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Asma laboral en personal sanitari

Work-related asthma in healthcare workers

Memòria presentada per en Jordi Delclòs i Clanchet per optar al títol de Doctor per la Universitat Pompeu Fabra. Aquest treball ha estat realitzat sota la direcció dels Drs. Fernando G. Benavides i Josep María Antó i Boqué del Departament de Ciències Experimentals i de la Salut de la Universitat Pompeu Fabra.

El sabater és el més mal calçat.
[Catalan proverb]

The cobbler's children go barefoot.
[English proverb]

En casa del herrero, cuchillo de palo.
[Spanish proverb]

Como siempre, para siempre.

A mi novia Conchita.

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The list is long, the expressions of appreciation insufficient, and the space limited. The omissions, whereas inadvertent, unintended and no doubt affected by a mind numbed at this stage, will nevertheless haunt me for time to come, I'm sure. So much for the description of the limitations for this section of the dissertation. The strengths, reflected by all who have supported me on this journey, are much greater in number.

To the original research team in Texas for what we ultimately termed the "NIOSH-funded Asthma Grant" or more affectionately, "NAG": Ahmed Arif, Chip Carson, Christine Lusk, Dejian Lai, Elaine Symanski, Keith Burau, Larry Whitehead, Lu Ann Aday, and Tom Stock, my deepest gratitude. You were on board with this project from when it was just an idea pursuant to a "hunch" that healthcare workers might truly represent an at-risk group for asthma. To Sarah Felknor, who has been a model of friendship, collegiality and support of our work in public health for more than 16 years, my thanks and respect. To Anne Dybala, Marice Barahona, Maria Arias and the staff on 10 West at The University of Texas School of Public Health, your selfless contributions and permanent sense of humor when I most needed both, were invaluable. It is a privilege to work with all of you.

To NIOSH, for its financial support of the project, my thanks as well. To the healthcare workers who, through their participation, provided both the inspiration and motivation (as well as the data, of course), my appreciation. You, as do all workers, serve as a permanent reminder to me that ideology is not dead, and that we can all do better in making service to others compatible with the protection of health and promotion of safety in the workplace.

Al Jan-Paul i el Josep Maria, en un principi només noms que apareixien un cop i un altre en els articles que llegia, representants d'un nivell altíssim de recerca en l'epidemiologia

del asma – qui m'havia de dir que un dia treballaríem junts? Espero i desitjo que no sigui l'últim. El meu respecte més profund, amb agraïment i humilitat.

I als meus estimats Fernando, David i Consol.....crec que les paraules sobren, cap sorpresa. Tant sols sabeu que, per sobre de tota la feina conjunta, tant en docència, decència i recerca, potser inclús per sobre del molt que us estimo, el que més us agraeixo és l'haver-me permès tornar a prendre un contacte real amb aquell país que tant estimo i que fa tant de temps vaig deixar. No podeu imaginar-vos el favor tan immens que m'heu fet. I només acabem de començar.

Als meus pares, per ser un model constant d'inspiració, de parella, de generositat i d'humilitat, d'amor pels fills i per les nostres cultures i, encara avui, de seny i sentit comú. Us estimo.

Y lo mejor para el final. Para esa asturiana que, pese a haberme aguantado más de 33 años, sigue ahí. Que sigue llamándome cinco minutos después de la hora "oficial" de cierre del trabajo para saber cuándo llegaré a casa, aunque conoce de sobras la respuesta....y que ésta nunca la satisface. Que, a pesar de cuatro maravillosos hijos a nuestras espaldas, sigue cogiéndome de la mano como cuando teníamos 16 o 17 años, y que tiene tan claras las cosas más básicas de la vida que me lo hace todo demasiado fácil. Si queremos hablar de desigualdades sociales, ahí tenéis un ejemplo un poco distinto. Sin duda, yo me llevé la mejor parte. Sigues recordándome la letra de cada canción.

Houston, a 10 de diciembre de 2006

PREFACE/PREFACI

La present tesi doctoral es basa en un projecte general de recerca titolat "Un qüestionari validat per estudis d'asma en personal sanitari" del qual he estat l'Investigador Principal, sent el responsable de la proposta original i del seu disseny metodològic i el director de l'equip multidisciplinari al llarg de la durada del projecte. Tanmateix, he estat el responsable principal de la gestió de les bases de dades, l'anàlisi estadística amb l'assistència dels meus col·legues, i he liderat l'elaboració dels manuscrits científics principals. El projecte de recerca va ser finançat per un període de 4 anys (2001-2005) pel projecte número 5R01OH03945-01 del U.S. National Institute for Occupational Safety and Health/Centers for Disease Control and Prevention (NIOSH/CDC) i també parcialment pel projecte número T42CCT610417 del NIOSH.

Els objectius principals del projecte eren avaluar la magnitud del risc d'asma, les associacions amb exposicions d'origen laboral i estimar la càrrega de l'asma relacionada amb el treball entre professionals sanitaris.

Aquesta tesi s'estructura en els següents apartats: : una introducció, els objectius, tres manuscrits científics (dos principals i un secundari) on es presenten els resultats principals del projecte, una discussió general dels resultats i les conclusions de l'estudi. En l'Annex s'inclou un quart manuscrit sobre estratègies analítiques per a la classificació de l'asma.

Amb excepció del prefaci i del resum, la resta de la tesi està escrita en anglès. Desitjo de tot cor que això no es consideri una manca de consideració per les meves dues altres llengües maternes, el català i el castellà, sinó mes aviat com a senyal d'estima del temps dels meus directors de tesi i del tribunal, així com per respecte pel valor dels arbres.

PREFACE

This doctoral thesis is based on a project entitled "A validated asthma questionnaire for healthcare workers", funded in 2001 by the U.S. National Institute for Occupational Safety and Health/Centers for Disease Control and Prevention (NIOSH/CDC) as Grant No. 5R01OH03945-01A1, for a period of four years; part of the work was also supported by NIOSH training grant T42CCT610417. I was Principal Investigator of both grants, developed the original proposal and study design, and directed the multidisciplinary research team throughout the project period. I also had the lead role in data management and statistical analysis with the assistance of my colleagues, and wrote the main papers.

The overall objective of the project was to assess the magnitude of asthma risk, evaluate associations with occupational exposures, and estimate the burden of work-associated asthma in healthcare professionals.

The thesis presents its principal findings, and is structured as an Introduction, Objectives, three scientific papers (two principal and one supplemental methods paper) presenting the main findings of the project, Discussion and Conclusions. In addition, the Appendices feature a fourth manuscript on analytical strategies for the classificatioin of asthma. All papers were written and accepted for publication in English. Hence, with the exception of the Preface and Summary, the main sections are written in English. I hope this is not taken as disrespect for my two other mother tongues, Catalan and Spanish, but rather as a sign of appreciation for the valuable time of my dissertation committee and tribunal, as well as of respect for the value of trees.

RESUM

Dades recents dels Estats Units assenyalen un augment entre el personal sanitari del risc d'asma relacionat amb el treball. No obstant, l'evidència és inconsistent i els estudis poc detallats. Per determinar la magnitud del risc d'asma, avaluar la seva associació amb les exposicions laborals, i estimar la càrrega d'asma relacionat amb el treball entre professionals sanitaris, es va dissenyar i validar un qüestionari que seguidament es va administrar en un estudi de camp. Aquest projecte es va desenvolupar com dos estudis separats i consecutius. En el primer estudi es va dissenyar, validar i revisar el qüestionari. En el segon estudi es va administrar el qüestionari mitjançant una enquesta postal a una mostra representativa de grups seleccionats de professionals sanitaris a l'Estat de Texas. En un tercer estudi complementari es van examinar els determinants de la resposta a la enquesta.

Al concloure el primer estudi s'havia produït un qüestionari d'onze pàgines que es podia completar entre 13 i 25 minuts. La fiabilitat *test-retest* dels ítems sobre asma i al·lèrgies fou del 75% al 95%, i la seva consistència interna fou excel·lent (α de Cronbach $\geq$ 0.86). Comparada amb la prova de metacolina com *gold standard*, es va identificar una combinació de 8 ítems sobre símptomes d'asma amb una sensibilitat del 71% i una especificitat del 70% per $PC_{20} \leq 8$ mg/ml i una sensibilitat del 61% i una especificat del 85% per $PC_{20} \leq 4$ mg/ml. Comparada amb el diagnòstic mèdic d'asma, aquesta mateixa combinació de símptomes tingué una sensibilitat del 79% i una especificitat del 98%.

En el segon estudi, usant el qüestionari prèviament validat, es va desenvolupar un estudi transversal entre 5600 professionals sanitaris de l'Estat de Texas. Es va seleccionar una mostra aleatòria de 1400 persones amb llicència professional activa durant l'any 2003 en quatre grups professionals: metges, infermers, tècnics en teràpia respiratòria i tècnics en teràpia ocupacional. La informació sobre asma i factors de risc no laborals, obtinguda amb el qüestionari, es va combinar amb informació sobre exposicions laborals derivada d'una matriu

de ocupació-exposició (dissenyada específicament per aquest estudi). L'enquesta es va distribuir entre els participants per correu postal donant-los l'opció de retornar-la per via postal o per Internet. La tasa de resposta general fou del 66%. La mostra final d'estudi inclogué 862 metges, 941 infermers, 968 tècnics en teràpia ocupacional i 879 tècnics en teràpia respiratòria (n=3650). Un 90% dels participants va tornar l'enquesta per via postal i un 10% per Internet. La probabilitat de respondre per Internet fou més alta entre els homes i entre les persones de més joves.

Es varen definir dues variables dependents *a priori*: a) asma diagnosticat per metge després d'haver començat a treballar al sector sanitari ('asma reportat'), i b) 'símptomes relacionats amb hiperreactivitat bronquial' definit en base al predictor de 8 ítems.

L'asma reportat es va associar amb la neteja/esterilització d'instrumental mèdic (odds ratio [OR], 2,22; interval de confiança [IC95%], 1,34-3,67), tasques generals de neteja (OR, 2,02; IC95%, 1,20-3,40), ús de guants de làtex amb pols entre els anys 1992 i 2000 (OR, 2,17; IC95%, 1,27-3,73) i administració de medicaments en aerosol (OR, 1,72; IC95%, 1,05-2,83). El risc associat amb l'ús de guants de làtex desaparegué després de l'any 2000. Els símptomes relacionats amb hiperreactivitat bronquial es varen associar amb tasques generals de neteja (OR, 1,63; IC95%, 1,21-2,19), administració de medicaments en aerosol (OR, 1,40; IC95%, 1,06-1,84), ús de productes adhesius en els malalts (OR, 1,65; IC95%, 1,22-2,24) i antecedents d'haver estat exposat a un vessament químic (OR, 2,02; IC95%, 1,28-3,21).

Aquest treball evidencia un risc elevat d'asma després d'haver començat a treballar al sector sanitari per aquelles tasques que inclouen neteja i desinfecció d'instruments mèdics, neteja general, l'ús de guants de làtex amb pols i l'administració de medicaments en aerosol. També s'evidencien associacions significatives entre símptomes relacionats amb hiperreactivitat bronquial i l'ús de productes generals de neteja, l'administració de medicaments en aerosol, l'aplicació de productes adhesius o dissolvents en malalts, així com

en aquelles persones amb antecedents d'haver estat exposat a un vessament químic. No s'observa risc d'asma per ús de làtex a partir de l'any 2000. Els resultats son consistents amb associacions prèviament descrites entre asma i exposicions laborals en personal sanitari; també s'identifiquen noves associacions que meriten més avaluació. Pensem que les exposicions laborals contribueixen de manera important a l'asma en el personal sanitari, motiu pel qual estan justificades tant la implementació de controls adequats com la recerca addicional.

SUMMARY

Recent U.S. data suggest an increased risk of work-related asthma among healthcare workers. However, results have been inconsistent and lacking in detail. To assess the magnitude of asthma risk, evaluate associations with occupational exposures, and estimate the burden of work-related asthma in healthcare professionals, a new survey instrument for work-related asthma among health care workers was developed, validated and administered in a field study. The project was conducted as two separate and consecutive studies. In Study I, the survey instrument was developed, validated and refined. In Study II the validated questionnaire was administered, via a postal survey, to a population-based sample of selected groups of health care workers in Texas. A third supplemental study (Study III) examined determinants of response to the survey.

Study I resulted in an 11-page questionnaire which required approximately 13 to 25 minutes to complete. Test-retest reliability of asthma and nonoccupational asthma risk factors items ranged from 75% to 95%, and internal consistency for these items was excellent (Cronbach's $\alpha \geq 0.86$). Against methacholine challenge, an 8-item combination of asthma symptom items had a sensitivity of 71% and specificity of 70% for $PC_{20} \leq 8$ mg/ml and a sensitivity of 61% and specificity of 85% for $PC_{20} \leq 4$ mg/ml. Against a physician diagnosis of asthma, this same combination showed a sensitivity of 79% and specificity of 98%.

In Study II, using the questionnaire validated in Study I, a cross-sectional statewide survey of 5600 Texas healthcare professionals (physicians, nurses, respiratory therapists and occupational therapists) was conducted. A simple random sample of 1400 persons was drawn from each of the four populations of professionals (physicians, nurses, respiratory therapists and occupational therapists) with active licenses in 2003. Information on asthma symptoms and nonoccupational asthma risk factors obtained from the survey was then linked to occupational exposures derived from an external asthma risk factor job-exposure matrix

(also developed for this study). The survey was initially sent by U.S. mail, but participants were given the option of responding via return reply envelope or over the internet. Overall response rate was 66%.

The final study population consisted of 862 physicians, 941 nurses, 968 occupational therapists and 879 respiratory therapists (n=3650). Ninety percent of respondents returned the survey via return reply envelope, and 10% over the internet. The likelihood of responding over the internet was greater among males and younger age groups.

There were two *a priori* defined outcomes: a) physician-diagnosed asthma with onset after entry into healthcare ('reported asthma'), and b) 'bronchial hyperresponsiveness-related symptoms', defined through the 8-item symptom-based predictor.

Reported asthma was associated with medical instrument cleaning (OR, 2.22; 95% CI, 1.34-3.67), general cleaning (OR, 2.02; 95% CI, 1.20-3.40), use of powdered latex gloves between the years 1992 and 2000 (OR, 2.17; 95% CI, 1.27 to 3.73) and administration of aerosolized medications (OR, 1.72; 95% CI, 1.05 to 2.83). The risk associated with latex gloves disappeared after 2000. Bronchial hyperresponsiveness-related symptoms were associated with general cleaning (OR, 1.63; 95% CI, 1.21-2.19), aerosolized medication administration (OR, 1.40; 95% CI, 1.06-1.84), use of adhesives on patients (OR, 1.65; 95% CI, 1.22-2.24) and exposure to a chemical spill (OR, 2.02; 95% CI, 1.28-3.21).

This study found an approximately two-fold increased likelihood of asthma after entry into a healthcare profession for tasks involving instrument cleaning and disinfection, general cleaning products used on indoor building surfaces, use of powdered latex gloves, and the administration of aerosolized medications. Significant associations were likewise found between BHR-related symptoms and use of surface cleaners, aerosolized medication administration, adhesives or solvents as products in patient care, as well as with a history of sustaining an acute exposure to a chemical or gas at work. Risk of asthma associated with use

of powdered latex gloves was not observed after the year 2000. Study findings are consistent with previously reported associations between asthma and occupational exposures in healthcare settings, and identify new relationships warranting further evaluation. Occupational exposures contribute importantly to asthma among healthcare professionals and are not trivial, meriting both further study and implementation of appropriate controls.

1. INTRODUCTION

1.1 Statement of the Problem

In 2002, healthcare workers (HCWs) comprised approximately 8% of the U.S. workforce.[1] Healthcare-related occupations represent 50% of the top 30 fastest growing occupations in the U.S., and are projected to grow to more than 15 million by 2012, or a 30% increase from 2002. Within the HCW group, job growth is greatest among nurses, physicians, respiratory therapists, occupational therapists/physical therapists, dental professions, and pharmacy professionals. By location, outpatient settings are the most affected, with average annual increases more than double those of the remainder of the U.S. economy.[1]

Work in healthcare settings is associated with a potential for occupational exposures that straddle the full spectrum of workplace hazards, including biological, physical, chemical, and radioactive agents, as well as psychosocial factors. In the 1990s, attention began focusing on respiratory hazards among HCWs, in part because of increasing concern over occupational latex allergy, including asthmatic reactions, following passage in the U.S. of the 1992 OSHA Bloodborne Pathogens standard[2], which resulted in a significant increase in the use of latex-containing personal protective equipment, such as gloves.[3] Potential asthmagens in healthcare settings go beyond latex, however, and may include disinfectants/sterilants (e.g., glutaraldehyde, formaldehyde), pharmaceuticals (e.g., psyllium, various antibiotics, platinum-containing antineoplastic agents), sensitizing metals (e.g., dental alloys), methacrylates, aerosolized medications and cleaning agents.[4-7] Furthermore, since there are potentially multiple sensitizers in healthcare environments, it is possible that interactions among these compounds could affect sensitization thresholds.[4]

Previous studies from various countries have reported cases of work-related asthma among specific groups of HCWs, including physicians [8,9], respiratory therapists[10,11], workers in endoscopy units and radiology departments[12], nurses [13], and general HCWs[14].

