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National income, self-reported wheezing and asthma diagnosis from the World Health Survey

G. Sembajwe*,#,¶, M. Cifuentes*, S.W. Tak*, D. Kriebel*, R. Gore* and L. Punnett*

ABSTRACT: The aims of this study were to quantify and describe the variations in respiratory symptoms and diagnosis prevalence across regions of the world according to national income.

In 2002 and 2003, the World Health Organization implemented the World Health Survey (WHS), which used a standardised survey instrument to compile comprehensive baseline information on health and healthcare expenditure. We analysed the WHS data to assess the global patterns of self-reported wheeze and doctor-diagnosed asthma, two commonly reported measures of respiratory health.

In total there were 308,218 participants with complete records, from 64 countries. The weighted mean age of the survey population was 43 yrs. Global prevalence of current wheezing symptoms ranged from 2.4% in Vietnam to 24% in Brazil; the prevalence of diagnosed asthma ranged from 1.8% in Vietnam to 32.8% in Australia. Overall, the prevalence of symptoms and diagnosis showed a U-shaped pattern with the largest prevalence reported in low- and high-income countries. The smallest prevalence was consistently found in middle-income countries.

These WHS analyses have provided global prevalence estimates of wheeze and doctor-diagnosed asthma using data gathered simultaneously and consistently across six continents. These findings support the need for continued global respiratory illness surveillance for disease prevention, health policy and management.

KEYWORDS: Asthma, income inequality, prevalence, wheezing, World Health Survey

Over the past several decades, worldwide increases in the prevalence of asthma have been reported in surveillance and epidemiological studies [1, 2]. Asthma is characterised by variable airflow limitation or airway hyperresponsiveness to various environmental stimuli [3–5]. Wheezing is the most common symptom associated with asthma, although wheezing, coughing, chest tightness and shortness of breath are all symptoms often used to define asthma [6–11].

The Global Initiative for Asthma (GINA) reports adult asthma prevalence ranging from 5–18% with increases in associated morbidity and decreasing associated mortality in industrialised countries [1, 12, 13]. GINA was established in 1989 by the United States National Heart, Lung, and Blood Institutes, National Institutes of Health and the World Health Organization (WHO), to raise awareness among health professionals, governments and the general public about the dangers and increasing prevalence of asthma [13–16]. In 2003 and 2004, GINA published reports on the global burden of asthma, based on literature reviews primarily from peer-reviewed publications based on the International Study of Asthma and Allergies in Childhood (ISAAC) and European Community Respiratory Health Survey (ECRHS). GINA continues to update the reports as new information becomes available [13, 17].

In 2002 and 2003, WHO implemented the World Health Survey (WHS), which used a standardised survey instrument to compile comprehensive baseline information on a wide range of health measures (including asthma) and healthcare expenditures. The broader aims of the WHS were to develop low-cost, valid, reliable and comparable cross-national information and an evidence

AFFILIATIONS
*Dept of Work Environment, University of Massachusetts Lowell, Lowell,
#Dept of Society, Human Development and Health, Harvard School of Public Health, and
¶Center for Community-Based Research, Dana-Farber Cancer Institute, Boston, MA, USA.

CORRESPONDENCE
G. Sembajwe
Dept of Society, Human Development and Health
Harvard School of Public Health
Boston
MA 02115
USA
E-mail: grace_sembajwe@dfci.harvard.edu

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base for surveillance and policy adjustment [18]. All 192 WHO member states were invited to take part in this effort and just over one-third participated.

While the WHS collected data across six continents from adults aged ⩾18 yrs, ECRHS only gathered information from Europe and Australia, and ISAAC is restricted data collection to children aged <15 yrs.

In the research described herein, WHS data were utilised to assess the global patterns of respiratory disease. The objectives of our study were to quantify the prevalence of respiratory symptoms and diagnosis worldwide using data collected with identical survey questions and systematic population survey methods; and to describe the variations in respiratory symptom and diagnosis prevalence across world regions according to national income.

MATERIALS AND METHODS

Study subjects and data collection methods

The WHS was administered in 70 countries, of which 68 responded to respiratory symptom questions and 64 reported on asthma diagnosis. Each country's national health ministry was responsible for the survey programme. The countries that chose to participate in the survey, their economic standing (income status), sample size and type of survey used (short or full) can be found on the WHO website for the WHS [18]. The full questionnaire included questions on several factors associated with living conditions in most economically developing nations (such as mud housing) and collected information on social habits in countries where such surveillance systems do not exist (such as smoking prevalence). The short version omitted several of these questions and was administered to mostly higher income countries. WHO provided each country with the relevant training to carry out the survey and conduct data analyses [18].

The WHS had a list of options and modules for the various survey components. The modules measured aspects of health in multiple domains: 1) risk factors, *e.g.* tobacco, alcohol and pollution; 2) responsiveness of health systems and whether health systems met expectations; 3) coverage, access and utilisation of key health services, *e.g.* immunisation, treatment of childhood illness, sexually transmitted diseases and HIV/AIDS; and 4) healthcare expenditures. Each country chose which combination of modules to use.

