Prevalence and population attributable risk for chronic airflow obstruction in a large multinational study

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Abstract

Rationale: The Global Burden of Disease programme identified smoking, and ambient and household air pollution as the main drivers of death and disability from Chronic Obstructive Pulmonary Disease (COPD).

Objective: To estimate the attributable risk of chronic airflow obstruction (CAO), a quantifiable characteristic of COPD, due to several risk factors.

Methods: The Burden of Obstructive Lung Disease study is a cross-sectional study of adults, aged≥40, in a globally distributed sample of 41 urban and rural sites. Based on data from 28,459 participants, we estimated the prevalence of CAO, defined as a post-bronchodilator one-second forced expiratory volume to forced vital capacity ratio < lower limit of normal, and the relative risks associated with different risk factors. Local RR were estimated using a Bayesian hierarchical model borrowing information from across sites. From these RR and the prevalence of risk factors, we estimated local Population Attributable Risks (PAR).

Measurements and Main Results: Mean prevalence of CAO was 11.2% in men and 8.6% in women. Mean PAR for smoking was 5.1% in men and 2.2% in women. The next most influential risk factors were poor education levels, working in a dusty job for ≥10 years, low body mass index (BMI), and a history of tuberculosis. The risk of CAO attributable to the different risk factors varied across sites.

Conclusions: While smoking remains the most important risk factor for CAO, in some areas poor education, low BMI and passive smoking are of greater importance. Dusty occupations and tuberculosis are important risk factors at some sites.

Introduction

Chronic lung disease is one of the four chronic diseases prioritised by the United Nations.[1] The Global Burden of Disease (GBD) programme concluded that in 2010 it was the third most common cause of death, responsible for the 9th highest years of life lost globally,[2] and the 9th most influential disease in reducing disability-adjusted life-years.[3]

The importance of smoking is well recognised both as a risk factor for chronic airflow obstruction (CAO), an essential component of chronic obstructive pulmonary disease (COPD), and as a risk factor for mortality attributed to COPD.[4] However, estimates of the proportion of disease caused by smoking have varied widely,[5] and recognition that many people with CAO have no history of smoking has led to the search for other causes.[6] Genetics, second-hand smoke, outdoor air pollution, indoor air pollution from biomass burning, diet, occupation, tuberculosis and longstanding asthma have all been suggested as additional causes.[6] The GBD programme has provided comprehensive estimates of the burden of COPD, measured as disability-adjusted life-years lost, attributable to different risk factors, concluding that the most important ones, in order, were smoking, outdoor particulate pollution, household pollution, occupational exposure to particles, exposure to ozone and second-hand tobacco smoke.[7] However, for most low- and middle-income countries these are based on indirect evidence.

We have previously identified the main modifiable risk factors for CAO in the Burden of Obstructive Lung Disease (BOLD) study,[8] and here we have quantified the local prevalence of CAO that can be attributed to each of these main risk factors in each of 41 sites in 35 countries.

Methods

Study population

The BOLD protocol has been published elsewhere.[9] Representative samples of adults, aged ≥40, were identified from centres with populations of at least 150,000 people. Standardised questionnaires were translated into the local language, back-translated and checked before being administered by trained fieldworkers. Questions were taken from standardised questionnaires, where these were available, and covered respiratory symptoms, smoking and other risk factors, including age, sex, educational attainment, a history of tuberculosis, and a history of working in a dusty job. Height and weight were measured and spirometry was performed using an EasyOne spirometer (ndd Medizintechnik AG, Zurich, Switzerland), before and after the administration of 200μg salbutamol via a spacer (Clement Clarke International, Harlow, UK). All spirometry was checked centrally by one of the two pulmonary function reading centres. Tests used had to include at least three acceptable curves (no hesitation, complete blow, no artefact affecting the FEV_1 or FVC), with the two best blows being within 200mL of each other.

Outcome and Exposures

We defined CAO as a post-bronchodilator FEV_1/FVC ratio < lower limit of normal using the equations for European Americans in the NHANESIII study.[10] As potential exposures, we analysed the modifiable risk factors for CAO identified in a preliminary analysis of only 14 of the BOLD sites,[8] omitting self-reported medical conditions and reports of hospitalisation with respiratory disease below the age of 10 as all these can be viewed as the consequences rather than the fundamental causes of CAO.

Statistical analysis

By population attributable risk (PAR) we mean the excess prevalence of CAO in the population that is attributable to a risk factor. We estimated the PAR for each of the following: body mass index (BMI) (underweight, normal weight, overweight, obese), doctor-diagnosed tuberculosis (ever/never), working in a dusty job (>10 years, ≤ 10 years), education (none to primary, secondary, more than secondary school), passive smoking (presence of somebody else smoking in the subject's home in the last two weeks), and pack-years of any smoking (never smoker, 1-5 pack-years, 6-15 pack-years, 16-25 pack-years, >25 pack-years). We defined a pack-year as consumption of 20 cigarettes/day for a year. Equivalent values for other types of smoking products were taken from the Smoking Pack-Years Calculator.[11]

PAR depends on the strength of the association between risk factor and outcome (relative risk), as well as the prevalence of the exposure to the risk factor and the prevalence of the outcome in the population of interest. For each of the 41 sites, we obtained a site-specific PAR ("local PAR") by first estimating the population attributable fraction (PAF) using the model-based approach described by Miettinen,[12] and then multiplying PAF by the prevalence of CAO to obtain PAR:

$$PAF = \frac{Pe\ (RR-1)}{RR} \qquad \text{[equation 1.1]}$$

$$PAR = PAF * Pd \qquad \text{[equation 1.2]}$$

where Pe is the proportion of cases exposed to the risk factor in the population under study, RR is the relative risk of CAO for the risk factor, and Pd is the prevalence of CAO in the population. Where there was no exposed individual to a given risk factor in the sample, we have not calculated a value for PAR and it is effectively estimated to be zero.

For smoking and education, we estimated the PAR for each category, and we also estimated the overall PAR for the variable by combining PAR values across categories "c", using the following formula:[13]

$$PAR = \left(\sum_{i=1}^{c} Pe_i \left(\frac{RR_i - 1}{RR_i}\right)\right) * Pd \qquad \text{[equation 1.3]}$$

where Pe_i is the proportion of cases exposed to the ith level of the risk factor and RRi is the RR for CAO for the ith category.

The RR of each risk factor was estimated by regressing the presence of CAO against age and all risk factors within each site using a log-binomial model, fitted separately for men and women. We investigated the heterogeneity of the RR estimates across sites using the I^2 statistic.[14] To increase the precision of the estimates of the site-specific RRs, and hence of site-specific PARs, we used a Bayesian hierarchical model where information on mean and variance of the RRs was borrowed across sites.[15] This leads to more robust point and interval estimates, particularly for sites with smaller sample sizes, lower prevalence of CAO or lower prevalence of exposure. The model assumes that the RRs vary across sites, but that all site-specific RRs come from the same underlying distribution. In this model, we accounted for non-response, by adjusting for variables that affect the probability of selection in the survey (see Supplement),[16] and for a cluster and/or stratified sampling framework in some sites, by including an additional level of hierarchy in the model.

The uncertainty around the PAR estimate, which reflects not only the uncertainty in RR but also the uncertainty in Pd and Pe (see Supplement), is expressed by 95% credible intervals (95%CrI), which represent the Bayesian equivalent to the frequentist 95% confidence intervals.

For each site, a *total* local PAR, representing the proportion of CAO at a single site explained by all risk factors considered, was derived by first estimating the *total* PAF using the formula proposed by Miettinen,[12] and then multiplying the total PAF by the prevalence of CAO:

$$Total\ PAF = 1 - \prod_{k=1}^{K}(1 - PAF_k) \quad \text{[equation 2.1]}$$

$$Total\ PAR = Total\ PAF * Pd \quad \text{[equation 2.2]}$$

where k represents the risk factor and K the total number of risk factors for which PAR is estimated.

Results

Of the 56,961 individuals invited to participate, 6.4% were ineligible and 7.9% could not be reached. A further 21.4% refused to take part and 4.1% did not complete the interviews. A further 10% had unacceptable spirometry. The 28,459 individuals included in the analyses thus represent 58.2% of the 48,830 people whom we were able to find and who were eligible for the study (Figure 1). The sampling strategy and response rates for each site are reported in table S1.

Just over half of the sample (52.6%) was female. The mean age was 55 years in men and 54 years in women, the youngest population being in Mysore (India) (48 in men; 46 in women) and the oldest being in Lisbon (Portugal) (64 in men; 63 in women) (Table 1). On average 59% of men and 22% of women had ever smoked, and 25% of men and 7% of women had smoked more than 20 pack-years; 31% of men and 14% of women had worked in dusty jobs for >10 years; 29% of men and 36% of women had had no more than primary school; and 3% of men and 2% of women reported a history of tuberculosis.

The mean prevalence of CAO was 11.2% in men and 8.6% in women, but ranged from 3.5% in Riyadh (Saudi Arabia) to 23.2% in Uitsig and Ravensmead (South Africa) in men, and from 2% in Sousse (Tunisia) to 19.4% in Salzburg (Austria) in women (Table 2).

After mutual adjustment, the RRs for the several risk factors were mostly consistent across sites, as shown by the I^2 values in Figure 2. Smoking more than 25 pack-years, compared to never smoking, was associated with a RR of 3.1 (95%CrI: 2.6, 3.8) in women and 3.4 (95%CrI: 2.8, 4.1) in men, with significant variation across the sites only for men. Other risk factors with statistically significant results were passive smoking, having secondary school or less, being underweight compared with normal weight, having a history of tuberculosis, and having worked >10 years in a dusty job.

The mean and range of the local PARs are given in Table 3. The local values of PAR for each risk factor associated with CAO are shown in Figures 3A (men) and 3B (women), with detailed results in Tables S2A (men) and S2B (women). On average, 5.2% of men and 2.2% of women aged ≥40 have CAO attributable to smoking, but in Uitsig and Ravensmead (South Africa) this figure is 11.7% for men and in Lexington, KY (USA) 9.5% for women. On average, 2.3% of men and 1.4% of women in the same age group have CAO attributable to poor education (defined as having secondary school or less), rising to 6.2% for men in Uitsig and Ravensmead (South Africa) and 4.3% for women in Kashmir (India). Lesser amounts of disease are attributable to long-term occupation in dusty jobs (men: 0.65%; women: 0.29%), being underweight (men: 0.43%; women: 0.30%), and having a history of tuberculosis (men: 0.36%; women: 0.26%), though in Uitsig and Ravensmead (South Africa) 3.8% of men and 2.1% of women had CAO attributable to tuberculosis.

All variables together explained on average 64.6% of CAO in men and 48.1% in women; over 75% of CAO was explained for men in Tirana (Albania), Guangzhou (China), Adana (Turkey),

Kashmir (India) and Uitsig and Ravensmead (South Africa), while for women over 75% of CAO was explained only in Limbe (Cameroon) (Table 3; Figures 3A and 3B).

Discussion

In this large study, the mean prevalence of CAO in adults aged ≥40 years was 11.2% in men and 8.6 % in women. The mean prevalence of CAO attributable to smoking was 5.2% in men and 2.2% in women. The next most influential risk factor was poor education, followed by low BMI, passive smoking, working in a dusty job for >10 years, and a history of tuberculosis, but the contributions of different risk factors varied markedly from place to place. This is the first attempt to provide estimates of local attributable risks for CAO from direct observation of post-bronchodilator lung function on a multinational scale within a standardised framework.

Because the RRs associated with each of the risk factors are similar in all sites, variation in PAR across sites is mostly determined by the prevalence of the risk factor. Tobacco consumption was the most influential risk factor, though there are many sites where it was not, particularly among women. The high prevalence of CAO attributable to tobacco in Kashmir is due to the high prevalence of hookah smoking in older people of both sexes in this area. As in a previous analysis,[8] we confirm a smaller, but still significant, RR associated with passive smoking, and >1% of women estimated to have CAO attributable to second-hand smoke in Adana (Turkey), Salzburg (Austria), Kashmir (India) Lexington, KY (USA) and Uitsig and Ravensmead (South Africa).

