

Economic burden of asthma in Singapore

Eric A Finkelstein,¹ Eden Lau,¹ Brett Doble,¹ Bennett Ong,² Mariko Siyue Koh^{3,4}

To cite: Finkelstein EA, Lau E, Doble B, *et al*. Economic burden of asthma in Singapore. *BMJ Open Resp Res* 2021;**8**:e000654. doi:10.1136/bmjresp-2020-000654

► Additional material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/bmjresp-2020-000654>).

Received 28 May 2020

Revised 9 November 2020

Accepted 21 February 2021

ABSTRACT

Background and objective Up-to-date economic burden of asthma in Singapore is currently unknown.

Methods We quantify the per capita and total annual costs of asthma for adults and children by level of symptom control (uncontrolled, partly controlled, and well controlled) via a cross-sectional online survey administered to a national web panel. Participants were asked about healthcare utilisation, days missed from work, and reduced productivity due to their symptoms. These values were then monetised and multiplied by prevalence estimates of adult and child asthmatics to generate total costs.

Results A total of 300 adults and 221 parents of children with asthma were included in analysis. The total annual cost of adult asthma was estimated to be SGD 1.74 billion (US\$1.25 billion) with 42% coming from the uncontrolled group, 45% from the partly controlled group, and 13% from the well-controlled group. For children, the total cost is SGD 0.35 billion (US\$0.25 billion), with 64%, 26% and 10% coming from each group respectively. Combined, the annual economic burden of asthma in Singapore is SGD 2.09 billion (US\$1.50 billion) with 79% due to productivity losses.

Conclusion Poorly controlled asthma imposes a significant economic burden. Therefore, better control of disease has the potential to generate not only health improvements, but also medical expenditure savings and productivity gains.

Key messages

- What is the annual economic burden of asthma among adults and children in Singapore?
- Annual economic burden of asthma is SGD 2.09 billion with 79% coming from lost productivity.
- We present the burden of asthma separately for adults and children, by direct and indirect costs, and by level of symptom control. We then discuss economic benefits of better symptom control.

visit or hospitalisation annually as a result of an asthma attack.^{2 13} Poorly managed asthma also generates avoidable direct costs through physician visits, diagnostic tests, medications and hospitalisations and greater indirect costs in the form of increased work absenteeism and presenteeism (ie, reduced productivity while at work), and in the case of a child asthmatic, time off for parents to care for sick children.^{14 15}

The direct and indirect burden due to asthma is available for numerous countries but no up to date information is available for Singapore.^{13 16–22} The most recent Singapore-based study is over two decades old and is likely no longer relevant due to changes in care pathways, costs of health services, and wage rates.²³ We therefore quantify the direct and indirect costs of asthma for adults and children by level of symptom control (uncontrolled, partly controlled, and well controlled). The results will help employers, providers and policy-makers understand the burden imposed by asthma for adults and children by level of symptom control.

INTRODUCTION

Asthma is a major chronic respiratory disease characterised by inflammation and constriction of the air passages.^{1 2} It manifests through recurrent attacks of symptoms, including shortness of breath, wheeze, chest tightness and cough.^{3 4} It affects approximately 340 million people globally and ranks 16th as the leading cause of years lived with disability.^{4 5}

Inhaled corticosteroids (ICS) are the most effective treatments and standard of care for asthma.^{4 6–8} ICS reduces asthma mortality and exacerbations while improving lung function and symptom control. In the Asia-Pacific region, despite the proven efficacy of ICS medications,^{9–12} most patients continue to rely on reliever medications to treat acute symptoms, resulting in suboptimal control.⁴ More than 40% of patients report at least one unscheduled emergency department (ED)

METHODS

A cross-sectional online survey was administered in English to Singapore residents who are members of a national web panel. Participants were recruited through email invitations in early 2020 and provided with a link to a screener. Eligibility, as shown in online supplemental appendix A, required being a Singaporean citizen or permanent resident over age 21, a previous diagnosis of asthma



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

¹Health Services and Systems Research Program, Duke-NUS Medical School, Singapore

²AstraZeneca Singapore Pte Ltd, Singapore

³Department of Respiratory and Critical Care Medicine, Singapore General Hospital, Singapore