A number of pre-tested survey administration tools were available and each country could choose the method that it judged most practical and cost-effective. The choices were the following: household face-to-face survey; computer-assisted telephone interview survey, which was conducted using computerised systems when there was good telephone network coverage; and computer-assisted personal interview survey using a portable personal computer to replace paper and pen methods of data collection.

The eligible population for the WHS consisted of adults aged ⩾18 yrs. The sample from each country was stratified by sex, age and type of residence (rural/urban). Individuals were sampled from these strata and each respondent was given a separate sampling probability value (or weight). Only one person from a randomly selected household was interviewed for the individual questionnaire and was ultimately included in these analyses.

National income

Countries were grouped by their per capita gross national income in purchasing power parity (GNI PPP) [18, 19], which were taken from the World Bank's data and statistics tables [19, 20]. Countries were classified into tertiles based on GNI PPP: per capita income of ⩽US$ 3,000 (low income); US$ 3,000 to US$ 8,000 (middle income); and >US$ 8,000 (high income). All analyses were conducted on ungrouped countries as well as with the tertiles.

Sampling weights

The WHS employed a probability sampling design. This meant that every individual in the sampling frame (⩾18 yrs) had a known and non-zero chance of being selected into the survey sample. Some countries used a single-stage random-sample strategy; however, most sites carried out multi-stage cluster sampling methods and probability weights were used for each stage. In either case, the WHS sampling frame aimed to cover 100% of the eligible population in the surveyed country. Therefore, the weighted estimates are corrected for the individual probabilities of being surveyed. Further details about the WHO sampling guidelines are available from WHO [18].

For a multi-stage cluster sample, the total probability of being sampled was calculated by multiplying all the probabilities within a sample stage. The inverse of this total probability was the probabilistic individual weight for a specific person within the country. A total weight was calculated for each country by adding all the individual weights and comparing the sum with the country population; for countries that used a single-stage random sample or when the sum of all the weights did not add up to the adult country population (⩾18 yrs), a correction factor was used. Therefore, the weighted data represented pooled data corrected by the individual probability of being surveyed (based on age, sex and urban/rural location) and country population.

Sex and age

Sex was recorded as female or male on the basis of the interviewer's observation. The WHS questionnaire had two questions for age. The primary question for age was a continuous variable. In cases where respondents declined to answer the question, interviewers were advised to estimate their age in categories. For the purpose of these analyses, the age ranges were re-grouped into three categories: 18–29 yrs (reference group), 30–49 yrs, and >50 yrs. A subgroup analysis was conducted in 18–44-yr-olds to compare with analyses of the entire the WHS population, as respiratory symptoms (for chronic obstructive pulmonary disease, for example) are far more common at older ages.

Smoking

The short version of the questionnaire omitted the questions relating to tobacco smoking. The question on the long version was, ''do you currently smoke any tobacco products such as cigarettes, cigars or pipes?'' with the following response choices: daily; yes, but not daily; and no, not at all. A respondent was considered a current smoker if he/she answered positively (daily or yes but not daily).

Urban/rural

The household survey for the WHS included information on location with the following categories used for classification: 1) urban; 2) peri-urban/semi-urban; 3) rural; and 4) other. These, along with external databases describing population distributions [21] for countries that had missing values in the WHS (Australia, Nepal, Norway, the Netherlands, and Slovenia), were used to distinguish urban and rural areas during analyses. Countries that had $\geqslant$50% rural households were classified as mostly rural; those with $<$50% rural were classified as mostly urban.

Income inequality

An external database was used to import information on country level income inequality (Gini coefficient) to merge with the WHS data [21]. The Gini coefficient is a measure of household income inequality within a country [21, 22]. Gini values for the Comoros were not available and analyses were conducted by placing the country as high inequality, then low inequality, then by leaving the country out entirely, to note any differences in disease prevalence for the categories. No difference was evident, so Gini for Comoros was left as missing. Countries with 45 or greater for a Gini coefficient were considered to have high income inequality, countries below 45 were considered to have low income inequality. Further summaries for the country classifications are available in the supplementary material.

Respiratory outcomes

Five questions on respiratory symptom and diagnosis were used to describe current wheezing symptoms and diagnosed asthma.

Current wheezing symptoms

These were indicated if there was a positive response to any of the following symptom questions. During the last 12 months, have you experienced any of the following: 1) attacks of wheezing or whistling breathing? (yes/no); or 2) attacks of wheezing that came on after you stopped exercising or some other physical activity? (yes/no). These questions differ slightly from those used in ECHRS (''have you had wheezing or whistling in your chest at any time in the last 12 months?'') [11, 23] and ISAAC (''have you had wheezing or whistling in the chest in the past 12 months?'' and ''how many attacks of wheezing have you had in the past 12 months?'') [24–26].

Diagnosed asthma

This was indicated if there was a positive response to any of the diagnosis questions: 1) ''have you ever been diagnosed with asthma (an allergic respiratory disease)?'' (yes/no/don't know); 2) ''have you ever been treated for it?'' (yes/no/don't know); 3) ''have you been taking any medications or other treatment for it during the last 2 weeks?'' (yes/no/don't know). Responses of ''don't know'' were coded as ''no'' for the respiratory outcomes. These questions differ slightly from those used in ECHRS (''have you ever had asthma?'' and ''was this confirmed by a doctor?'') [11, 23] and ISAAC (no direct questions on asthma diagnosis in the core questionnaire) [24–26].