The risk factor with the highest PAR after tobacco was poor education. This is one of several markers of social position associated with COPD. In an earlier analysis involving a subset of

277 BOLD sites, a lower prevalence of CAO was associated with a higher asset score based on
278 household assets. This effect was largely independent of education and other variables,
279 suggesting that education accounts for only part of the effects of deprivation.[17,18] Because
280 the asset score was measured only in some sites, we could not include it in this analysis.
281 CAO was associated with being underweight, as previously shown in a subset of the BOLD
282 sites.[19] We have presented the risk here in comparison to the normal weight group
283 (18.5<BMI<25), though in fact the risk continues to decline in the overweight and obese
284 groups. The association is consistent, independent of other risk factors, such as smoking,
285 and has been shown in non-smokers.[20] Although a low BMI could be the result of the illness
286 causing CAO (reverse causation), prospective analysis of FEV_1 decline in clinical trials has
287 shown a slower decline in those with a higher BMI[21] and obstruction has been shown to
288 develop in people with a low body mass for reasons unconnected to airway disease, such as
289 anorexia nervosa.[22] We suggest that this association is at least partly causal, possibly linked
290 to an inadequate diet, including, potentially a poor diet in early life or during gestation and
291 other factors affecting BMI from childhood. We estimate that >1% of men have CAO
292 attributable to being underweight in Sri Lanka, Nampicuan-Talugtug (Philippines), Chikwawa
293 (Malawi) and Uitsig and Ravensmead (South Africa).
294 We confirmed that there is a consistent association between working in a dusty job for >10
295 years and CAO. However, we have found the PAR to be much lower than would be implied
296 by some earlier estimates,[23] the highest prevalence of CAO attributable to >10 years in a
297 dusty job being 1.6% (95%CrI: 0.4, 3.6) in men from Karachi (Pakistan) and 0.9% (95%CrI:
298 0.25, 1.76) in women from Salzburg (Austria). Our questionnaire uses a very simple question
299 and the definition of a dusty job could be expected to vary considerably both from person to
300 person and from place to place, and any random error in the answers to this question would

reduce the estimated RR. However, this question is the same as that used in other studies, including some reporting the much higher estimates that are often quoted.[24,25] In addition, there is very little heterogeneity between places in the association (RR) between a positive answer to this question and the probability of CAO, but there are wide variations in the PAR ranging up to 0.9% of women in Salzburg (Austria) with CAO attributable to working in a dusty job and to 1.6% among men in Karachi (Pakistan). Where previous studies have been undertaken preferentially in populations where the exposure is more prevalent, as might be expected in studies focused on occupational risks, this will have given an inflated estimate of the average contribution of occupation. Our figures might also be lower because we have not included exposure to gases and fumes and because we asked about dust exposure lasting at least 10 years, so excluding short term effects. Nevertheless, we are not the first to suggest that the effects of occupation on airflow obstruction reported in the literature may have been exagerated.[26]

An association between tuberculosis and CAO has been known for many years in addition to any association with reduced lung volumes,[27] and in our study the RR was very consistent across sites. Our definition of tuberculosis is based on a self-reported history. It seems unlikely that people would not know if they had been treated for tuberculosis, though there might be reluctance in some communities to admit to the diagnosis. In many sites there was no mention of tuberculosis by any of the participants, but in sites with a high burden of tuberculosis, CAO attributable to tuberculosis was a substantial problem. In Uitsig and Ravensmead (South Africa) 4% of men and 2.05% of women aged ≥40 have CAO attributable to tuberculosis.

The GBD programme is the most comprehensive attempt to estimate attributable risks for COPD as they relate to mortality and disability-adjusted life-years lost.[7] Both the GBD

analysis and the current analysis agree that the most important risk factor is tobacco smoking, but the GBD analysis places particulate air pollution and indoor pollution as the next most important factors. We were not able to find any association between CAO and burning solid fuels in previous BOLD analyses.[28] Three large Chinese cohorts that have recorded both lung function and cooking fuel use have also failed to show any such association.[29-31] The main evidence for the contrary view comes from small studies which are more prone to the play of chance and which demonstrate a strong publication bias.[32] The evidence from BOLD does not support the view that indoor air pollution causes a substantial amount of CAO. We do not have individual data on personal exposure to outdoor air pollution in this study and did not investigate this further in this analysis.

In order to present findings that are intuitively accessible, we have reported results with reference to the prevalence of CAO. We have defined this by the lower limit of normal using NHANES III equations for European Americans.[10] The use of a single standard for all population groups is reasonable for the FEV_1/FVC ratio, while this is not true for the FEV_1 and the FVC on their own. Kiefer et al. showed that whereas >10% of the variance in the FEV_1 or FVC was explained by ethnicity in the NHANES III study,[33] this was <1% for the FEV_1/FVC ratio. We have selected the 5^{th} centile as the definition of "normal". This is an arbitrary cut-off to define CAO and, although it does determine the nominal prevalence of "CAO", it does not affect the estimate of PAR.[34]

The sites in BOLD were selected to represent all the regions defined by the GBD except for Latin America and the high-income countries of Asia Pacific. We also failed to find a site in Oceania. Within this plan, the sites were self-selecting as they had to have local teams able and willing to take on the project. The stipulation that the sampled population had to have a size of at least 150,000 individuals prevented very small and unrepresentative populations

from being selected, but the sites themselves are not strictly representative of the regions. The very consistent RRs estimates across sites suggest that these could be used to estimate local PAR for other areas, if local estimates of the prevalence of risk factors and CAO are known.

Exposure to all the risk factors were assessed by self-report, as in most other similar studies. Differences in reporting across sites do not appear to have affected the RRs, which appear to be very consistent across sites. Differences in reporting will, however, have had more influence on the estimated prevalence of the risk factors, which could have affected the estimates of attributable risk.

Attributable risks can sum to more than 1.[35] All estimates of attributable risk make a strong assumption that the estimated associations are entirely causal. Some parts of these associations, however, are either confounded or the product of reverse causation. Mutual adjustment of the RRs used in the current analysis reduces the problem of confounding, but does not eliminate it, and does not address the issue of reverse causation. We estimated risk from cross-sectional rather than longitudinal data. In a chronic irreversible condition this is likely to lead to less bias than with some other conditions, but differences in mortality in different risk groups may still bias the RR estimates. Other risks of bias include the "healthy worker"[36] and even a "healthy smoker"[37] effect that can lead people with poorer health to avoid certain risky exposures possibly including, in this case, dusty jobs and smoking. We are unable to address this limitation further in a cross-sectional study. With all these limitations, the risk factors considered in this analysis account for, on average, 64.6% of CAO in men and 48.1% in women. The measurement of some of the risk factors was very crude and with better measurements we would expect to explain more of the condition,

and addition of other unmeasured risks such as a more specific estimate of wealth might also have accounted for more.

Conclusions

There is substantial variation in the prevalence of CAO and the single most important risk factor globally remains tobacco smoking, followed by measures that we interpret as indicators of deprivation, such as poor education and low BMI. Passive smoking is also an important risk factor. Of the more specific risk factors, >10 years in a dusty job is associated with CAO, but the risk attributable to this exposure in the BOLD sites is less than some previous reports have suggested. Dusty jobs need further investigation to identify the main contributing occupations and exposures and how these can be remediated. Tuberculosis is also an important risk factor in areas where this disease is still common. More needs to be done to understand the link between poor education and the prevalence of CAO. Local estimates of PARs are important for prioritising public health programmes, and these results should contribute to this process.

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Table 1A. Characteristics of study population and prevalence of risk factors in 41 sites (men).

					Smoking (Pack-years)						Education				
Site	Sample size	Age (Mean)	BMI (Mean)	Underweight (%)	Never-smokers (%)	(1-5) (%)	(6-15) (%)	(16-25) (%)	(25+) (%)	Passive smoking (%)	None to primary school (%)	Secondary school (%)	More than secondary school (%)	History of TB (%)	Dusty job, >10y(%)
Albania (Tirana)	467	56.40	27.81	0.21	37.04	0.86	7.92	8.57	45.61	22.91	13.06	46.68	40.26	1.07	55.89
Algeria (Annaba)	442	53.34	25.74	3.85	23.53	7.01	16.29	16.52	36.65	5.88	32.13	36.88	31	3.39	42.08
Australia (Sydney)	251	58.33	28.02	0.40	39.44	15.94	12.35	11.55	20.72	10.76	2.39	31.47	66.14	1.20	26.69
Austria (Salzburg)	685	57.87	26.68	0.58	35.62	10.80	12.99	13.72	26.86	19.27	8.47	65.26	26.28	2.48	23.36
Benin (Sèmè-Kpodji)	237	53.22	24.61	4.22	95.78	1.27	1.69	0.84	0.42	0	68.78	25.32	5.91	0.84	31.65
Cameroon (Limbe)	171	52.42	25.20	1.75	63.16	9.94	15.20	5.85	5.85	2.92	53.22	34.50	12.28	0.58	50.29
Canada (Vancouver)	343	54.43	27.07	0.58	34.11	19.83	12.83	9.91	23.32	6.71	2.04	18.08	79.88	3.21	16.33
China (Guangzhou)	236	54.03	23.30	5.08	18.64	6.36	14.83	21.61	38.56	18.64	20.76	63.14	16.10	4.66	30.93
England (London)	323	57.92	27.55	0.31	28.17	12.38	16.72	11.76	30.96	15.17	5.88	40.25	53.87	2.17	21.05
Estonia (Tartu)	307	59.97	28.32	0.98	36.16	11.07	15.64	12.70	24.43	10.42	2.93	44.95	52.12	7.82	23.78
Germany (Hannover)	349	58.56	27.71	0.57	26.93	12.89	16.05	14.04	30.09	15.19	1.43	63.32	35.24	3.15	20.06
Iceland (Reykjavik)	403	55.90	28.30	0.50	29.28	19.60	11.17	16.87	23.08	16.38	7.20	14.64	78.16	3.97	24.32
India (Kashmir)	411	51.62	21.80	10.22	23.60	2.19	7.06	1.70	65.45	61.80	73.24	22.87	3.89	0.24	0.73
India (Mumbai)	275	51.44	23.45	8.36	84.36	2.91	6.18	4	2.55	0.36	11.27	51.27	37.45	0.36	8.36
India (Mysore)	256	47.96	24.61	2.73	77.73	3.13	11.33	4.30	3.52	0	12.89	42.58	44.53	0	3.52
India (Pune)	501	53.38	22.20	16.37	79.04	14.37	4.39	1.60	0.60	10.58	42.51	47.31	10.18	1.20	10.58
Jamaica	243	56.94	24.04	9.05	35.80	8.23	11.93	12.76	31.28	12.76	27.57	61.32	11.11	0.41	54.32
Kyrgyztan (Chui)	270	52.95	26.22	1.11	22.59	12.96	13.33	14.44	36.67	1.85	1.11	52.59	46.30	1.48	32.96
Kyrgyztan (Naryn)	315	52.83	25.19	2.22	39.37	12.70	17.14	10.79	20	0.32	4.76	40	55.24	0.32	6.67
Malawi (Blantyre)	160	53.73	22.98	10.63	69.38	15	10	3.13	2.50	3.13	47.50	46.88	5.63	4.38	18.75
Malawi (Chikwawa)	221	54.91	20.89	19.46	51.58	20.81	20.81	3.62	3.17	1.36	88.24	11.31	0.45	4.07	20.36
Malaysia (Penang)	340	54.98	25.78	2.94	50.29	5.88	13.53	8.53	21.76	16.47	32.06	61.47	6.47	0	35.88
Morocco (Fes)	354	56.51	25.85	1.98	40.68	10.73	12.99	9.89	25.71	7.91	65.25	23.16	11.58	1.13	53.67
Netherlands (Maastricht)	297	57.54	27.43	0	25.93	15.49	15.15	14.81	28.62	21.89	12.12	27.61	60.27	0.67	18.86
Nigeria (Ile-Ife)	345	56.17	23.83	5.22	76.52	15.36	5.22	1.45	1.45	1.74	34.78	39.13	26.09	0.87	25.80
Norway (Bergen)	323	58.94	26.86	0.62	29.10	9.91	20.43	18.89	21.67	24.46	5.57	54.18	40.25	0.62	35.91
Pakistan (Karachi)	268	54.29	25.09	8.58	51.49	10.07	11.94	7.46	19.03	9.33	44.40	38.06	17.54	0.37	34.70
Philippines (Manila)	378	52.16	24.37	8.73	16.14	15.87	21.69	16.14	30.16	39.68	7.67	71.43	20.90	10.58	40.21
Philippines (Nampicuan-Talugtug)	356	53.79	21.35	20.51	23.03	5.90	13.76	20.51	36.80	36.52	16.29	69.94	13.76	5.06	25.28
Poland (Krakow)	265	55.26	27.43	0	20.75	6.04	15.09	16.98	41.13	40.75	34.72	52.08	13.21	3.77	57.36
Portugal (Lisbon)	331	63.98	27.97	0	38.37	10.27	6.65	8.76	35.95	11.18	44.41	31.12	24.47	5.74	45.62
Saudi Arabia (Riyadh)	371	50.66	29.59	0.81	51.75	5.12	9.97	9.70	23.45	3.23	20.75	44.47	34.77	2.70	19.41
South Africa (Uitsig & Ravensmead)	311	53.56	24.64	11.25	15.76	14.47	30.87	19.61	19.29	47.59	40.51	50.80	8.68	19.61	38.26
Sri Lanka	457	54.15	23.17	13.35	51.42	18.16	17.29	6.56	6.56	5.03	30.85	66.74	2.41	1.09	43.54
Sudan (Gezeira)	298	55.44	23.94	8.72	52.68	16.44	15.44	7.38	8.05	6.71	64.43	27.52	8.05	0.34	27.18
Sudan (Khartoum)	306	55.74	25.17	5.88	61.44	8.82	14.05	6.86	8.82	4.25	55.56	29.74	14.71	0.65	21.90
Sweden (Uppsala)	283	58.45	27.22	0	31.45	18.73	19.08	12.37	18.37	6.71	13.78	37.81	48.41	0.71	27.56
Trinidad & Tobago	435	55.46	26.98	2.30	48.97	7.36	11.03	10.80	21.84	17.47	37.47	39.77	22.76	0	40.23
Tunisia (Sousse)	309	53.33	26.94	1.62	20.06	1.29	8.41	18.12	52.10	20.39	35.92	47.25	16.83	0	51.78
Turkey (Adana)	389	53.80	27.66	0.77	19.02	7.97	11.05	14.14	47.81	44.99	72.75	22.11	5.14	2.83	49.10
USA (Lexington, KY)	205	57.20	30.29	0	20.98	13.17	6.83	4.88	54.15	28.78	2.44	50.73	46.83	1.46	51.71