Confirmation and estimation of risk in population-based studies, however, has been more problematic. In a cross-sectional analysis of the European Community Respiratory Health Study (ECRHS), significant excesses of risk among HCWs were not consistently observed across countries[15]. In the U.S., using data from the National Health and Nutrition Examination Survey (NHANES) III, conducted between 1988 and 1994, the odds for either work-related asthma or wheezing in health-related industries and occupations were not significantly increased[16,17]. Data from the 2001 National Health Interview Survey did find significantly increased odds for physician-diagnosed asthma in the U.S. healthcare industry, but this excess was limited to white females[18]. On the other hand, recent surveillance data from four U.S. states found that work-related asthma among HCWs represented 16% of total reported cases, exceeding their representation in the workforce (8%)[5]. The agents most frequently associated with these reported asthma cases included latex, cleaning products and poor indoor air quality. Interestingly, the U.S. National Institute for Occupational Safety and Health (NIOSH) reported that 5 of the top 11 industries and 9 of the 22 leading occupations associated with significantly increased asthma *mortality* were related to healthcare services.[19,20]

Thus, there is evidence that workers in healthcare settings are at an increased risk of asthma, albeit somewhat inconsistently. Despite this, important gaps remain literature with respect to better risk characterization of healthcare worker subgroups, identification and assessment of specific exposures to asthmagenic compounds, estimation of the impact of asthma on work patterns and productivity among healthcare workers, and implementation of appropriate preventive measures.

1.2 Asthma in the Workplace

There are approximately 16 million people in the United States with asthma, and the incidence and prevalence of asthma have been increasing in the general population, both worldwide and in the United States, for the past two and a half decades.[21]

In the U.S., the annual economic and social consequences of asthma are staggering, as evidenced by more than 100 million days of restricted activity yearly, nearly 500,000 hospitalizations, over 5,000 deaths, and billions of dollars in both direct medical and indirect costs.[22-24] Various factors have been implicated in explaining these worsening epidemiological trends, including contaminants present in workplaces. It has been estimated that there are over 20 million workers potentially exposed to occupational asthmagens, 9 million of whom are exposed to established asthma sensitizers and irritants.[25]

In the strictest sense, *occupational asthma* (OA) is defined as variable airflow limitation and bronchial hyperresponsiveness due to causes and conditions encountered in an occupational environment and not outside the workplace.[26] OA is presently the most frequently reported diagnosis of occupational respiratory disease in developed nations, including the United Kingdom, Canada and the United States.[7,26] To date, over 300 workplace agents have been identified as specific causes of OA.[4]

OA is further classified into two major types, depending on mechanism: 1) allergy-mediated asthma which is induced by immunologic mechanisms, and 2) irritant-induced asthma which is caused by finite overexposure(s) to respiratory irritants.[4,27-29] In addition to asthma caused by occupational exposures, workplace exposures may also aggravate asthma in workers whose disease was pre-existing, a condition often referred to as *work-aggravated asthma*.[30] The term *work-related asthma* encompasses the concepts of both occupational asthma and work-aggravated asthma.[4]

Definitions of work-related asthma can vary depending on the purpose of the study, the population studied and the context in which the detection of asthma is conducted. [31,32] In clinical settings, where the focus is on etiology and/or diagnosis for both clinical and medical-legal purposes, a strict or deterministic definition of OA is generally needed. Implicit in this definition is the emphasis on *individual causation* of new asthma; hence, aggravation of pre-existing asthma is excluded. These determinations are typically based on an individualized process involving a clinical history, physical examination, pulmonary function studies, other complementary tests and, not infrequently, several visits over time. If, however, case detection centers on *populations* rather than individuals, for the purpose of examining asthma prevalence in different populations, or for identifying high-risk groups and/or opportunities for prevention, then a more probabilistic definition may be in order. The latter involves a relative judgment of increased frequency of asthma in an occupational population in comparison to a non-occupationally exposed (reference) population.[33,34]

The objectives of the present doctoral thesis were framed within this context of a probabilistic asthma definition. Furthermore, as proposed by Wagner and Wegman [31], later modified by Malo and Chan-Yeung [32], the term *work-related asthma* employed in this thesis encompasses:

- *allergy-mediated asthma* (also known as sensitizer-induced, immunologically mediated and/or asthma with latency)
- *irritant-induced asthma* (also known as non-immunologically mediated asthma, including but not limited to reactive airways dysfunction syndrome or "RADS")
- pre-existing asthma exacerbated by workplace exposures, i.e., *work-aggravated asthma*.

Estimates of the proportion of asthma in adults that is occupational in origin have varied widely, likely due to several factors, including geographic area, lack of recognition of

occupational factors,[35] an absence of statewide surveillance systems for asthma,[36] variations in asthma case definitions and differences among denominator populations. In a review and synthesis of 43 attributable risk estimates, the median value for attributable risk of occupationally associated asthma was 9%, although this figure increased to 15% when only high-quality studies were considered.[37]

In the United States, recent evidence suggests that the attributable fraction may be even higher. In a recent study of employed persons belonging to a large health maintenance organization, 29% of adult-onset asthma was attributable to workplace exposures, with 26% and 22% of cases attributable to occupational irritant and sensitizer exposures, respectively.[38] These results approach those of another study based on adult population data from the U.S. National Health and Nutrition Examination Survey III (1988-1994), where the attributable fractions of work-related asthma and work-related wheezing among at-risk occupations were 26% and 27%, respectively. [16, 17] These figures are high in comparison to Europe and Spain, where the proportion of asthma attributable to occupation was in the 5%-10% range, based on data from the ECRHS.[15,39]. However, in the ECRHS the age range of study participants (20-44 years) was narrower than in the NHANES III population (age 20 years and over), and the prevalence of overall asthma in most of Europe seems to be lower than in English-speaking countries.[40] In Catalunya, occupational asthma is the most frequently reported occupational respiratory disease, comprising approximately 48.5% of all voluntarily reported cases. The estimated annual incidence rate is 77.2 cases per 10^6 person-years, although this figure is suspected to be low because of underreporting through the existing compulsory notification system.[41]

Certain occupational groups are known to be at particularly high risk of developing OA, including Western red cedar workers,[42] isocyanate-exposed chemical workers,[43] construction workers,[44] farmers,[45] bakers and cleaners,[46] textile workers,[47] and animal

handlers.[48] Whereas the magnitude of the risk and etiologic agents are well characterized for many of these occupational groups (e.g., red cedar workers, bakers and animal handlers), this is less well-studied in the case of HCWs, where data are largely derived from case series and some surveillance systems, but relatively few population surveys. In order to examine these factors in greater detail in HCW populations, however, certain methodological limitations inherent to many occupational epidemiological studies, including those focused on asthma, should be recognized and addressed.

1.3 Methodological Issues in Epidemiology Studies of Workplace Asthma

In 1996, Cullen lamented the paucity of available instruments for field studies and underscored the importance of developing a reliable, standardized and practical survey instrument for OA, suitable for estimating both prevalence and incidence of OA in cross-sectional and longitudinal studies.[49] As is the case with many occupational epidemiological studies, key methodological dilemmas center around accurate definition of both the outcome (asthma) and assessment of workplace exposures.

1.3.1. Ascertainment of asthma

Questionnaires have long been a cornerstone of asthma epidemiology studies, mainly for the detection of asthma prevalence in different populations, but less so for the study of associations between workplace exposures and disease. Much work has gone into standardizing asthma questionnaires for use in the general population, by groups such as the British Medical Research Council (MRC), American Thoracic Society (ATS), and the International Union Against Tuberculosis and Lung Disease (IUATLD).[50-52] However, questionnaire-based definitions of asthma and/or symptoms consistent with asthma may not

necessarily correspond to the clinical definition of asthma. In fact, there is no universally accepted "gold standard" definition of asthma for use in epidemiology studies.

According to the 1997 National Asthma Expert Panel guidelines, asthma can be defined as a "chronic inflammatory disease of airways characterized by widespread, variable, often reversible airflow limitation, and increased airway hyperresponsiveness resulting in clinical symptoms of wheezing, cough and breathlessness."[53] Prior studies attempting to validate asthma questionnaires have generally relied on either a physician diagnosis of asthma or on physiological measurements of bronchial hyperresponsiveness as "gold standards". Not uncommonly, a physician diagnosis of asthma can both over and underestimate this disease, especially when the diagnosis is not based on objective measures of lung function.[53] In adults, furthermore, this error is likely to increase with age because of the confounding effects of chronic obstructive pulmonary disease (COPD). Nonspecific bronchial hyperresponsiveness (BHR), on the other hand, is a near universal feature in symptomatic asthma (in the clinical setting), and reflects two of the identifying characteristics contained in the NHLBI definition of asthma, i.e., variable airflow limitation and BHR.[54] However, BHR may also be present in asymptomatic individuals, and is not synonymous with asthma.

The selection of a deterministic versus probabilistic definition of asthma for use in occupational studies is reflective of the broader issue of measuring asthma in population-based studies. How asthma is best determined in such studies has been the topic of some debate, but is generally based on use of symptom questionnaires, physiologic tests such as measurement of BHR via bronchial challenge testing, or different combinations of both.[33,34,55] Pekkanen, Pearce and Beasley have elegantly summarized the issues, noting that a single definition of asthma is not applicable to all epidemiological studies.[33,34] Instead, final choice of an asthma definition in population-based studies should consider study aim and instrument

validity, in addition to feasibility, cost, ease of implementation, and likelihood of achieving high response rates. For studies in which the aim is to compare asthma prevalence across groups, definitions that exhibit the best combination of sensitivity and specificity (or Youden´s index, i.e., sensitivity + specificity – 1) are preferred. In contrast, when examining associations between asthma and potential risk factors, such as in case-control or cohort studies, more specific definitions are warranted, with positive predictive value being an important determinant of validity.[33]

Two essential characteristics of a survey instrument that determine its scientific value are the reliability (repeatability) and validity (accuracy) of its measures.[56] Reliability can be assessed by administering the questionnaire on two or more occasions to the same individuals (test-retest reliability), by comparing responses when the same data are gathered by different observers (inter-rater reliability) and/or by asking different questions about the same concept (internal consistency). Testing the degree to which questionnaires accurately detect the concept of interest (validity) is more complex, and ideally involves a series of sequential steps. *Content* validity refers to whether the questions adequately represent the concept they intend to reflect. *Criterion* validity assesses the degree to which questionnaire items agree with some recognized "gold standard" for the measure. *Construct* validity measures the extent to which a particular item relates to other measures consistent with known hypotheses concerning the underlying concepts being measured.[56]

Relatively few studies have been published with information on formal validation of asthma questionnaires. In those cases where this was done, questionnaire items on asthma and asthma-like symptoms were usually compared to putative "gold standards", e.g., physiologic measures of nonspecific BHR, previously used questionnaires or physician-diagnosed asthma.[52,57,58] Burney et al. originally validated the IUATLD questionnaire in 833 adults in two English villages.[52] A cluster of five questions on asthma symptoms (wheeze

during the last 12 months; a post-exercise attack of shortness of breath during the last 12 months; waking at night because of shortness of breath during the last 12 months; description of breathing patterns; and chest tightness in the presence of dust or feathers) collectively referred to as the "Discriminative Function Predictor" (DFP), was validated against histamine bronchial challenge. The DFP was highly specific (0.90) but only moderately sensitive (0.53). This questionnaire has also been translated and validated in different languages in four European countries (N=175).[59] Kongerud et al. used a modified MRC questionnaire to test 296 workers in a Norwegian aluminum plant.[58] Questionnaire responses were compared to the clinical judgment of a chest physician. The question on wheezing had a sensitivity of 0.77 and specificity of 0.82, whereas the question on dyspnea had a sensitivity of 0.75 and specificity of 0.88. Abramson et al. validated asthma symptom items on the IUATLD questionnaire against a modified British MRC questionnaire and methacholine bronchial challenge test in aluminum smelter workers in Australia.[57] Construct validity of the IUATLD items was evaluated by comparing responses to similar questions on a modified MRC questionnaire. Responses to questions concerning past asthma, wheezing, and morning cough were comparable in both questionnaires. Comparing responses to the IUATLD questionnaire against methacholine bronchial challenge tested criterion validity. In that study, questions on wheeze (Q1), asthma in the previous 12 months (Q13), asthma medication (Q14), spontaneous shortness of breath (Q3), awakening at night because of shortness of breath (Q5), morning chest tightness (Q2), nocturnal cough (Q6), attack of shortness of breath after stopping exercise (Q4) and breathing difficulty (Q10) exhibited high validity.

1.3.2 Retrospective occupational exposure assessment

Different methods can be used to retrospectively assess occupational exposures in epidemiology studies, including self-reported exposure, detailed interviews with workers or

relatives, expert industrial hygiene assessment of occupational histories, and use of *a priori* developed job-exposure matrices.

Self-reported exposure to checklists of chemical agents has been reported to have high specificity (ranging from 0.83 to 0.97), but low sensitivity (median, 0.61; range 0.39 to 0.91) when compared to expert assessment by a team of industrial hygienists and chemists, which could lead to significant misclassification of exposure when used in population-based studies.[60] Detailed interviews with workers or their proxy require a large time commitment, are costly and often logistically difficult, and have exhibited inconsistent validity.[61-64] Fritschi et al questioned whether use of expensive, time-consuming expert assessment by hygienists was an acceptable "gold standard", acknowledging that few data exist on the validity of this method.[60] Louik et al further noted that expert assessment is also limited by a scarcity of qualified experts.[64]

Job-exposure matrices (JEM), on the other hand, involve organizing information in such a way that job titles are systematically linked to specific workplace exposures, to provide unbiased (or less biased) exposure estimates for use in epidemiological studies. The information used to develop a JEM often comes from multiple sources, including period-specific and industry-specific exposure measurements, review by teams of experts, and direct observation of a sample of workplaces. In addition to dichotomizing exposures (i.e., exposed/non-exposed), a semiquantitative approach can be applied whereby exposures are classified into different levels (e.g., low, medium, high) or likelihood (none, possible, probably) of exposure.

Construction of a JEM is generally viewed as a less expensive method of assigning exposures than costly, time-consuming, individualized industrial hygiene reviews. However, concerns have been raised about limitations associated with the use of JEMs, including the potential for misclassification of exposure, assumption of homogeneity of exposure within a

given cell, the possible loss of statistical power due to grouping of subjects by job, and the lack of formal validation of most JEMs.[60,64,65] Features of a JEM that seem to increase validity include limiting the JEM to specific exposures (e.g., carcinogens, asthmagens), industries or worker populations (e.g., healthcare workers), and using semiquantitative scales to assign probability of exposure.[64,66]

Between 1981 and 1983, NIOSH conducted the National Occupational Exposure Survey (NOES) to obtain data on potential exposure agents and profile health and safety programs in United States workplaces.[67] A sample of 4,490 businesses (excluding agriculture, mining and government) in 98 different geographic regions was surveyed, via on-site visits, administration of questionnaires to plant managers, direct observation of processes and operations, and recording of potential worker exposures. The sample involved 523 different industries, with 1,800,000 workers, and over 10,000 different potentially hazardous agents were identified. Using data from NOES, a JEM was later developed by NIOSH investigators based on potential exposure data, using a methodology similar to one employed in an earlier NIOSH survey.[68] The final NOES-based JEM consists of 489,623 records, publicly available on CD-ROM. An extract of this JEM, specific for health services, is also publicly available, but apparently has not been widely used to date in research.[69] Advantages to use of this generic JEM could include its origin based on direct observations of a representative sample of U.S. workplaces, its public availability, the fact that it considers exposures that may no longer exist (important in diseases where past exposures may be determinants of future disease, such as cancer), and the use of common industry, occupation and hazard codes that allow combination with other databases. Limitations include the lack of quantitative exposure measurements and the information possibly being outdated and not including new hazardous agents discovered since the time the NOES was conducted.

In 1997, de la Hoz and colleagues also used data on hazardous agents from the NOES, combined with information from Bernstein et al, to produce a list of 367 occupational asthmagens.[70,71] This list included allergens (i.e., sensitizers), irritants and pharmacological bronchoconstrictors. The authors then calculated the number of total asthmagen exposures, asthmagen exposures per worker and unprotected asthmagen exposures for different occupations and industries. The health services industry had the highest number of production workers potentially exposed to one or more asthmagens. By using this approach, the authors provided useful data to guide future surveillance and prevention efforts for work-related asthma.

Although more commonly used in occupational epidemiological studies of cancer, JEMs have recently been adapted successfully to study work-related asthma, most notably one constructed by Kennedy and colleagues.[72] Conceivably, the two NOES-derived databases developed by Sieber and de la Hoz could also prove useful for the development of a new industry-specific JEM for studies of workplace asthma, if modified to focus on HCWs and asthma risk factors, and supplemented with updated information on new asthmagens that have since appeared in healthcare settings. Furthermore, if a semiquantitative scale for exposure coding were incorporated, this could add value by allowing examination of dose-response relationships of significant associations, which could strengthen causal inferences derived from a particular study.

2. RATIONALE

With broad stakeholder input, in 1996 NIOSH published its National Occupational Research Agenda (NORA), which formed the basis of a targeted effort to coordinate research efforts in occupational health and safety so that the large burden of occupational illness and injury in the U.S. could be effectively addressed.[25] Among the 21 areas identified as research priorities at the time, three were directly addressed by the topic of this doctoral thesis:

1. asthma and chronic obstructive pulmonary disease;
2. exposure assessment methods, particularly addressing the need for validated, inexpensive, simple tools with which to better identify at-risk workers;
3. surveillance research methods, by providing a method for identifying populations at increased risk of asthma in a manner that allows targeting of preventive interventions.