Statistical analysis

The authors received the final country datasets from WHO in August 2005. All analyses were conducted using SAS statistical software (SAS Institute, Inc., Cary, NC, USA) [27, 28]. SAS survey procedures (proc surveyfreq and surveymeans) were used to account for sampling weights and the complex sampling design effect. Further details of the data analysis methods are described elsewhere [29, 30]. Proc glimmix (SAS Institute, Inc.) was used to obtain weighted multilevel prevalence ratios as a measure of risk in these cross-sectional data.

Except for a few nonparametric analyses (to obtain Spearman's rank correlation coefficients), all analyses used the individual weights described above and accounted for the complex sampling design effect. Results were stratified by sex, smoking status (where available) and national income.

Missing data

Respondents who did not provide data on respiratory outcomes were excluded from the analyses. Current wheezing symptoms were not asked in Hungary and Nepal, and diagnosed asthma data was not obtained from Guatemala, Ethiopia, Nepal, Hungary, Israel or Mexico. Consequently, these countries do not appear in any tables or figures for those outcomes.

Miscoded responses or out-of-range codes were changed to missing and excluded from the analysis. The question on tobacco smoking was not included in the short questionnaire, thus the following countries are missing from the analyses with smoking: Austria, Australia, Belgium, Denmark, Finland, France, Germany, UK, Greece, Ireland, Israel, Italy, Luxembourg, the Netherlands, Norway and Portugal.

The study materials and methods were approved by the institutional review board at the University of Massachusetts (Lowell, MA, USA).

RESULTS

The total sample in the WHS was 308,218 (table 1). The weighted mean age of the survey population was 43 yrs. Finland had the highest weighted mean age overall (53 yrs) and Slovakia had the lowest at 34 yrs. Among the portion of respondents that answered the tobacco use questions, current smokers were less frequent than nonsmokers. Rural households accounted for 70% overall and there were slightly more countries with high income inequality (55%). The middle GNI PPP category accounted for 44% of the global study population, while 35% were in the low-income group and 21% in the high-income countries.

Respiratory outcomes and population characteristics

Current wheezing symptoms were more prevalent than diagnosed asthma (table 1). Smokers and those aged $>$50 yrs showed the highest prevalence of both categories of asthma. Males more frequently reported current wheezing symptoms than females. Overall prevalence patterns of current wheezing symptoms and diagnosed asthma showed some expected patterns: an increase with age and more common in smokers than nonsmokers.

Respiratory outcomes among countries

There was a 10-fold variation in current wheezing symptom prevalence across countries (2.4% in Vietnam and 24.3% in Brazil). With a few exceptions, most of the countries geographically in the global north had a higher prevalence of

TABLE 1 Characteristics of the World Health Survey population[#] and distribution of asthma

Sex	
Female	157152 (52.2)
Male	125005 (47.8)
Age yrs	
18–29	81389 (25.8)
30–49	118505 (39.9)
>50	82480 (34.3)
Smoking status	
Current	61558 (29.9)
Non-smoker	194185 (70.1)
Household setting	
Mostly urban	175793 (29.7)
Mostly rural	132123 (70.3)
Income inequality: Gini coefficient	
Low Gini	173294 (55.4)
High Gini	132762 (44.6)
GNI PPP stratum	
Low	113169 (34.7)
Middle	90305 (44.4)
High	104442 (20.8)
Respiratory outcome	
Current wheezing symptoms	25617 (9.2)
Diagnosed asthma	14723 (6.0)

Data are presented as unweighted frequency n (weighted %). GNI PPP: per capita gross national income adjusted for purchasing power parity. Gini coefficient is a measure of household income inequality within a country [21, 22]. [#]: includes only the complete records for males and females, missing records have not been included.

current wheezing symptoms than most of the countries in the global south (fig. 1).

Diagnosed asthma showed a narrower range in prevalence across countries; the majority of estimates fell within a four-fold range of prevalence, with Vietnam the lowest at 1.8% and Australia the highest at 32.8% (fig. 2).

Respiratory outcomes and national income

Regression analyses that included national income without grouping the countries into tertiles showed almost no association with respiratory symptoms or diagnosis (adjusted PR 1.00001, 95% CI 1.00001–1.00002 and PR 1.00003, 95% CI 1.00002–1.00003 for wheezing symptoms and asthma diagnosis, respectively). However, for countries grouped by national income, the high-national income group had the highest overall weighted prevalence for all respiratory outcomes, with current wheezing symptoms at 11.7% (fig. 1) and diagnosed asthma at 9.3% (fig. 2). Prevalence was lowest in the middle-national income group, with current wheezing symptoms at 6.7% and diagnosed asthma at 4.5%. Nevertheless, the middle income countries had the largest inter-country range in prevalence of current wheezing symptoms (3.3% in China and 24.3% in Brazil). For diagnosed asthma, the widest range in prevalence was found in the high national income group (4.2% in Russia and 32.8% in Australia). Overall, the prevalence of current wheezing symptoms and diagnosed