Table 1B. Characteristics of study population and prevalence of risk factors in 41 sites (women).

					Smoking (Pack-years)						Education				
Site	Sample size	Age (Mean)	BMI (Mean)	Underweight (%)	Never-smokers (%)	(1-5) (%)	(6-15) (%)	(16-25) (%)	(25+) (%)	Passive smoking (%)	None to primary school (%)	Secondary school (%)	More than secondary school (%)	History of TB (%)	Dusty job, >10y (%)
Albania (Tirana)	472	52.79	28.28	0.64	88.56	1.69	4.24	3.60	1.91	45.55	12.08	48.73	39.19	0.42	48.09
Algeria (Annaba)	448	51.65	30.84	0.22	99.33	0.22	0.22	0	0.22	17.19	50	38.62	11.38	1.12	5.36
Australia (Sydney)	265	58.93	27.92	0.38	52.08	13.21	11.70	8.30	14.72	11.70	3.77	39.25	56.98	0.38	12.08
Austria (Salzburg)	573	57.41	26.12	1.57	55.67	8.55	13.96	8.73	13.09	25.48	13.96	63.53	22.51	2.97	13.61
Benin (Sèmè-Kpodji)	308	50.50	28.07	3.25	100	0	0	0	0	0.32	84.09	14.61	1.30	0.32	13.96
Cameroon (Limbe)	116	51.95	28.75	2.59	99.14	0.86	0	0	0	1.72	63.79	30.17	6.03	1.72	62.07
Canada (Vancouver)	483	57.20	26.45	1.04	49.69	13.46	12.42	8.70	15.73	5.38	2.48	24.22	73.29	3.11	9.73
China (Guangzhou)	236	54.22	23.38	5.51	93.64	1.69	1.69	0.42	2.54	28.81	37.71	53.81	8.47	2.12	27.54
England (London)	354	58.39	26.69	1.13	42.94	12.15	14.41	9.89	20.62	17.51	5.37	38.98	55.65	2.82	6.78
Estonia (Tartu)	305	61.72	28.62	1.31	68.52	11.15	10.49	6.89	2.95	18.36	3.28	43.61	53.11	7.21	15.74
Germany (Hannover)	334	57.64	26.84	0.90	50	9.28	11.98	10.48	18.26	22.16	1.80	73.65	24.55	4.19	8.08
Iceland (Reykjavik)	354	57.03	27.53	0.28	38.70	16.38	16.95	11.86	16.10	17.51	10.45	43.79	45.76	5.65	5.93
India (Kashmir)	341	51.13	23.18	10.26	70.97	1.76	1.76	0.29	25.22	68.62	91.79	6.74	1.47	0.59	0
India (Mumbai)	165	50.41	24.43	7.27	100	0	0	0	0	2.42	37.58	47.27	15.15	1.82	1.21
India (Mysore)	345	45.91	24.77	5.51	98.55	0.58	0.29	0.58	0	0	25.22	51.01	23.77	0	1.16
India (Pune)	341	51.06	21.82	22.29	99.71	0	0	0	0.29	12.02	78.89	19.35	1.76	0.29	2.64
Jamaica	335	55.13	30.05	2.99	81.49	6.87	5.37	3.28	2.99	17.91	19.70	65.37	14.93	0.90	17.91
Kyrgyzstan (Chui)	588	52.96	29.55	1.02	92.35	3.40	1.70	1.87	0.68	9.69	3.57	57.48	38.95	1.19	16.33
Kyrgyzstan (Naryn)	505	53.66	28.11	1.58	97.43	2.18	0	0	0.40	4.75	5.74	37.62	56.63	0.99	1.19
Malawi (Blantyre)	241	51.27	26.42	3.73	97.51	1.24	0.83	0.41	0	2.90	66.80	29.88	3.32	6.22	11.62
Malawi (Chikwawa)	211	52.69	22.68	12.32	88.63	5.21	3.79	0.47	1.90	5.21	93.84	5.69	0.4	3.79	2.84
Malaysia (Penang)	323	54.06	26.34	2.17	100	0	0	0	0	35.29	38.70	53.56	7.74	0	12.38
Morocco (Fes)	414	53.93	29.62	1.21	99.03	0	0.24	0.24	0.48	18.84	84.30	12.56	3.14	2.17	13.04
Netherlands (Maastricht)	289	57.54	27.46	1.04	39.79	10.73	14.88	11.76	22.84	17.99	13.84	36.33	49.83	2.08	4.84
Nigeria (Ile-Ife)	538	54.84	26.32	5.02	96.28	2.97	0.56	0.19	0	1.67	56.69	27.14	16.17	0.19	12.08
Norway (Bergen)	334	60.56	26.25	1.20	42.22	8.38	22.46	13.17	13.77	18.56	9.28	57.19	33.53	0	18.56
Pakistan (Karachi)	339	49.38	27.55	3.83	92.04	2.06	0.88	1.18	3.83	15.34	67.55	20.06	12.39	0.59	9.14
Philippines (Manila)	515	52.48	25.30	5.24	68.93	16.12	8.54	3.11	3.30	55.15	12.23	63.50	24.27	5.24	19.03
Philippines (Nampicuan-Talugtug)	366	54.33	21.74	21.58	69.95	9.56	11.75	5.74	3.01	55.74	15.30	71.04	13.66	2.19	13.66
Poland (Krakow)	257	55.92	28.03	1.56	55.64	10.12	14.40	10.51	9.34	38.91	41.25	44.36	14.40	1.56	22.96
Portugal (Lisbon)	379	62.80	28.44	0.26	78.10	5.80	5.54	1.58	8.97	19.79	49.87	33.25	16.89	3.69	39.31
Saudi Arabia (Riyadh)	325	49.95	33.14	0.31	97.85	0	0.62	0.31	1.23	7.69	54.77	30.77	14.46	0.92	1.23
South Africa (Uitsig & Ravensmead)	529	54.47	29.79	5.48	42.16	11.91	25.14	9.64	11.15	50.85	47.26	46.69	6.05	12.48	22.87
Sri Lanka	566	53.41	25.05	7.07	99.82	0	0	0.18	0	11.31	24.56	72.44	3	0.53	12.01
Sudan (Gezeira)	277	52.27	28.86	0.72	98.56	1.08	0.36	0	0	17.69	66.79	27.08	6.14	0.72	7.58
Sudan (Khartoum)	210	51.51	28.32	7.62	97.14	1.43	0.95	0.48	0	11.90	57.62	30.95	11.43	1.43	5.71
Sweden (Uppsala)	264	58.35	26.79	0	47.35	13.26	15.53	10.98	12.88	5.30	12.12	37.12	50.76	1.52	9.47
Trinidad & Tobago	656	53.26	30.20	2.44	87.96	3.20	3.51	2.44	2.90	26.22	39.18	41.01	19.82	0	10.52
Tunisia (Sousse)	352	52.71	31.26	0.85	90.91	1.70	3.98	1.14	2.27	51.14	65.06	29.55	5.40	0	25.57
Turkey (Adana)	417	53.47	31.45	0.48	69.54	9.59	8.63	5.76	6.47	63.07	84.41	13.67	1.92	2.16	29.26
USA (Lexington, KY)	302	56.18	31.11	0.33	45.70	7.95	7.28	8.28	30.79	32.12	2.98	48.68	48.34	1.99	16.23

Table 2. Prevalence of chronic airflow obstruction (CAO) by site and sex.