In 2005, NIOSH decided to retool and relaunch the NORA initiative, after evaluating its successes during the previous ten years. In doing so, it is adopting a more sector-based approach, targeting those industrial sectors that, by virtue of the magnitude of their exposed worker populations and/or seriousness of their corresponding workplace injury and illness profiles, are felt to be particularly high risk. One of these sectors is the healthcare and social assistance sector, which in 2003 alone had reported more than 650,000 occupational injuries and illnesses to the U.S. Bureau of Labor Statistics.[73]

Thus, there is evidence that workers in healthcare settings are likely to be at increased risk of work-related asthma. However, results have been inconsistent, and few studies have been conducted in HCW populations allowing a more detailed characterization of potential associations between asthma and various workplace exposures. Important methodological issues remain as well. Although some questionnaires exist for the evaluation of asthma in the workplace, few have undergone formal, in-depth validation. Furthermore, in order to

adequately study associations between asthma and occupational and non-occupational exposures, it is essential that exposure characterization also be reliable and valid. Assessment of both current and past exposures remains a major challenge in occupational epidemiological studies, particularly when direct quantitative measurements are not available. Consequently, there is a need for better and more scientifically-based survey instruments that allow the detection of asthma in representative samples of specific worker populations, and its characterization in relation to potential etiologic agents and triggers. Studies that address these remaining issues are particularly important considering the share of the U.S. workforce comprised by HCWs.

3. OBJECTVES

3.1. Study I Objectives

To develop, validate and conduct test-retest reliability of a new survey instrument of work-related asthma, for use in healthcare worker populations.

3.2. Study II Objectives

To field test the new survey instrument in population-based representative samples of four occupational groups of health care workers (HCWs): physicians, nurses, respiratory therapists and occupational therapists.

To adapt, refine and update a previously developed National Occupational Exposure Survey (NOES)-based Job-Exposure Matrix (JEM) for use in the health services industry, to reflect exposures to known and suspected asthma risk factors.

To evaluate associations of asthma prevalence with occupational exposures in four specific groups of healthcare professionals (physicians, nurses, respiratory and occupational therapists), and to estimate their magnitude.

3.3. Study III Objectives

To examine determinants of method of survey response preferences (mail versus the internet) among health professionals.

4. PAPER # 1

A validated asthma questionnaire for use in healthcare workers.

Occupational and Environmental Medicine 2006; 63:173-179.

TITLE: Validation of an asthma questionnaire for use in healthcare workers

AUTHORS: George L Delclos, MD, MPH[1,3] Ahmed A Arif, MD, PhD [2]; LuAnn Aday, PhD[1]; Arch Carson, MD, PhD[1] ; Dejian Lai, PhD[1] ; Christine Lusk, MPH [1] ; Thomas Stock, PhD, CIH[1]; Elaine Symanski, PhD [1] ; Lawrence W Whitehead, PhD, CIH [1]; Fernando G Benavides, MD, PhD [3] ; Josep M Antó, MD, PhD[3,4]

AFFILIATIONS:

[1]The University of Texas School of Public Health, Houston, Texas, USA.

[2] Department of Family and Community Medicine, Division of Health Services Research, Texas Tech University Health Science Center, Lubbock, Texas, USA.

[3] Department of Experimental and Health Sciences, Pompeu Fabra University, Barcelona, Spain.

[4] Municipal Institut of Medical Research (IMIM-IMAS), Barcelona, Spain.

CORRESPONDING AUTHOR:

George L. Delclos, MD, MPH
The University of Texas-Houston
School of Public Health
1200 Herman Pressler St
Suite RAS W1018
Houston, TX-77030

Tel: (713) 500-9459
Fax: (713) 500-9442
e-mail: George.Delclos@uth.tmc.edu

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ABSTRACT

Background: Previous studies describe increased occurrence of asthma among health care workers, but to our knowledge there are no validated survey questionnaires with which to study this occupational group. The study purpose was to develop, validate and refine a new survey instrument on asthma for use in epidemiological studies of healthcare workers.

Methods: An inital draft questionnaire, designed by a multidisciplinary team, used previously validated questions where possible; the occupational exposure section was developed by updating health services-specific chemical lists through hospital walk-through surveys and review of material safety data sheets. A cross-sectional validation study was conducted in 118 nonsmoking subjects, who also underwent bronchial challenge testing, an interview with an industrial hygienist and measurement of specific IgE antibodies to common aeroallergens.

Results: The final version consisted of 43 main questions in four sections. Time to completion of the questionnaire ranged from 13 to 25 minutes. Test-retest reliability of asthma and allergy items ranged from 75% to 94%, and internal consistency for these items was excellent (Cronbach's $\alpha \geq 0.86$). Against methacholine challenge, an 8-item combination of asthma-related symptoms had a sensitivity of 71% and specificity of 70%; against a physician diagnosis of asthma, this same combination showed a sensitivity of 79% and specificity of 98%. Agreement between self-reported exposures and industrial hygienist review was similar to previous studies and only moderate, indicating the need to incorporate more reliable methods of exposure assessment. Against the aerollergen panel, the best combinations of sensitivity and specificity were obtained for a history of allergies to dust, dust mite and animals.

Conclusions: Initial evaluation of this new questionnaire indicates good validity and reliability, and further field testing and cross-validation in a larger healthcare worker population is in progress. The need for development of more reliable occupational exposure assessment methods that go beyond self-report is underscored.

INTRODUCTION

Previous studies in various countries have described an increased occurrence of asthma among specific groups of health care workers (HCWs), including nurses and respiratory therapists.[1][2][3][4][5][6][7][8][9][10][11] In the U.S., the health services industry was second only to the transportation equipment manufacturing sector in total number of reported asthma cases (16% of the total), and five of the top 11 industries and nine of the 22 leading occupations associated with significantly increased asthma mortality were related to healthcare services.[12]

Validation of asthma questionnaires to date has largely focused on their ability to predict asthma in populations.[13][14][15][16][17][18][19] Recent studies have underscored the importance, when conducting aetiological research on asthma rather than screening, of developing instruments that favor specificity over sensitivity, both for the definition of asthma as well as for exposure assessment.[20][21][22] To our knowledge few or no asthma questionnaires, designed for aetiological research, have undergone formal validation in a putative high-risk population such as that of healthcare workers.[20][23][24]

The purpose of this study was to develop, validate, measure reliability and refine a new asthma survey instrument for subsequent use in epidemiological studies of healthcare workers.

METHODS

Questionnaire development

The initial draft questionnaire was designed to be completed in under 30 minutes and consisted of four sections: a) asthma and asthma symptoms (12 questions, with subquestions); b) occupational exposures and job history (17 questions, with subquestions);

c) non-occupational exposures and asthma risk factors (9 questions); and d) demographics (8 questions). The survey development team was multidisciplinary and included industrial hygienists, occupational/pulmonary physicians, epidemiologists and survey design experts. A preliminary version of the questionnaire was first tested for language clarity, ease of completion, timing and cognition in an initial small pilot study of volunteer HCWs from the Houston area.

Asthma-related questions were originally derived from the International Union Against Tuberculosis and Lung Diseases (IUATLD) bronchial symptom questionnaire, and included a cluster of five questions from that instrument that had exhibited the best combination of sensitivity and specificity for the detection of bronchial hyperresponsiveness (collectively referred to as the "Discriminant Function Predictor" or DFP).[15] A separate question on physician-diagnosed asthma was also included, as well as questions on age or year of asthma diagnosis and on work absences due to asthma or respiratory symptoms.

The occupational exposure section focused on current and longest jobs held, job titles, practice setting, duration and frequency of exposure to a list of specific chemicals and a history of exposure to accidental chemical spills or gas releases. Lists and descriptions of chemical agents present in healthcare settings were initially identified from the literature and collapsed into specific sections for development of individual questionnaire items, with the input of three industrial hygienists (TS, ES, LW) and two occupational physicians (GD, AC).[9] [23] [25] To update these lists, this team also conducted a series of walk-through surveys and review of material safety data sheets in three large Houston hospitals: a 350 bed pediatric hospital (3200 employees), a 450 bed specialty cancer referral center (10 000 employees), and a 1200 bed tertiary referral and general hospital (4600 employees). This process resulted in the development and inclusion of two separate chemical lists in the initial draft questionnaire: a) a list of 39 chemical agents, for which respondents were asked to

indicate any exposure on at least one occasion per month for 6 months or longer, and b) a separate set of questions regarding frequency of exposure (never, at least once a month, at least once a week, every day or more than once a day) to nine general classes of agents (disinfectants, cleaning agents, latex products, microorganisms, aerosolized medications, mildew, adhesives/glues, gases/vapors, and paints/craft materials).

The nonoccupational exposure and asthma risk factors section of the draft survey instrument contained questions related to common environmental aeroallergens and allergies, family history of atopy and asthma, household pets, smoking habits, residential housing characteristics and recreational exposures, derived where possible from previously developed questionnaires.[14] [23]

Validation study

A cross-sectional study was conducted in a convenience sample of nonsmoking, currently employed HCWs between 18 and 65 years of age, both with and without asthma, recruited via widespread advertisement in the Houston metropolitan area. Exclusion criteria included pregnancy, a prior diagnosis of COPD, emphysema and/or chronic bronchitis. Sample size calculations were based on information obtained from the initial pilot study; calculations were made separately for the asthma (median sensitivity, 55%; specificity, 80%) and nonoccupational exposure ("allergy") (median sensitivity, 41%; specificity, 50%) sections of the questionnaire.[26] The resulting minimum sample size was approximately 96 persons.

The study protocol was approved by the University of Texas – Houston Committee for the Protection of Human Subjects. Study participants completed the draft questionnaire, a nonspecific bronchial challenge test with methacholine, a detailed occupational exposure interview with an industrial hygienist and provided a blood sample for measurement of

RAST specific IgE antibodies to a panel of indoor and outdoor aeroallergens common in the southwestern U.S. The order in which these various tests were performed was random, and the research team was blinded to the medical histories and questionnaire responses of the study participants. Two weeks after this session, participants were asked to complete a second, abbreviated questionnaire to assess test-retest reliability of responses, measured by the kappa (κ) statistic.[27]

Internal consistency reliability for item groups in the asthma and nonoccupational exposure sections of the questionnaire was measured by Cronbach's α values.[28] Internal consistency was also assessed through exploratory principal factor analysis, applied to the asthma section of the questionnaire, as reported recently.[18] The same procedure was used to identify groupings of chemical agents in the occupational exposure section, in order to shorten the original list of 39 chemicals .[29]

Asthma-related items were validated against two measures, the provocative concentration of methacholine that produced a 20% or greater decrease in forced expired volume in one second (FEV_1) from the baseline (PC_{20}) and a previous physician diagnosis of asthma (MD asthma). Two separate cutoff points for PC_{20} were evaluated, ≤ 8 mg/ml and ≤ 4 mg/ml. Previous studies have shown that a "cut point" of 8 mg/ml is clinically practical, as virtually 100% of symptomatic asthmatics and only 4.5% of non-asthmatic subjects will have values at or below this concentration of either methacholine or histamine. The ≤ 4 mg/ml level was added as a second cutoff level that could add greater specificity.[30] Performance of these questions was also compared to that of the 5-question DFP.[15][16] Prediction equations were developed using $PC_{20} \leq 8$ mg/ml, $PC_{20} \leq 4$ mg/ml and MD asthma as dichotomous outcome variables. Variables related to asthma symptoms were then added into the logistic model and sensitivity, specificity and % correctly classified were computed, based on an analysis of receiver operating curve characteristics (ROC). To evaluate construct

validity, these questionnaire items were tested for associations with two known nonoccupational asthma risk factors (atopy defined by RAST panel results and a family history of hay fever) and one established occupational risk factor (latex sensitization, defined as an elevated anti-latex IgE antibody). Strength of these associations was expressed as the crude odds ratios (OR) and corresponding 95% confidence intervals.

For the occupational exposure section, criterion validity was assessed by comparing the level of agreement (κ) between the industrial hygienists (taken as the "gold standard") and the study subject's self-reported exposure history for selected questions on job/industry classification, as well as for exposure (type, frequency within ± one category level) to the 9 classes of agents. Construct validity was evaluated, in a limited fashion, by testing the known association between latex allergy (as self-reported on the questionnaire) and both MD asthma and $PC_{20} \leq 8$ mg/ml.

Criterion validity for the nonoccupational and asthma risk factor section of the questionnaire was determined by comparison of the allergy-related questions to RAST panel serum titers. A serum titer of ≥ 0.35 kU/l (Class I) for one or more allergens was considered indicative of atopy. Those items that offered the best combination of sensitivity and specificity were retained in the final version of the questionnaire. Construct validity was then examined by testing these latter items for expected associations with asthma and bronchial hyperresponsiveness, as defined by MD asthma and $PC_{20} \leq 8$ mg/ml respecively, using simple logistic regression.

RESULTS

One hundred eighteen subjects participated in the validation study. Descriptive statistics of the study population are presented in Table 1. Time to completion of the questionnaire ranged from 13 to 25 minutes.

Table 1. Study population descriptive statistics (n=118).

Gender:	
Male	30 (25.4%)
Female	88 (74.6%)
Race/ethnicity:	
Non-Hispanic White	43 (36.4%)
Hispanic	27 (22.9%)
Non-Hispanic Black	31 (26.3%)
Other	17 (14.4%)
Age (mean ± S.D.)	35.8 ± 10.2 years
Years employed as health professional (mean ± S.D.)	13.4 ± 10.1 years
Ever asthma (self-reported)	27 (22.9%)
Prior physician diagnosis of asthma	24 (20.3%)
$PC_{20} \leq 8$ *mg/ml*	65 (55.1%)
$PC_{20} \leq 4$ *mg/ml*	57 (48.3%)
DFP positive (*)	44 (37.3%)
Atopy (**)	56 (47.5%)
Elevated anti-latex IgE antibody (**)	13 (11%)

(*) Five-item discriminant function predictor (DFP) for bronchial hyperresponsiveness: Burney et al. Int J Epid 1989; 18:165-173.[15]
(**) A specific IgE serum titer of ≥ 0.35 kU/l (Class I) for one or more common indoor and outdoor aeroallergens was considered indicative of atopy; the same cutoff value was used for the anti-latex IgE antibody.

Reliability

Internal consistency for respiratory symptoms (Cronbach's α = 0.86), allergic symptoms when near animals or trees (Cronbach's α = 0.86), and allergy questions (Cronbach's α = 0.89) was excellent. Exploratory principal factor analysis produced a 12-item model that separated asthma-related questions into three domains: "wheezing" (4 items: wheezing, wheezing at home, nocturnal wheezing and nocturnal cough), "shortness of breath" (5 items: shortness of breath, shortness of breath with activity, shortness of breath at home, nocturnal chest tightness and trouble breathing), and "no asthma" (3 items: absence of

wheezing with a cold, absence of a history of asthma and absence of a prior physician diagnosis of asthma). Each domain was then tested for associations with $PC_{20} \leq 8$ mg/ml; all yielded significant associations in the expected direction ("wheezing" OR= 1.52, p=0.047; "shortness of breath" OR= 1.68, p=0.017; "no asthma" OR= 0.53, p=0.008). Similarly, when tested for associations with $PC_{20} \leq 4$ mg/ml, all three domains yielded significant odds ratios ("wheezing" OR= 1.49, p=0.049; "shortness of breath" OR= 2.00, p=0.002; "no asthma" OR= 0.54, p=0.006).

Principal factor analysis conducted on the list of 39 chemical agents produced a 28-item model, collapsed into five domains: "cleaning agents", "sterilizing agents/disinfectants", "strong odors", "anesthetics/nebulized medications" and "miscellaneous" (Table 2).

Test-retest reliability ranged from 75% to 95% for both asthma- and allergy-related questionnaire items (overall κ=0.70).

Table 2. Final classification of chemical agents, based on exploratory principal factor analysis.

Domain	Agent
"Cleaning agents"	Bleach Cleaners for rooms and counter tops Cleaners/abrasives Cleaners for restrooms and toilets Detergents Disinfectants
"Sterilizing agents"	Glutaraldehyde Ortho-phtaldehyde Chloramines
"Anesthetics/nebulized medications"	Anesthetics Antiseptics Antibiotics Bronchodilators Nebulized medications (e.g., pentamidine, ribavirin) Talc Iodine
"Strong odors"	Ammonia Paints (acrylics, stains, varnishes) Solvents like toluene, xylene, benzene, hexane, mineral spirits, paint thinners Pesticides Tobacco smoke (including passive) Toner for copiers or printers Glues and adhesives
"Miscellaneous"	Acetaldehyde Alkalis Ethylene oxide Formalin/formaldehyde Nitric oxide

Validity

Analysis of ROC characteristics identified a subset of eight asthma-related items that offered the best combination of sensitivity and specificity, while retaining good internal

consistency (Cronbach's $\alpha = 0.75$), when tested against PC_{20} and MD asthma. Table 3 lists the individual questionnaire items for both the 8-question predictor and the DFP.

Table 4 summarizes the results of the 8-question predictor and the 5-item DFP when applied to this study population. Use of the 8-question predictor resulted in 70% to 94% of study participants being correctly classified with regards to asthma and bronchial hyperresponsiveness, versus 65% to 93% for the DFP.

Construct validity testing for associations between each of the asthma definitions (8-item predictor, MD asthma and DFP) and known nonoccupational (atopy, family history of hay fever) and occupational (latex sensitization) factors yielded elevated odds ratios in the expected direction, although some of the confidence intervals included the null (Table 5).

Table 3. Individual questionnaire items for the 8-item predictor and 5-item discriminant function predictor (DFP)*.