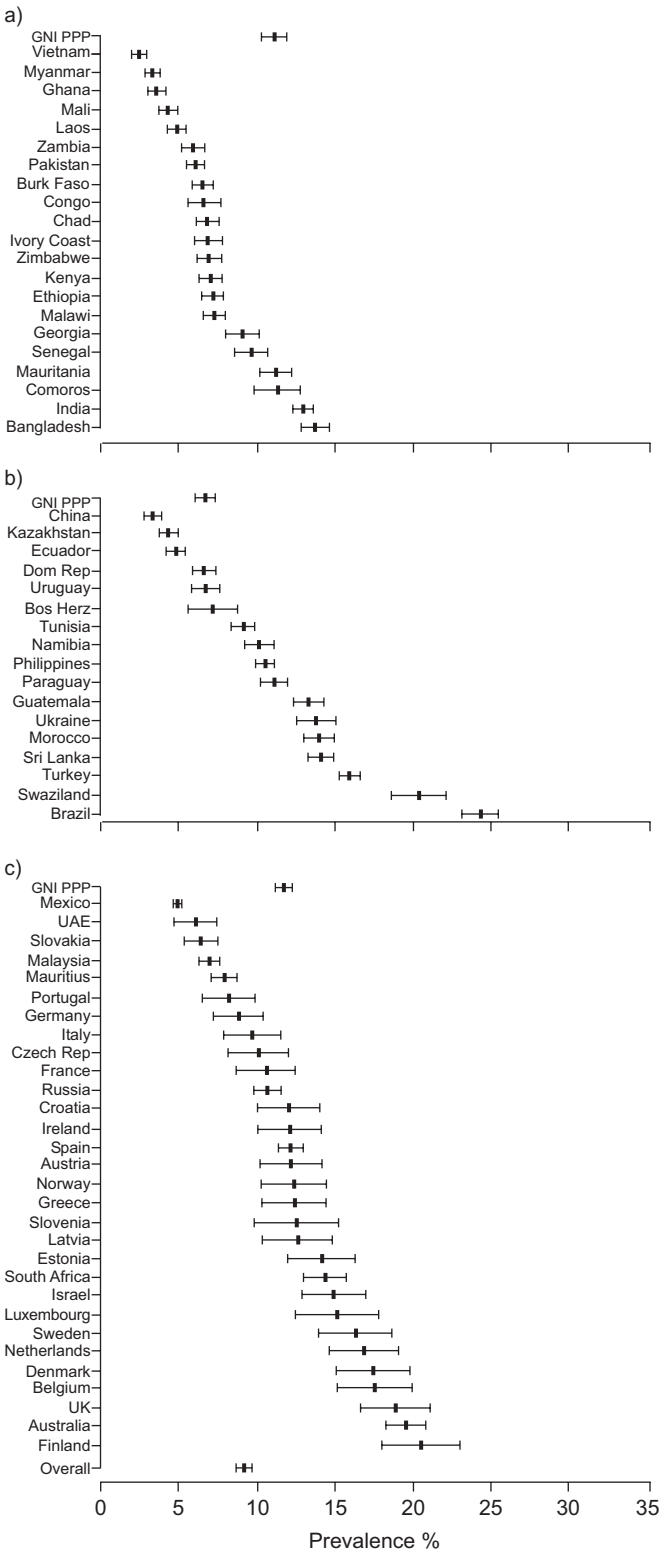

FIGURE 1. World Health Survey weighted prevalence and 95% confidence intervals of current wheezing symptoms by country and per capita gross national income adjusted for purchasing power parity (GNI PPP). a) low GNI PPP ⩽US$ 3,000, b) middle GNI PPP >US$ 3,000 to ⩽US$ 8,000 and c) high GNI PPP >US$ 8,000. Burk Faso: Burkina Faso; Dom Rep: Dominican Republic; Bos Herz: Bosnia Herzegovina; UAE: United Arab Emirates.

