the incremental costs for those in higher BMI categories. One way to look at this is to conclude that the costs of overweight and obesity are less for Indians and Malays compared with Chinese. However, an alternative view, and one consistent with the limited data on chronic disease prevalence that we report, is that Indians and Malays in the normal weight BMI category and this age group are already experiencing the ill health effects resulting from an obesity-promoting lifestyle, even if their BMI does not yet reflect it. Data from The Singapore Multiethnic Cohort study reveals that Indians and Malays are more inactive (with fewer hour of moderate–vigorous intensity activities) and consume less healthy diets (with higher carbohydrates and fat intake), compared with Chinese.[15] Deurenberg-Yap *et al* further show that the relationship between body fat percentage and BMI differs among the three ethnic groups.[16] They show that Indians and Malays

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of normal weight have substantially higher visceral body fat at lower BMI values compared with Chinese. Liew *et al* showed that Indians in Singapore who are lean were more insulin resistant and had higher blood pressure and lipid levels compared with Chinese and Caucasians.[17] Similarly, in a separate study comparing lean Indians, Malays and Chinese in Singapore, Khoo *et al* showed that at a lower body fat, Indians displayed lower insulin sensitivity compared with Chinese and Malays but when the amount of body fat increases, the drop in insulin sensitivity was significantly more pronounced in Chinese and Malays compared with their Indian counterparts.[18] These findings may partly explain our result of higher healthcare expenditure at the healthy-range BMI among Indians and the relatively greater increase in healthcare utilisation as BMI increases to the overweight and obese categories. It also suggests that the use of BMI alone may not be the best measure for quantifying excess weight and its impact among these population subsets. It is likely that an alternative measure that better identifies Indians and Malays of healthy weight would show lower disease prevalence and costs for this group and thus higher costs for those in higher risk weight categories. A study in Malaysia, Singapore's neighbour with similarly diverse ethnicities, highlighted similar differences between obesity prevalence among ethnic groups, with obesity prevalence highest among Malays and Indians, follows by Chinese.[19] Differences in medical spending across races were also found in the USA, where excess weight had a significant impact on healthcare expenditures among whites but not among blacks or Hispanics.[20] These studies and ours highlight the uneven distribution of obesity burden across different ethnic groups.

Our study has many strengths. The sample is relatively large and representative of Singaporeans aged 40–80 years within each ethnicity, with prevalence data on obesity and demographics closely matching that from population based surveys.[9] Height and weight were measured, thus not subjected to reporting bias inherent.[9] Having data at the individual level allowed for estimating costs while adjusting for potential confounders, such as education and housing type, which is a proxy for income.

A key limitation of this study is the self-reported nature of healthcare utilisation, absenteeism and other key variables. Any bias in reporting of these metrics may result in biased estimates of the costs of overweight and obesity. The recall period of 1 month for outpatient visits, including hospital outpatient clinic or physician's office visits is short. However, it is unclear whether a longer recall period would be preferable as this may result in an underestimate of utilisation, especially for high users who may not be able to recall all visits over an extended period. Despite these limitations, the primary conclusion that excess weight imposes substantial health and absenteeism costs among older Singaporeans is undeniable. Effective efforts to prevent or reduce excess weight may have both health and financial benefits.

Contributors VAH and CJ contributed to data analysis. EAF contributed in the design and formulation of the study. VAH, CJ and EAF contributed to the initial draft of the manuscript. EL and KWT revised and provided critical input to the final version. All authors contributed to the interpretation of the findings and critical review of the manuscript. EAF is the guarantor of the study and is responsible for the overall content.

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Patient consent for publication Not required.

Ethics approval This study involves human participants and was approved by National University of Singapore Institution Review Board. NUS-IRB-2021-756 Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request.