⁴Duke-NUS Medical School, Singapore

Correspondence to

Dr Eric A Finkelstein;
eric.finkelstein@duke-nus.edu.sg



or experiencing two or more of the following symptoms not otherwise explained: wheezing, shortness of breath, cough or tightness in the chest with worsening symptoms at night and/or in the morning or that vary over time or in intensity. These criteria were adapted from the National Asthma Education and Prevention Program diagnostic guidelines in consultation with clinical experts.²⁴

The screener identified 315 adult asthmatics (aged 21–65) and additionally, 257 adults who are parents of at least one child (aged 4–20 years) with asthma who consented to participate. Those who completed the questionnaire were compensated by the vendor.

All respondents reported demographic information and monthly employment income (online supplemental appendix A). Participants also responded to Section A of the Global Initiative for Asthma (GINA) questionnaire,⁸ a validated four-question instrument to measure degree of symptom control: frequency of symptoms, reliever use and inhibition in daily activities. Scoring of symptom control was done according to GINA recommendations: well controlled if responses to all questions were 'No', partly controlled if one to two responses were 'Yes', and uncontrolled if three to four responses were 'Yes'.⁸

To quantify healthcare utilisation, participants were asked about frequency of healthcare use 'due to your symptoms' over the prior 12 months as shown in online supplemental appendix A. Checklists were provided which inquired about frequency of physician and outpatient visits, medications, diagnostic tests, ED visits and hospitalisations. To monetise utilisation, unit costs were applied to each type of service based on costs collected through publicly available sources (online supplemental appendix tables C1 and C2). Only those in the labour force were able to generate costs for absenteeism and presenteeism. All costs are reported in 2020 Singapore dollars accompanied by the equivalent in US dollars (SGD 1=US\$0.72).

Lost productivity was quantified using a modified version of the Workplace Productivity and Activity Impairment Questionnaire: Specific Health Problem v2.²⁵ Given the episodic nature of asthma, the investigators found it more appropriate to apply a recall period of 1 month instead of the instrument's original period of 1 week. Absenteeism was captured by having respondents indicate the number of hours missed from work due to problems associated with asthma in the past month. This figure was then multiplied by 11.5 to generate annual hours missed and monetised by multiplying by an hourly wage for each respondent. For full-time employees (160+monthly hours), hourly wages were calculated by dividing reported monthly income by the sum of reported number of monthly hours worked and hours missed from work. Monthly income was assumed to be the midpoint of the reported income category or SGD 10 500 for those who report earnings in the SGD 10 000 or more category. For part-time employees or full-time employees with missing income data, hourly wages were estimated based on the mean hourly wage for full-time

employees in the corresponding occupation category. If a mean hourly wage for full-time employees was not available for a category, missing income was estimated based on the mean hourly wage for full-time employees in the entire sample.

Presenteeism was captured by participants indicating the degree to which asthma symptoms affect their productivity while working on a scale of 0–10, with 0 being 'no symptoms and/or symptoms had no effect on my work' and 10 being 'symptoms completely prevented me from working'. Monthly presenteeism hours were calculated as the product of a participants' presenteeism scale response and their reported monthly number of hours worked.²⁵ This estimate was then annualised and monetised using an analogous approach as for absenteeism.

Surveys for parents answering on behalf of their child were similar except questions were framed with 'due to your child's asthma'. If a participant indicated more than one child with asthma, they were asked to consider only the oldest child. Aside from this framing, the questions were analogous to the adult survey, except for absenteeism which was captured using the Caregiver Indirect and Informal Care Cost Assessment Questionnaire.²⁶ Absenteeism costs were conservatively set to zero for respondents not in the labour force.

Once the data were available, logic checks were conducted to ensure the reported data were in plausible ranges and to identify any responses that seemed problematic. The resulting dataset allowed for quantifying the per capita direct healthcare costs and indirect costs for absenteeism and presenteeism separately for adults and children. These were then stratified by levels of symptom control (well controlled, partly controlled, and uncontrolled) to generate averaged per capita costs for each stratum, which could then be multiplied by the number of individuals within each stratum to generate total costs by strata. The latter figure required us to know how many adults and children in Singapore currently suffer from asthma stratified by symptom control. This could be estimated by multiplying population counts for adults and children times the prevalence rate for asthma for each subgroup of interest. For healthcare costs, we applied population counts for all adults and children but for costs of lost productivity we considered only counts for employed adults.