Predictor	**Questionnaire item**
8-item predictor	Have you ever had trouble with your breathing? (continuously or repeatedly)
	Have you had an attack/episode of shortness of breath at any time in the last 12 months?
	Have you had wheezing or whistling in your chest at any time in the last 12 months?
	Have you been awakened during the night by an attack of any of the following symptoms in the last 12 months: a) cough? b) chest tightness?
	When you are near animals, feathers or in a dusty part of the house, do you ever get itchy or watery eyes?
	When you are near animals, feathers or in a dusty part of the house, do you ever get a feeling of tightness in your chest?
	When you are near trees, grass or flowers, or when there is a lot of pollen around, do you ever get itchy or watery eyes?
5- item DFP*	Have you ever had trouble with your breathing? (continuously or repeatedly)
	Have you had an attack/episode of shortness of breath that came on following strenuous activity at any time in the last 12 months?
	Have you had wheezing or whistling in your chest at any time in the last 12 months?
	Have you been awakened during the night by an attack of any of the following symptoms in the last 12 months: a) shortness of breath
	When you are near animals, feathers or in a dusty part of the house, do you ever get a feeling of tightness in your chest?

(*)From: Burney et al. Int J Epid 1989; 18:165-173.[15]

Table 4. Criterion validity: performance of the 8-item predictor and 5-item discriminant function predictor* (DFP) versus bronchial hyperresponsiveness (PC_{20}) and a prior physician diagnosis of asthma (MD asthma) (n=118 subjects).

Predictor	Test positive	Sensitivity	Specificity	Correctly classified (%)
8-item predictor**				
$PC_{20} \leq 8$ mg/ml	62 (52.5%)	71%	70%	70%
$PC_{20} \leq 4$ mg/ml	44 (37.2%)	61%	85%	74%
MD asthma	21 (17.8%)	79%	98%	94%
5-item DFP				
$PC_{20} \leq 8$ mg/ml	44 (37.2%)	52%	81%	65%
$PC_{20} \leq 4$ mg/ml	33 (30.0%)	47%	90%	69%
MD asthma	18 (15.3%)	71%	99%	93%

(*)From: Burney et al. Int J Epid 1989; 18:165-173.[15]
(**) For each dichotomized outcome variable, separate 8-item logistic regression models were developed based on the best combination of sensitivity and specificity. In each case, the 8 items included ever experiencing trouble breathing (continuously or repeatedly), wheezing in the previous 12 months, an attack of shortness of breath in the previous 12 months, having been awakened by nocturnal cough and/or chest tightness, and allergic respiratory symptoms when around animals, feathers, a dusty part of the house or outdoor environmental allergens and pollens.

Table 5. Construct validity: association between two different indicators of asthma and known asthma risk factors, and between different indicators of common allergies and asthma.

Indicator	Risk factor	OR	95% C.I.
Asthma			
8-item predictor*	Atopy	3.41	1.30-8.94
	Family history of hay fever	2.09	0.76-5.73
	Elevated latex IgE antibody	5.37	0.68-42.47
MD asthma**	Atopy	4.91	1.69-14.27
	Family history of hay fever	3.14	1.25-7.89
	Elevated latex IgE antibody	4.20	1.44-12.28
5-item DFP**	Atopy	1.97	0.92-4.22
	Family history of hay fever	3.47	1.58-7.65
	Elevated latex IgE antibody	4.25	1.46-12.34
Allergies			
Animals	MD asthma**	4.04	1.55-10.50
	$PC_{20} \leq 8$ mg/ml	4.21	1.64-10.79
Dust	MD asthma**	4.42	1.61-12.16
	$PC_{20} \leq 8$ mg/ml	2.05	0.98-4.29
Dust mite*****	MD asthma**	10.25	3.21-32.71
	$PC_{20} \leq 8$ mg/ml	2.24	0.92-5.44
Latex	MD asthma**	1.71	0.57-5.17
	$PC_{20} \leq 8$ mg/ml	1.46	0.58-3.65

OR – odds ratio. 95% C.I. – 95% confidence interval. (*) 8-item predictor for $PC_{20} \leq 8$ mg/ml.(**) MD asthma – history of physician-diagnosed asthma. (***) From: Burney et al. Int J Epid 1989; 18:165-173.[15] (****) N=118 subjects for all associations except with dust mite allergen (n=102).

In the occupational exposure history section of the questionnaire, when self-reported exposures were compared to the industrial hygienist's assignment of individual exposures, greater agreement was observed with respect to job titles (κ = 0.57 and 0.67, for longest held and current/most recent job, respectively) than for practice setting (κ=0.46 and 0.51, for longest held and current/most recent job, respectively). Agreement on type and duration of exposure to agents varied, depending on the agent class. For current/most recent job, agreement was greatest for exposure to latex products (κ = 0.60), disinfectants/steriliants (κ = 0.59), cleaning agents (κ = 0.56), aerosolized medications (κ = 0.53), gases/vapors (κ = 0.48) and marginal for exposure to bacteria/viruses (κ = 0.43) and adhesives/glues (κ = 0.41). Agreement was poor (κ < 0.40) for exposure to mildew/fungi and paints/crafts materials. For longest held job, agreement was greatest for exposure to latex products (κ = 0.63), disinfectants/steriliants (κ = 0.60), bacteria/viruses (κ = 0.53), aerosolized medications (κ = 0.45), and marginal for exposure to cleaning agents (κ = 0.44) and gases/vapors (κ = 0.42). Agreement was poor (κ < 0.40) for exposure to mildew/fungi, adhesives/glues and paints/crafts materials. The odds ratios for an association between self-reported latex allergy and both MD asthma or $PC_{20} \leq 8$ mg/ml were elevated in the expected direction, although confidence intervals included the null (Table 5).

In the nonoccupational and asthma risk factor section, items regarding a personal history of allergic conditions and family history of allergic conditions exhibited a wide range of sensitivity (19% to 74%), but high specificity (71% to 89%) when compared to RAST panel results. Sensitivity was highest for a history of hay fever (74%) and "dust" allergy (68%), and lowest for allergy to chemicals (19%) and a family history of skin allergies (28%). Specificity was highest for a history of allergy to chemicals (89%), animals (86%), dust mite (86%) and medications (82%), and lowest for hay fever (45%). The best combinations of sensitivity and

specificity were obtained for a history of allergies to dust, dust mite and animals. In the evaluation of construct validity, the odds for an association with either MD asthma or $PC_{20} \leq 8$ mg/ml were elevated for all three of these items (Table 5).

DISCUSSION

It is well recognized that questionnaire-based definitions of asthma may not necessarily correspond to the clinical definition of asthma, and that there is no universally accepted "gold standard" definition of asthma for use in epidemiology studies.[18] Prior validation studies of asthma questionnaires have generally relied on comparison of questionnaire items on asthma and asthma-like symptoms to putative gold standards, including physiologic measures of nonspecific bronchial hyperresponsiveness, previously validated questionnaires or physician-diagnosed asthma.[15] [31][32] Depending on the standard used, as well as on the nature of the questionnaire items, sensitivity and specificity have varied.

The present study used an approach that compared the performance of the asthma section of the questionnaire to all three of these standards (PC_{20}, MD asthma and the previously validated DFP). The DFP exhibited a specificity of 81% and sensitivity of 52%, virtually identical to those obtained by Burney et al in their original validation studies.[15] In contrast, the 8-item predictor in this study showed a higher sensitivity (71%) and lower specificity (70%), but resulted in a slightly higher percentage of "correctly classified" cases than the DFP (70% versus 65%). As a predictor of bronchial hyperresponsiveness, therefore, there was little measurable difference between the 8-item predictor and the DFP. Kongerud et al used a modified MRC questionnaire to test 296 workers in a Norwegian aluminum plant, and compared questionnaire responses to the clinical judgment of a chest physician.[32] Questions on wheezing

and dyspnea showed sensitivities of 77% and 75%, and specificities of 82% and 88%, respectively. The sensitivity of 79% and specificity of 98% found with our 8-item predictor (94% of cases correctly classified), therefore, compares favorably with these results and slightly better than the DFP, supporting its suitability for use in future asthma epidemiology studies. The combination of several symptom-based questions to define asthma has been found to perform better, and is less conducive to misclassification, than reliance on a single question or questions that include the term "asthma".[18]

An important limitation of many occupational asthma surveys is the inability to distinguish between pre-existing asthma and work-related asthma. Although not specifically validated in this study, this questionnaire also includes items regarding time of asthma onset (relative to entry into the healthcare profession), worsening of asthma and/or respiratory symptoms with work, amelioration when away from work and work absences due to asthma and/or respiratory symptoms. Combining these questions with the validated asthma and bronchial hyperresponsiveness predictors should allow a better approximation to these asthma-workplace relationships.[5][33]

Various methods are used to retrospectively assess occupational exposures in epidemiology studies, including self-reported exposure, detailed interviews with workers or relatives, expert industrial hygiene assessment of occupational histories, and use of a priori developed job-exposure matrices; each of these methods has its limitations. In this study, the occupational exposure section of the questionnaire is based on self-reported exposures to a list of agents, established through a detailed process that included review of previous lists, hospital walk-through surveys, and exploratory principal factor analysis, to identify a fairly comprehensive checklist of agents that is still brief enough to be answered in a short period of

time. Agreement between study participants and the industrial hygienists (median $\kappa = 0.45$) was similar to a previous study that examined this issue in a case-control study of cancer and occupational exposures in Canada (median $\kappa = 0.51$).[34] Self-reported exposure to checklists of chemical agents has been reported to have high specificity (ranging from 83%-97%), but low sensitivity (median, 61%; range 39%-91%) when compared to expert assessment by hygienists and chemists, which could lead to misclassification of exposure when used in population-based studies.[34] On the other hand, detailed industrial hygiene interviews with workers or their proxy require a large time commitment, are costly and often logistically difficult, and have exhibited suboptimal validity.[35][36][37][38] Fritschi and colleagues also questioned whether use of expensive, time-consuming expert assessment was an acceptable "gold standard", acknowledging that few data exist on the validity of this method.[34] Louik et al further note that expert assessment is also limited by a scarcity of qualified experts.[38]

The similarity of findings between this validation study and previous studies underscores the need to incorporate more reliable methods of exposure assessment that go beyond self-report. Conceivably, in the case of our questionnaire, some advantage might be gained by combining both methods sequentially, i.e., the self-reported exposures could be subjected to subsequent additional review by one or more industrial hygiene experts, and this is being explored. However, we have also developed a healthcare worker-specific job-exposure matrix, focused on asthmagens, that emphasizes high specificity, and which is undergoing detailed validation and field testing.[20][21][33]

Certain limitations of this study should be noted. Although methacholine challenge testing was selected as the "gold standard" for asthma, it is well known that airway hyperresponsiveness is present in a certain proportion of asymptomatic persons without asthma,

which could affect the specificity of certain questionnaire items.[39][40] Use of more than one "gold standard" for the definition of asthma in this study probably offset this effect, by providing a range of sensitivity and specificity values for the 8-item predictor that may allow a broader characterization of susceptible subgroups. A similar issue arises for the RAST antibody panel, where some asymptomatic persons may have significantly elevated titers of these antibodies.[41] However, the good specificity (86%) shown by the questionnaire items for allergens known to be strongly related to asthma (dust mite and animals) suggests that this effect was small. Differences in opinions and judgment among professionals are a fact of life, and using an industrial hygienist review and classification of occupational exposures as the "gold standard" for questionnaire items in the occupational exposure section can introduce misclassification bias. The development of the previously mentioned highly specific job-exposure matrix, with multiple levels of expert input, should decrease this effect.

In this convenience sample, the large number of persons with previously diagnosed asthma, bronchial hyperresponsiveness and atopy provided a sufficient number of cases to test questionnaire validity. In this regard, the study population was not likely to be strictly representative of the target population. On the other hand, the study population would be expected to be representative of the general healthcare worker population by virtue of profession (all were healthcare workers), educational level and language, providing confidence on the relevance, understanding, ease of completion, and applicability of the various questionnaire items to this worker population.

All study participants were nonsmokers, in order to reduce confounding from COPD in the validation study. It may be more difficult to control this effect when the questionnaire is

applied in a population-based study. A section on smoking history is part of the final questionnaire, which will allow control for this confounder.

Based on findings from this validation study, the questionnaire was reduced to 43 main and appeared to be easily completed by participants, making it applicable for use in other healthcare worker groups, including housekeeping personnel, security, facilities maintenance, etc. The education level of the study population was quite high, however, thus care should be taken before using this questionnaire in a broader cross-section without further cognitive testing and validation.

In summary, initial evaluation of the performance of this new questionnaire for the evaluation of asthma in healthcare workers indicates good validity and reliability for the detection of asthma and for the characterization of nonoccupational exposures and other asthma risk factors. Although occupational exposure assessment was shown to have a reliability similar to previous studies, it would be preferable to develop additional approaches that go beyond self-report, providing a separate measure of exposure to workplace risk factors. Further field testing and cross-validation of this instrument are currently being undertaken by our group in a large cross-sectional study of licensed health care professionals in Texas. Although the instrument was specifically designed for use in the healthcare sector, if the field studies support this validation study, then this methodology could also be adapted to studies of other worker populations.

MAIN MESSAGES

1. Previous studies in various countries have described an increased occurrence of asthma among specific groups of health care workers.

2. Although some questionnaires exist for the evaluation of asthma and exposures in the workplace, to our knowledge none have undergone formal validation in a healthcare worker population. Evaluation of the performance of this new questionnaire for the study of asthma in healthcare workers indicates good validity and reliability for the detection of asthma and for the characterization of nonoccupational exposures and other asthma risk factors. The validity and reliability of assessment of occupational exposures was only moderate and similar to previous studies based on self-report.
3. Although the instrument was specifically designed for use in the healthcare sector, this validation methodology could also be adapted for studies of other worker populations.

POLICY IMPLICATIONS

1. Use of this validated questionnaire in epidemiological studies of healthcare workers should improve the quality of asthma research in this large sector of the employed workforce.
2. The rigorous methodological approach to questionnaire validation employed in this study may serve as a model for epidemiological studies of other occupational groups.

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APPENDIX

A copy of the final survey instrument is provided as an online link to the electronic version of this paper, formatted for use with the Cardiff Teleform™ software (Cardiff Software, Inc., Vista, CA), to facilitate direct data entry.

COMPETING INTERESTS DECLARATION

All of the authors involved in this study declare that they have no competing or financial interests related to the design, conduct, analysis, conclusions and/or opinions expressed in this paper.

5. PAPER # 2

Occupational risk factors and asthma among healthcare professionals

American Journal of Respiratory and Critical Care Medicine [accepted]

TITLE: OCCUPATIONAL RISK FACTORS AND ASTHMA AMONG HEALTHCARE PROFESSIONALS

Running title: Work-associated asthma in healthcare professionals

AUTHORS: George L Delclos, MD, MPH[1,2] , David Gimeno, PhD[1,3], Ahmed A Arif, MD, PhD[4]; Keith D. Burau, PhD[1]; Arch Carson, MD, PhD[1] ; Christine Lusk, MPH [1] ; Thomas Stock, PhD, CIH[1]; Elaine Symanski, PhD [1] ; Lawrence W Whitehead, PhD, CIH [1]; Jan-Paul Zock, PhD[5,6], Fernando G Benavides, MD, PhD [2] ; Josep M Antó, MD, PhD[2,5,6]

AFFILIATIONS:

[1]The University of Texas School of Public Health, Houston, Texas, USA.

[2] Department of Experimental and Health Sciences, Pompeu Fabra University, Barcelona, Spain.

[3] International Institute for Society and Health, Department of Epidemiology and Public Health, University College London, London, United Kingdom.

[4] Department of Family and Community Medicine, Division of Health Services Research, Texas Tech University Health Science Center, Lubbock, Texas, USA.

[5] Municipal Institut of Medical Research (IMIM-IMAS), Barcelona, Spain.

[6]Center for Research in Environmental Epidemiology (CREAL), Barcelona, Spain.

Address correspondence and requests for reprints to:

George L. Delclos, MD, MPH
The University of Texas-Houston
School of Public Health
1200 Herman Pressler St
Suite RAS W1018
Houston, TX-77030

Tel: (713) 500-9459
Fax: (713) 500-9442
E-mail: George.Delclos@uth.tmc.edu

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Running head: Asthma in healthcare professionals

Descriptor: 114. Occupational asthma

WORD COUNT: 4976

ABSTRACT

Rationale: Recent U.S. data suggest an increased risk of work-related asthma among healthcare workers, yet only a few specific determinants have been elucidated.

Objectives: To evaluate associations of asthma prevalence with occupational exposures in a cross-sectional survey of healthcare professionals.

Methods: A detailed questionnaire was mailed to a random sample (n=5600) of all Texas physicians, nurses, respiratory therapists and occupational therapists with active licenses in 2003. Information on asthma symptoms and nonoccupational asthma risk factors obtained from the questionnaire was linked to occupational exposures derived through an industry specific job-exposure matrix.

Measurements: Two *a priori* defined outcomes: a) physician-diagnosed asthma with onset after entry into healthcare ('reported asthma'), and b) 'bronchial hyperresponsiveness-related symptoms', defined through an 8-item symptom-based predictor.

Main Results: Overall response rate was 66%. The final study population consisted of 862 physicians, 941 nurses, 968 occupational therapists and 879 respiratory therapists (n=3650). Reported asthma was associated with medical instrument cleaning (OR,2.22; 95%CI, 1.34-3.67), general cleaning (OR,2.02; 95%CI, 1.20-3.40), use of powdered latex gloves between the years 1992 and 2000 (OR,2.17; 95%CI, 1.27-3.73) and administration of aerosolized medications (OR,1.72; 95%CI, 1.05-2.83). The risk associated with latex glove use was not apparent after the year 2000. Bronchial hyperresponsiveness-related symptoms were associated with general cleaning (OR,1.63; 95%CI,1.21-2.19), aerosolized medication administration (OR,1.40; 95%CI,1.06-1.84), use of adhesives on patients (OR,1.65; 95%CI, 1.22-2.24) and exposure to a chemical spill (OR,2.02; 95%CI,1.28-3.21).