	Men			Women		
Site	Sample size	CAO N	CAO %	Sample size	CAO N	CAO %
Albania (Tirana)	467	60	12.85	472	20	4.24
Algeria (Annaba)	442	41	9.28	448	20	4.46
Australia (Sydney)	251	19	7.57	265	35	13.21
Austria (Salzburg)	685	88	12.85	573	111	19.37
Benin (Sèmè-Kpodji)	237	18	7.59	308	24	7.79
Cameroon (Limbe)	171	9	5.26	116	4	3.45
Canada (Vancouver)	343	44	12.83	483	58	12.01
China (Guangzhou)	236	22	9.32	236	15	6.36
England (London)	323	52	16.10	354	56	15.82
Estonia (Tartu)	307	27	8.79	305	16	5.25
Germany (Hannover)	349	35	10.03	334	26	7.78
Iceland (Reykjavik)	403	36	8.93	354	47	13.28
India (Kashmir)	411	71	17.27	341	53	15.54
India (Mumbai)	275	17	6.18	165	13	7.88
India (Mysore)	256	29	11.33	345	19	5.51
India (Pune)	501	29	5.79	341	23	6.74
Jamaica	243	25	10.29	335	25	7.46
Kyrgyzstan (Chui)	270	39	14.44	588	47	7.99
Kyrgyzstan (Naryn)	315	36	11.43	505	25	4.95
Malawi (Blantyre)	160	11	6.88	241	22	9.13
Malawi (Chikwawa)	221	40	18.10	211	20	9.48
Malaysia (Penang)	340	15	4.41	323	11	3.41
Morocco (Fes)	354	42	11.86	414	31	7.49
Netherlands (Maastricht)	297	57	19.19	289	50	17.30
Nigeria (Ile-Ife)	345	26	7.54	538	36	6.69
Norway (Bergen)	323	48	14.86	334	34	10.18
Pakistan (Karachi)	268	39	14.55	339	22	6.49
Philippines (Manila)	378	49	12.96	515	27	5.24
Philippines (Nampicuan-Talugtug)	356	58	16.29	366	45	12.30
Poland (Krakow)	265	40	15.09	257	31	12.06
Portugal (Lisbon)	331	46	13.90	379	36	9.50
Saudi Arabia (Riyadh)	371	13	3.50	325	9	2.77
South Africa (Uitsig & Ravensmead)	311	73	23.47	529	86	16.26
Sri Lanka	457	54	11.82	566	22	3.89
Sudan (Gezeira)	298	17	5.70	277	15	5.42
Sudan (Khartoum)	306	32	10.46	210	21	10.00
Sweden (Uppsala)	283	29	10.25	264	22	8.33
Trinidad & Tobago	435	28	6.44	656	44	6.71
Tunisia (Sousse)	309	26	8.41	352	7	1.99
Turkey (Adana)	389	77	19.79	417	38	9.11
USA (Lexington, KY)	205	28	13.66	302	49	16.23

Table 3. Mean and range of population attributable risks (PAR)* for chronic airflow obstruction across study sites by risk factor and sex.

	Men		Women	
PAR by risk factor	Mean	(Min, Max)	Mean	(Min, Max)
Smoking	5.07	(0.53, 11.7)	2.11	(0, 9.46)
Poor education#	2.33	(0.65, 6.25)	1.37	(0.34, 4.32)
Passive smoking	0.31	(0, 1.64)	0.48	(0, 2.18)
History of tuberculosis	0.36	(0, 3.77)	0.26	(0, 2.05)
Working in a dusty job, (>10 years)	0.65	(0.02, 1.6)	0.29	(0, 0.9)
Underweight	0.43	(0, 3)	0.30	(0, 1.52)
Total PAR (unadjusted)†	9.15	(2.6, 27.79)	4.81	(0.92, 15.77)
Total PAR (adjusted)‡	7.24	(2.21, 18.17)	4.14	(0.94, 11.21)
Total prevalence	11.2		8.6	
% Prevalence explained	64.6		48.1	

*PAR represents the percentage of the total population (aged ≥40 years) with chronic airflow obstruction attributable to the specified risk factor. #Poor education, defined as having secondary school or less. †The total unadjusted PAR is the sum of all estimates across all causes. It is slightly different from the sum of the figures reported above because it is computed from the individual sites and there is some rounding effect. ‡The total adjusted PAR is obtained using equations 2.1 and 2.2 in the methods section and is slightly less than the unadjusted PAR.

Table S1. Sampling strategy and response rate for each site.

Site	Sampling design	N	N*	N**	Response rate (%)	Cooperation rate (%)
Albania (Tirana)	Cluster sample	997	941	939	82	84
Algeria (Annaba)	Stratified random sample	917	892	890	95	95
Australia (Sydney)	Stratified random sample	585	541	516	25	33
Austria (Salzburg)	Stratified random sample	1349	1258	1,258	65	67
Benin (Sèmè-Kpodji)	Stratified cluster sample	848	694	545	97	97
Cameroon (Limbe)	Stratified random sampling	433	321	287	71	71
Canada (Vancouver)	Random digit dialling	856	827	826	26	51
China (Guangzhou)	Stratified random sample	602	473	472	87	87
England (London)	Stratified random sample	697	677	677	17	37
Estonia (Tartu)	Stratified random sample	658	615	612	49	70
Germany (Hannover)	Stratified random sample	713	683	683	59	61
Iceland (Reykjavik)	Simple random sample	758	757	757	81	84
India (Kashmir)	Stratified cluster sample	953	763	752	87	88
India (Mumbai)	Stratified cluster sample	515	440	440	55	66
India (Mysore)	Cluster sample	725	601	601	98	99
India (Pune)	Simple random sample	1388	849	842	97	97
Jamaica	Cluster sampling	796	578	578	89	90
Kyrgyzstan (Chui)	Cluster sample	1070	891	858	98	100
Kyrgyzstan (Naryn)	Cluster sample	1105	859	820	98	100
Malawi (Blantyre)	Stratified random sample	586	403	401	85	85
Malawi (Chikwawa)	Stratified random sampling	828	448	432	100	100
Malaysia (Penang)	Stratified random sample	713	670	663	59	88
Morocco (Fes)	Cluster sample	966	769	768	98	98
Netherlands (Maastricht)	Stratified random sample	634	590	586	48	55
Nigeria (Ile-Ife)	Stratified cluster sample	1148	904	883	76	98
Norway (Bergen)	Stratified random sample	707	658	657	68	71
Pakistan (Karachi)	Cluster sampling	1052	610	607	63	100
Philippines (Manila)	Stratified cluster sample	918	893	893	58	58
Philippines (Nampicuan-Talugtug)	Stratified cluster sample	991	722	722	86	86
Poland (Krakow)	Stratified random sample	603	526	522	78	79
Portugal (Lisbon)	Stratified cluster sample	745	714	710	10	27
Saudi Arabia (Riyadh)	Stratified random sample	784	700	696	98	98
South Africa (Uitsig & Ravensmead)	Cluster sample	896	847	840	63	68
Sri Lanka	Stratified cluster sample	1184	1036	1,023	85	85
Sudan (Gezeira)	Cluster sampling	834	590	575	79	79
Sudan (Khartoum)	Simple random sampling	595	516	516	93	93
Sweden (Uppsala)	Stratified random sample	588	547	547	61	63
Trinidad & Tobago	Stratified random sampling	1387	1097	1,091	100	100
Tunisia (Sousse)	Stratified cluster sample	717	661	661	90	92
Turkey (Adana)	Stratified cluster sample	875	806	806	82	85
USA (Lexington, KY)	Random digit dialling	563	508	507	14	27

The response rate is the number with complete information for this analysis divided by the total number of people contacted. The cooperation rate is the number of responders divided by the total number of responders plus active refusers. N, total number of responders: defined as participants who completed the core questionnaire and have post-bronchodilator spirometry; N*, participants with post-bronchodilator FEV_1/FVC; N**, Non-missing data for this analysis.

Table S2A. Population attributable risks for chronic airflow obstruction, expressed as percent of total population aged ≥40 years, with 95% credible intervals, by risk factors and site (men).

Site	Smoking	Poor education	Passive smoking	History of tuberculosis	Dusty job, >10 years	Underweight	Total PAR
Albania (Tirana)	7.78 (5.76 - 10.10)	2.23 (1.12 - 3.67)	0.40 (-0.85 - 1.11)	0.30 (0.08 - 0.77)	1.35 (-0.07 - 2.77)	0.04 (0.00 - 0.24)	9.36 (7.16 - 11.95)
Algeria (Annaba)	5.17 (3.46 - 7.40)	1.92 (1.00 - 3.26)	0.11 (-0.07 - 0.40)	0.46 (0.15 - 1.04)	0.58 (-0.23 - 1.39)	0.41 (0.08 - 1.03)	6.65 (4.72 - 9.05)
Australia (Sydney)	3.91 (2.15 - 6.37)	0.79 (0.13 - 1.85)	0.20 (-0.09 - 0.71)	0.38 (0.08 - 1.13)	0.28 (-0.10 - 0.91)	0.20 (0.00 - 0.77)	4.84 (2.92 - 7.60)
Austria (Salzburg)	5.71 (4.19 - 7.49)	2.37 (0.89 - 4.08)	0.42 (-0.03 - 1.08)	0.30 (0.10 - 0.66)	0.48 (-0.06 - 1.07)	0.05 (-0.04 - 0.23)	7.62 (5.89 - 9.68)
Benin (Sèmè-Kpodji)	0.53 (0.05 - 1.59)	2.35 (1.17 - 4.12)	/	0.10 (0.00 - 0.58)	0.58 (-0.12 - 1.49)	0.33 (0.01 - 1.11)	3.53 (1.99 - 5.69)
Cameroon (Limbe)	2.09 (0.71 - 4.82)	1.33 (0.50 - 2.84)	0.09 (-0.07 - 0.52)	0.34 (0.05 - 1.25)	0.43 (-0.19 - 1.33)	0.12 (-0.00 - 0.76)	3.58 (1.69 - 6.57)
Canada (Vancouver)	6.15 (4.05 - 9.05)	0.65 (0.05 - 1.44)	0.04 (-0.06 - 0.22)	0.27 (0.05 - 0.77)	0.24 (-0.10 - 0.69)	0.14 (0.00 - 0.60)	6.93 (4.72 - 9.80)
China (Guangzhou)	5.70 (3.34 - 8.94)	1.81 (0.57 - 3.52)	0.47 (-0.08 - 1.42)	0.39 (0.07 - 1.17)	0.60 (-0.09 - 1.61)	0.50 (0.09 - 1.40)	7.18 (4.59 - 10.65)
England (London)	7.75 (5.20 - 10.78)	1.90 (-0.01 - 3.64)	0.29 (-0.37 - 0.90)	0.36 (0.09 - 0.97)	0.95 (0.04 - 2.10)	0.10 (-0.14 - 0.50)	9.58 (6.65 - 12.88)
Estonia (Tartu)	4.75 (2.79 - 7.60)	0.95 (-0.11 - 2.02)	0.20 (-0.16 - 0.65)	0.40 (0.07 - 1.02)	0.16 (-0.20 - 0.56)	0.05 (-0.03 - 0.38)	5.61 (3.46 - 8.42)
Germany (Hannover)	5.63 (3.66 - 8.25)	1.79 (0.35 - 3.60)	0.29 (-0.10 - 0.89)	0.27 (0.05 - 0.78)	0.50 (0.01 - 1.21)	0.05 (-0.00 - 0.36)	6.91 (4.71 - 9.77)
Iceland (Reykjavik)	4.07 (2.51 - 6.09)	0.94 (0.38 - 1.83)	0.19 (-0.17 - 0.58)	0.23 (0.04 - 0.69)	0.29 (-0.16 - 0.83)	0.12 (0.00 - 0.49)	5.07 (3.33 - 7.19)
India (Kashmir)	10.58 (8.06 - 13.53)	5.00 (2.59 - 7.51)	1.05 (-0.95 - 2.64)	0.06 (0.00 - 0.34)	0.02 (-0.02 - 0.15)	0.47 (-0.32 - 1.20)	13.02 (10.18 - 16.24)
India (Mumbai)	2.40 (1.10 - 4.69)	1.05 (0.17 - 2.20)	0.02 (-0.02 - 0.18)	0.22 (0.02 - 0.79)	0.24 (-0.04 - 0.78)	0.40 (0.03 - 1.16)	3.64 (1.99 - 6.05)
India (Mysore)	2.52 (1.01 - 4.60)	2.00 (0.90 - 3.60)	/	/	0.08 (-0.02 - 0.39)	0.18 (-0.00 - 0.70)	4.83 (2.82 - 7.43)
India (Pune)	0.65 (0.11 - 1.48)	1.38 (0.64 - 2.38)	0.10 (-0.06 - 0.33)	0.19 (0.04 - 0.57)	0.12 (-0.04 - 0.39)	0.87 (0.29 - 1.77)	2.78 (1.68 - 4.19)
Jamaica	4.99 (2.88 - 8.07)	2.46 (1.12 - 4.53)	0.23 (-0.12 - 0.80)	0.10 (0.00 - 0.55)	0.64 (-0.32 - 1.69)	0.90 (0.22 - 2.16)	7.16 (4.65 - 10.60)
Kyrgyzstan (Chui)	6.60 (4.15 - 9.91)	1.38 (0.09 - 2.87)	0.06 (-0.05 - 0.32)	0.21 (0.03 - 0.76)	0.95 (0.01 - 2.18)	0.18 (0.02 - 0.74)	8.17 (5.50 - 11.57)
Kyrgyzstan (Naryn)	3.69 (1.98 - 6.00)	1.48 (0.38 - 2.93)	0.02 (-0.03 - 0.16)	0.07 (0.00 - 0.43)	0.16 (-0.04 - 0.53)	0.06 (-0.01 - 0.36)	4.98 (3.01 - 7.46)
Malawi (Blantyre)	1.94 (0.58 - 4.44)	2.05 (0.86 - 4.09)	0.04 (-0.04 - 0.33)	0.15 (0.00 - 0.86)	0.20 (-0.15 - 0.80)	0.91 (0.14 - 2.45)	4.30 (2.16 - 7.42)
Malawi (Chikwawa)	4.09 (1.66 - 7.60)	6.25 (3.52 - 9.57)	0.03 (-0.04 - 0.23)	0.72 (0.20 - 1.74)	1.23 (0.07 - 2.89)	2.44 (0.86 - 4.75)	11.21 (7.83 - 15.38)