The numbers of adults and children were available from the Singapore Department of Statistics²⁷ and the employment rate was available from the Ministry of Manpower.²⁸ Asthma prevalence rates were not readily available. For adults and children, we applied prevalence rates of 5.1% and 8.9%, respectively, based on two studies from 2004 as more recent prevalence data was not available.^{29 30} Moreover, the prevalence estimates do not contain information on level of symptom control. Therefore, we estimated the prevalence rate within each symptom control category by assuming the distribution across the three categories is the same in Singapore as it is among respondents to our survey.

Patient and public involvement

The public was involved in the research only during the data collection stage, through invitations to take an online survey. They were not involved in any other parts of the research.

RESULTS

After removing suspect responses (see online supplemental appendix B), 300 adults and 221 parents of children were included in analysis. Out of the adults, 24% were uncontrolled, 38% were partly controlled, and 38% were well controlled. For children, 45% were uncontrolled, 30% partly controlled and 25% well controlled. Using these relative values and ensuring that the sum of the three categories adds to the population prevalence of 5.1% for adults and 8.9% for children yields asthma prevalence of 1.2%, 1.9% and 1.9% for uncontrolled, partly

controlled, and well controlled for adults and 4.0%, 2.7%, and 2.3%, respectively, for children.

Sample characteristics stratified by control status are reported in table 1. Adult participants were on average, 36 years old, of Chinese descent (80%), married (60%), and had completed at least tertiary education (58%). Parents were on average, 39 years old, predominantly Chinese (78%), and had completed at least tertiary education (65%).

Per capita costs are presented in table 2 and online supplemental appendix table D. The left panel reveals that per capita healthcare expenditures for adults are SGD 3150 (US\$2270), SGD 1010 (US\$730) and SGD 270 (US\$190) for the uncontrolled, partly controlled and well-controlled groups, respectively. As shown in online supplemental appendix table D, the largest contributor to healthcare costs are medications.

Table 1 Sample characteristics by asthma control*

	Adult sample (n=300)			Parent sample† (n=221)		
	Uncontrolled (n=72)	Partly controlled (n=114)	Well controlled (n=114)	Uncontrolled (n=99)	Partly controlled (n=66)	Well controlled (n=56)
Age of survey respondent (mean (SD))	33 (8)	37 (10)	39 (34)	37 (8)	39 (9)	43 (9)
Female (%)	32	40	50	–	–	–
Chinese (%)	75	79	85	84	74	73
Married (%)	69	63	50	–	–	–
Employment status (%)						
Employed full time	18	34	32	7	14	7
Employed part time	79	57	54	72	53	57
Unemployed	3	9	13	19	32	34
Unknown	–	–	–	2	2	2
Education level (%)						
Employed full time						
No formal education	–	–	–	1	–	–
Primary to junior college‡	28	41	50	31	38	36
University and above	72	58	50	67	62	64
Unknown	–	0	–	1	–	–
Monthly income (%)						
Less than \$2999	14	18	33	13	20	29
\$3000–5999	40	54	38	34	42	30
\$6,000–9999	26	23	18	32	23	23
\$10 000 and above	18	4	4	19	15	14
Prefer not to answer	1	2	6	1	–	4

*Columns may not sum up to 100 due to rounding.

†Sample characteristics are representative of the parents who responded on behalf of their children.

‡This includes junior college, the Singapore-Cambridge General Certificate of Education Advanced Level (A-Level) examination, polytechnic education, diplomas, vocational training, and Institute of Technical Education (ITE) education. The A-Level is a national examination held annually in Singapore. The examination is taken by school candidates on the completion of preuniversity education at junior colleges, centralised institutions, and Integrated Programmes, and is also open to private candidates. ITE is a public vocational education institution agency in Singapore that provides pre-employment training to secondary school graduates, and continuing education and training to working adults.