Conclusions: The contribution of occupational exposures to asthma in healthcare professionals is not trivial, meriting both implementation of appropriate controls and further study.

Word count: 250

Key words: work-related asthma, healthcare workers

INTRODUCTION

It is well established that certain occupational groups are at increased risk of developing asthma, including Western red cedar workers[1], isocyanate chemical workers[2], construction workers[3], and farmers[4]. However, whereas the risk magnitude and etiologic agents are well characterized for many of these occupations, this has been less well studied in the case of healthcare workers (HCWs), where data largely derive from case series but relatively few population-based studies or surveillance systems.

In the 1990s, attention began focusing on respiratory hazards among HCWs, partly because of increasing concern over occupational latex allergy following passage of the 1992 Occupational Safety and Health Administration (OSHA) Bloodborne Pathogens standard, which resulted in a significant increase in the use of latex-containing personal protective equipment, such as powdered latex gloves. However, potential asthmagens in healthcare settings go beyond latex, and may include disinfectants and sterilants (e.g., glutaraldehyde, formaldehyde), pharmaceuticals (e.g., psyllium, antibiotics), sensitizing metals (e.g., dental alloys), methacrylates, irritant aerosolized medications (e.g., pentamidine and ribavirin) and cleaning products[5,6].

Previous work from various countries have reported cases of work-related asthma among specific groups of HCWs, including physicians[7,], respiratory therapists[8], workers in endoscopy units and radiology departments[9], nurses [10], and general HCWs[5]. Confirmation and estimation of risk, however, in population-based studies has been more problematic. In a cross-sectional analysis of the European Community Respiratory Health Study (ECRHS), significant excesses of risk among HCWs were not consistently observed[4]. In the U.S., using data from the National Health and Nutrition Examination Survey (NHANES) III, conducted between 1988 and 1994,

the odds for either work-related asthma or wheezing in health-related occupations were not significantly increased[11]. Data from the 2001 National Health Interview Survey did find significantly increased odds for physician-diagnosed asthma in the U.S. healthcare industry, but this excess was limited to white females[12]. More recently, surveillance data from four U.S. states found that work-related asthma among HCWs represented 16% of total reported cases, exceeding their representation in the workforce (8%)[6]. Interestingly, the U.S. National Institute for Occupational Safety and Health (NIOSH) reported that 5 of the top 11 industries and 9 of the 22 leading occupations associated with significantly increased asthma *mortality* were related to healthcare services[13].

Thus, results are inconsistent, and few studies have been conducted in HCW populations allowing a more detailed characterization of potential associations between asthma and various workplace exposures. Studies that address these remaining issues are particularly important considering that HCWs comprise approximately 8% of the U.S. workforce, and constitute one of the fastest growing sectors of the workforce[14]. Using representative samples of selected HCW groups in Texas, the purpose of this study was to evaluate associations of asthma prevalence with occupational exposures in healthcare professionals, and to estimate their magnitude.

METHODS

Survey population

Four groups of Texas health professionals with active professional licenses in 2003 were targeted for a cross-sectional confidential mail survey of asthma: physicians (n=52,542), nurses (n=161,557), respiratory therapists (n=10,085) and occupational therapists (n=7,207). Based on sample size calculations to assure α=0.05 and β=0.20, adjusted for an expected response rate of

at least 50% and an expected proportion of eligible respondents of 90%, a random sample of 1400 individuals in each of the four groups was generated (total = 5600)[15]. Given historically low response rates of physicians to mail surveys[16], limited post-hoc oversampling of this group was performed to assure a sufficient number of physicians for final analysis.

Survey instrument and conduct

Development and validation of the survey questionnaire was carried out by a multidisciplinary team of industrial hygienists, occupational and pulmonary physicians, epidemiologists and survey design experts as previously described[17]. Asthma symptom items were originally derived from the International Union against Tuberculosis and Lung Diseases bronchial symptoms questionnaire,[18] supplemented with questions on physician-diagnosed asthma and age at asthma diagnosis. The final validated survey instrument was formatted in two versions: a hard copy booklet and an identically-appearing web-based version**.**

Based on the approach of Dillman[19], up to five contacts with potential study participants were planned. An initial "warm contact" letter was followed by a hard copy questionnaire, an explanatory cover letter, a $1 token financial incentive, and a business reply envelope. Information on how to complete the survey online rather than by hard copy was included. Follow-up post card reminders, a replacement questionnaire and a final reminder letter were subsequently sent, if needed, over the next five weeks.

Ethical approval for the study was obtained from The University of Texas Committee for the Protection of Human Subjects prior to study initiation.

Asthma risk factor job-exposure matrix

Occupational exposures were determined on the basis of an externally developed asthma risk factor job-exposure matrix (JEM), specifically designed for use in healthcare worker populations. More commonly used for cancer studies, JEMs have recently been used successfully to study work-related asthma[20]. Development of our JEM consisted of several steps. The initial information source for the development of the JEM was the NIOSH National Occupational Exposure Survey (NOES), conducted over 20 years ago[21]. Advantages of the NOES database included its origin based on direct observations of a representative sample of U.S. workplaces, its public availability, the consideration of exposures that may no longer exist, and the use of common industry, occupation and hazard codes. Next, additional sources of chemical lists developed after publication of the NOES were identified from the literature and reviewed. A subset of a generic job-exposure matrix developed with data from the NOES, limited to the health services industry[22] was combined with a list of 367 asthmagens, cross-referenced on NOES hazard codes[23], to produce an initial health services-specific matrix for known and suspected asthmagens. This matrix was then updated based on a series of hospital walk-through surveys conducted in 2002 in three Houston hospitals (a 350 bed pediatric hospital; a 450 bed cancer hospital and a 1200 bed tertiary referral and general hospital) by industrial hygienists and occupational physicians. All three hospitals were accredited by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). The final matrix structure featured two axes: a) a job axis, subclassifying professional job titles (nurse, physician, etc.) by main practice setting (hospital, outpatient clinic, nursing home, etc.) and b) an exposure axis, consisting of five main exposure classes (cleaning products, powdered latex gloves, aerosolized medications, adhesives/solvents/gases and sensitizing metals). Cleaning products were

subclassified by task into patient-centered cleaning/disinfection, instrument cleaning/disinfection and cleaning/disinfection of building surfaces. Similarly, adhesives/solvents/gases were subdivided into patient-centered, application to non-patient surfaces and a nonspecific miscellaneous category. Powdered latex glove use was subdivided according to time period of exposure, relative to the year of implementation of the OSHA bloodborne pathogens standard[24]: pre-1992, 1992 to 2000 and post-2000.

Five experts (among the authors) (one occupational physician, three academic industrial hygienists and an industrial hygienist/safety specialist employed in a hospital) assigned codes to each matrix cell, based on probability that the majority of workers in that cell were occupationally exposed at least once per week to this class of agents. A code of '0' was assigned if there was a high probability of no exposure; a '1' or a '2' were assigned when the probability of exposure was either low or high, respectively. Disagreements among the experts were resolved by consensus. The coded matrix was then applied to each respondent's current and longest held job as a HCW, based on the job title and practice setting reported for that job.

Study variables

Two dichotomous outcome variables were defined: a) physician-diagnosed asthma with onset after entry into the healthcare profession ('reported asthma'), and b) bronchial hyperresponsiveness (BHR)-related symptoms. Reported asthma was calculated among persons with a history of physician-diagnosed asthma by comparing the age at which this diagnosis was made to the number of years employed as a healthcare professional. The presence of BHR-related symptoms was determined based on an 8-item, symptom-based, predictor of $PC_{20} \leq 4$ mg/ml for methacholine developed in the validation study (sensitivity-61%, specificity-85%)[17].

The eight items related to trouble breathing, wheezing and/or attacks of shortness of breath in the previous 12 months, nocturnal cough and/or chest tightness in the previous 12 months and current allergic symptoms when in the presence of animals, feathers, dust, trees, grasses, flowers or pollen.

After examining the coded JEM, it became apparent that the number of ocupation-practice setting combinations assigned a code '1' (low probability) for exposure was very small for almost all considered exposures. As a result, this intermediate exposure group as such appeared to be too small for meaningful analyses. Therefore, occupational exposure variables were dichotomized by collapsing codes 1 and 2 from the JEM into a single 'exposed' category, with code '0' reflecting the nonexposed groups. Sensitizing metals were excluded given the very small number of cells coded as exposed. JEM codes for longest held job were used since the majority (~60%) of respondents indicated that their current job was also their longest held job. For those with longest held job outside the healthcare sector, JEM codes from the current job were used. Additionally, from the questionnaire, a self-reported dichotomous occupational exposure variable, related to having ever been involved in a chemical spill or gas release at work, was included.

Covariates from the questionnaire were age, gender, race/ethnicity, professional group, years as a health professional ('seniority'), smoking and obesity (body mass index [BMI, kg/m^2] $\geq$30). Atopy was defined based on a combination of history of allergies to dust and animals, developed in the validation study (sensitivity-68%, specificity-85%)[17].

Statistical analysis

Post-stratification weighting was performed to obtain estimates of both counts and prevalences that were representative of the actual population sizes for each professional group. Regression analyses were performed on a subsample that excluded anyone with missing values for any variable. After evaluating collinearity, variables with a $p<0.25$ in the univariate analyses were entered into unconditional multiple logistic regression models for each outcome. Interactions between atopy and occupational exposure were explored. Associations were expressed as the adjusted logistic odds ratio (OR) and 95% confidence interval (95% CI). Goodness-of-fit was assessed as recommended for survey sample data[25]. STATA/SE v.9.2® (Stata Corporation, College Station, TX) was used for statistical analyses.

RESULTS

From the initial 5600 mailed questionnaires, 213 participants were excluded due to death (7) and incorrect addresses (206), leaving a final eligible population of 5387. Surveys were received from 3529 participants (941 nurses, 968 occupational therapists, 741 physicians and 879 respiratory therapists). Group response rates were highest for occupational therapists (73%) and nurses (70%), and lowest for physicians (54%) and respiratory therapists (65%), for an overall response rate of 66%. Physician oversampling resulted in an additional 121 surveys. The final number of returned completed surveys was 3650.

Prevalence of reported asthma was 4.2% for physicians, 7.3% for nurses, 5.6% for respiratory therapists and 4.5% for occupational therapists. BHR-related symptoms prevalence varied by professional group: 18.0% in physicians, 29.2% in nurses, 30.3% in respiratory therapists and 33.7% in occupational therapists. The overall weighted prevalences of reported

asthma and BHR-related symptoms were 6.6% and 27.2%, respectively. Table 1 summarizes the descriptive statistics for the final analytic sample (n= 2738) and the excluded sample (n=912). As compared to the analytic sample, the excluded sample (i.e., those with incomplete questionnaires) was significantly older ($P<0.001$), had a higher proportion of women ($P<0.001$), a lower proportion of non-Hispanic whites ($P=0.02$), had worked longer in health care ($P<0.001$) and had a lower proportion of physicians ($P=0.02$). There were no significant differences between the two groups with respect to prevalence of atopy, obesity, smoking status, or asthma outcomes. In addition, there were no significant differences between the two populations with respect to any of the JEM-derived occupational exposure variables: patient-centered cleaning ($P=0.19$), instrument cleaning/disinfection ($P=0.14$), cleaning of general surfaces ($P=0.05$), powdered latex glove use pre-1992 ($P=0.64$), powdered latex glove use between 1992 and 2000 ($P=0.41$), powdered latex glove use after 2000 ($P=0.24$), administration of aerosolized medications ($P=0.15$), use of adhesives on patients ($P=0.36$), use of adhesives on non-patient surfaces ($P=0.76$), or miscellaneous use of adhesives ($P=0.82$). Likewise, no signifcant difference between the analyzed and excluded populations was observed with ever having sustained an exposure to a chemical spill at work ($P=0.58$).

Strong collinearity (correlation coefficients$\geq$0.70) was found between age and seniority, as well as between professional group and most of the occupational exposure variables (e.g., respiratory therapist and administration of aerosolized medications), raising an issue of quasi-complete case separation. Gender was strongly related with two of the professions (nursing and occupational therapy), with approximately 90% in each group being female. Some of the occupational exposures were also highly correlated (e.g., instrument cleaning and use of latex

gloves, administration of aerosolized medications and use of latex gloves). For this reason, separate regression models were built for each class of occupational exposures.

In the univariate analyses (Table 2) for reported asthma, significantly elevated odds ratios were observed for age, gender, obesity, atopy, seniority, instrument cleaning, cleaning products used on building surfaces, use of powdered latex gloves between 1992 and 2000, administration of aerosolized medications and application of adhesives/vapors/gases in patient care. Significant inverse associations were observed for use of adhesives on surfaces and miscellaneous use of adhesives/solvents/gases. BHR-related symptoms were significantly and positively associated with gender, race/ethnicity, obesity, atopy, exposure to a chemical spill at work, instrument cleaning, cleaning products used on building surfaces, use of powdered latex gloves in the 1992-2000 period, administration of aerosolized medications, and use of adhesives/solvents/gases in patient care. Age and miscellaneous use of adhesives/solvents/gases showed significant inverse associations. Smoking was not associated with either outcome.

Final multivariable models for each class of occupational exposures were adjusted for seniority (quartiles), race/ethnicity, obesity and atopy (Table 3). For reported asthma, statistically significant associations were observed for instrument cleaning (OR, 2.22; 95% CI, 1.34 to 3.67), cleaning products used on building surfaces (OR, 2.02; 95% CI, 1.20 to 3.40), powdered latex glove use in the 1992-2000 period (OR, 2.17; 95% CI, 1.27 to 3.73) and administration of aerosolized medications (OR, 1.72; 95% CI, 1.05 to 2.83). A significant inverse association was found for miscellaneous use of adhesives/solvents/gases (OR, 0.53; 95% CI, 0.32-0.88). For BHR-related symptoms, significant associations were found for cleaning products used on building surfaces (OR, 1.63; 95% CI, 1.21 to 2.19), administration of aerosolized medications (OR, 1.40; 95% CI, 1.06 to 1.84), use of adhesives/solvents/gases in

patient care (OR, 1.65; 95% CI, 1.22 to 2.24) and exposure to a chemical spill at work (OR, 2.02; 95% CI, 1.28 to 3.21). None of the tested interactions were significant. Model fit was good for all of the models (F-adjusted mean residual test, $p>0.05$).

DISCUSSION

This study found an approximately two-fold increased likelihood of asthma after entry into a healthcare profession for tasks involving instrument cleaning and disinfection, general cleaning products used on indoor building surfaces, use of powdered latex gloves, and the administration of aerosolized medications. Significant associations were likewise found between BHR-related symptoms and use of surface cleaners, aerosolized medication administration, adhesives or solvents as products in patient care, as well as with a history of sustaining an acute exposure to a chemical or gas at work. Study findings are consistent with previously reported associations between asthma and occupational exposures in healthcare settings, and identify new relationships warranting further evaluation. The associations observed with a history of acute exposures to chemical spills or gas releases at work and with tasks involving use of respiratory irritants provide further support for irritant-induced asthma in this population.

This study has several strengths. By drawing its sample from the actual populations of four groups of HCWs, it provides more accurate estimates of the magnitude of work-related asthma in these workers. Use of an externally developed JEM to assign exposures reduces the chances of recall bias. In contrast, use of self-reported exposures from questionnaires may lead to a differential bias, i.e., asthmatics and non-asthmatics may recall differently.[26,27] When we compared our original JEM codings to self-reported exposures derived from the questionnaire in the full study population of 3650 persons, asthmatics tended to show slightly greater agreement

with the JEM than non-asthmatics for patient-care related cleaning, instrument cleaning, and administration of aerosolized medications; there was little difference with respect to latex glove use (data not shown). Our comparisons were not always on an identical category-by-category basis, however. For example, in the questionnaire we asked about glutaraldehyde, but not about medical instrument cleaning as was the case for the JEM category.

The inventory of chemical products found in the hospital walk-throughs should be generalizable to other JCAHO-accredited U.S. hospitals, although it is less clear whether they can be extrapolated to hospitals outside the U.S. JCAHO has uniform standards for infection control, including general cleaning/disinfection and instrument cleaning. Furthermore, we found that many of the chemical products overlapped, although the type of hospital was different. Although there could be some variation in the brand name products (e.g., for general cleaning and medical instrument cleaning) across the hospitals, the active ingredients used in these products were similar (e.g., quaternary ammonium compounds, bleach, citric-based cleaners, glutaraldehyde, paraffinic hydrocarbons, etc.). In recent years JCAHO has also placed greater emphasis on employee protections, so policies and procedures such as those governing protective clothing, including gloves, tend to be similar across healthcare settings.

Among the study limitations, there were differences in sociodemographic and professional characteristics with the analytic sample, although none regarding any of the health-related or main occupational exposure variables. Since a response to all 8 items was required in order to compute the BHR-related symptom, most of the missing values (n=657, or 72%) were related to this variable. However, results using the full sample of 3650 respondents (data not shown) remained essentially unchanged. Consequently, the magnitude of any bias is likely to have been small. On the other hand, restricting the analysis to a sample with no missing values

allowed for the construction of more robust models as well as for better comparisons of the various associations found with the different models.