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Appendix Table 1. Non-subsidized unit costs of healthcare services

Category	**Unit Cost (S$)**	**Details**	**Source(s)**
Inpatient admission	S$4,503.70	Fees for hospitalization for Ward A (non-subsidized ward) in SGH, TTSH, NUH. The average of median bill sizes divided by average days hospitalized results in the average bill size per hospitalization day.	1. Singapore General Hospital - $5123.27 2. 2. Tan Tock Seng Hospital - $3887.90 3. National University Hospital - $4499.94 Historical transacted bill information for July 2018 – June 2019 (https://www.moh.gov.sg/cost-financing/fee-benchmarks-and-bill- amount-information)
Emergency Department (ED) Visit	S$123.33	Average of non-subsidised prices for ED visits at 3 major public hospitals	1.Singapore General Hospital: $121 (https://www.sgh.com.sg/patient-care/visiting-specialist/charges-payments-singapore-general-hospital) 2. Tan Tock Seng Hospital: $128 (https://www.ttsh.com.sg/Patients- and-Visitors/Your-Clinic-Visit/Pages/Outpatient-Charges.aspx) 3. National University Hospital: $121 (https://www.nuh.com.sg/patients-visitors/Pages/Charges- Payment.aspx)
Outpatient Visit	S$51.48	Average of non-resident price for General Practitioner visits at polyclinics run by 3 major public healthcare institutions	1. SingHealth clinics: $51.50 for non-resident (https://polyclinic.singhealth.com.sg/Pages/FeesAndPayment.aspx) 2. National Healthcare Group: $51.47 for non-resident (https://www.nhgp.com.sg/charges_and_payment/) 3. NUHS polyclinics: $51.47 for non-resident (https://www.nup.com.sg/Pages/Fees%20and%20Charges/bbk.aspx)

Appendix Table 2. Distribution of obesity across ethnic groups using Asian BMI cut-offs

BMI range (kg/m^2)	**WHO classification for general population**	**WHO classification for Asian population**	**Chinese n = 2,467** %	**Indian n = 2,128** %	**Malay n = 1,253** %	P-value[a]
18.5 – 23.0	Normal	Normal	41.5%	20.8%	18.1%	<0.001
23.0 – 25.0		Overweight	23.2%	19.4%	15.8%	
25.0 – 29.9	Overweight	Obese I	29.2%	40.9%	40.8%	
≥30	Obese	Obese II	6.1%	18.9%	25.3%	

a: Chi-square Test for whether the distribution of Normal and Overweight categories using Asian BMI cut-offs are different by ethnic groups

Appendix Table 3. Incremental Medical Expenditures and Productivity Losses Attributable to Excess weight using Asian BMI cut-offs.

	Medical expenditure, S$ (95% CI)	Absenteeism days (95% CI)^	Absenteeism cost, S$ (95% CI) ^
Chinese			
Normal (ref)	-	-	-
Overweight	-68 (-275,138)	0.9* (-0.1,2.0)	196** (7,384)
Obese I	30 (-191,251)	1.4*** (0.4,2.3)	220** (51,390)
Obese II	711** (66,1358)	2.0 (-0.8,4.8)	380 (-199,960)
Number of observations	2,427	1,335	1,335
Indian			
Normal (ref)	-	-	-
Overweight	-229 (-619,160)	-1.0 (-2.9,0.8)	-136 (-350,79)
Obese I	-98 (-442,246)	-0.1 (-2.0,1.8)	-50 (-265,165)
Obese II	-98 (-516,321)	1.3 (-1.3,4.0)	238 (-135,612)
Number of observations	2,107	1,166	1,166
Malay			
Normal (ref)	-	-	-
Overweight	386 (-303,1075)	-2.2 (-4.9,0.5)	-326 (-848,197)
Obese I	293 (-270,857)	-0.5 (-3.3,2.3)	-67 (-626,493)
Obese II	518 (-99,1135)	-0.5 (-3.4,2.5)	-63 (-575,449)
Number of observations	1,225	515	515

CI, confidence interval; Reference category is Normal, 18.5 – 22.9 kg/m^2; Overweight, 23.0 – 24.9 BMI; Obese I, 25.0 – 29.9 kg/m^2; Obese II, ≥30.0 kg/m^2; ^ Among employed workers only; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Appendix Table 4. Aggregate Medical Expenditures and Productivity Losses Attributable to Excess weight using Asian BMI cut-offs.