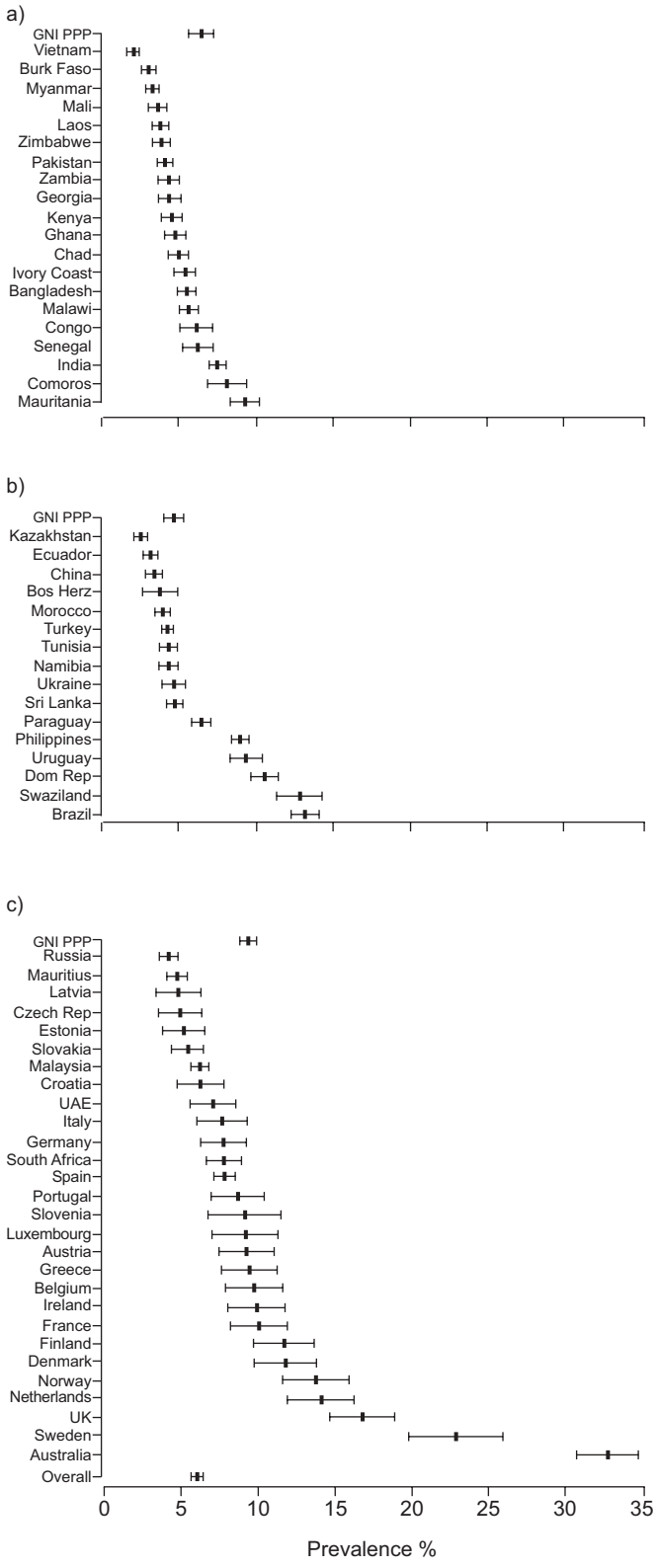

FIGURE 2. World Health Survey weighted prevalence and 95% confidence intervals of diagnosed asthma by country and per capita gross national income adjusted for purchasing power parity (GNI PPP). a) low GNI PPP ⩽US$ 3,000, b) middle GNI PPP >US$ 3,000 to ⩽US$ 8,000 and c) high GNI PPP >US$ 8,000. Note, no data were available for Guatemala, Ethiopia, Israel and Mexico. Burk Faso: Burkina Faso; Bos Herz: Bosnia Herzegovina; Dom Rep: Dominican Republic; UAE: United Arab Emirates.

asthma showed a U-shaped pattern with higher prevalence of respiratory outcome reported in low- and high-income countries. Exceptions to this pattern were found for mostly urban regions and low-Gini countries, where the pattern showed a peak in current wheezing symptoms for middle-income countries and an increasing upward trend in diagnosed asthma prevalence (moving from low- to high-income countries) for urban regions only. This U-shaped prevalence pattern remained in individual categories of smoking and sex, as well as in mostly rural regions and among high-Gini countries, even after adjusting for age (table 2). The U-shaped pattern remained even in subgroup analyses of 18–44-yr-olds.

It should also be noted that the highest prevalence of current wheezing symptoms was found in low-income countries with high income inequality (table 2).

The country-level correlation between diagnosed asthma and current wheezing symptoms was lowest in the middle national-income group (Spearman's correlation coefficient: $r=0.37$, $p<0.0001$) and somewhat higher in both the low national income group ($r=0.46$, $p<0.0001$) and the high national income group of countries ($r=0.45$, $p<0.0001$).

DISCUSSION

Among the 68 countries with responses to wheezing symptoms and the 64 countries surveying diagnosed asthma outcomes in the WHS, the prevalence varied greatly, ranging from 2.4% to 24.3% for current wheezing symptoms and 1.8%–32.8% for diagnosed asthma. In general, highly industrialised (higher income) countries, such as Australia and countries in Western Europe, had the higher prevalence of current wheezing symptoms and diagnosed asthma, while lower prevalence was found in middle-income countries, particularly in eastern and central Europe. Brazil, as a middle-income country, was notable for its very high prevalence of both diagnosed asthma and current wheezing symptoms. Although Brazil was in the middle-income countries, it had a high Gini coefficient [21] and, thus, high within country income inequality and also had almost 85% (see online supplementary material) of the survey population responding from urban households (high urbanisation) indicating that both the income inequality and high urbanisation might be factors in the high prevalence of respiratory disease reporting from Brazil [15].