Site	Smoking	Poor education	Passive smoking	History of tuberculosis	Dusty job, >10 years	Underweight	Total PAR
Malaysia (Penang)	2.30 (1.18 - 4.04)	0.84 (0.29 - 1.77)	0.07 (-0.08 - 0.32)	/	0.51 (-0.01 - 1.29)	0.05 (-0.04 - 0.33)	3.09 (1.82 - 5.07)
Morocco (Fes)	4.73 (3.01 - 7.02)	3.12 (1.57 - 4.97)	0.17 (-0.08 - 0.58)	0.27 (0.06 - 0.77)	1.00 (-0.64 - 2.22)	0.12 (-0.04 - 0.50)	7.38 (5.14 - 10.05)
Netherlands (Maastricht)	10.11 (7.12 - 13.85)	2.70 (1.25 - 4.61)	0.49 (-0.49 - 1.40)	0.08 (0.00 - 0.45)	0.59 (-0.22 - 1.48)	/	11.95 (8.73 - 15.79)
Nigeria (Ile-Ife)	0.69 (0.03 - 1.68)	1.66 (0.79 - 2.92)	0.02 (-0.03 - 0.15)	0.28 (0.06 - 0.83)	0.27 (-0.20 - 0.75)	0.11 (-0.05 - 0.48)	2.77 (1.57 - 4.39)
Norway (Bergen)	6.39 (4.14 - 9.64)	2.66 (1.03 - 4.67)	0.56 (-0.17 - 1.43)	0.07 (0.00 - 0.42)	0.92 (-0.18 - 2.06)	0.15 (0.01 - 0.61)	8.83 (6.23 - 12.18)
Pakistan (Karachi)	4.74 (2.75 - 7.34)	3.74 (2.00 - 6.05)	0.34 (-0.10 - 1.06)	0.09 (0.00 - 0.52)	1.60 (0.29 - 3.45)	0.45 (-0.08 - 1.27)	8.64 (5.93 - 11.87)
Philippines (Manila)	6.46 (4.25 - 9.09)	2.63 (0.79 - 4.60)	0.72 (-0.32 - 1.76)	1.27 (0.54 - 2.26)	1.25 (-0.02 - 2.73)	0.49 (-0.43 - 1.25)	9.21 (6.61 - 12.14)
Philippines (Nampicuan-Talugtug)	8.48 (6.08 - 11.48)	3.11 (1.22 - 5.17)	0.83 (-0.23 - 1.94)	1.00 (0.44 - 1.92)	0.72 (-0.21 - 1.61)	2.12 (0.61 - 3.85)	11.72 (8.92 - 14.96)
Poland (Krakow)	8.75 (5.85 - 12.36)	3.50 (1.74 - 5.69)	1.10 (-0.17 - 2.72)	0.08 (0.00 - 0.47)	1.44 (-0.30 - 3.17)	/	11.21 (8.06 - 14.93)
Portugal (Lisbon)	6.31 (4.30 - 8.98)	3.30 (1.81 - 5.25)	0.14 (-0.12 - 0.51)	0.95 (0.40 - 1.90)	1.50 (0.22 - 3.21)	/	9.29 (6.76 - 12.42)
Saudi Arabia (Riyadh)	1.59 (0.69 - 3.02)	0.65 (0.17 - 1.48)	0.04 (-0.04 - 0.23)	0.06 (0.00 - 0.37)	0.13 (-0.04 - 0.44)	0.13 (0.00 - 0.55)	2.21 (1.14 - 3.84)
South Africa (Uitsig & Ravensmead)	11.70 (8.32 - 16.13)	6.22 (3.79 - 9.25)	1.64 (-0.12 - 3.49)	3.77 (2.21 - 5.77)	1.46 (0.08 - 3.04)	3.00 (1.64 - 5.01)	18.17 (14.30 - 22.49)
Sri Lanka	3.09 (1.68 - 4.90)	2.80 (1.32 - 4.49)	0.05 (-0.06 - 0.23)	0.13 (0.02 - 0.47)	0.51 (-0.43 - 1.27)	1.37 (0.60 - 2.63)	6.36 (4.40 - 8.60)
Sudan (Gezeira)	1.32 (0.42 - 2.83)	1.60 (0.75 - 2.91)	0.05 (-0.04 - 0.28)	0.08 (0.00 - 0.47)	0.35 (-0.13 - 0.94)	0.63 (0.14 - 1.57)	3.30 (1.86 - 5.26)
Sudan (Khartoum)	1.93 (0.78 - 3.66)	2.65 (1.35 - 4.43)	0.05 (-0.05 - 0.27)	0.19 (0.02 - 0.71)	0.30 (-0.13 - 0.89)	0.13 (-0.05 - 0.57)	4.61 (2.85 - 6.90)
Sweden (Uppsala)	4.76 (2.76 - 7.61)	1.64 (0.72 - 3.02)	0.13 (-0.10 - 0.52)	0.20 (0.02 - 0.74)	0.37 (-0.24 - 1.00)	/	6.11 (3.93 - 9.01)
Trinidad & Tobago	2.51 (1.40 - 4.13)	1.56 (0.74 - 2.76)	0.16 (-0.12 - 0.51)	/	0.70 (0.06 - 1.66)	0.18 (0.01 - 0.59)	4.06 (2.60 - 5.97)
Tunisia (Sousse)	4.40 (2.61 - 6.88)	1.96 (0.92 - 3.47)	0.10 (-0.18 - 0.42)	/	0.84 (-0.15 - 1.95)	0.06 (-0.01 - 0.40)	5.87 (3.80 - 8.61)
Turkey (Adana)	11.54 (8.83 - 14.85)	5.36 (2.86 - 7.90)	1.16 (-0.39 - 2.67)	0.41 (0.12 - 0.98)	1.39 (-0.39 - 2.96)	0.04 (-0.02 - 0.29)	14.72 (11.73 - 18.22)
USA (Lexington, KY)	9.34 (6.28 - 13.19)	1.59 (0.22 - 3.31)	0.56 (-0.26 - 1.63)	0.12 (0.00 - 0.63)	0.92 (-0.26 - 2.24)	/	10.45 (7.13 - 14.51)

The Total PAR is adjusted using equations 2.1. and 2.2 in the Methods section of the paper. The Total PAR is less than the sum of the individual estimates.

Table S2B. Population attributable risks for chronic airflow obstruction, expressed as percent of total population aged ≥40 years, with 95% credible intervals, by risk factors and site (women).

Site	Smoking	Poor education	Passive smoking	History of tuberculosis	Dusty job, >10 years	Underweight	Total PAR
Albania (Tirana)	0.64 (0.14 - 1.43)	0.52 (-0.26 - 1.23)	0.49 (-0.02 - 1.15)	0.06 (0.00 - 0.31)	0.66 (0.14 - 1.50)	0.05 (0.00 - 0.29)	2.01 (1.01 - 3.37)
Algeria (Annaba)	0.27 (-0.06 - 0.86)	0.76 (0.04 - 1.65)	0.19 (-0.01 - 0.53)	0.06 (0.00 - 0.34)	0.06 (-0.03 - 0.27)	0.05 (0.00 - 0.30)	1.36 (0.53 - 2.43)
Australia (Sydney)	5.05 (2.84 - 8.02)	1.12 (-0.86 - 2.89)	0.38 (-0.06 - 1.04)	0.10 (0.00 - 0.59)	0.14 (-0.13 - 0.54)	0.22 (0.03 - 0.79)	6.31 (3.84 - 9.38)
Austria (Salzburg)	5.98 (4.09 - 8.26)	2.65 (0.31 - 4.94)	1.06 (0.17 - 1.93)	0.38 (0.13 - 0.87)	0.90 (0.25 - 1.76)	0.16 (0.02 - 0.47)	9.31 (6.85 - 11.93)
Benin (Sèmè-Kpodji)	/	1.78 (0.10 - 3.58)	0.04 (-0.00 - 0.26)	0.09 (0.00 - 0.47)	0.20 (-0.04 - 0.64)	0.18 (0.02 - 0.66)	2.57 (0.84 - 4.51)
Cameroon (Limbe)	1.00 (-0.17 - 3.38)	1.03 (0.18 - 2.85)	0.09 (-0.01 - 0.65)	0.23 (0.01 - 1.27)	0.37 (-0.10 - 1.37)	0.50 (0.07 - 1.75)	2.68 (0.93 - 5.85)
Canada (Vancouver)	4.46 (2.69 - 6.55)	0.81 (-0.21 - 2.07)	0.25 (0.02 - 0.67)	0.39 (0.12 - 0.93)	0.23 (-0.04 - 0.62)	0.05 (0.00 - 0.29)	5.58 (3.69 - 7.74)
China (Guangzhou)	1.60 (0.51 - 3.52)	1.35 (0.05 - 2.96)	0.41 (-0.04 - 1.17)	0.12 (0.00 - 0.63)	0.22 (-0.19 - 0.77)	0.39 (0.07 - 1.18)	3.43 (1.73 - 5.91)
England (London)	7.45 (5.13 - 10.43)	1.19 (-0.63 - 3.06)	0.88 (0.21 - 1.84)	0.54 (0.16 - 1.26)	0.37 (-0.03 - 0.94)	0.25 (0.05 - 0.75)	9.13 (6.53 - 12.33)
Estonia (Tartu)	0.95 (0.10 - 2.23)	0.34 (-0.51 - 1.10)	0.20 (-0.04 - 0.63)	0.33 (0.07 - 0.99)	0.07 (-0.10 - 0.38)	0.07 (0.00 - 0.43)	1.83 (0.67 - 3.45)
Germany (Hannover)	2.81 (1.31 - 4.85)	0.79 (-0.66 - 2.28)	0.46 (-0.00 - 1.14)	0.20 (0.02 - 0.68)	0.18 (-0.06 - 0.63)	0.07 (0.00 - 0.41)	3.93 (2.18 - 6.24)
Iceland (Reykjavik)	5.72 (3.64 - 8.38)	0.95 (-0.62 - 2.31)	0.58 (0.03 - 1.34)	0.41 (0.11 - 1.04)	0.35 (-0.01 - 0.89)	0.06 (0.00 - 0.37)	7.06 (4.76 - 9.85)
India (Kashmir)	3.30 (1.50 - 5.42)	4.32 (1.19 - 7.65)	1.72 (-1.11 - 3.60)	0.20 (0.03 - 0.69)	/	0.95 (0.34 - 1.89)	8.38 (4.97 - 11.68)
India (Mumbai)	/	1.51 (0.20 - 3.42)	0.18 (0.01 - 0.76)	0.65 (0.15 - 1.79)	0.16 (-0.03 - 0.71)	0.33 (0.04 - 1.22)	3.28 (1.45 - 5.90)
India (Mysore)	0.49 (0.04 - 1.29)	1.01 (-0.03 - 2.42)	/	/	0.03 (-0.01 - 0.22)	0.27 (0.05 - 0.81)	1.83 (0.67 - 3.39)
India (Pune)	0.35 (-0.08 - 1.08)	1.51 (0.23 - 3.04)	0.07 (-0.05 - 0.33)	0.08 (0.00 - 0.46)	0.14 (0.00 - 0.51)	0.87 (0.30 - 1.77)	2.72 (1.35 - 4.53)
Jamaica	1.22 (0.35 - 2.58)	0.90 (-0.57 - 2.16)	0.17 (-0.06 - 0.57)	0.08 (0.00 - 0.44)	0.58 (0.08 - 1.39)	0.51 (0.15 - 1.24)	3.02 (1.50 - 4.93)
Kyrgyzstan (Chui)	0.76 (0.21 - 1.53)	0.60 (-0.67 - 1.73)	0.20 (0.00 - 0.54)	0.18 (0.04 - 0.54)	0.32 (-0.06 - 0.77)	0.04 (0.00 - 0.22)	1.98 (0.71 - 3.29)
Kyrgyzstan (Naryn)	0.32 (-0.11 - 0.92)	0.47 (-0.12 - 1.12)	0.02 (-0.01 - 0.15)	0.05 (0.00 - 0.30)	0.02 (-0.01 - 0.16)	0.04 (0.00 - 0.26)	0.94 (0.24 - 1.83)
Malawi (Blantyre)	0.49 (-0.19 - 1.50)	1.88 (0.44 - 3.91)	0.05 (-0.00 - 0.32)	0.43 (0.09 - 1.23)	0.55 (0.07 - 1.50)	0.09 (0.00 - 0.53)	3.26 (1.58 - 5.60)
Malawi (Chikwawa)	1.26 (0.00 - 2.91)	2.65 (0.73 - 5.11)	0.22 (-0.00 - 0.79)	0.69 (0.17 - 1.75)	0.05 (-0.02 - 0.37)	0.56 (0.11 - 1.45)	4.63 (2.45 - 7.56)