	Number of residents with excess weight	Medical expenditure, S$ million (95% CI)	Absenteeism cost, S$ million (95% CI)^	Total cost, S$ million (95% CI)†
Chinese				
Overweight	352,107	-22 (-97, 53)	51** (2, 101)	14 (-79, 106)
Obese I	443,828	12 (-88, 112)	70** (16, 124)	65 (-52, 183)
Obese II	92,336	63** (5, 121)	24 (-12, 60)	81** (5, 156)
Excess weight	888,271	53 (-114, 220)	145*** (57, 233)	159 (-36, 354)
Indian				
Overweight	32,333	-8 (-21, 4)	-3 (-8, 2)	-9 (-23, 4)
Obese I	68,354	-7 (-31, 16)	-3 (-14, 8)	-7 (-33, 18)
Obese II	31,626	-3 (-16, 10)	5 (-3, 12)	2 (-14, 18)
Excess weight	132,313	-19 (-60, 23)	-1 (-20, 18)	-15 (-62, 32)
Malay				
Overweight	34,874	14 (-12, 39)	-8 (-21, 5)	12 (-15, 38)
Obese I	90,002	24 (-26, 74)	-5 (-43, 34)	27 (-30, 83)
Obese II	55,833	28* (-5, 61)	-2 (-21, 16)	32 (-6, 70)
Excess weight	180,709	65 (-26, 157)	-15 (-79, 50)	71 (-32, 174)
Total[#]				
Overweight	419,314	-28 (-127, 71)	49* (-7, 105)	12 (-104, 128)
Obese I	602,184	23 (-125, 170)	102*** (32, 1733)	100 (-66, 265)
Obese II	179,796	106** (23, 188)	45** (6, 85)	139*** (39, 240)
Excess weight	1,201,293	148 (-114, 410)	208*** (96, 320)	306** (14, 598)

CI, confidence interval; Reference category is Normal, 18.5 – 24.9 kg/m^2; Overweight, 25.0 – 29.9 kg/m^2; Obese, 30.0+ kg/m^2;
Weighted by population proportion;
^ Among employed workers only
† Absenteeism cost is assigned as 0 for non-working individuals; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix Table 5. Rates of comorbidities among Chinese, Indians and Malays across BMI categories.

BMI range (kg/m^2)	WHO classification for general population	WHO classification for Asian population	Chinese n= 2,467 %	P-value[a]	Indian n= 2,128 %	P-value[a]	Malay n= 1,253 %	P-value[a]
Diabetes								
18.5 – 23.0	Normal	Normal	9.7%	0.003	33.0%	0.505	23.8%	0.038
23.0 – 25.0		Overweight	14.7%		35.2%		32.8%	
25.0 – 29.9	Overweight	Obese I	20.4%		36.7%		34.8%	
≥30	Obese	Obese II	29.3%		42.9%		38.5%	
Hypertension								
18.5 – 23.0	Normal	Normal	35.8%	0.002	42.8%	0.730	48.9%	0.395
23.0 – 25.0		Overweight	43.9%		43.9%		53%	
25.0 – 29.9	Overweight	Obese I	57.6%		47.6%		59.7%	
≥30	Obese	Obese II	68.7%		59.8%		69.7%	
High Cholesterol								
18.5 – 23.0	Normal	Normal	38.9%	0.001	50.0%	0.777	47.6%	0.064
23.0 – 25.0		Overweight	47.4%		51.0%		56.6%	
25.0 – 29.9	Overweight	Obese I	56.7%		52.6%		62.2%	
≥30	Obese	Obese II	58.7%		64.8%		68.8%	

a: Chi-square Test between proportion of Normal (18.5 – 23.0) and Overweight (23.0 – 25.0) who have the comorbidities (diabetes, hypertension and cholesterol)

Supplementary Method. Total aggregate burden prediction using Weighted regression methodology.

We ran weighted regressions to account for disproportionate number of Indian and Malay participants in the pooled data. A probability weight was assigned to each ethnic group, calculated as the ratio of the population proportion of each ethnic group over the sample proportion (**Table A**). Calculations for per capita burden and aggregate burden are based on these weight regression coefficient estimates.

Table A. Racial weight for overall regressions.

Ethnicity	**Population proportion (excluding Other ethnic groups)**	**Sample proportion**	**Probability Weight**
Chinese	79.7%	42.2%	1.89
Indian	8.8%	36.4%	0.24
Malay	11.6%	21.4%	0.54