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Direct health costs of environmental tobacco smoke exposure and indirect health benefits due to smoking ban introduction

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Background: Introducing comprehensive smoke-free policies to public places is expected to reduce health costs. This includes prevented health damages by avoiding environmental tobacco smoke (ETS) exposure as well as indirect health benefits from reduced tobacco consumption. **Methods:** The aim of this study was to estimate direct health costs of ETS exposure in public places and indirect health benefits from reduced tobacco consumption. We calculated attributable hospital days and years of life lost (YLL), based on the observed passive smoking and disease rates in Switzerland. The exposure–response associations of all relevant health outcomes were derived by meta-analysis from prospective cohort studies in order to calculate the direct health costs. To assess the indirect health benefits, a meta-analysis of smoking ban studies on hospital admissions for acute myocardial infarction was conducted. **Results:** ETS exposure in public places in Switzerland causes 32 000 preventable hospital days (95% CI: 10 000–61 000), 3000 YLL (95% CI: 1000–5000), corresponding to health costs of 330 Mio CHF. The number of hospital days for ischaemic heart disease attributable to passive smoking is much larger if derived from smoking ban studies (41 000) than from prospective cohort studies (3200), resulting in additional health costs of 89 Mio CHF, which are attributed to the indirect health benefits of a smoking ban introduction. **Conclusion:** The example of smoking ban studies on ischaemic heart disease hospitalization rates suggests that total health costs that can be prevented with smoking bans are considerably larger than the costs arising from the direct health impact of ETS exposure in public places.

Keywords: attributable cases, health care costs, life expectancy, smoking ban, tobacco smoke pollution

Introduction

During the past years, comprehensive smoke-free policies for public places have been introduced in various countries (France, Ireland, Italy, the UK, parts of the USA and Canada). Other countries (Switzerland, Germany or Japan) do not have comprehensive smoking bans.[1–3] The introduction of smoking bans for public places resulted in a reduction of environmental tobacco smoke (ETS) exposure of hospitality workers[4,5]as well as of the general population.[6,7]

Beside reduction of ETS exposure, studies demonstrated that the introduction of smoking bans in public places and workplaces were followed by a reduction of the tobacco consumption in many countries, such as Italy,[8] the USA, Australia, Canada and Germany.[9]

After the introduction of smoking bans, regional studies in Europe and North America found reductions of hospital admissions due to myocardial infarctions.[10–12]

Such smoking ban studies have the advantage of not only considering the direct health effects from ETS exposure, but also the indirect health effects that accompany the introduction of a smoking ban such as the reduction of tobacco consumption of smokers. These indirect benefits are also relevant for policy decision makers in order to estimate the total health benefits associated with the introduction of a comprehensive smoke-free policy. However, these indirect benefits are not captured by conventional health impact assessments (HIA) that quantify only the direct health consequences of passive smoking based on exposure–response associations between health outcomes and ETS exposure derived from epidemiological studies.

To our knowledge, smoking ban studies have not been used for HIA, so far, to estimate direct and indirect preventable health costs when introducing a smoking ban. Therefore, our aim is to estimate the direct health costs related to ETS exposure in public places in Switzerland from available epidemiological research and additionally by evaluating indirect preventable health costs by considering the results of recently published smoking ban studies.

Methods

Selection of the health effects

All health outcomes with sufficient or suggestive causal relationship to ETS exposure according to the Surgeon General report were considered relevant for this HIA *a priori*.[13] From these, we did not consider health effects for which health costs cannot be determined (e.g. annoyance). In addition, we only included clearly delimitable health effects in order to avoid double counts. Breast cancer was excluded because we found no increased risk in a meta-analysis of prospective cohort studies. Finally, we were left with the following outcomes: ischaemic heart disease, stroke, lung cancer, nasal sinus cancer, chronic obstructive pulmonary disease (COPD), asthma, hospital admissions due to respiratory diseases and preterm delivery.

Derivation of the exposure–response associations

The exposure–response associations between ETS exposure and the selected health outcomes were derived from epidemiologic literature. For lung cancer and ischaemic heart disease, we carried out a systematic literature review including a meta-analysis. For all other health effects, we derived the exposure–response association by meta-analysis from all studies mentioned in the Surgeon General report[13] or we used newer peer reviewed meta-analyses in the case of stroke.[14,15]

We only considered prospective cohort studies as they are not prone to recall bias and generally assumed to be most reliable. In addition, we considered smoking ban studies in order to evaluate indirect health benefits of smoking ban introduction on ischaemic heart disease hospitalization rates.