At the community or national level, respiratory disease/asthma reporting could greatly affect the estimated prevalence, especially if mortality rates from these conditions are high. In most of the countries identified in the middle-national income group, GINA reports have identified very high-mortality rates due to asthma relative to the low prevalence reported for this group [13, 16, 17]. However, even with low country reporting rates, other influential factors may be at play, such as: environmental (urban air) pollution, which has been identified as a risk factor for respiratory illness in both children [31–34] and adults [17, 35]; access to healthcare and disease information (which allow for disease identification, treatment, and management) [17, 36–38]; and the highly contested hygiene hypothesis [39–44], which postulates that a lack of exposure to dirt in childhood may increase an individual's susceptibly to respiratory illnesses, asthma in particular, and may explain the high asthma prevalence observed for the high-income

TABLE 2 Age-adjusted weighted prevalence of respiratory outcomes associated with country level income stratified by sex and smoking status

	Current wheezing symptoms			Diagnosed asthma		
	Low GNI[#]	Middle GNI[¶]	High GNI[+]	Low GNI[§]	Middle GNI[ƒ]	High GNI[##]
Overall	13.3 (12.3–14.4)	7.6 (6.7–8.5)	13.0 (12.3–13.7)	8.2 (7.0–9.3)	5.2 (4.3–6.0)	9.4 (8.7–10.0)
Female	12.5 (11.1–13.9)	7.1 (6.7–8.7)	13.0 (12.1–14.0)	7.6 (6.5–8.8)	5.1 (4.2–6.1)	9.7 (8.8–10.7)
Male	14.1 (12.8–15.4)	7.4 (6.0–8.7)	12.9 (12.0–13.7)	8.6 (7.2–10.0)	5.2 (3.9–6.5)	8.8 (8.2–9.4)
Current smoker	18.0 (16.1–19.8)	7.3 (5.5–9.1)	13.1 (11.5–14.6)	10.4 (8.8–12.0)	4.4 (3.0–5.7)	5.9 (4.6–7.1)
Non-smoker	10.7 (9.4–12.0)	7.7 (6.7–8.6)	12.1 (10.3–13.8)	6.9 (5.8–8.0)	5.5 (4.4–6.6)	7.0 (5.4–8.6)
Mostly urban	9.9 (9.0–10.8)	18.0 (17.2–18.8)	13.2 (12.5–13.9)	5.7 (5.1–6.3)	8.9 (8.3–9.4)	9.3 (8.8–9.9)
Mostly rural	13.3 (12.3–14.4)	4.6 (3.5–5.7)	10.8 (7.8–13.8)	8.2 (7.1–9.3)	4.1 (2.9–5.3)	9.9 (7.2–12.7)
Low Gini	13.1 (12.1–14.2)	14.7 (13.8–15.8)	13.5 (12.7–14.3)	8.1 (7.0–9.3)	4.8 (4.3–5.3)	9.2 (8.5–9.8)
High Gini	23.5 (22.3–24.7)	6.8 (5.9–7.8)	8.9 (8.1–9.7)	10.8 (9.9–11.7)	5.2 (4.3–6.1)	12.6 (11.4–13.7)

Data are presented as weighted prevalence % (95% CI). GNI: per capita gross national income; Gini coefficient is a measure of household income inequality within a country [21, 22]. [#]: weighted frequency n=8,657; [¶]: weighted frequency n=9,951; [+]: weighted frequency n=7,391; [§]: weighted frequency n=4,429; [ƒ]: weighted frequency n=4,705; [##]: weighted frequency n=5,580.

countries [1, 2, 13, 17, 34, 40], although high urbanisation is more likely to be the driving factor. Among low-income countries, the influencing factors may be exacerbated by poorer access to healthcare.

The middle national income group was also distinguished by a high within-group range in prevalence of current wheezing symptoms, while for diagnosed asthma, the within group range was highest among the high-national income group. This difference in within group range between diagnosed asthma and current wheezing symptoms may reflect the variation in reporting, as well as the disparity in access to healthcare and disease information between countries, particularly within the national income groups. For affirmative responses to diagnosed asthma, the participant had to have seen a physician and/or been taking asthma medications. Therefore, one would expect, as seen here, that asthma diagnosis questions would be more sensitive to country level of development (and hence access to medical care) than the current wheezing symptoms questions.

One might also expect that the correlation between current wheezing symptoms and asthma diagnosis would vary by socioeconomic and cultural differences, for which national income may be a partial proxy. Country-level features, such as access to healthcare, health literacy, willingness to report symptoms and cultural differences in how breathing problems are labelled and understood, could all affect the ratio of current symptoms to diagnosis of asthma. Consistent with this idea, the country-level correlation between diagnosed asthma and current wheezing symptoms was lowest in the middle-national income group (Spearman's correlation coefficient: $r=0.37$, $p<0.0001$) and somewhat higher in both the low-national income group ($r=0.46$, $p<0.0001$) and the high-national income group of countries ($r=0.45$, $p<0.0001$).

The U-shape for the pattern of symptom prevalence across tertiles of GNI PPP seems to counteract the hypotheses that relate increases in respiratory symptom prevalence to increased industrialisation and, thus, increased national income [45–49]. However, country level factors other than national level income, such as pollution levels (as in urban settings), may be far more influential in the association with respiratory symptom prevalence [13, 15]. Clearly, the prevalence of both symptoms and diagnosis was quite high across urban regions regardless of national income. It is likely that this U-shape pattern represented a net effect of several different factors, with some contributing to higher risk in low-income countries (occupational hazards, pollution and poor access to healthcare) and others tending to increase asthma risk and reporting in high-income countries (pollution and greater awareness of asthma). Factors such as these may ''balance out'' in such a way that the middle-income countries have the lowest risks.