Site	Smoking	Poor education	Passive smoking	History of tuberculosis	Dusty job, >10 years	Underweight	Total PAR
Malaysia (Penang)	/	0.62 (-0.13 - 1.51)	0.24 (-0.10 - 0.72)	/	0.33 (0.03 - 0.92)	0.07 (0.00 - 0.42)	1.53 (0.62 - 2.87)
Morocco (Fes)	0.29 (-0.08 - 0.88)	1.86 (0.59 - 3.43)	0.50 (0.08 - 1.14)	0.25 (0.05 - 0.72)	0.19 (-0.04 - 0.55)	0.22 (0.05 - 0.67)	2.98 (1.60 - 4.71)
Netherlands (Maastricht)	6.75 (3.98 - 10.04)	1.09 (-1.43 - 2.58)	0.54 (-0.18 - 1.30)	0.52 (0.15 - 1.29)	0.28 (-0.02 - 0.81)	0.20 (0.03 - 0.71)	8.31 (5.31 - 11.74)
Nigeria (Ile-Ife)	0.33 (-0.36 - 0.87)	1.23 (0.24 - 2.37)	0.02 (-0.00 - 0.14)	0.05 (0.00 - 0.29)	0.21 (-0.04 - 0.57)	0.30 (0.08 - 0.74)	2.00 (0.91 - 3.28)
Norway (Bergen)	4.66 (2.70 - 7.32)	1.28 (-0.44 - 3.28)	0.92 (0.19 - 2.03)	0.08 (0.00 - 0.46)	0.36 (-0.15 - 0.97)	0.17 (0.02 - 0.62)	6.17 (3.96 - 9.13)
Pakistan (Karachi)	0.47 (-0.06 - 1.26)	1.16 (0.12 - 2.49)	0.07 (-0.04 - 0.33)	0.08 (0.00 - 0.45)	0.32 (0.02 - 0.90)	0.17 (0.02 - 0.61)	2.14 (0.92 - 3.77)
Philippines (Manila)	0.80 (0.06 - 1.74)	0.67 (-0.32 - 1.71)	0.64 (0.00 - 1.37)	0.37 (0.12 - 0.88)	0.04 (-0.06 - 0.20)	0.39 (0.13 - 0.91)	2.42 (1.27 - 3.87)
Philippines (Nampicuan-Talugtug)	2.22 (0.86 - 3.95)	1.47 (-1.11 - 3.37)	1.20 (-0.16 - 2.52)	0.29 (0.06 - 0.84)	0.48 (-0.16 - 1.15)	1.43 (0.55 - 2.61)	5.72 (3.31 - 8.26)
Poland (Krakow)	2.04 (0.53 - 3.89)	2.29 (0.18 - 4.56)	0.64 (-0.42 - 1.65)	0.10 (0.00 - 0.59)	0.67 (-0.04 - 1.62)	0.22 (0.02 - 0.82)	5.13 (2.78 - 7.93)
Portugal (Lisbon)	1.93 (0.94 - 3.45)	1.89 (0.19 - 3.62)	0.44 (0.01 - 1.08)	0.39 (0.11 - 0.99)	0.76 (-0.08 - 1.63)	0.06 (0.00 - 0.36)	4.52 (2.75 - 6.71)
Saudi Arabia (Riyadh)	0.38 (-0.06 - 1.21)	0.58 (0.08 - 1.48)	0.09 (0.00 - 0.39)	0.20 (0.03 - 0.71)	0.03 (-0.02 - 0.23)	0.07 (0.00 - 0.41)	1.26 (0.52 - 2.52)
South Africa (Uitsig & Ravensmead)	6.04 (4.01 - 8.60)	3.41 (1.24 - 5.89)	2.18 (0.68 - 3.76)	2.05 (1.24 - 3.18)	0.57 (-0.28 - 1.23)	1.52 (0.83 - 2.55)	11.03 (8.51 - 13.88)
Sri Lanka	0.22 (-0.05 - 0.67)	0.71 (-0.29 - 1.54)	0.12 (0.01 - 0.37)	0.05 (0.00 - 0.27)	0.23 (-0.00 - 0.62)	0.36 (0.12 - 0.83)	1.50 (0.60 - 2.54)
Sudan (Gezeira)	0.43 (-0.10 - 1.35)	1.11 (0.09 - 2.40)	0.09 (-0.04 - 0.41)	0.10 (0.00 - 0.55)	0.09 (-0.02 - 0.42)	0.08 (0.00 - 0.47)	1.85 (0.69 - 3.46)
Sudan (Khartoum)	0.57 (-0.20 - 1.78)	2.13 (0.47 - 4.38)	0.65 (0.13 - 1.64)	0.31 (0.04 - 1.13)	0.12 (-0.03 - 0.54)	0.96 (0.32 - 2.22)	4.21 (2.18 - 6.97)
Sweden (Uppsala)	2.67 (1.06 - 4.95)	1.13 (-0.19 - 2.71)	0.25 (0.01 - 0.78)	0.25 (0.03 - 0.90)	0.31 (0.01 - 0.92)	/	4.10 (2.21 - 6.64)
Trinidad & Tobago	0.62 (0.17 - 1.28)	0.97 (0.00 - 1.94)	0.38 (0.01 - 0.84)	/	0.14 (-0.04 - 0.40)	0.03 (0.00 - 0.20)	2.02 (1.03 - 3.16)
Tunisia (Sousse)	0.60 (0.08 - 1.65)	0.47 (0.07 - 1.17)	0.23 (-0.01 - 0.70)	/	0.18 (-0.02 - 0.60)	0.17 (0.02 - 0.61)	1.38 (0.59 - 2.75)
Turkey (Adana)	1.81 (0.48 - 3.19)	2.39 (0.67 - 4.30)	1.10 (0.03 - 2.25)	0.16 (0.02 - 0.55)	0.52 (-0.07 - 1.22)	0.14 (0.02 - 0.53)	4.86 (3.05 - 7.07)
USA (Lexington, KY)	9.46 (6.62 - 12.97)	1.68 (-0.48 - 4.15)	1.52 (0.45 - 2.97)	0.21 (0.02 - 0.74)	0.64 (-0.06 - 1.47)	0.19 (0.02 - 0.67)	11.21 (8.15 - 14.86)

The Total PAR is adjusted using equations 2.1. and 2.2 in the Methods section of the paper. The Total PAR is less than the sum of the individual estimates.

Figure 1. Flow diagram showing recruitment to the study.