In our systematic review of lung cancer and ischaemic heart disease studies, we searched EMBASE and MEDLINE to identify relevant studies published prior to 2009. From each publication, data were independently extracted by two experienced epidemiologists using structured data extraction sheets. To be considered for inclusion, the relevant studies had to be in English or German and had to be carried out in Europe, North America, Japan, South Korea, Australia and New Zealand, since these regions represent most adequately the Swiss situation in terms of exposure. Relevant studies had to quantify the ETS exposure as well as the exposure–response associations including measure of precision (e.g. confidence interval). In addition, selected studies had to be peer reviewed. If several publications were available from the same cohort, we only considered the most comprehensive data analysis. We excluded studies that were solely done in patients. We calculated separate effect estimates for YLL and hospital days' calculation based on incidence (morbidity) and/or mortality studies. Depending on the heterogeneity between the studies, we used random or fixed effect models for our meta-analyses.

Determination of the ETS exposure

In the framework of our research question, we only considered ETS exposure in public places (restaurants, cafes, bars, events, workplaces, schools and universities). We took into account data on ETS exposure for the year 2006 when no smoke-free policies had been implemented on a compulsory base in Switzerland. Public transport had introduced a smoking ban in trains at the end of 2005.

Data on the ETS exposure of the Swiss population were obtained from the Swiss tobacco monitoring, which is carried out on behalf of the Federal Office of Public Health every 3 months, since 2001.[16,17] It is a representative survey among 2500 persons in Switzerland aged between 14 and 65 years. We used the data from the fourth quarter of 2006 to calculate the cumulative exposure time per week for all type of public places including work places. For the age group >65 years, we used the data from the age group 55–65 years but excluded ETS exposure at workplace.

For our HIA, we assumed that ETS exposure of >7 h a week at public places is approximately the same as living with a smoker. This is the typical exposure status of exposed study participants in prospective cohort studies.

Observed health frequencies

For all morbidity outcomes except preterm delivery, we calculated the attributable hospital days as this is particularly relevant for the cost estimates. Age-specific numbers of hospital days were obtained for each relevant diagnosis using the number of stationary cases and the average length of stay of the year 2006 from the medical statistics of Swiss hospitals.[18] Mortality data for the YLL calculation were derived from the official Swiss mortality statistics of the year 2006.[19]

Calculation of attributable cases

For our calculation, we used a hypothetical scenario with a smoking ban in force, i.e. no ETS exposure at public places. Thus the expected number of hospital days for the hypothetical scenario (N_h) is obtained from the observed number of hospital days (N_o) the following way:

$$N_h = \frac{N_o}{RR_{exp}} \quad (1)$$

where,

$$RR_{exp} = P_{not\,exposed} + (P_{exposed} \cdot RR) \quad (2)$$

RR is the exposure response association of ETS exposure, and *P* is the proportion of the population exposed or not exposed, respectively. Smoking ban studies are based on the whole population, and thus do not require knowledge about the exposure distribution of the target population. Thus, the number of expected hospital days after the introduction of a smoking ban is obtained from the pooled risk estimate of the smoking ban studies (RR_{ban}) the following way:

$$N_h = N_o \cdot RR_{ban} \quad (3)$$

To obtain the hospital days attributable to passive smoking, we subtracted the expected number of hospital days of the hypothetical scenario (N_h) from the observed number of hospital days. Since ETS exposure and the observed health frequencies are age dependent, we calculated all attributable cases for three different age groups separately (15–39, 40–69, ≥70 years) and added them up.