We were unable to distinguish between occupational asthma (i.e., *de novo* asthma caused by a workplace exposure) and work-aggravated asthma (i.e., pre-existing asthma worsened by a workplace exposure)[5]. However, the use of reported asthma (i.e., physician-diagnosed asthma with onset after entry into a healthcare profession) can be viewed as a surrogate for new-onset asthma, as has been done recently[8]. Inclusion of both a "sensitive" symptom-based definition for BHR, a cardinal feature of asthma, and a more "specific" asthma definition based on physician diagnosis, allowed a broader assessment of the spectrum of asthma. The similar directionality of the point estimates for both asthma outcomes, with regard to the main associations found suggests that these associations are real. Moreover, the associations tended to become stronger with reported asthma, i.e., the more specific outcome. Greater specificity might have been gained by applying the JEM to a period of time around which a participant was diagnosed with asthma. The cross-sectional study design, though, made this difficult to do. We did not obtain full lifetime job histories for all participants; instead, information was collected only on current and longest held jobs. Data on time period for these jobs was limited to start and end dates; in many cases, this encompassed several years, making it difficult to define a sufficiently narrow window of time around the date of diagnosis of asthma.

Among persons who had ever had a physician diagnosis of asthma, 70% also responded positively to BHR-related symptoms. In addition to the possibility of false negatives, the 30% of asthmatics who did not report BHR-related symptoms could also represent asthmatics who were either asymptomatic or under good medical control. The latter is particularly possible since many of the BHR-related symptom items referred to a more recent time frame of the previous 12

months. Among persons without a physician diagnosis of asthma, 80% did not respond positively to BHR-related symptoms. In addition to false positives, the remaining 20% who had BHR-related symptoms could also represent individuals with respiratory symptoms not due to asthma, atopic persons or as yet undiagnosed asthmatics.

A dose-response relationship was found between reported asthma and increasing seniority in the univariate analysis. This is not unexpected, since the chances of being diagnosed with asthma increase with both age and longer at-risk periods. However, this pattern was not observed with BHR-related symptoms. In fact, the highest quartile of seniority showed a significant inverse relationship between seniority and BHR-related symptoms. Seniority represented the total number of years devoted to a healthcare profession. This self-reported variable was therefore, to a certain extent, independent of the exposure classification by the JEM. It is possible that persons with a long seniority and reported asthma were no longer in a job that triggered their asthma symptoms and/or were under good therapeutic control.

Although cross-sectional studies are limited with regard to causal inference, this limitation was partly offset by use of the longest-held, instead of current, job which probably reduced the likelihood of persons with respiratory symptoms self-selecting themselves out of the respondent pool.

It is also unclear whether the results would be generalizable to other HCWs, in the U.S. or abroad. In many countries, respiratory and/or occupational therapy are not officially recognized professions; hence, their tasks are fulfilled by other HCWs. In this regard, the emphasis that this study placed on *tasks* rather than professional credentials should serve to make the findings more generalizable and relevant.

Since first described in the ECRHS, data linking asthma to general cleaning tasks has accumulated in both Europe and the U.S.[4,11]. Most of the reported increased risk, however, has been described in cleaners employed in non-healthcare industrial and private home settings[28,29]. Nevertheless, there is some limited evidence that cleaning in healthcare settings may pose a risk as well[29,30], although these studies primarily focused on professional cleaners. There has been less evidence of such an association when HCWs themselves engage in general cleaning tasks. In a recent registry study, the most commonly reported exposure linked to asthma among HCWs were cleaning products, which accounted for 24% of all cases, including 21% of the cases reported among nurses[6]. Both general (e.g., bleach, ammonia) and more specific (e.g., quaternary ammonium compounds) cleaning products have been linked to occupational asthma[31]. These and other commercial product ingredients, known to be potential respiratory sensitizers and/or irritants, were identified in the walkthroughs conducted for the development of our JEM (Table 4). The associations between exposure to cleaning products and both reported asthma and BHR-related symptoms in this study, taken together with the existing literature on asthma and cleaners, and the biological plausibility of such an association, provide sufficiently strong evidence to warrant consideration of interventions. The high prevalence of exposure to general cleaning products in this population (71%) and the strength of the associations observed produce an estimated attributable fraction of 33%, which suggests the proportion of reported asthma that might potentially be avoided through control of these exposures.

Tasks associated with cleaning and/or disinfection of medical instruments were also associated with an increased prevalence of reported asthma. Glutaraldehyde, also identified in our walkthroughs, has been linked to occupational asthma in several reports[9,32,33], and its incidence may be increasing[34]. Glutaraldehyde is especially useful for disinfecting heat-sensitive

equipment, including fiberscopes, dialysis instruments and surgical instruments; it is also used as a tissue fixative in pathology laboratories or for developing radiographs. Dimich-Ward and colleagues found a prevalence of 6.9% for reported asthma among respiratory therapists in British Columbia[8]. Sterilization of instruments with glutaraldehyde was associated with increased odds of wheeze and reported asthma, findings consistent with ours. Because of concerns with glutaraldehyde, NIOSH and OSHA recently recommended implementation of controls, including substitution with less toxic alternatives[35,36]. Subtilisins are bacterially-derived enzymes used in detergents for their ability to remove stains and deposits. In the 1960s, exposure to subtilisins derived from *Bacillus subtilis* among detergent manufacturing workers was found to cause sensitization and occupational asthma[37]. However, subsequent product reformulations aimed at reducing subtilisin-containing aerosols, coupled with stringent recommended exposure levels, have generally been successful at controlling further cases of asthma, especially among detergent end-users[38]. In our walkthroughs, we identified subtilisins as a component of some products used in medical instrument cleaning (Table 4). Although, to our knowledge, no cases of occupational asthma linked to these compounds have been reported in HCWs, this finding may warrant further research.

Powdered latex glove use is a well-established cause of occupational asthma in HCWs[10,34, 39]. However, this study adds important information to the body of literature. In addition to the finding of a two-fold increase in risk of reported asthma, the time period of this statistically significant elevated risk was restricted to 1992-2000. Although the magnitude in the odds ratios for the pre-1992 and 1992-2000 periods were similar, the former had wide confidence intervals and was not statistically significant. This is consistent with events in the 1990s that resulted in an initial increase, and subsequent decrease, in the use of powdered latex

gloves. Passage of the 1992 OSHA Bloodborne Pathogens Standard mandated the implementation of universal precautions when handling hazardous body fluids. This was promptly followed by a marked increase in use of personal protective equipment in healthcare settings, including latex gloves[40]. In 1997, in response to increasing reports of latex allergic reactions, NIOSH issued an alert calling for a reduction in undue use of powdered latex gloves[41]. Subsequently, although overall sales in the United States have continued to increase, the total protein and powder content in gloves has decreased markedly[40]. Findings from this study point to an encouraging reduction in risk after 2000. They also strengthen recent, generally single-site, reports indicating the effectiveness of substitution of powdered latex gloves by low-latex alternatives and other control measures[42,43]. For the remaining JEM exposure categories, use of similar classification by calendar periods was not possible. In contrast to powdered latex gloves, which represent a "single" product, the other categories (cleaning agents, aerosolized medications, and adhesives) included a number of different compounds, not all of which may have changed over time.

We also found an increased risk of both reported asthma and BHR-related symptoms associated with administration of aerosolized medications, consistent with previous studies conducted mostly among respiratory therapists. The most commonly cited agents have been aerosolized pentamidine and ribavirin[8, 44,,45]. However, administration of aerosolized medications is not limited to respiratory therapists, as this task may also be performed by nurses and, less often, by physicians. This is particularly true in countries where the profession of respiratory therapist does not exist, and these duties are assumed by other workers. Given the previous literature and findings from this study, the estimated attributable fraction of preventable asthma or asthma symptoms in this worker population would range from 7% to 14%.

A new association was found between BHR-related symptoms and tasks involving application of adhesives, adhesive removers, solvents or similar products on patients. The odds ratio was elevated to a similar degree for reported asthma, but was marginally not significant. Such compounds are commonly used for application and/or removal of dressings, adhesive bandages or in stoma care. The walkthroughs identified several potential respiratory irritants among the compounds used for these purposes (Table 4). Many have noticeably strong odors; some are solvents and may be linked more to transient respiratory symptoms than actual asthma. In a study by Pechter and colleagues, exposure to solvents accounted for 7% of reported work-related asthma; 29% of "aides/therapists" with asthma identified miscellaneous chemicals (including glues and solvents) with their asthma[6]. At present, though, evidence of a causal link should be considered speculative. A single, statistically significant inverse association was also observed between reported asthma and exposure to a miscellaneous category of adhesives, adhesive removers, solvents, or gases/vapors. Compounds in this category were few, generally unrelated, and with relatively little detail to allow further examination. The reason for this association, therefore, is unclear pending further confirmation, and may well be spurious.

Although most occupational asthma is felt to be allergic in origin[5], evidence is accumulating that irritant-induced asthma may be more common than previously thought. The European literature on asthma in cleaners suggests that a large proportion of cases are related to exposure to chemical irritants[46]. Among physician reports of work-related asthma in California, over 50% of cases were associated with agents not known to be allergens[28]. Typically, irritant-induced asthma is characterized by overexposure to an established respiratory irritant, with no latency between exposure and development of asthma symptoms. In its best-known presentation, reactive airways dysfunction syndrome (RADS), the inciting event is a single, one-time intense

exposure, such as a chemical spill or gas release[47]. This has also been described in HCWs, following an acute overexposure to glacial acetic acid[48]. An alternative presentation is a series of short-term overexposures to respiratory irritants occurring over days to a few weeks[49]. It is less clear whether chronic low-level exposure to irritants can lead to asthma[5], although it is well established that airborne irritants can trigger asthma exacerbations[50]. In this study, we found an increased association between having sustained an acute exposure to a chemical spill or gas release at work and BHR-related symptoms, but not with reported asthma. Because the 8-item predictor for BHR-related symptoms emphasized recent (i.e., current and/or within past 12 months) asthma symptoms, it is not possible to distinguish causation from aggravation or nonspecific triggering of symptoms, although the finding is certainly suggestive of an underlying irritant mechanism. Future studies should explore in greater detail both the nature of these acute exposures as well as their relationship to onset of asthma in HCWs.

Healthcare-related occupations represent 50% of the top 30 fastest growing occupations in the U.S., and all four professional groups included in this study are expected to grow by more than 20% by 2012[14]. Healthcare settings present an opportunity for exposure to several respiratory irritants and sensitizers, and our findings indicate that the contribution of occupational exposures to asthma in HCWs is not trivial. For previously described associations confirmed by this study, the evidence is sufficiently strong to justify moving from descriptive studies to the implementation and evaluation of appropriate controls. For newly described findings, additional, more focused confirmatory studies appear to be warranted.

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Table 1. Comparison of baseline descriptive statistics between the analytic sample (all missing values excluded) and the excluded sample (only those with missing values). Total study population = 3650.

Variable	Analytic sample (no missing values) (n=2738)	Excluded sample (missing values) (n=912)	*P* value*
Age (years **[**mean ± S.E.M.])	46.7 ± 0.32	51.0 ± 0.57	<0.001
Gender (%):			<0.001
Male	935 (24.6)	218 (16.4)	
Female	1803 (75.4)	634 (83.6)	
Race/ethnicity (%):			0.02
Non-Hispanic white	1983 (75.0)	514 (65.7)	
Hispanic	381 (11.7)	114 (13.2)	
Non-Hispanic black	143 (4.9)	54 (7.5)	
Other	231 (8.4)	85 (13.5)	
Atopy	447 (15.4)	129 (15.7)	0.51
Obesity (BMI ≥ 30 kg/m^2)	584 (23.7)	159 (20.4)	0.26
Smoking (%)			
Nonsmokers	1816 (66.3)	568 65.8)	
Current smokers	264 (9.6)	69 (8.0)	0.203
Former smokers	658 (24.0)	226 (26.2)	
Seniority (quartiles) (%)			
0-9 years	689 (25.2)	157 (18.3)	
10-16 years	706 (25.8)	218 (25.4)	<0.001
17-26 years	675 (24.7)	225 (26.2)	
≥ 27 years	668 (24.4)	258 (30.1)	
Profession (%):			
Physicians	682 (24.9)	180 (19.7)	
Occupational therapists	717 (26.2)	251 (27.5)	0.02
Nurses	695 (25.4)	246 (27.0)	
Respiratory therapists	644 (23.5)	235 (25.8)	
Reported asthma † (%)	145 (6.6)	53 (6.4)	0.55
BHR-related symptoms ‡ (%)	761 (27.4)	75 (25.2)	0.58

* Comparison of analytic and excluded samples, based on student's t-test for continuous variables and chi-square for categorical variables for sample survey data. † Asthma diagnosed by a physician after entry into the healthcare profession. ‡ 8-item predictor for bronchial hyperresponsiveness (BHR), $PC_{20} \leq 4$ mg/ml.

Table 2. Univariate analysis between independent variables, as assessed by a job-exposure matrix (JEM) and questionnaire for longest held job among Texas healthcare workers, and two asthma outcomes, weighted by survey sample size in the analytic sample (n=2738).

	Reported asthma*		BHR-related symptoms†	
Variable	**Odds Ratio (95% CI)**	**p value**	**Odds Ratio (95% CI)**	**p value**
Sociodemographics				
Age (per 10 year increments)	1.18 (1.00-1.38)	0.05	0.88 (0.79-0.98)	0.02
Gender (Male)	1.00		1.00	
Female	2.31 (1.35-3.94)	0.002	2.28 (1.73-3.01)	<0.001
Race/ethnicity (Non-Hispanic White)	1.00	0.006‡	1.00	0.04‡
Hispanic	1.62 (0.86-3.04)		0.70 (0.46-1.07)	
Non-Hispanic Black	0.20 (0.07-0.58)		1.23 (0.69-2.20)	
Other	1.13 (0.49-2.63)		0.56 (0.34-0.92)	
Obesity (BMI ≥ 30 kg/m^2)	2.03 (1.23-3.34)	0.002	1.59 (1.18-2.13)	0.005
Smoking				
Nonsmokers	1.00		1.00	
Current smokers	1.16 (0.52-2.61)	0.75‡	0.95 (0.60-1.51)	0.86‡
Former smokers	1.22 (0.71-2.10)		1.08 (0.80-1.45)	
Atopy	3.31 (1.99-5.48)	<0.001	8.80 (6.22-12.45)	<0.001
Occupational Exposures§				
Seniority (quartiles)				
0-9 years	1.00	0.03‡	1	0.15‡
10-16 years	2.08 (0.64- 6.73)		0.67 (0.45-1.02)	
17-26 years	3.37 (1.10-10.26)		0.78 (0.52-1.16)	
≥ 27 years	4.10 (1.39-12.11)		0.66 (0.45-0.96)	
Professional group (Physicians)				
Physicians	1.00	0.02‡	1	<0.001‡
Occupational therapists	1.06 (0.63-1.78)		2.32 (1.80-2.98)	
Nurses	1.89 (1.18-3.03)		1.95 (1.51-2.52)	
Respiratory therapists	1.30 (0.78-2.17)		2.01 (1.55-2.61)	
Spill at work	1.32 (0.58-2.99)	0.51	1.82 (1.16-2.85)	0.01
Cleaning agents				
Patient care	1.43 (0.19-10.81)	0.73	0.72 (0.29-1.75)	0.47
Instrument cleaning	2.07 (1.29-3.33)	0.003	1.40 (1.09-1.79)	0.01
Building surfaces	1.87 (1.14-3.05)	0.01	1.74 (1.34-2.26)	<0.001
Latex gloves				
< 1992	1.84 (0.84-4.06)	0.13	1.02 (0.72-1.45)	0.91
1992 – 2000	1.94 (1.15-3.28)	0.01	1.36 (1.03-1.79)	0.03
> 2000	0.51 (0.16-1.65)	0.26	0.71 (0.42-1.21)	0.21
Aerosolized medications	1.66 (1.03-2.66)	0.04	1.57 (1.22-2.01)	<0.001
Adhesives/solvents/gases				
Patient care	1.67 (1.01-2.77)	0.05	1.86 (1.42-2.44)	<0.001
On surfaces	0.58 (0.36-0.93)	0.02	1.25 (0.98-1.59)	0.08
Miscellaneous/other	0.52 (0.32-0.84)	0.008	0.74 (0.57-0.95)	0.02

*Self-reported history of physician-diagnosed asthma, with onset after entry into the healthcare profession. † 8-item predictor for bronchial hyperresponsiveness (BHR), $PC_{20} \leq 4$ mg/ml. ‡ Based on F-test for categorical variables for sample survey data. § All exposures as assessed by external JEM (low or high probability of exposure), except seniority and spill at work which were self-reported through questionnaire. Except where indicated, reference category for all exposure variables is the absence of such exposure.

Table 3. Associations between occupational exposures and asthma among Texas healthcare workers: final multivariable logistic regression models[*] (n=2738).

Occupational exposure	N (%)	Reported asthma[†] Odds Ratio (95% CI) [§]	BHR-related symptoms[‡] Odds Ratio (95% CI) [§]
Cleaning agents			
Used in patient care	2705 (98.8)	1.60 (0.18-14.16)	0.79 (0.35-1.78)
Instrument cleaning	1257 (45.9)	**2.22 (1.34-3.67)**	1.26 (0.95-1.67)
Surface cleaners	1943 (71.0)	**2.02 (1.20-3.40)**	**1.63 (1.21-2.19)**
Latex			
Pre-1992	1907 (69.7)	2.04 (0.87-4.75)	1.04 (0.72-1.51)
1992-2000	1556 (56.8)	**2.17 (1.27-3.73)**	1.26 (0.93-1.72)
After 2000	88 (3.2)	0.42 (0.13-1.29)	0.61 (0.34-1.11)
Aerosolized medications	1255 (45.8)	**1.72 (1.05-2.83)**	**1.40 (1.06-1.84)**
Adhesives/solvents/gases			
Used in patient care	1921 (70.2)	1.68 (0.99-2.86)	**1.65 (1.22-2.24)**
On surfaces	581 (21.2)	0.59 (0.26-1.33)	0.98 (0.64-1.51)
Miscellaneous	869 (31.7)	**0.53 (0.32-0.88)**	0.78 (0.60-1.01)
Spill at work	163 (6.0)	1.23 (0.53-2.87)	**2.02 (1.28-3.21)**

[*]Adjusted for seniority (quartiles), race/ethnicity, body mass index, and atopy; weighted survey samples. [†]Self-reported history of physician-diagnosed asthma, with onset after entry into the healthcare profession. [‡] 8-item predictor for bronchial hyperresponsiveness (BHR), $PC_{20} \leq 4$ mg/ml. [§]Goodness-of-fit, assessed through F-adjusted mean residual test for sample survey data, $p>0.05$ for all models. Reference category for all exposure variables is the absence of such exposure.