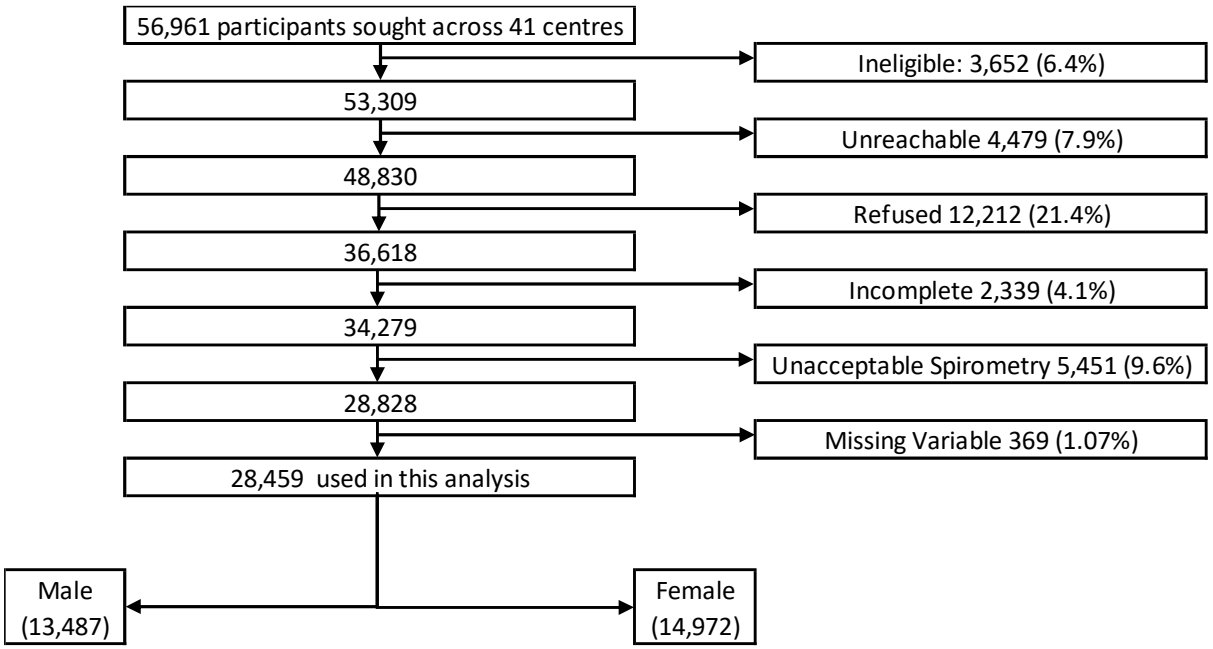
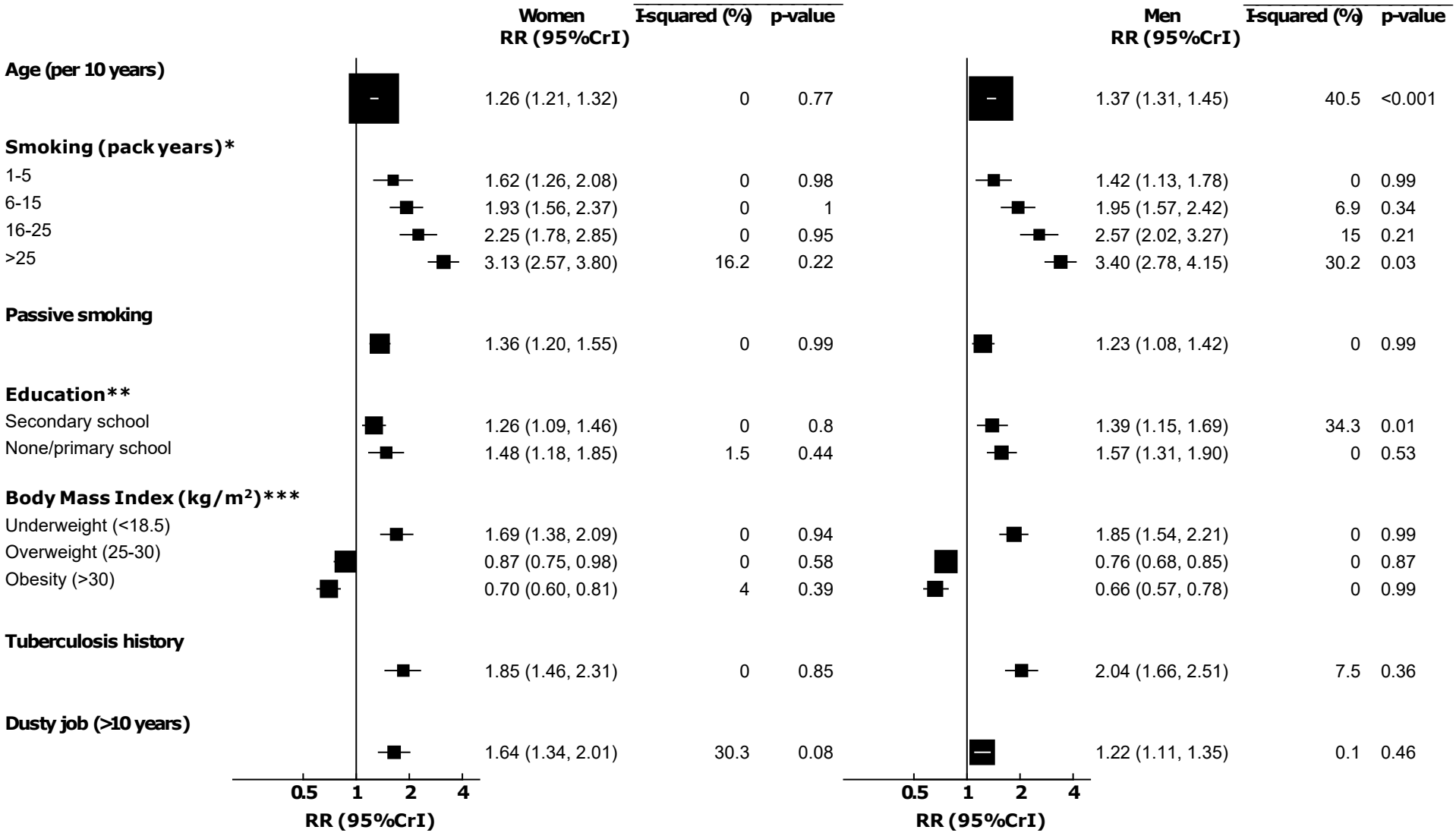
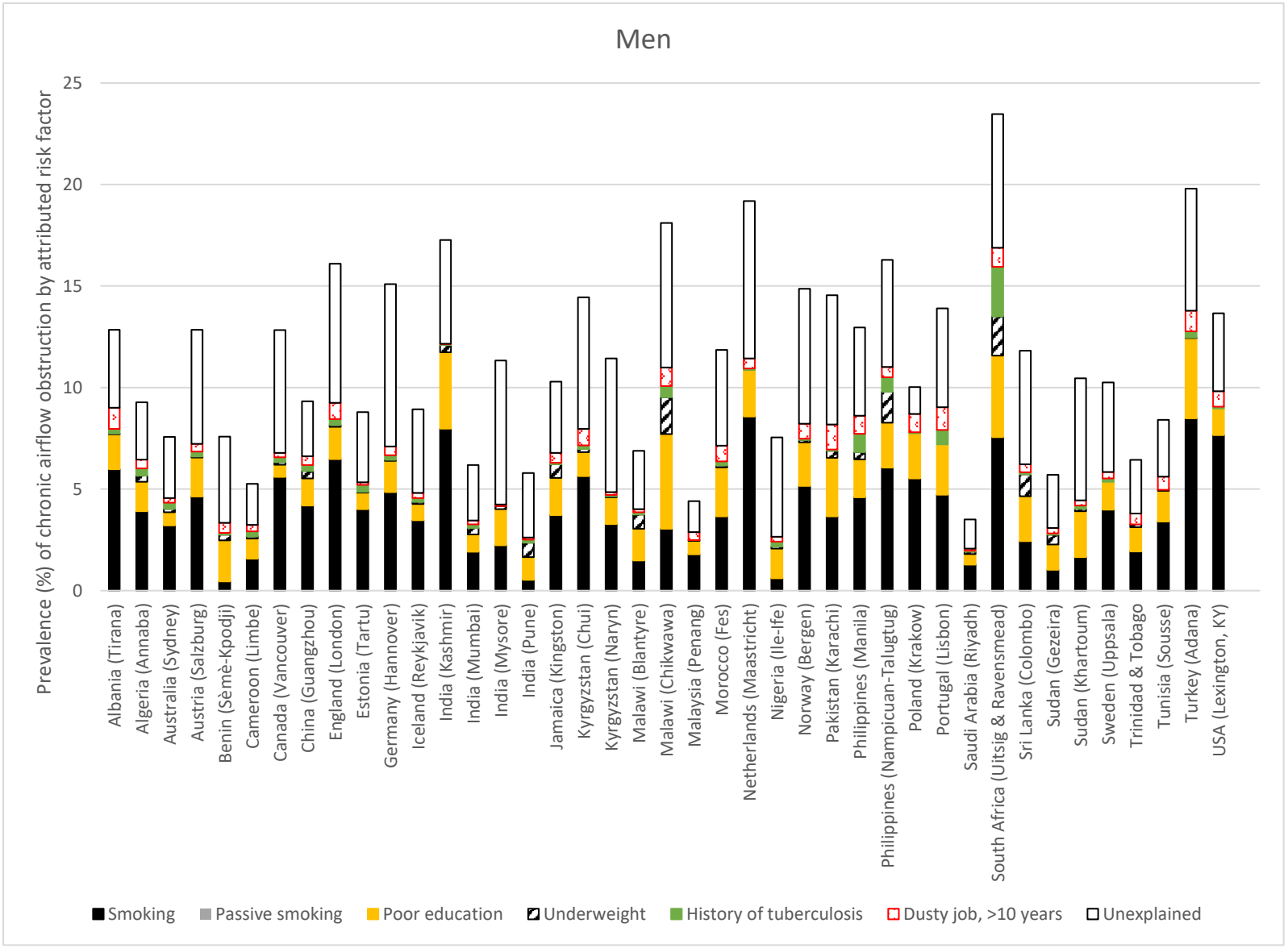


Figure 2. Sex-specific relative risk for chronic airflow obstruction among 28,459 adults age 40-89 years, and their variation across sites.



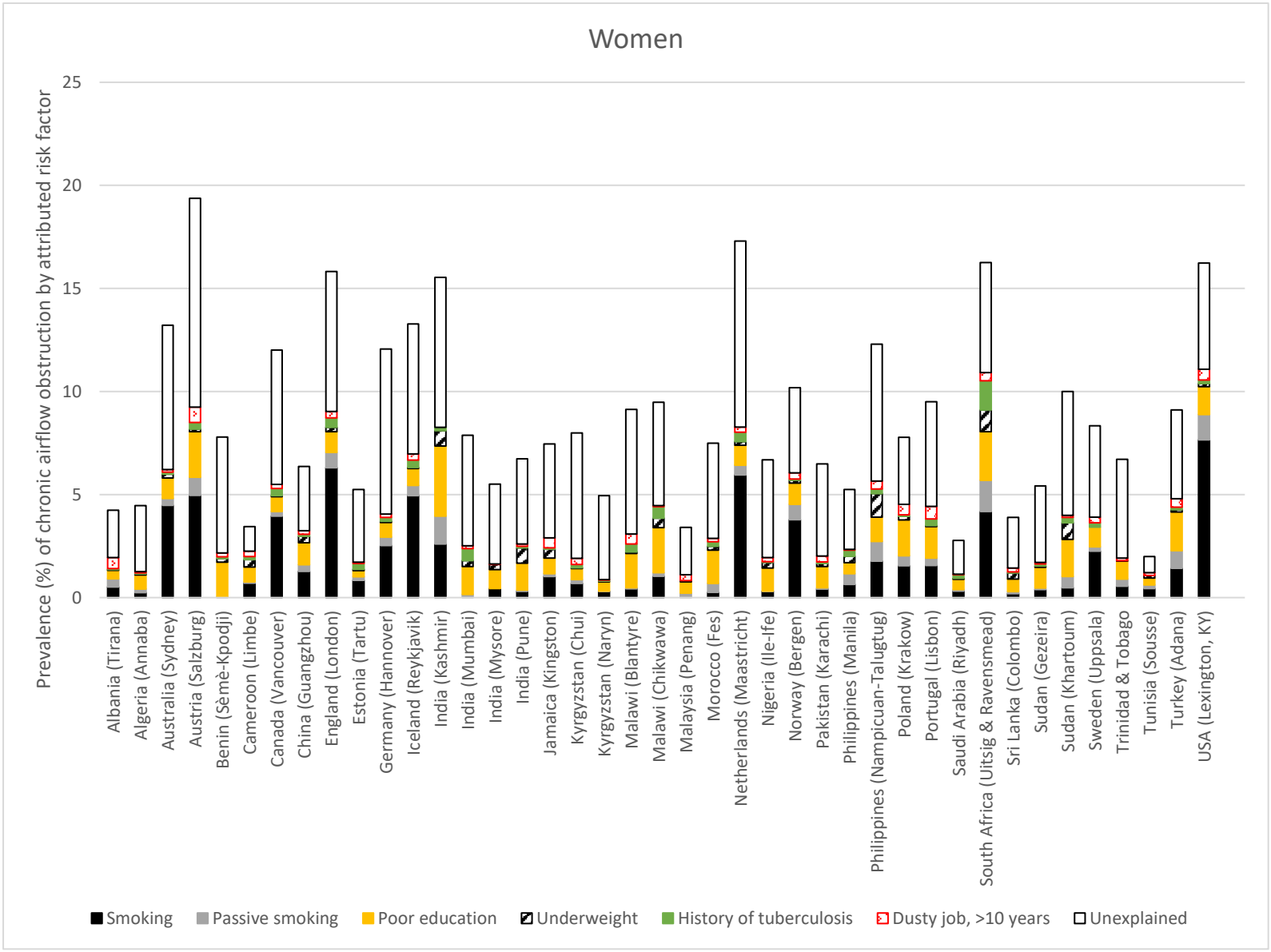
The I-squared statistic indicates the percent variability across sites. The p-value relates to the significance of the I-squared value. Square sizes reflect the amount of statistical information (ie, inversely proportional to the variance of the log RR), together with the 95% credible intervals (horizontal lines) representing the Bayesian equivalent to the frequentist 95% confidence intervals. RR, relative risk mutually adjusted for all risk factors shown here. *Reference: Never smoker; **Reference: More than secondary school; ***Reference: Normal weight (18.5-24.9 kg/m^2).

Figure 3A. Population Attributable Risk (PAR) (i.e. prevalence of chronic airflow obstruction (CAO) attributable to different risk factors) by site for men.



The heights of the bars represent the prevalence of CAO. Values have been scaled back so that the total PAR explained in the figure is equal to the total PAR adjusted using equations 2.1. and 2.2.

Figure 3B. Population Attributable Risk (PAR) (i.e. prevalence of chronic airflow obstruction attributable to different risk factors) by site for women.



The heights of the bars represent the prevalence of CAO. Values have been scaled back so that the total PAR explained in the figure is equal to the total PAR adjusted using equations 2.1. and 2.2.