Table 2 Per capita costs by asthma control (SGD) for employed residents

Per capita costs (SD)	Adults			Children		
	Uncontrolled	Partly controlled	Well controlled	Uncontrolled	Partly controlled	Well controlled
Healthcare*	\$3150 (3930)	\$1010 (1870)	\$270 (860)	\$6000 (7410)	\$3680 (5290)	\$1430 (5020)
Absenteeism	\$4870 (12 610)	\$2400 (3820)	\$430 (1150)	\$4110 (5110)	\$2610 (3920)	\$1330 (2050)
Presenteeism	\$17 610 (18 150)	\$14 260 (15 360)	\$4530 (8360)			
Total	\$25 630 (25 000)	\$17 670 (17 450)	\$5230 (8750)	\$10 110 (9050)	\$6290 (7330)	\$2760 (6250)

*Healthcare costs per capita are assumed to be identical for individuals employed and unemployed.

The average number of asthma-related days missed from work per year for employed adults was 19 days, 10 days and 2 days, respectively (online supplemental appendix table E.1). Monetised this translates to SGD 4870 (US\$3510), SGD 2400 (US\$1730) and SGD 430 (US\$310). Presenteeism estimates were much higher. The mean presenteeism score reported was 6, 4 and 2, which translates to annual work loss valued at 62 days, 59 days and 21 days (online supplemental appendix table E.1). Note that although the presenteeism score for the partly controlled group is one-third lower than for the uncontrolled group, annual work loss is only slightly lower because nearly twice as many in the former group work full time (35% vs 18%), thus generating much greater work loss even for the same presenteeism score. Monetised the work loss converts to losses of SGD 17 610 (US\$12 680), SGD 14 260 (US\$10 270), and SGD 4530 (US\$3 260), respectively. Summing the three categories yields per capita total costs of SGD 25 630 (US\$18 450), SGD 17 670 (US\$12 720) and SGD 5230 (US\$3770), for the uncontrolled, partly controlled and well-controlled groups, respectively, for those who are either fully or partly employed. The largest percentage of per capita total costs come from presenteeism at 69%, 81% and 87%. Healthcare expenditures represent 12%, 6% and 5% of the total, respectively (online supplemental appendix table D).

The right panel of [table 2](#) shows per capita costs for children. Trends are similar; children with uncontrolled asthma generate the highest healthcare and

absenteeism costs and children with well-controlled asthma generating the lowest costs. Healthcare expenditures make up the vast majority of costs for children. Additional details are included in online supplemental appendix table D.

Adult residents in Singapore total 3 193 502 and child residents total 627 923. The percentage of adults or parents employed either full or part time is 69%. Multiplying these counts times the asthma prevalence estimates times the per capita total costs yields total costs among adult asthmatics of SGD 0.73 billion (US\$0.53 billion), SGD 0.78 billion (US\$0.56 billion) and SGD 0.23 billion (US\$0.17 billion) for the uncontrolled, partly controlled and well-controlled asthma groups ([table 3](#)). Aggregating across the three groups results in a total cost of adult asthma of SGD 1.74 billion (US\$1.25 billion) with 42% coming from the uncontrolled group, 45% from the partly controlled group and 13% from the well-controlled group.

For children, total costs are SGD 0.22 billion (US\$0.16 billion), SGD 0.09 billion (US\$0.06 billion) and SGD 0.03 billion (US\$0.02 billion), respectively ([table 3](#)). Summing across groups yields a total cost of SGD 0.35 billion (US\$0.25 billion) for child asthma, with 64% coming from those with uncontrolled asthma, 26% from partly controlled and 10% from the well-controlled group. Aggregating costs for adults and children reveals that the total annual economic burden of asthma in Singapore is SGD 2.09 billion (US\$1.50 billion), with 46% coming from those with uncontrolled asthma, and

Table 3 Total cost of asthma in Singapore by asthma control*†

	Cost of asthma (SGD, billions)			
	Uncontrolled	Partly controlled	Well controlled	Total
Adults	\$0.73	\$0.78	\$0.23	\$1.74
Children	\$0.22	\$0.09	\$0.03	\$0.35
Total	\$0.95	\$0.87	\$0.26	\$2.09

*Numbers may not add up due to rounding.