Calculation of the YLL

YLL were calculated using the method described in Miller and Hurley[20,21] for fatal health outcomes (ischaemic heart diseases, stroke, lung cancer, nasal sinus cancer and COPD). We calculated life tables using the observed hazard rates for the reference scenario and the modified hazard rates without ETS exposure for the hypothetical scenario without ETS exposure at public places. For the reference scenario, we applied the observed age-specific mortality rates to project and estimate the age-specific number of deaths for every fatal health outcome in each year until the year 2100 and computed the number of life years using a cohort life table. The same procedure was applied with modified survival functions reflecting the absence of ETS exposure. Calculations were done for 10-year age categories reflecting the exposure situation and relative risk of the corresponding age groups. We also took into account a time lag between ETS exposure and health impact (latency of 13 years for carcinogenic diseases, 1.5 years for cardiovascular disease[22] and 2 years for COPD).[23]

Determination of the health costs

The health costs consist of medical treatment costs (hospital days), costs due to net loss of production, the costs of reoccupation due to death of an employee and the immaterial costs that comprise the costs for pain and suffering. The cost rates and their sources are given in table A1.

Medical treatment costs were determined for each health outcome separately from the All Patient Diagnosis Related Groups (APDRG) Suisse.[24] The data of the APDRG Suisse are based on a sample of 290 000 hospitalizations, collected between 2001 and 2003.

The costs due to net loss of production arise from work absence of adults (between 17 and 65 years). Work absence was assumed to be doubled as long as the stay at the hospital, as it was done in other impact assessments.[25–27] Unlike costs per case of illness, costs per day due to net loss of production are independent of the disease and the same costs per hospital day were used for all health outcomes. Net production loss of a YLL corresponds to a full year of work absence, which is CHF 49 000.[28]

The immaterial costs were estimated by the willingness to pay method. Immaterial costs of a hospital day were determined from a Californian survey that is based on a sample of 394 persons of a median age of 67 years.[29] The cost rate, published in this study, lies between those of two European studies.[27,30] In this study, cost rates for hospital days were not different according to diagnosis. The cost rate for the immaterial costs of an YLL corresponds to the value of a life year lost (VLYL), which is independent from the age structure of the concerned people. Since there are no estimations for VLYL, the VLYL are derived from the discounted sum of the YLL. Thereby a discount rate of 2% was used. This procedure was also applied in several projects of the European Union (UNITE, HEATCO, IMPACT)[31–33] and in other Swiss health impact assessment.[26]

For preterm delivery, the additional costs compared to a normal birth are considered. These costs are also provided by the APDRG Suisse.[24]

In order to estimate the health costs that can be prevented by the introduction of a smoking ban, estimated cost rates for every health outcome were multiplied with the attributable cases and YLL. We also took into account the costs of ETS exposure in 2006 which arose after 2006. Thereby, the YLL were multiplied with a discount rate of 1%, considering a discount rate of 2% but corrected by the real wage growth.

Results

In 2006, 21% of the Swiss population were exposed to ETS in public places for >7 h a week. Exposure was highest in 20- to 24-year-old people (53%) decreasing with increasing age (Supplementary table S1).

In our systematic review, the pooled effect estimate of ETS exposure for ischaemic heart disease morbidity was 1.17 (95% CI: 1.12–1.23) based on 10 prospective studies on ischaemic heart disease morbidity and mortality (Supplementary figure S1), 1.17 (95% CI: 1.12–1.22) for ischaemic heart disease mortality based on 8 prospective cohort studies (Supplementary figure S2), 1.63 (95% CI: 1.29–2.04) for lung cancer morbidity based on four prospective studies (Supplementary figure S3) and 1.36 (95% CI: 1.17–1.58) for lung cancer mortality based on five prospective studies (Supplementary figure S4). Table A2 gives an overview on all effect estimates obtained from meta-analyses.

Combining relative risks from prospective cohort studies with observed hospital days (table A2) and the number of exposed individuals yields the direct health consequences of ETS exposure. In total, exposure to ETS in public places in Switzerland results in approximately 32 000 (95% CI: 10 000–61 000) additional hospital days and 179 (95% CI: 0–682) preterm deliveries (table A3). Life table calculations yielded about 3000 YLL (95% CI: 1500–5000) due to ETS exposure in public places, mainly owing to lung cancer [1500 (95% CI: 700–2300)] and ischaemic heart disease [1000 (95% CI: (700–1300)].

Overall, the direct health consequences from ETS exposure in public places causes health costs of 330 Mio CHF thereof 129 Mio CHF are attributable to lung cancer and 93 Mio CHF are attributable to ischaemic heart disease (table A3).