Supplement

Prevalence and population attributable risk for chronic airflow obstruction in a large multinational study

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The population attributable risk (PAR) is the prevalence of disease in the total population (P_d) minus the prevalence of disease in the unexposed population (P_u).[1]

$PAR = P_d - P_u$ [1]

The population attributable fraction (PAF) is the population attributable disease divided by the total prevalence of disease in the population.[2]

$PAF = (P_d - P_u)/P_d$ [2]

Based on [1] and [2], the formula for PAR can be rewritten as:

$PAR = PAF * P_d$ [3]

PAF can also be estimated from the relative risk (RR) of the disease and the prevalence of exposure (P_e) using the formula given by Miettinen:[3]

$$PAF = \frac{Pe\ (RR-1)}{RR}$$ [4]

So that PAR becomes:

$$PAR = \frac{Pe\ (RR-1)}{RR} * Pd$$ [5]

Using formula [5], a PAR ("local PAR") for a given risk factor was calculated from the RR, Pd and Pe for each study site. A RR adjusted for confounders and for the other risk factors was estimated by multivariable regression analysis using a log-binomial model.

For smoking and education, we estimated the PAR for each category, and we also estimated the overall PAR for the variable by combining PAR values across categories "c", using the following formula:[4]

$$PAR = \left(\sum_{i=1}^{c} Pe_i \left(\frac{RR_i - 1}{RR_i}\right)\right) * Pd$$ [6]

where Pe_i is the proportion of cases exposed to the i^{th} level of the risk factor and RRi is the RR for CAO for the i^{th} category.

A difficulty arises when the numbers in any one site are too low to get a precise estimate of the RR and of PAR. For this reason, we used a Bayesian hierarchical log-binomial model to estimate the RR for each site, assuming that all local estimates of RR come from a common distribution. This allows us to "borrow" information from the other sites to increase the precision of the RR estimate in each single site.[5] By adjusting the log-binomial model for age (confounder) and level of education as a proxy measure for socio-economic status (risk factor of interest), we accounted for non-response as these are the main factors affecting the probability of selection in the survey.[6] Additionally, we accounted for a cluster and/or stratified sampling framework in some sites by including an additional level of hierarchy in the model.[7] We used separate models for men and women.

For Pe and Pd, we assumed that under the cross-sectional design, when the total sample size of the site is fixed, the observed number of subjects in each cross-classification of the disease by exposure contingency table follows the multinomial distribution.[8] Both models, hierarchical log-binomial and multinomial model, were implemented simultaneously to estimate PAF and PAR.

The parameters of interest were estimated by an iterative Monte Carlo Markov Chain (MCMC) process using the Gibbs sampling, implemented in the freely available OpenBUGS package.[9] Our model was run with two chains, using a burn-in of 50,000 iterations and 50,000iterations to estimate the posterior distribution of each parameter. In order to reduce the autocorrelation in the chains, we retained only 1 in every 10 iterations in the posterior sample. To check the convergence of the model, we calculated the Gelman-Rubin statistic (R-hat)[10] and inspected the trace plots, as well as the density plots of all estimated PARs. We calculated the posterior mean, 95% credible interval limit (Crl) using 2.5% and 97.5% percentiles of the PAR for all modifiable variables in the model.

The analysis was conducted in the statistical package Stata, version 14, with a user-written program to call OpenBUGS into Stata.[11] Across all analyses, the R-hat statistic for all parameters was between 0.99 to 1.01, suggesting that convergence was reached. The trace plots showed that the two chains were mixing well for all parameters in all models. The density plots for the PAR estimate for all risk factors of interest showed good convergence of the model, except for sites with a low prevalence of the risk factor of interest.

Details of our model, as applied to the specific example of PAR of chronic airflow obstruction (CAO) for passive smoking is given in the OpenBUGS code below. Covariates used in the model are: pack-years (five categories: never-smoker (reference), 1-5 pack-years, 6-15 pack-years, 16-25 pack-years, >25 pack-years), education (three categories: none to primary, secondary, more than secondary school (reference)), passive smoking (yes/no), doctor-diagnosed tuberculosis (ever/never), working in a dusty job (>10 years vs. ≤ 10 years), body mass index (BMI) (four categories: underweight, normal weight (reference), overweight, obese), age.

 # OpenBUGS code:

```
model {
for (j in 1:N) {                    # j stands for number of observations
# Defining log-binomial hierarchical model
CAO[j]~dbern(p[j])
log(p[j])  <- (alpha[centre[j]] + b.pack_5cat[pack_5cat[j],centre[j]] + b.age[centre[j]]*age10[j]
+ b.bmi[bmicat4[j],centre[j]] + b.educ[educ3[j],centre[j]] +  b.passive[passive[j],centre[j]] +
b.tb[tuberc[j],centre[j]]  + b.dusty[dusty10cat[j],centre[j]] + b.cluster[cluster[j]] +
b.strata[strata[j]])
```

```
#  Restricting probabilities between 0 and 1.
ones[j] <- 1
ones[j] ~ dbern(C1[j])
C1[j] <- step(1-p[j])
 }
# cluster = 1 which represents those centres which do not use cluster sampling
b.cluster[1]<-0
#strata = 1 which represents those centres which did not use stratified sampling
b.strata[1]<-0

# Priors
 for ( r in 1:R) {            # r represents the centre number
   alpha[r] ~ dnorm(alpha_mu, alpha_prec)
   b.pack_5cat[1,r] <-0
   b.pack_5cat[2,r] ~ dnorm(mu_pack3, prec_pack2)
   b.pack_5cat[3,r] ~ dnorm(mu_pack3, prec_pack3)
   b.pack_5cat[4,r] ~ dnorm(mu_pack4, prec_pack4)
   b.pack_5cat[5,r] ~ dnorm(mu_pack5, prec_pack5)
   b.age[r] ~ dnorm(mu_age, prec_age)
   b.bmi[1,r] <-0
   b.bmi[2,r] ~ dnorm(mu_bmi2, prec_bmi2)
   b.bmi[3,r] ~ dnorm(mu_bmi3, prec_bmi3)
   b.bmi[4,r] ~ dnorm(mu_bmi4, prec_bmi4)
   b.educ[3,r] <- 0
```

```
174     b.educ[1,r] ~ dnorm(mu_educ1, prec_educ1)
175     b.educ[2,r] ~ dnorm(mu_educ2, prec_educ2)
176     b.passive[2,r] <-0
177     b.passive[1,r] ~  dnorm(mu_passive,prec_passive)
178     b.tb[2,r] <-0
179     b.tb[1,r] ~ dnorm(mu_tb, prec_tb)
180     b.dusty[2,r] <- 0
181     b.dusty[1,r] ~ dnorm(mu_dusty10, prec_dusty10)
182
183     # Calculation of RRs
184     RR_pack2[r] <- exp(b.pack_5cat[2,r])
185     RR_pack3[r] <- exp(b.pack_5cat[3,r])
186     RR_pack4[r] <- exp(b.pack_5cat[4,r])
187     RR_pack5[r] <- exp(b.pack_5cat[5,r])
188     RR_age[r] <- exp(b.age[r])
189     RR_bmi2[r] <- exp(b.bmi[2,r])
190     RR_bmi3[r] <- exp(b.bmi[3,r])
191     RR_bmi4[r] <- exp(b.bmi[4,r])
192     RR_educ1[r] <- exp(b.educ[1,r])
193     RR_educ2[r] <- exp(b.educ[2,r])
194     RR_passive[r] <- exp(b.passive[1,r])
195     RR_tb[r] <- exp(b.tb[1,r])
196     RR_dusty[r] <- exp(b.dusty[1,r])
197
```

```
198     for ( k in 2:C) {            # k stands for number of clusters
199     b.cluster[k] ~
200     dnorm(mu_cluster[in.which.centre.cluster[k]],tau_cluster[in.which.centre.cluster[k]])   #
201     in.which.centre tells the programme to include only centres  with cluster exist
202     RR_cluster[k] <- exp(b.cluster[k])
203     }
204     for ( s in 2:S) {                        # s stands for number of strata
205     # in.which.strata tells the programme to include only centres with strata
206     b.strata[s] ~
207     dnorm(mu_strata[in.which.centre.strata[s]],tau_strata[in.which.centre.strata[s]])
208     }
209     # Introducing a Hierarchy on cluster, c- indicates cluster number
210     mu_c [r] ~ dnorm(0.0, 0.01)
211     tau_c[r] ~ dgamma(1, 0.005)
212     mu_cluster[r] <- step(cluster.start[r]-2)*mu_c [r]
213     tau_cluster[r] <- step(cluster.start[r]-2)*tau_c[r]
214
215     # Introducing a Hierarchy on strata, s - indicates strata number
216     mu_s [r] ~ dnorm(0.0, 0.01)
217     tau_s[r] ~ dgamma(1, 0.005)
218     mu_strata [r] <- step(strata.start[r]-2)*mu_s [r]
219     tau_strata[r] <- step(strata.start[r]-2)*tau_s[r]
220
221
```

```
#Calculation of multinomial probabilities
# a, b, c ,d are the cells of 4x4 table for outcome X exposure
eta[r,1]<-a[r]+beta[r,1]
eta[r,2]<-b[r]+beta[r,2]
eta[r,3]<-c[r]+beta[r,3]
eta[r,4]<-d[r]+beta[r,4]
f[r,1:4] ~ ddirich(eta[r,1:4])
Pa[r] <-f[r,1]
Pb[r] <-f[r,2]
Pc[r] <-f[r,3]
Pd[r] <-f[r,4]

# Calculating proportion of the cases exposed to passive smoking (Pe_passive) and
proportion of CAO in the population (Pd_passive)
Pe_passive[r] <-  Pc[r] /(Pa[r]  +  Pc[r])
Pd_passive[r] <- (Pc[r]  +  Pa[r]) /( Pb[r]  +  Pa[r] + Pc[r]  +  Pd[r] )

# Estimating centre-specific PAF and PAR for passive smoking
PAF_passive[r] <- (Pe_passive[r]* ((RR_passive[r]-1) / RR_passive[r]))
PAR_passive[r] <- ((Pe_passive[r]* ((RR_passive[r]-1) / RR_passive[r]))) * Pd_passive[r]
}
# Hyper Prior distributions for all coefficients and intercept (alpha)
alpha_mu ~ dnorm(0.0, 0.0001)
alpha_prec  ~ dgamma(1, 0.005)
```

```
246     mu_age ~ dnorm(0.0, 0.01)
247     prec_age ~ dgamma(1, 0.005)
248     mu_bmi2 ~ dnorm(0.0, 0.01)
249     prec_bmi2  ~ dgamma(1, 0.005)
250     mu_bmi3 ~ dnorm(0.0, 0.01)
251     prec_bmi3  ~ dgamma(1, 0.005)
252     mu_bmi4 ~ dnorm(0.0, 0.01)
253     prec_bmi4  ~ dgamma(1, 0.005)
254     mu_pack2 ~ dnorm(0.0, 0.01)
255     prec_pack2  ~ dgamma(1, 0.005)
256     mu_pack3 ~ dnorm(0.0, 0.01)
257     prec_pack3  ~ dgamma(1, 0.005)
258     mu_pack4 ~ dnorm(0.0, 0.01)
259     prec_pack4  ~ dgamma(1, 0.005)
260     mu_pack5 ~ dnorm(0.0, 0.01)
261     prec_pack5  ~ dgamma(1, 0.005)
262     mu_passive ~ dnorm(0.0, 0.01)
263     prec_passive  ~ dgamma(1, 0.005)
264     mu_tb ~ dnorm(0.0, 0.01)
265     prec_tb  ~ dgamma(1, 0.005)
266     mu_educ1 ~ dnorm(0.0, 0.01)
267     prec_educ1  ~ dgamma(1, 0.005)
268     mu_educ2 ~ dnorm(0.0, 0.01)
269     prec_educ2  ~ dgamma(1, 0.005)
```

```
mu_dusty10 ~ dnorm(0.0, 0.01)
prec_dusty10  ~ dgamma(1, 0.005)
}
```

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