†Total productivity costs are multiplied by the employment rate in Singapore before adding the total healthcare costs to adjust for those unemployed.

only 13% from those with well-controlled asthma. Children are responsible for 17% of the total.

DISCUSSION

This study quantified the economic burden of asthma in Singapore by level of symptom control. These costs are substantial, totaling SGD 2.09 billion (US\$1.50 billion) annually, with 79% of coming from lost productivity. These costs mainly come from presenteeism, as results reveal that those with asthma tend to come to work but perform below their potential due to their symptoms. Moreover, although they represent only 29% of the total asthma group, the uncontrolled group is responsible for 46% of total costs, whereas the 35% of the asthma population that is well controlled represent only 13% of the total. As a result, if all those with suboptimal control could be improved to well-controlled without cost, the total cost of asthma would be reduced by SGD 1.35 billion (US\$0.97 billion). Although greater control would come at a cost, many of the asthma control interventions, including national asthma programmes,^{31 32} ICS medications, newer biological treatments³³ and bronchial thermoplasty^{34 35} have been shown to be cost effective.^{4 36} Our results further show the potential for cost savings given the high medical cost and productivity burden among those with poor control.

Our results are in line with prior estimates. We find that 87% of our sample has uncontrolled or partly controlled asthma, which is identical to that reported in a prior study in Singapore.³⁷ We estimate annual asthma per capita healthcare costs across all symptom groups at SGD 1290 (US\$930). Consistent with Singapore being a low-cost provider of health services, this estimate is below that of Switzerland (Swiss Health Consumer Price Index (CPI): <http://www.oecd.org/sdd>; exchange rate: CHF 1=SGD 1.47) (SGD 2603), USA (USA Medical Care CPI: <https://fred.stlouisfed.org/series/CPIMEDSL>; exchange rate: US\$1=SGD 1.38) (SGD 2021), and Hong Kong (Hong Kong CPI: <https://data.worldbank.org/indicator/FP.CPI.TOTL?locations=HK>; costs were in US\$) (SGD 1957) after accounting for inflation and converting to SGD.^{13 17 38} For absenteeism, our sample reports an average of 6.6 hours missed over the past month, which is roughly half of the 13.6 hours average reported in a study of six countries.³⁹ Our respondents also report an average score of 4 on the presenteeism scale, just one unit above the average score from the same international study (4 vs 3).³⁹

This study is not without limitations. A primary limitation is the potential for selection bias of the survey respondents. The survey relies on a convenience sample of asthma participants (and their parents) from an online panel and there is no way to determine whether those who chose to participate are representative of individuals with asthma in the broader community. Because the survey relies on self-report, it is also prone to recall and self (and parent)-report bias. Also, although we were

able to quantify per capita and total medical costs, we did not assess whether these costs are paid by government, private insurance, out of pocket or other sources. Future studies should validate these results with utilisation or claims data from other sources and identify the percentage of costs that are funded by various payers.

Because we do not have asthma prevalence data by race or socioeconomic status, we also assume there are no differences by these factors in the use of health services. Yet, in Singapore, Malay asthmatics have higher health-care utilisation⁴⁰ and greater work impairment.⁴¹ They are also under-represented in the online panel, suggesting an additional source of potential bias. The analysis is also limited by use of dated statistics and imputation to generate current asthma prevalence by level of symptom control, by excluding those below age 4 and over age 65, and by not including caregiver costs for those who may take care of adult asthmatics. For all of these reasons, our prevalence, unit cost and total cost estimates are potentially biased and associated with high variability that could not be properly estimated. Rather than attempt to incorporate this uncertainty into the analysis, we note that even if our figures are off by an order of magnitude, more precise estimates will not change the conclusion that asthma imposes a significant economic burden in Singapore and that the potential exists to reduce the burden through effective policies and treatments.

Contributors EAF supervised this study overall. He conceptualised the study and methodology, conducted formal analyses, validated the survey, drafted the original version of the manuscript and was involved in all manuscript revisions leading to submission. EL conducted formal analyses, drafted the original version of the manuscript and was involved in all manuscript revisions leading to submission. BD conceptualised the study and methodology, validated the survey, worked on writing and editing the manuscript. BO acquired funding for this study, conceptualised the study and methodology, validated the survey, and was involved in all manuscript revisions leading to submission. MSK conceptualised the study and methodology, validated the survey, and was involved in all manuscript revisions leading to submission.

