Can the U.S. EPA BASE Study be used to provide reference levels for building-related symptoms in offices?

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SUMMARY
Thorough environmental/mechanical inspections are often helpful in remediating building-related symptoms (BRS, sometimes called sick building syndrome) in office buildings after complaint episodes. Using such inspections routinely in all buildings for <u>prevention</u> would be preferable, but not economically feasible. Availability of BRS "reference levels" for office buildings might identify buildings with unusually frequent BRS for investigation of unrecognized environmental problems. For this purpose, we assessed data from the U.S. Environmental Protection Agency's BASE Study, collected on more than 4000 workers in 100 representative U.S. office buildings. Frequencies of specific symptom types varied widely within and across buildings. Multiple personal factors correlated strongly with symptoms and, if distributed differently across buildings, could substantially distort symptom comparisons. Simultaneous statistical control for multiple personal factors was not feasible. Thus, using unadjusted symptom data from the BASE study to provide reference levels for assessing individual buildings for potential environmental problems should be done with caution.

KEYWORDS
building-related symptoms, sick building syndrome, office buildings, indoor environmental quality, reference levels

INTRODUCTION

Building-related symptoms (BRS), sometimes called sick building syndrome symptoms, have been reported by occupants in modern office and commercial buildings since the 1970s. Although a variety of environmental correlates of these symptoms have been reported (e.g., dampness/leaks), measured concentrations of specific pollutants have not consistently predicted BRS. Investigations in a building with many spontaneous "complaints" of symptoms among occupants may identify previously unrecognized indoor environmental problems that can be remedied (e.g., related to ventilation, temperature, or dampness/mold). However, it has been shown in systematic surveys that many buildings without widespread occupant complaints have reported symptom levels that are higher than those in obvious complaint buildings (Burge, 1987). Because deficient indoor environments that cause BRS are considered likely to cause reduced work performance among workers whether or not they are complaining about building-related symptoms, it is in the interest of both employees and employers to remedy, or better yet, prevent high levels of BRS. Still, strategies to identify high levels of BRS have not been available in the U.S., other than reacting to mass complaints from building occupants, which presumably indicate already longstanding problems. And conducting extensive proactive environmental investigations regularly in all buildings is not considered economically feasible.

Thus, it may be useful to develop reference levels of symptoms, collected in a standardized survey from a large baseline population of representative buildings. Comparison of reference data with symptom data from a comparably designed survey of specific office buildings of interest would then allow identification of buildings with unusually high BRS levels and thus locations for targeted environmental investigations. The aim of this project was to assess the usefulness of data from a large representative study of office buildings to create reference data for BRS among office workers, in ways that might assist building managers and investigators in the interpretation of symptoms surveyed from specific offices**.** We used data from the U.S. Environmental Protection Agency's Building Assessment Survey and Evaluation (BASE) Study, collected between 1994-1998 on more than 4000 workers in 100 representative U.S. office buildings with no history as "problem" buildings with related investigations.

METHODS

We calculated distributions of frequencies across buildings for BRS of six types (lower respiratory symptoms, upper respiratory symptoms, eye symptoms, skin symptoms, headache, and fatigue or difficulty concentrating). Each type of BRS required symptoms occurring at least one day per week (in the prior 4 weeks) and improving away from the workplace. We also explored major personal/non-environmental influences on symptoms.

Analyses included the following steps:

1) We estimated, in multivariate logistic regression models, the mutually adjusted associations between selected personal variables (prior asthma diagnosis, less than very satisfied with job, female gender, >40 hours worked per week, 3 or more people sharing a workspace, and more than 1 year working in the building) and prevalence of six types of BRS. Models estimated odds ratios (ORs) and 95% confidence intervals.
2) We calculated distributions of symptom prevalence across 100 buildings (minimum; 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles; maximum), overall and by subgroups of key personal covariates identified in step (1).
3) We explored adjusting building-specific symptom prevalence for multiple personal factors using indirect standardization.

RESULTS

Table 1 provides distributions for the overall building-level prevalence of six types of BRS within 100 BASE buildings. These unadjusted frequencies within buildings for the different BRS symptoms varied widely. The least frequent were lower respiratory symptoms (median 3.6%, maximum 17.9%); the most frequent were upper respiratory symptoms (median 18.4%, maximum 49.1%).

Five of the six personal variables we assessed were, after mutual adjustment in models, strongly related to most or all symptoms, sometimes with more than a doubling. The ranges of statistically significant ORs for the six BRS outcomes included: prior asthma diagnosis (1.5-4.7), female gender (1.8-2.9), more than 1 year working in the building (1.3-2.2), less than very satisfied with job (1.3-1.7), and 3 or more people sharing a workspace (1.4-1.5). "Less than very satisfied with job" included categories of somewhat satisfied, somewhat unsatisfied, and not at all satisfied.