Indirect health benefits from smoking bans are evaluated with smoking ban studies. The introduction of a smoking ban reduced hospital admissions for ischaemic heart disease by 0.84 (95% CI: 0.80–0.88) (Supplementary figure S5). Estimating hospital admissions for ischaemic heart disease from smoking ban studies instead of prospective cohort studies results in 13 times higher number of estimated attributable cases, because the relative risk reduction is relevant to the whole population and not only to the exposed proportion (table A4). Hence, health costs due to ischaemic heart disease morbidity are 89 Mio CHF in addition to the conventional HIA of 8 Mio CHF based on prospective cohort studies.

Using the effect estimate for hospital admissions for ischaemic heart disease derived from smoking ban studies instead of the one from prospective cohort studies to estimate the number of YLL due to ischaemic heart disease mortality would result in a 16 times higher estimate (YLL = 15 000; 95% CI: 11 000–20 000), and hence health costs due to ischaemic heart disease would almost amount to 1.5 billion CHF (table A4).

Discussion

In 2006, 21% of the Swiss population were exposed to ETS for at least 7 h/week. This caused 32 000 hospital days (95% CI: 10 000–61 000), 3000 YLL (95% CI: 1500–5000) and thus direct health consequences of ETS exposure correspond to 330 Mio CHF in health costs. Smoking ban studies on hospital admissions due to ischaemic heart diseases suggest that an additional 38 000 hospital days corresponding to 89 Mio CHF can be avoided if a comprehensive smoking ban is introduced.

Our estimates of the direct health consequences of passive smoking tended to be somewhat lower than in similar studies from Spain and the UK. For instance, we estimated that 1.7% of all ischaemic heart disease deaths among people in working age (aged between 15 and 69 years) in Switzerland were due to ETS exposure (table A4).

In the UK, workplace-related ETS exposure was estimated to be responsible for 2.2% of all ischaemic heart disease deaths;[34] and in Spain, workplace-related ETS exposure was estimated to cause between 1.1% and 3.9% of all ischaemic heart disease deaths.[35]

For lung cancer, the attributable fractions were 3.4% in Switzerland, 2.6% in the UK and 2.1–12.3% in Spain. The main reason for our rather low estimates is the lower ETS exposure in our study. Whether this is a true difference between the three countries or whether exposure differences are due to different methods that were used to determine the proportion of the exposed population cannot be answered with the available information.

To our knowledge, this is the first HIA that takes into account smoking ban studies to estimate preventable health costs when introducing a smoking ban to public places.

Interestingly, compared with the conventional HIA approach that quantifies the direct health consequences of passive smoking based on prospective cohort studies, the consideration of smoking ban studies resulted in a much higher estimated number of preventable hospital days due to ischaemic heart disease. At a first glance, this substantial difference seems to be implausible because the relative risks of these studies are similar. A relative risk of 0.84 for smoking ban introduction corresponds quite well to the converse of the relative risk of the prospective cohort studies (1.18), which is the pooled effect estimate for persons being exposed to ETS at home from their partner. However, smoking ban studies are based on the whole population whereas prospective cohort studies express the risk only for a relatively small proportion of exposed persons. As a consequence, similar relative risks mean totally different number of attributable cases. Recently, Lightwood and Glantz[36] demonstrated that the results of the smoking ban studies are compatible with the prospective cohort studies if one assumes that the introduction of comprehensive smoke-free policies reduces tobacco consumption and results in quitting smokers as observed in various countries.[8,9] It was demonstrated among Japanese women and men that 1 year after having quit smoking, the relative risk of cardiovascular disease was reduced by 19%.[37]

The indirect health benefit of a smoking ban on smokers is supported by 2 smoking ban studies with separate analyses for smokers and non-smokers, which found similar relative reduction rates in hospital admissions for acute myocardial infarction for smokers and non-smokers.[7,38] Hence, the introduction of smoking bans in public places could also help to reduce health costs due to active smoking that are assumed to be much higher than the costs resulting from the direct health consequences of ETS exposure.