Funding Funding for the study was provided by AstraZeneca Pte. Ltd., Singapore.

Competing interests EAF: has done paid consulting work for AstraZeneca and other Pharma companies. BO: is an employee of AstraZeneca. However, he had no role in the analysis and AstraZeneca did not have a right of refusal on publication. MSK: has grant support from Astra-Zeneca, and received honoraria for lectures and advisory board meetings paid to her hospital (Singapore General Hospital) from GlaxoSmithKline, Astra-Zeneca, Sanofi, Novartis and Boehringer Ingelheim, outside the submitted work.

Patient consent for publication Not required.

Ethics approval Institutional Review Board (IRB) approval was obtained (NUS-IRB Ref: S19-289)

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Deidentified data can be made available to replicate these results with an approved IRB document.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

REFERENCES

- 1 Braman SS. The global burden of asthma. *Chest* 2006;130:4S–12.
- 2 Lai CKW, De Guia TS, Kim Y-Y, *et al.* Asthma control in the Asia-Pacific region: the asthma insights and reality in Asia-Pacific study. *J Allergy Clin Immunol* 2003;111:263–8.
- 3 World Health Organization. *Asthma*, 2019.
- 4 Global Asthma Network. *The global asthma report 2018*. Auckland, New Zealand, 2018: 93.
- 5 Andiappan AK, Puan KJ, Lee B, *et al.* Allergic airway diseases in a tropical urban environment are driven by dominant mono-specific sensitization against house dust mites. *Allergy* 2014;69:501–9.
- 6 Barnes PJ. Inhaled corticosteroids. *Pharmaceuticals* 2010;3:514–40.
- 7 British Thoracic Society and Scottish Intercollegiate Guidelines Network. *British guideline on the management of asthma*, 2019.
- 8 Global Initiative for Asthma. *Global strategy for asthma management and prevention*, 2019.
- 9 Bahadori K, Doyle-Waters MM, Marra C, *et al.* Economic burden of asthma: a systematic review. *BMC Pulm Med* 2009;9:24.
- 10 Accordini S, Bugiani M, Arossa W, *et al.* Poor control increases the economic cost of asthma. A multicentre population-based study. *Int Arch Allergy Immunol* 2006;141:189–98.
- 11 Smith DH, Malone DC, Lawson KA, *et al.* A national estimate of the economic costs of asthma. *Am J Respir Crit Care Med* 1997;156:787–93.
- 12 Stock S, Redaelli M, Luengen M, *et al.* Asthma: prevalence and cost of illness. *Eur Respir J* 2005;25:47–53.
- 13 CKW L, Kim Y-Y, Kuo S-H. Cost of asthma in the Asia-Pacific region. *Eur Respir Rev* 2006;15:7.
- 14 Hiles SA, Harvey ES, McDonald VM, *et al.* Working while unwell: workplace impairment in people with severe asthma. *Clin Exp Allergy* 2018;48:650–62.
- 15 Nguyen HV, Nadkarni NV, Sankari U, *et al.* Association between asthma control and asthma cost: results from a longitudinal study in a primary care setting. *Respirology* 2017;22:454–9.
- 16 Krahn MD, Berka C, Langlois P, *et al.* Direct and indirect costs of asthma in Canada, 1990. *CMAJ* 1996;154:821–31.
- 17 Szucs TD, Anderhub H, Rutishauser M. The economic burden of asthma: direct and indirect costs in Switzerland. *Eur Respir J* 1999;13:281–6.
- 18 Kim C-yup, Park H-W, Ko S-K, *et al.* The financial burden of asthma: a nationwide comprehensive survey conducted in the Republic of Korea. *Allergy Asthma Immunol Res* 2011;3:34–8.
- 19 Asthma Australia and National Asthma Council Australia. *The hidden cost of asthma. Deloitte access economics*, 2015.
- 20 Weiss KB, Sullivan SD, Lyttle CS. Trends in the cost of illness for asthma in the United States, 1985–1994. *J Allergy Clin Immunol* 2000;106:493–9.