Table 4. Partial listing of products and chemicals used for instrument cleaning, building surface cleaners and adhesives or solvents used for patient care, identified through a series of Houston area hospital walkthroughs in 2002-2003.

Instrument cleaning/disinfection	Building surface cleaners	Adhesives used in patient care
Glutaraldehyde	Acetic acid/acetic acid anhydride	*Adhesive removers*:
Isopropanol	Ammonia/ammonium hydroxide	Acetone
Orthophthaldehyde	Bleach	Dipropylene glycol methyl ether
Sodium sesquicarbonate	Butyl paraben, ethyl paraben, methyl paraben	Ethanol
Subtilisins (enzymatic cleaners)	Diethanolamine	Isoparaffinic hydrocarbons
	Diethylene-glycol n-butyl ether	Isopropanol
	Hydrochloric acid	*Stoma care products*
	Isoparaffinic hydrocarbons	Carboxymethyl ether
	Phosphoric acid	Hexane-based skin bond
	Quaternary ammonium compounds	Methylbenzene
	Sodium sulfate	*Other:*
	Sulfuric acid	Methylene chloride
		Trichloroethane

6. PAPER # 3

Mail versus Internet surveys: determinants of method of response preferences among health professionals

Evaluation & the Health Professions [in press]

TITLE: MAIL VERSUS INTERNET SURVEYS: DETERMINANTS OF METHOD OF RESPONSE PREFERENCES AMONG HEALTH PROFESSIONALS

AUTHORS: Christine Lusk, MPH [1]; George L Delclos, MD, MPH[1,2]; Keith Burau, PhD[1]; Derek Drawhorn, M.A[1], Lu Ann Aday, PhD[1]

AFFILIATIONS: [1]The University of Texas School of Public Health, Houston, Texas, USA. [2] Department of Experimental and Health Sciences, Pompeu Fabra University, Barcelona, Spain.

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CORRESPONDENCE AND REQUESTS FOR REPRINTS:

George Delclos, MD, MPH
The University of Texas-Houston
School of Public Health
1200 Herman Pressler St
Suite RAS W1004
Houston, TX-77030

Tel: (713) 500-9459
Fax: (713) 500-9442
e-mail: George.Delclos@uth.tmc.edu

ABSTRACT

The Internet provides an attractive approach to survey research, yet few studies have evaluated the determinants of response to Internet-based surveys in healthcare workers. We examined this issue in a survey (n=5600) of Texas healthcare professionals, where participants were given the option of responding by mail or over the Web (response, 66%). Internet respondents were younger ($p<.001$), had worked fewer years as a health professional ($p<.001$), were more likely to be male ($p<.001$) and to work in a hospital ($p=.007$). Physicians were less likely to reply via the Web, whereas respiratory therapists responded more often electronically. The proportion of missing questionnaire items was significantly higher among Web responders with regard to self-reported age, sex, race, body mass index and smoking (all $p<.001$). In the final multivariate logistic regression model, only male gender (odds ratio [OR] 2.09, 95% CI 1.56-2.80) and younger age remained significantly associated with response over the Internet. An inverse gradient between age quartile and responding electronically was observed. Among healthcare professionals, respondents choosing Internet over mail as a method for responding to a survey request differ in terms of demographics and patterns of response. When taken together with *a priori* knowledge of the demographic and professional profile of a study population, these findings can be useful in planning and implementation of surveys among healthcare workers.

Key words: Internet surveys, determinants, response rate, healthcare professionals

INTRODUCTION

Obtaining high response rates from mail surveys is critical to achieving reliable and valid results from survey research. Certain populations are well known for low response rates to mail surveys. Health professionals, and especially physicians, have been one such group. Depending on the purpose of the study, modes of administration, and target populations, typical response rates for health professionals vary widely, from 16% to 91% (Donaldson, Moinpour, & Bush,1999; Kasprzyk, Montaño, St. Lawrence & Phillips, 2001; Field et al, 2002; Mavis & Brocato, 1998; Schleyer & Forrest2000; Gore-Felton, Koopman, Bridges, Thoresen & Spiegel, 2002; Rimm, Stempfer, Colditz, Giovannucci & Willett, 1990; Harrison, Hold & Elton; Leung, Ho, Chan, Johnston, & Wong, 2002; Puleo, Zapka, White, Mouchawar, Somkin & Taplin, 2002).

Aside from the study population, the method of survey distribution and follow-up are known to affect response rates. Access to electronic media and the Internet, whether by e-mail or the World Wide Web, provides an increasingly attractive approach to survey research because of significant cost reductions, multiple formatting features and ease of use. However, use of electronic media poses new and different issues regarding strategy, design and dissemination of a survey (Dillman, 2000). To date, relatively few studies have evaluated the determinants of response to Internet-based surveys as compared to more traditional means.

Using the experience obtained from a large survey of health professionals in Texas, we examined determinants that influence study participant choice of survey response method.

METHODS

Survey population

In 2004, we conducted a large, federally funded cross-sectional group-comparison survey of asthma in a representative sample of four groups of health professionals in Texas: physicians, nurses, respiratory therapists and occupational therapists. The sampling frame was defined as all members of each group, with a current Texas mailing address, listed on the rosters of their respective licensing boards as of September 2003. From these, a random sample of 1400 individuals from each of the four groups (n=5600) were selected to receive the survey instrument.

Survey instrument

The purpose of the survey was to gather self-reported data on asthma diagnosis, symptoms and risk factors, as part of an epidemiological study of asthma in healthcare professionals. Development and validation of the survey instrument was carried out by a multidisciplinary team of survey design experts, epidemiologists, industrial hygienists, and physicians, as previously described (Delclos et al, 2006). In brief, the initial draft questionnaire consisted of four sections: 1) asthma-related items; 2) occupational exposures; 3) non-occupational asthma risk factors; and 4) sociodemographics. Validation was conducted in a convenience sample of 118 currently employed healthcare workers from the Houston metropolitan area. Time to completion of the questionnaire ranged from 13 to 25 minutes. Test-retest reliability ranged from 0.75 to 0.94; internal consistency was excellent (Cronbach's $\alpha \geq 0.86$). Depending on the gold standard used, the percentage of asthmatics "correctly classified" by the questionnaire ranged from 70% to 94%. Agreement between self-reported occupational

exposures and industrial hygienist review was moderate (kappa = 0.45), similar to previous studies. When compared to panel of serum IgE antibodies to a panel of aeroallergens common in the southwestern U.S., questionnaire items on asthma risk factors (allergies) had a sensitivity of 68% and specificity of 85%.

After revisions, the final validated survey instrument was formatted in two versions. A hard copy booklet was designed to be used in conjunction with the Cardiff Teleform^{TM} software (Cardiff Software, Inc., Vista, CA), which allowed direct optical scanning of completed data entry forms into a database. In addition, a Web-based version of the questionnaire was prepared using Active Server Pages (ASP). Questionnaire items, skip patterns, and general appearance of the questions were identical in both versions, except that, depending on their answers, online responders may have seen fewer items overall (i.e., skip patterns allowed the viewing of fewer screens). Completion of the online version of the survey led to direct data entry. A copy of the final hard copy survey instrument can be obtained from the authors upon request.

Following the approach of Salant and Dillman (1994) and Dillman (2000), a total of five contacts were planned to potential study participants. Contacts were stopped once a participant returned their completed questionnaire or indicated that he/she declined participation. The initial contact was a "warm letter". This was followed one week later by a hard copy questionnaire (via mail), with an explanatory cover letter, a $1 token financial incentive, and a business reply envelope. This mailing included information on how the study participant could complete the survey online rather than completing the hard copy survey. The participant was provided with the secure website address, along with an individual passcode. This same information was repeated in each of the subsequent contacts. One week later a follow-up postcard was sent, thanking those who had returned the survey and politely requesting a response from

nonresponders. Three weeks after the first questionnaire mailing, a new personalized letter along with a replacement hard copy of the questionnaire and business reply envelope was sent to all non-responders; a final letter was sent two weeks after the replacement questionnaire mailing.

Study variables

The main dependent variable was method of survey completion (mail versus Internet), tracked on a daily basis. The independent variables, obtained from either the questionnaire responses or from the licensing board data were age, gender, race/ethnicity, geographic area of residence (urban versus rural), education, professional group, years as a health professional, number of hours worked per week and primary practice setting (hospital versus non-hospital). In addition, responses to other questionnaire variables were examined for distribution of missing items, specifically smoking, body mass index (calculated on the basis of self-reported height and weight), a prior asthma diagnosis and a history of wheezing in the previous 12 months.

Statistical analysis

After examining the distribution of the various dependent and independent variables, individual associations between each independent variable and the main dependent variable were examined, using two-sided t-tests for continuous variables, chi-square statistics for categorical variables and univariate logistic regression analysis. The distribution of proportions of missing responses for selected substantive questionnaire items (age, gender, race/ethnicity, body mass index, smoking, prior asthma diagnosis and wheezing), by method of survey response, was also assessed through chi-square statistics.

Variables with a p-value of <0.25 in the univariate analysis were then entered into an unconditional multiple logistic regression model with completion of the online version of the survey as the binary dependent variable. Final results were expressed as the adjusted logistic odds ratio (OR) and 95% confidence interval (95% C.I.). Model fit was assessed by the Hosmer-Lemeshow goodness-of-fit test. All statistical analyses were performed using STATA/SE v.9.2® (Stata Corporation, College Station, TX).

RESULTS

The initial mailing consisted of 5600 questionnaires; 213 participants were excluded due to death and bad addresses (n = 7 and 206, respectively), leaving a final eligible population of 5387. Completed surveys were received from 3529 participants (941 nurses, 968 occupational therapists, 741 physicians and 879 respiratory therapists), for an overall response rate of 65.5%. Group response rates were highest for occupational therapists (73%) and nurses (70%), and lowest for physicians (54%) and respiratory therapists (65%). Responses over the Internet were received from 328 participants (9.3% of the total number of responses received); by group these were 8.5% for nurses, 8.6% for occupational therapists, 7.7% for physicians and 12.2% for respiratory therapists.

Figure 1 summarizes the response rate trend, by method of survey response, for the study period. Overall, Web-based responses represented a consistent 9% to 10% of the total responses from the day of receipt of the first completed surveys, and did not appear to be affected by any of the subsequent contacts. This effect was maintained for each of the four professional groups.

Table 1 summarizes the distribution of results, by method of survey response, for each of the main independent variables. Internet respondents were younger (p<.001), had worked fewer

years as a health professional (p<.001), were more likely to be male (p<.001) and to work in a hospital setting (p=.007). Physicians were the least likely to reply via the Web (58 of 741, or 7.8%), whereas respiratory therapists responded more often electronically (107 of 879, or 12.2%).

The proportion of missing questionnaire items was significantly higher among Web responders with regard to self-reported age, sex, race, body mass index and smoking (all p<.001) (Table 2). There were no differences with respect to self-reported Hispanic ethnicity, prior asthma diagnosis or history of recent wheezing.

Based on a threshold of p <0.25 in the univariate analysis, the following variables were selected for inclusion in the final multiple logistic regression model: age quartiles, gender, Hispanic ethnicity, professional group, level of education (dichotomized as graduate level versus lower), and practice setting (hospital-based versus non-hospital-based). Although years of work as a health professional was also significantly associated with mode of response in the univariate analysis, it was excluded from the model because of strong collinearity with age (Pearson's correlation coefficient >0.70).

Table 3 presents the final multiple logistic regression model, which allowed assessment of the effects of each independent variable while simultaneously controlling for the effect of the remaining variables. In the final model, only male gender (adjusted OR 2.09, 95% CI 1.56 to 2.81) and age remained significantly associated with a greater likelihood of responding via the Internet. With each increase in age quartile, the likelihood of response via the Internet decreased consistently, and was statistically significant for the two highest quartiles (adjusted OR 0.56, 95% CI 0.40 to 0.78, and adjusted OR 0.35, 95% CI 0.24 to 0.52, respectively).

DISCUSSION

Enhancement of response rates in surveys of health professionals has been extensively addressed in the literature, both because of the uniqueness of this professional population in terms of the type of information sought and because of historically low response rates. Achievement of an adequate response rate is essential to the value of survey research for several reasons. Higher response rates provide greater statistical power, decrease survey error, should be more representative of the target population and, hence, results more generalizable because of better external validity (Gore-Felton, Koopman, Bridges, Thoresen & Spiegel, 2002). In different surveys of health professionals, typical response rates over the years have varied widely, from less than 20% to over 90% (Donaldson, Moinpour, & Bush,1999; Kasprzyk, Montaño, St. Lawrence & Phillips, 2001; Everett, Price, Bedell, & Telljohann, 1997; Field et al, 2002; Mavis & Brocato, 1998; Schleyer & Forrest2000; Gore-Felton, Koopman, Bridges, Thoresen & Spiegel, 2002; Del Valle, Morgenstern, Rogstad, Albright & Vickrey,1997; Rimm, Stempfer, Colditz, Giovannucci & Willett, 1990; Harrison, Hold & Elton; Leung, Ho, Chan, Johnston, & Wong, 2002; Puleo, Zapka, White, Mouchawar, Somkin & Taplin, 2002; Lensing, Gillaspy, Simpson, Jones, James, & Smith, 2000). These studies also varied in terms of the specific subpopulation of healthcare professionals targeted (e.g., physicians, psychologists, primary care providers, etc.), study purpose (e.g., professional practice patterns, adherence to standard of care guidelines, etc.), and/or modes of survey administration (certified mail, email, Internet, phone, multiple contact waves, use of financial incentives, etc). The best response rates have tended to involve mixed modes of survey delivery and response methods. In a study on adoption and implementation of gynecological cancer screening guidelines conducted among primary care providers in health maintenance organizations, a phenomenal 91% response rate was achieved over four contact

phases (Puleo, Zapka, White, Mouchawar, Somkin & Taplin, 2002). The authors combined questionnaire brevity, strategic questionnaire layout, first-class mailing with prepaid return envelopes, and a $3 gift coupon token incentive in their mailings. Two initial mailings were performed. After this, nonrespondents were contacted by local "champions", either by phone or electronic mail, to encourage response. Remaining nonrespondents were recontacted, in a fourth and final phase, using computer-assisted phone interviews performed by a survey research firm. Response rate after the first two mailings was 64%; thus, the subsequent two rounds of telephone contacts were critical in maximizing return. However, as the authors acknowledged, this multifaceted approach can be resource-intensive and costly. In addition, this study was conducted prior to implementation of the federal 'Do Not Call Registry' in 2003, which greatly limited the number of unsolicited phone calls to residences. Although survey research is exempted from this registry, it is still unclear how this measure has impacted telephone contacts as a mode of survey administration for academic research.

Use of the Internet could provide an attractive, lower-cost and possibly less obtrusive alternative, but much remains unanswered as to its effectiveness and effect on response bias, particularly in the very specific population of healthcare professionals. In 2003, Braithwaite and colleagues conducted a systematic review of Internet-based surveys of health professionals, to examine external validity. A total of 17 studies were retrieved, with response rates varying from 9% to 94% (Braithwaite, Emery, De Lusignan & Sutton, 2004). In contrast to our study, none of the studies identified drew their samples from comprehensive health professional populations; instead, specific subgroups (e.g., urologists, primary care physicians, dental practitioners) were usually targeted. Overall, Internet-based surveys were associated with low response rates. Exceptions to this, with response rates over 80%, included one study directed at trainees in

academic public health (i.e., a young population) and another, with a 94% response rate, was limited to "Web-using doctors". Response rates were not able to be calculated for several of the retrieved studies because of the absence of a known denominator population.

In our study, both mail and Internet-based survey completion provided a useful means for gathering survey data. The study design allowed the comparison of two methods of responding to a survey within the same study, and used a large sample size (n=3529). Differences in number of mailings, survey instrument, study population, and research question were controlled, which allowed *choice* of response to be directly assessed. This is in contrast to most previous studies, where mode of response was either randomized among sub-samples of the study population (i.e., choice, other than nonresponse, is not an option) or the survey was designed to be entirely Web-based from the outset.. In the latter case, the Web feature was usually one of several elements of the survey strategy, such as repeated contacts or use of token incentives, and therefore it was difficult to tease out the effect of administering the survey electronically.

A second strength, in contrast to many Web-originated surveys was that we were able to calculate very accurate response rates. The target population was clearly definable (professionals with an active license in 2003), allowing the definition of accurate denominators. Furthermore, there were no specific subsets selected within the four large professional groups of physicians, nurses, respiratory therapists and occupational therapists, allowing us to examine the study question in the total professional group and provide response rates that are representative of the whole. In contrast, most previous studies target selected subgroups, which limits both accurate calculation of denominator populations and comparability of response rates across more general categories.