Table 1. Quantiles of building-level distributions of BRS in 100 BASE buildings, all subjects

	Quantiles of Building Prevalence (%)					
Symptom	**0**	**25**	**50**	**75**	**95**	**100**
Lower Respiratory	1.2	2.0	3.6	5.7	11.6	17.9
Upper Respiratory	3.6	13.5	18.4	24.2	39.3	49.1
Dry, Irritated or Itching Eyes	2.6	12.5	17.5	21.8	32.1	40.2
Fatigue or Difficulty Concentrating	3.1	10.0	14.7	19.2	30.9	34.2
Headache	2.9	9.7	14.3	20.0	24.4	28.9
Irritated or Itching Skin	1.4	3.8	7.5	11.1	13.0	15.4

Table 2 provides selected quantile values for building-level prevalence of six types of BRS among all subjects, and among selected subgroups. Although these are not adjusted values, values only in a subgroup eliminate confounding by that specific variable (but not by others).

Table 2. Selected quantiles of building-level distributions of BRS in 100 BASE buildings – comparisons between all and selected subsets of subjects

	All		**Female**		**Less than very satisfied with job**	
	Quantiles (%)					
Symptom	**75**	**95**	**75**	**95**	**75**	**95**
Lower Respiratory	5.7	11.6	7.0	15.8	6.7	13.3
Upper Respiratory	24.2	39.3	29.7	43.8	28.6	44.0
Dry, Irritated or Itching Eyes	21.8	32.1	27.1	40.7	25.9	40.0
Fatigue or Difficulty Concentrating	19.2	30.9	25.0	33.6	25.0	37.5
Headache	20.0	24.4	24.2	31.3	23.3	31.3
Irritated or Itching Skin	11.1	13.0	9.3	15.8	8.6	16.3

Subgroup-specific comparisons were not feasible for simultaneous consideration of multiple personal variables. We also explored the calculation of "expected" symptom prevalence for an office building, using a statistical technique called "indirect standardization" to adjust for proportions in the building of personal variables strongly related to symptom reporting, but with different distribution than in the BASE buildings (e.g., more females, more dissatisfied). This technique in practice could not be applied to subgroups defined by the combination of multiple factors (e.g., female, dissatisfied with work, asthmatic), because the numbers within subgroups in a specific building of interest would generally be too small and estimates would be unstable. Multiple regression techniques for this purpose were also problematic.

DISCUSSION

Availability of BRS “reference levels” for office buildings might identify buildings with unusually frequent BRS for targeted investigation of unrecognized environmental problems. However, different distributions of personal factors in the target building than in the reference buildings would distort symptom frequencies. This could lead to unwarranted investigations or missed needs for investigation. Simultaneous statistical control for multiple personal factors, in order to avoid this, would not be feasible except in large buildings; however, in large buildings, environmental problems on specific floors or ventilation zones might be missed through pooling with many other areas without problems. Thus unadjusted symptom data from the BASE study should be used only with caution as reference levels for identifying potential indoor environmental problems. Potential users might compare distributions of key factors across the two populations and, with increasing differences, use more caution.

A current European system (the Őrebro model) using a questionnaire developed in Sweden, compares data collected with a standardized questionnaire in a building of interest with data previously collected from 319 workers in nine “healthy” buildings (7 offices, 2 schools) without known indoor environmental problems (Andersson K, et al., http://www.orebroll.se/ upload/USO/YMK/ Dokument/school%20environment %20manual.pdo; accessed Nov 11, 2008). It is not clear how the small size and diversity of the reference population and lack of adjustment for personal factors of this system would influence the results.

Key issues in using reference distributions of BRS include how to interpret symptom findings in a specific building – what kind of symptom definition to use (e.g., retrospective frequency or current severity; work-related or anywhere) , which symptom(s) to use, what level of symptoms should trigger what investigation, and how to consider effects of personal factors in interpreting the findings? These issues require further analysis, discussion, and consensus.

CONCLUSIONS

The use of BRS “reference levels” from office buildings to identify buildings with unusually frequent BRS that merit investigation for unrecognized environmental problems is appealing. However, multiple personal factors correlated strongly with symptom frequencies but distributed differently across buildings could substantially distort symptom comparisons. Because statistical control for such distortion is often not feasible, we suggest caution in interpreting symptom data from reference buildings to draw inference about potential indoor environmental problems in a single building of interest.

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