A further challenge in data collection is that even in clinical settings, asthma is not very well-defined [9, 13–16]. Physician diagnosis varies greatly by country and many asthmatics are not diagnosed [13–16, 24]. These complexities in defining asthma also lead to difficulties in linking factors that may be associated with asthma aetiology or exacerbation [1, 13–17]. Nevertheless, most surveys have found questions on wheezing to be a reliable indicator for asthma [9, 11, 13–17, 23, 24, 50, 51].

With these data, our analyses of the WHS presents an effort to present information beyond that collected in other large respiratory disease studies, such as ECRHS and ISAAC.

Conclusions

These WHS analyses have provided global estimates of wheezing and doctor-diagnosed asthma prevalence using data that were gathered concurrently, in a consistent and reliable fashion, across a wide sample of countries. The patterns in these results suggest different causes for self-reported wheezing and asthma diagnoses in different socioeconomic contexts; there is a clear U-shaped pattern of disease prevalence across strata of national income. These analyses of validated questions in WHS identify relationships between country characteristics and respiratory disease prevalence that are consistent with global trends in socioepidemiological approaches to structural determinants of health [13–17, 30].

Our analyses additionally strengthen the body of evidence supporting the use of questionnaires for studying respiratory symptoms. We encourage simpler, standardised sampling strategies to facilitate ongoing data collection in more countries worldwide. We further believe that these types of studies will be valuable in global respiratory illness surveillance for disease prevention, health policy and management.

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STATEMENT OF INTEREST

None declared.

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REFERENCES

1 Bousquet J, Clark TJH, Hurd S, *et al.* GINA guidelines on asthma and beyond. *Allergy* 2007; 62: 102–112.
2 Farrar JR. The global burden of asthma and current approaches to its management. *Eur Pharmacother* 2005; 126: 998–1000.
3 Eisen EA, Wegman DH, Kriebel D. Application of peak expiratory flow in epidemiologic studies of occupation. *Occup Med* 1993; 8: 265–277.
4 Kriebel D, Sama SR, Cocanour B. Reversible pulmonary responses to formaldehyde. A study of clinical anatomy students. *Am Rev Respir Dis* 1993; 148: 1509–1515.
5 Milton D K, Wypij D, Kriebel D, *et al.* Endotoxin exposure-response in a fiberglass manufacturing facility. *Am J Ind Med* 1996; 29: 3–13.
6 Guidelines for the evaluation of impairment/disability in patients with asthma. American Thoracic Society. Medical Section of the American Lung Association. *Am Rev Respir Dis* 1993; 147: 1056–1061.
7 Bernstein IL, Bernstein DI, Chan-Yeung M, *et al.* Definition and classification of asthma. *In*: Bernstein IL, Chan-Yeung M, Malo JL, *et al.*, eds. Asthma in the Workplace. Marcel Dekker, New York, 1999; pp. 1–3.
8 Driscoll T, Steenland K, D Imel Nelson, *et al.* Occupational airborne particulates. Assessing the environmental burden of disease at national and local levels. Environmental Burden of Disease Series, No. 7. Geneva, World Health Organization, 2004.
9 National Asthma Education and Prevention Program. Clinical Guidelines. Expert Panel Report 2. Guidelines for the Diagnosis and Management of Asthma. Publication No. 95-3659. National Institutes of Health. National Heart Lung and Blood Institute. 1995.
10 Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease (COPD) and asthma. *Am Rev Respir Dis* 1987; 136: 225–244.
11 United Medical and Dental School of Guy's and St Thomas Hospital. Protocol for the European Community Respiratory Health Survey. London, Dept of Public Health Medicine, 1993. Available from: www.ecrhs.org
12 Abramson MJ, Bailey MJ, Couper FJ, *et al.* Are asthma medications and management related to deaths from asthma? *Am J Respir Crit Care Med* 2001; 163: 12–18.
13 Masoli M, Fabian D, Holt S, *et al.* The global burden of asthma: executive summary of the GINA Dissemination Committee Report. *Allergy* 2004; 59: 469–478.
14 Britto MC, Freire EF, Bezerra PG, *et al.* Low income as a protective factor against asthma in children and adolescents treated *via* the Brazilian Unified Health System. *J Bras Pneumol* 2008; 34: 251–255.
15 Cooper PJ, Rodrigues LC, Cruz AA, *et al.* Asthma in Latin America: a public heath challenge and research opportunity. *Allergy* 2009; 64: 5–17.
16 Kramer MS, Matush L, Bogdanovich N, *et al.* The low prevalence of allergic disease in Eastern Europe: are risk factors consistent with the hygiene hypothesis? *Clin Exp Allergy* 2009; 39: 708–716.
17 Global Initiative for Asthma. Global strategy for asthma management and prevention. 2006. Available from: www.theipcrg.org/resources/nov2006/gina_final_06.pdf
18 Bedirhan-Üstin T, Chatterji S, Villanueva M, *et al.* WHO Multi-country Survey Study on Health and Responsiveness 2000–2001. Geneva, World Health Organization, World Health Survey, 2001.
19 Population Reference Bureau. DataFinder Sources. www.prb.org/DataFinder.aspx Date last accessed: August 25, 2009.
20 Encylopaedia Tiscali. Encyclopaedia Search. www.tiscali.co.uk/reference/encyclopaedia/hutchinson/ Date last accessed: August 25, 2009.
21 Central Intelligence Agency. The World Factbook. www.cia.gov/library/publications/the-world-factbook/fields/2172.html Date last accessed: August 25, 2009.
22 The World Bank. Data and statistics. Quick reference tables. www.worldbank.org/data/quickreference/quickref.html Date last accessed: August 25, 2009.
23 European Community Respiratory Health Survey (ECHRS). Variations in the prevalence of respiratory symptoms, self-reported asthma attacks, and use of asthma medication in the European Community Respiratory Health Survey (ECRHS). *Eur Respir J* 1996; 9: 687–695.
24 Asher I. The International Study of Asthma and Allergies in Childhood (ISAAC). *N Z Med J* 2008; 121: 117–118.
25 Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. The International Study Asthma Allergy Childhood (ISAAC) Steer Committee. *Lancet* 1998; 351: 1225–1232.
26 ISAAC. ISAAC Manual. 2nd Edn. Steering Committee. Auckland/Münster, ISAAC 1993.
27 SAS Institute Inc. SAS Language Reference, Version 8. Cary, SAS Institute, Inc., 2001.
28 SAS Institute Inc. The Glimmix Procedure, Nov. 2005. SAS Language Reference, Version 9.1.3. Cary, SAS Institute, Inc., 2005.
29 Sembajwe G. Common Variable Bias in Occupational Epidemiology. PhD thesis. University of Massachusetts Lowell, Lowell, MA, USA, 2007.
30 Cifuentes M, Sembajwe G, Tak S, *et al.* The association of major depressive episodes with income inequality and the human development index. *Soc Sci Med* 2008; 67: 529–539.
31 Beasley R, Keil U, Von Mutius E, *et al.* Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. *Lancet* 1998; 351: 1225–1232.
32 Gold DR, Wright R. Population disparities in asthma. *Annu Rev Public Health* 2005; 26: 89–113.
33 Weiland S, Husing A, Strachan D, *et al.* Climate and the prevalence of symptoms of asthma, allergic rhinitis, and atopic eczema in children. *Occup Environ Med* 2004; 61: 609–615.
34 Nickmilder M, Carbonnelle S, Bernard A. House cleaning with chlorine bleach and the risks of allergic and respiratory diseases in children. *Pediatr Allergy Immunol* 2007; 18: 27–35.