Unfortunately, smoking ban studies are not eligible for investigating long-term effects such as lung cancer and thus the studies available to date have only addressed acute effects on ischaemic heart disease hospitalization rates. Thus, indirect health benefits of smoking ban introduction can only be quantified for this outcome. If one applied the effect estimate for hospitalization rates also on ischaemic heart disease mortality to estimate the YLL, the fraction of ischaemic heart disease mortality attributable to ETS exposure would be much higher (16.5%) and the corresponding health cost estimates would exceed 1 billion CHF (table A4). This demonstrates that the indirect health benefits of a smoking ban introduction may be considerably higher than the direct health benefits from avoiding ETS exposure in public places.

Nevertheless, the extent of the direct and the indirect health benefits depend on the type of smoke-free policy. The more comprehensive a smoking ban is implemented, the more health benefits are expected. Smoking ban studies were mainly conducted in countries with comprehensive smoke-free policies such as Scotland, Ireland and Italy. In Switzerland, a few regions have introduced smoke-free policies since 2006. But most of these regulations allow exceptions like separate smoking rooms in restaurants. Similarly, the national law on the protection from ETS exposure, which will come into force on 1 May 2010, allows several exceptions as smoking will be still allowed in restaurants with a total square footage of up to 80 m^2 and customers are also served in smoking lounges. A measurement campaign in Swiss hospitality venues demonstrated that fine particulate matter concentrations (PM2.5) in non-smoking rooms of restaurants that allow smoking in a separate room are more than twice as high as in venues were smoking is not allowed at all. This reduces the direct health benefits from a smoking ban.[39] Possibly, smoke-free policies with many exceptions such as the national law in Switzerland from the 1st May 2010 have little impact on tobacco consumption and the quitting rates among smokers. This also reduces indirect health benefits of smoking ban introduction. Actually, this hypothesis is in line with the result of a recent small smoking ban study from one Swiss region where declined acute myocardial infarction hospitalization rates were observed in non-smokers but not in smokers.[12]

In conclusion, our HIA based on smoking ban studies suggests that the prevented health costs from introducing a smoking ban are considerably larger than what would be expected from the ETS exposure alone, because indirect health benefits in smokers have been demonstrated as well. The extent of these indirect effects, however, depends on the type of smoke-free regulation. The more widespread smoking is removed from the public places, the more health benefits can be expected.

Supplementary Data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- This is the first HIA which takes into account smoking ban studies to estimate preventable health costs when introducing a smoking ban to public places.
- Our study captures not only the direct effects of ETS exposure on myocardial infarction, but also indirect health benefits due to the introduction of smoking bans in public places such as the reduction of tobacco consumption in smokers.
- This study suggests that these indirect effects are even more public health relevant than the direct exposure effects.
- The extent of these indirect effects depends on the type of smoke-free regulation. The more widespread smoking is removed from public places, the more health benefits can be expected.

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Appendix 1

Table A1 Cost rates in CHF

	Medical treatment costs	Net production loss[a]	Immaterial costs	Total
Costs per hospital day				
Ischaemic heart disease	1453[b]	269[d]	814[c]	2535
Stroke	863[b]	269[d]	814[c]	1945
Lung cancer	911[b]	269[d]	814[c]	1993
Nasal sinus cancer	1386[b]	269[d]	814[c]	2468
Asthma	759[b]	269[d]	814[c]	1841
COPD	739[b]	269[d]	814[c]	1822
Other respiratory disease	1066[b]	269[d]	814[c]	2149
Additional costs due to preterm delivery	24 235[b]		n.a.	24 235
Costs per YLL				
All health end points		49 008[d]	93 567[e]	142 575
Reoccupation costs per death of an employee				28 009[f]

a: Net production loss is only calculated for employees, whereas all other costs are always taken into account. The cost rate per hospital day has been doubled to take into account the convalescence at home
b: Based on own evaluation of the APDRG Suisse (all patient diagnosis related groups)[24]
c: Based on Chestnut *et al*., 2006[29]
d: Based on official statistics from Switzerland (Swiss Statistics)[28]
e: Based on €1.5 millions (1998 market prices) from the EU-project UNITE[33]
f: Based on official salary data (Swiss Statistics) and reoccupation costs of 50% of a yearly salary[40,41]
n.a. = not available.