- 21 Cisternas MG, Blanc PD, Yen IH, *et al.* A comprehensive study of the direct and indirect costs of adult asthma. *J Allergy Clin Immunol* 2003;111:1212–8.
- 22 Accordini S, Corsico A, Cerveri I, *et al.* The socio-economic burden of asthma is substantial in Europe. *Allergy* 2008;63:116–24.
- 23 Chew FT, Goh DY, Lee BW. The economic cost of asthma in Singapore. *Aust N Z J Med* 1999;29:228–33.
- 24 U.S. Department of Health and Human Services. *Expert panel report 3: guidelines for the diagnosis and management of asthma*, 2007.
- 25 Reilly MC, Zbrozek AS, Duker EM. The validity and reproducibility of a work productivity and activity impairment instrument. *Pharmacoeconomics* 1993;4:353–65.
- 26 Landfeldt E, Zethraeus N, Lindgren P. Standardized questionnaire for the measurement, valuation, and estimation of costs of informal care based on the opportunity cost and proxy good method. *Appl Health Econ Health Policy* 2019;17:15–24.
- 27 Singapore Department of Statistics. *Singapore residents by age group, ethnic group and sex, end June, annual, 2019*.
- 28 Ministry of Manpower Singapore. *Resident Employment Rate by Age and Sex, 2009 - 2019 (June)*, 2019.
- 29 Lu Y, Feng L, Lim L, *et al.* Asthma, life events and psychiatric disorders: a population-based study. *Soc Psychiatry Psychiatr Epidemiol* 2013;48:1273–82.
- 30 Yang KS, Ng TP, Kwang YP, *et al.* Prevalence of childhood asthma and control in children assessed in a pilot school-based intervention programme in Singapore. *J Paediatr Child Health* 2007;43:353–8.
- 31 Haahtela T, Herse F, Karjalainen J, *et al.* The Finnish experience to save asthma costs by improving care in 1987–2013. *J Allergy Clin Immunol* 2017;139:e402:408–14.
- 32 Franco R, Santos AC, do Nascimento HF, *et al.* Cost-Effectiveness analysis of a state funded programme for control of severe asthma. *BMC Public Health* 2007;7:82.
- 33 McQueen RB, Sheehan DN, Whittington MD, *et al.* Cost-Effectiveness of biological asthma treatments: a systematic review and recommendations for future economic evaluations. *Pharmacoeconomics* 2018;36:957–71.
- 34 Zein JG, Menegay MC, Singer ME, *et al.* Cost effectiveness of bronchial thermoplasty in patients with severe uncontrolled asthma. *J Asthma* 2016;53:194–200.
- 35 Zafari Z, Sadatsafavi M, Marra CA, *et al.* Cost-Effectiveness of bronchial thermoplasty, omalizumab, and standard therapy for moderate-to-severe allergic asthma. *PLoS One* 2016;11:e0146003.
- 36 Terwindt F, Rajan D, Soucat A. Priority-setting for national health policies, strategies and plans. In: Schmetts G, Rajan D, Kadandale S, eds. *Strategizing National health in the 21st century: a Handbook*. Geneva: World Health Organization, 2016: 71.
- 37 Thompson PJ, Salvi S, Lin J, *et al.* Insights, attitudes and perceptions about asthma and its treatment: findings from a multinational survey of patients from 8 Asia-Pacific countries and Hong Kong. *Respirology* 2013;18:957–67.
- 38 Druss BG, Marcus SC, Olfson M, *et al.* Comparing the National economic burden of five chronic conditions. *Health Aff* 2001;20:233–41.
- 39 Gruffydd-Jones K, Thomas M, Roman-Rodríguez M, *et al.* Asthma impacts on workplace productivity in employed patients who are symptomatic despite background therapy: a multinational survey. *J Asthma Allergy* 2019;12:183–94.
- 40 Zheng LF, Koh YLE, Sankari U, *et al.* Asthma care based on chronic care model in an aging Asian community. *NPJ Prim Care Respir Med* 2019;29:1–5.
- 41 ASE O, Chan AKW, Sultana R. Impact of psychological impairment on quality of life and work impairment in severe asthma. *J Asthma* 2020;1–10.