35 Montnemery P, Bengtsson P, Elliot A, *et al.* Prevalence of obstructive lung diseases and respiratory symptoms in relation to living environment and socio-economic group. *Respir Med* 2001; 95: 744–752.
36 American Thoracic Society. What constitutes an adverse health effect of air pollution? Official statement of the American Thoracic Society. *Am J Respir Crit Care Med* 2000; 161: 665–673.
37 Gauderman WJ, Avol E, Gilliland F, *et al.* The effect of air pollution on lung development from 10 to 18 years of age. *N Engl J Med* 2004; 351: 1057–1067.
38 Gauderman WJ, Vora H, McConnell R, *et al.* Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. *Lancet* 2007; 369: 571–577.
39 Erb K, Holloway J, Sobeck A, *et al.* Infection of mice with Mycobacterium bovis-Bacillus Calmette-Guérin (BCG) suppresses allergen-induced airway eosinophilia. *J Exp Med* 1998; 187: 561–569.
40 Goldberg S, Israeli E, Schwartz S, *et al.* Asthma prevalence, family size and birth order. *Chest* 2007; 131: 1747–1752.
41 Hertzen LC. The hygiene hypothesis in the development of atopy and asthma – still a matter of controversy? *QJM* 1998; 91: 767–771.
42 Douwes J, Pearce N. Commentary: the end of the hygiene hypothesis? *Int J Epidemiol* 2008; 37: 570–572.
43 Weiss ST. Eat dirt – the hygiene hypothesis and allergic diseases. *N Engl J Med* 2002; 347: 930–931.
44 Weiss ST. Asthma in early life: is the hygiene hypothesis correct? *J Pediatr (Rio J)* 2008; 84: 475–476.
45 Ebtekar M. Air pollution induced asthma and alterations in cytokine patterns. *Iran J Allergy Asthma Immunol* 2006; 5: 47–56.
46 Heinrich J, Wichmann HE. Traffic related pollutants in Europe and their effect on allergic disease. *Curr Opin Allergy Clin Immunol* 2004; 4: 341–348.
47 Ramos RG, Talbott EO, Youk A, *et al.* Community urbanization and hospitalization of adults for asthma. *J Environ Health 2006; 68*, 26–32: 44.
48 Von Hertzen L, Haahtela T. Disconnection of man and the soil: reason for the asthma and atopy epidemic? *J Allergy Clin Immunol* 2006; 117: 334–344.
49 Von Hertzen LC, Haahtela T. Asthma and atopy – the price of affluence? *Allergy* 2004; 59: 121–123.
50 Ferris BG. Epidemiology Standardization Project (American Thoracic Society). *Am Rev Respir Dis* 1978; 118: 1–120.
51 Meyer JD, Holt DL, Chen Y, *et al.* SWORD '99: surveillance of work-related and occupational respiratory disease in the UK. *Occup Med (Lond)* 2001; 51: 204–208.