Table A2 Observed hospital days, deaths and effect estimates, derived from meta-analyses of epidemiologic studies

Health effect	Observed frequencies	Effect estimate (95% CI)
Cardiovascular diseases		
Hospital days due to ischaemic heart disease (smoking ban introduction)	248 205	0.84 (0.80–0.88)
Hospital days due to ischaemic heart disease (prospective studies on ischaemic heart disease mortality and morbidity)		1.17 (1.12–1.23)
Death from ischaemic heart disease	9190	1.17 (1.12–1.22)
Hospital days due to stroke	208 958	1.14 (0.99–1.31)
Death from stroke	3320	1.14 (0.99–1.31)
Carcinogenic diseases		
Hospital days due to lung cancer	75 318	1.63 (1.29–2.04)
Death from lung cancer	2942	1.36 (1.17–1.58)
Hospital days due to breast cancer	63 951	1.01 (0.92–1.11)
Death from breast cancer (women)	1330	1.01 (0.92–1.11)
Hospital days due to nasal sinus cancer	472	2.06 (1.18–3.61)
Death from nasal sinus cancer (women)	8	2.06 (1.18–3.61)
Respiratory diseases		
Hospital days due to COPD	97 926	1.40 (1.10–1.77)
Death from COPD	1584	1.40 (1.10–1.77)
Hospital days due to asthma	35271	1.67 (0.88–3.17)
Hospital days due to other respiratory disease	338 515	1.56 (1.14–2.12)
Other diseases		
Number of preterm deliveries	6603	1.13 (0.83–1.53)

Table A3 Estimated hospital days, deaths, YLL and health costs, attributable to ETS (direct health effects)

Number of cases						Costs (Mio CHF)		
Health effect	Attributable hospital days				YLL total	Morbidity	YLL	Total
	15–39 years	40–69 years	≥70 years	Total				
Cardiovascular diseases								
Ischaemic heart disease	111 (79–143)	1836 (1297–2390)	1265 (892–1651)	3212 (2268–4184)	952 (660–1259)	7.68	85.38	93.06
Stroke	133 (0–290)	814 (0–1830)	1039 (0–2355)	1986 (0–4475)	219 (0–497)	3.52	19.50	23.02
Carcinogenic diseases								
Lung cancer	70 (36–106)	2323 (1123–3730)	1115 (532–1819)	3508 (1691–5655)	1453 (703–2312)	6.54	122.28	128.82
Nasal sinus cancer	5 (1–9)	23 (4–51)	11 (2–24)	39 (7–84)	11 (2–26)	0.09	0.90	0.99
Respiratory diseases								
Asthma	1369 (0–3280)	1244 (0–3537)	210 (0–630)	2823 (0–7447)		4.97	0	4.97
COPD	77 (21–136)	1265 (333–2375)	1309 (340–2493)	2651 (694–5004)	379 (98–729)	4.39	33.36	37.75
Other respiratory disease (without asthma, COPD)	7569 (2170–13 419)	5460 (1467–10 443)	5094 (1346–9949)	18 123 (4983–33 811)		36.74	0	36.74
Preterm delivery[a]				179 (0–682)				4.33
Total	9334 (2307–17 383)	12 965 (4224–24 356)	10 043 (3112–18 921)	32 342 (9643–60 660)	3014 (1463–4823)	63.93	261.42	329.68

a: not hospital days but number of preterm deliveries

Table A4 Estimated number of hospital days, deaths, YLL and health costs due to ischaemic heart disease: comparison of smoking ban studies and prospective cohort studies

Effect estimates			Number of cases									Costs (Mio CHF)		
Type of study	Morbidity	Mortality	Attributable hospital days				Attributable deaths				YLL total	Morbidity	YLL	Total
			15–39 years	15–69 years	≥70 years	total	15–39 years	15–69 years	≥70 years	Total				
Prospective cohort studies	1.17 (1.12–1.23)	1.17 (1.12–1.22)	111 (79–143)	1836 (1297–2390)	1265 (892–1651)	3212 (2268–4184)	1 (1–2)	20 (14–27)	72 (50–95)	93 (65–124)	952 (660–1259)	7.68	85.38	93.06
Smoking ban studies	0.84 (0.8–0.88)	0.84 (0.8–0.88)	399 (297–496)	18 313 (13 651–22 752)	22 242 (16 580–27 634)	40 954 (30 528–50 882)	5 (4–7)	208 (155–259)	1303 (971–1619)	1516 (1130–1885)	15 409 (11 144–19 738)	96.66	1372.24	1468.9