Overall, when given a choice, we found that respondents overwhelmingly continued to prefer mail as a method of return, accounting for approximately 90% of the responses. This is consistent with the consensus of a recent advisory panel on Internet-based research (Kraut, Olson, Banaji, Bruckman, Cohen & Couper, 2004). In the Braithwaite systematic review, studies that compared electronic versus mail responses among healthcare workers found that Internet surveys had low response rates in comparison to paper surveys (Braithwaite, Emery, De Lusignan & Sutton, 2004). In 1998 researchers from Michigan State University compared response rates of a survey distributed to 200 subscribers of an Internet listserv (Mavis & Brocato, 1998). Half of the sample received surveys via the Internet (n=100), the other half by postal service (n=100). Response rates were significantly higher for response by mail (77%) than by electronic means (56%). However, electronic responses were received earlier. Jones and Pitt (1999) estimated response rates of a three-question health survey conducted in a convenience sample of 500 university staff,, comparing electronic mail, electronic mail with a www link to the survey, or a postal questionnaire. Postal surveys had the highest response rate (72%) compared to 34% for electronic mail and 17% for the www-linked survey. While the higher response rate justified the continued use of postal surveys, the authors concluded that the rapid societal changes in computer use justified reassessment of the method in the future. Both of these studies had smaller sample sizes and shorter questionnaires than our study, which also found a greater number of responses via postal return of a completed hard copy questionnaire. In contrast to our study, however, which controlled for a number of elements, respondents in these two prior studies were not given a choice of method of survey return. This did not allow the authors to profile and contrast respondent characteristics by preference. However, the general preference for mail can be affected by participant age and degree of access to the Internet. In a study of

alcohol and other substance abuse among 7,000 undergraduate students at a single university, participants were randomized to either completion of a survey via the Web or through U.S. mail (McCabe, Boyd, Couper, Crawford & D'Arcy, 2002). Response rates for the Web group was significantly higher than for the U.S. mail mode (63% versus 40%). However, this was a much younger population than in our study, and the authors estimated that 98% of these campus-based students had access to the Internet.

In our study, the profiles of respondents to one or the other form of survey completion differed in key demographic aspects. Among healthcare professionals, Internet respondents were more likely to be male and of younger age. There was also a clear inverse association between increasing age and decreasing likelihood of response over the Internet. Interestingly, after adjustment for other covariates, practice-related variables, including professional title, years of practice, educational level or primary practice setting did not remain as important determinants of response mode. In the study by McCabe and colleagues, although women undergraduates were more likely overall to respond to the survey, the proportion of males responding via the Web was higher than by mail (44% versus 38%) (McCabe, Boyd, Couper, Crawford & D'Arcy, 2002). Web responders were also less likely to be black, yet neither race nor Hispanic ethnicity were determinants of mode of response in our study. In the Braithwaite study, while there was little information provided in the reviewed studies on demographic determinants for responding to an Internet based survey, Internet responders reviewed were also more likely to be male (Braithwaite, Emery, De Lusignan & Sutton, 2004).

Although we did not specifically address individual access to the Internet, living in a rural setting (a possible surrogate for Internet access) was not found to be a limiting factor. However, health care professionals may not be representative of general rural residents in terms

of possibly having greater access to the Internet. On the other hand, recent reports indicate that the percentage of U.S. rural households with access to broadband Internet, while still lagging behind that in urban areas, is increasing dramatically, from approximately 9% in 2003 to 25% in 2006. Growth of Internet access in rural areas between 2005 and 2006 alone was 39% (Pew Internet & American Life Project, 2006).

We also observed that the proportion of responses via the Internet (i.e., approximately 10% of all returned surveys), as compared to responses by mail, tended to be relatively constant and unaffected by consecutive contact waves (Figure 1). Initially, this may seem to contrast with the review by Braithwaite, where use of follow-up reminders was reported to have resulted in large increases in response rates (Braithwaite, Emery, De Lusignan & Sutton, 2004). Overall, in our study, each of the contacts *did* result in an important increase in response rates; however, the magnitude of this increase was not greater for one mode versus the other. Thus, it appears that the demographic differences between Web and mail responders, present at the outset, were not greatly affected by subsequent survey implementation measures to enhance response.

Internet respondents were also more likely to skip or not answer certain questions on demographics or lifestyle habits, yet no differences were noted with respect to the primary outcome variable for the parent study (asthma). The reason for this is unclear. All of the demographic and lifestyle questions were on the last page of the questionnaire, so one possibility could be that, on the Web version, the program stalled on this page for these few respondents. Thus, all of the information collected prior to this page would have been retained, but the participant would have been unable to complete the final portion. In contrast, the questions on asthma and wheezing, for which no significant differences were noted between the two groups, were located at the beginning of the questionnaire. A higher proportion of incomplete

questionnaires among Web responders were also found by McCabe et al, who attributed this to breaks in the flow of electronic information (McCabe, Boyd, Couper, Crawford & D'Arcy, 2002). However, in our study, although it is true that all of the sociodemographic items were on the last page and that, for several of the nonresponse items, the number of Web nonresponders was identical (n=27, Table 2), this was not uniform. Specifically, the item on Hispanic ethnicity was on the same page, located between the questions on gender and race, and yet there were only 13 nonresponses, with no significant differences between the Web and mail responders. Thus, the possibility that there is a differential nonresponse for potentially sensitive questions between Web and mail responders should not be entirely ruled out. When taken together with *a priori* knowledge of the demographic and professional profile of a study population, these findings can be useful in planning and implementation of surveys among healthcare workers. For example, if one were conducting a survey among healthcare professional groups dominated by one or other gender (e.g., nurses and occupational therapists, where ~90% in Texas are female) or younger age groups (e.g., surveys conducted in medical or nursing schools), our findings could help guide choice of method of response. In addition, knowing that certain substantive questionnaire items (e.g., sex, age, smoking) might be more susceptible to not being answered via the Web could lead to choice of traditional mail surveys and/or use of a different approach to measurement of these variables in order to increase the likelihood of item response.

There are also limitations to our study. Since the research targeted healthcare professionals, results may not be generalizable to surveys of non-healthcare professionals. Future studies should also incorporate some means of accounting for differences in access to technology when contrasting newer versus more traditional means of conducting surveys. In addition, we were not able to assess whether an initial contact via electronic means would have

influenced the method of response, mail or Internet. It is not clear if individuals naturally respond using the same method in which the survey is received. All notices were received by mail, so the results could simply reflect a behavioral tendency to respond using the same method by which participants were initially contacted. Furthermore, for certain types of surveys, there are good reasons to prefer more traditional methods. For example, choosing mail over Internet allows researchers to avoid problems associated with frequent changes of electronic address in the absence of a standardized method to capture forwarding information such as has been established by the U.S. Postal Service. Another consideration that may limit generalizability of findings to other surveys conducted in health professionals is that the primary purpose of our study focused on asthma as a personal health issue among these professionals. This contrasts with the majority of surveys of health professionals, which tend to address aspects related to these professionals' practices. Finally, it would be wise to remember that profiles of Internet users and familiarity with its use as an everyday tool are rapidly changing, so our findings may need to be reassessed in the future, in light of these changing trends.

In summary, we found that respondents choosing Internet over mail as a method for completing and responding to a survey request differ in terms of basic demographic, but not professional, characteristics. Given the paucity of studies in health professionals comparing the merit of Internet-based surveys to a more traditional method (mail), the findings add to our understanding of the effectiveness of using Internet-based surveys and help profile differences in the type of respondent while controlling for other survey techniques like multiple mailings and incentives. Studies of this kind should prove useful for survey design and implementation, aiding survey researchers in their decision to choose Internet-based data collection methods over, or as a complement to, traditional methods.

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Figure 1. Survey response trends, by method of response: mail versus Internet. Survey of Texas healthcare professionals, 2004.

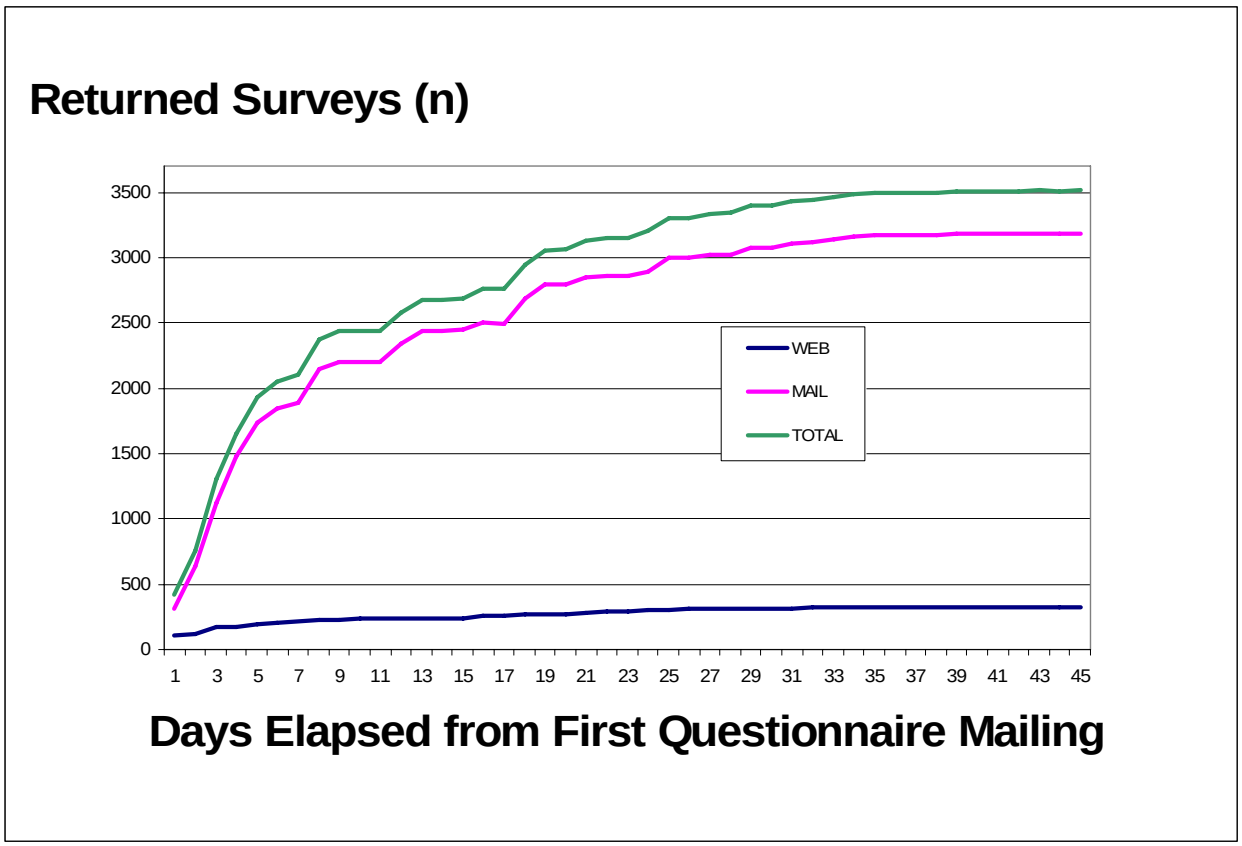

Table 1. Comparison of mail versus Internet-based survey response, by main independent variables (n= 3529). Survey of Texas healthcare professionals, 2004.

Independent variable	Mail (n=3201)	Internet (n=328)	p-value (*)
Age (years) (mean ± S.D.)	45.5 ±11.9	41.2 ±10.2	**<.001**
Gender			
Male	945 (29.8%)	122 (40.5%)	**<.001**
Female	2224 (70.2%)	179 (59.5%)	
Race			
White	2457 (76.8%)	254 (77.4%)	0.56
Black	209 (6.5%)	17 (5.2%)	
Asian	255 (8.0%)	23 (7.0%)	
Other	280 (8.8%)	34 (10.4 %)	
Hispanic ethnicity	427 (13.9%)	53 (16.8%)	0.16
Area of residence(**)			
Urban	2775 (86.9%)	283 (86.3%)	0.75
Rural	418 (13.1%)	45 (13.7%)	
Education level			
No college degree	7 (0.2%)	0 (0%)	0.24
2 year college degree	927 (29.3%)	91 (30.2%)	
4 year college degree	1135 (35.9%)	121 (40.2%)	
≥ Graduate degree	1097 (34.7%)	89 (29.6%)	
Professional group			
Physician	683 (21.3%)	58 (17.7%)	**.008**
Occupational therapist	885 (27.7%)	83 (25.3%)	
Nurse	861 (26.9%)	80 (24.4%)	
Respiratory therapist	772 (24.12%)	107 (32.6%)	
Years as a health professional	19.1 ±11.9	16.7 ±10.2	**<0.001**
Hours worked per week	43.1 ±15.2	43.6 ±14.9	0.71
Primary practice setting			
Hospital-based	1639 (51.5%)	192 (59.4%)	**.007**
Non-hospital based***	1543 (48.5%)	131 (40.6%)	

(*) Based on two-sided t-tests for continuous variables and chi-square tests for categorical variables. (**) Urban – counties with population ≥ 50,000. Rural – counties with population < 50,000. (***) Includes academia, home health, private practice, outpatient clinic, nursing home, health department, public school, health insurance agency, research, medical sales and other.

Table 2. Comparison of proportion of missing values by method of survey response (mail versus Internet-based) (n= 3529). Survey of Texas healthcare professionals, 2004.

Variable	Missing items-mail responders (% missing per item)	Missing items-Internet responders (% missing per item)	p-value (*)
Age	57 (1.8%)	27 (8.2%)	**P<.001**
Gender	32 (1.0%)	27 (8.2%)	**P<.001**
Race	64 (2.0%)	27 (8.2%)	**P<.001**
Hispanic ethnicity	128 (4.0%)	13 (4.0%)	0.98
Body mass index**	67 (2.1%)	28 (8.5%)	**P<.001**
Ever smoker	22 (0.7%)	27 (8.2%)	**P<.001**
Have you ever had asthma?	44 (1.4%)	1 (0.3%)	0.10
Wheezing in the past 12 months	56 (1.8%)	2 (0.6%)	0.12

(*) Based on two-sided t-tests for continuous variables and chi-square tests for categorical variables.

(**) Body mass index calculated based on self-reported height and weight.

Table 3. Multivariate logistic regression analysis of main determinants of survey response method (n=3529). Final model. Survey of Texas healthcare professionals, 2004. Dependent variable: Internet-based survey response**.**

Variable	**O.R.(*)**	**95% C.I. (**)**
Age		
First quartile	1.00	-
Second quartile	0.75	0.55-1.02
Third quartile	**0.56**	**0.40-0.78**
Fourth quartile	**0.35**	**0.24-0.52**
Gender:		
Female	1.00	-
Male	**2.09**	**1.56-2.81**
Hispanic ethnicity	1.15	0.83-1.61
Professional group:		
Physicians	1.00	-
Occupational therapists	1.30	0.79-2.15
Nurses	1.45	0.83-2.50
Respiratory therapists	1.50	0.88-2.56
Graduate school education	0.97	0.66-1.43
Hospital-based practice setting	1.16	0.87-1.53

(*) O.R. - Adjusted odds ratio (**) 95% C.I. – 95% Confidence Interval
Hosmer-Lemeshow goodness-of-fit, p>.05.

7. GENERAL DISCUSSION

This section is intended to supplement the discussion sections of each of the two main papers (Studies I and II), emphasizing their contribution to the body of literature, as well as additional comments regarding strengths and limitations. Comments on Study III are inserted where relevant. The references for this section, as well as for the Introduction, are presented in Section 9. References for each of the three papers are listed within each of those papers.

7.1. Study I

The main outcome of Study I was the development of a new and validated survey instrument on asthma for use in epidemiological studies of healthcare workers (Appendix A). For two of the questionnaire sections (asthma and nonoccupational asthma risk factors), there was good validity and reliability. In the occupational exposure section, although the level of agreement between self-reported workplace exposures by study participants and the industrial hygienists was similar to that found in other studies, this agreement was still only moderate. Therefore, we felt that more reliable occupational exposure assessment methods that go beyond self-report, and provide a separate measure of exposure to workplace risk factors, were needed. Ultimately, this resulted in the development of the healthcare worker-specific JEM, focused on asthma risk factors (Appendix B).

It is well recognized that questionnaire-based definitions of asthma may not necessarily correspond to the clinical definition of asthma, and that there is no universally accepted "gold standard" definition of asthma for use in epidemiology studies[74]. Previous validation studies of asthma questionnaires have generally relied on comparison of questionnaire items on asthma and asthma-like symptoms to putative gold standards, including physician-diagnosed asthma, physiologic measures of nonspecific bronchial

hyperresponsiveness, or previously validated questionnaires.[57-59,74] Depending on the gold standard used, as well as on the nature of the questionnaire items, sensitivity and specificity have varied.

Study I used an approach that compared the performance of the asthma section of the questionnaire to three different "gold standards" (physician-diagnosed asthma, PC_{20} and the DFP previously validated by Burney and colleagues), providing a range of sensitivity and specificity values that may allow a broader characterization of susceptible subgroups. Through the statistical analysis, a weighted combination of eight symptoms emerged that performed well against the three gold standards. The combination of several symptom-based questions to define asthma has been found to perform better, and is less conducive to misclassification, than reliance on a single question[32]. The sensitivity of 0.79 and specificity of 0.98 found with the 8-item predictor against physician-diagnosed asthma (94% of cases correctly classified) compares favorably with prior studies, supporting its suitability for use in future asthma epidemiology studies. However, caution should also be exercised in interpreting a positive response to the 8-item predictor as necessarily indicating the presence of asthma. Although methacholine challenge testing was selected as one of the "gold standards", it is well known that airway hyperresponsiveness is not synonymous with asthma (although it is a cardinal feature) and can be present in a certain proportion of asymptomatic persons without asthma, which could affect the specificity of certain questionnaire items.[75,76] Taken together with the relatively high proportion of persons in Study I who exhibited a positive response to this combination of questionnaire items, the 8-item predictor is best interpreted as reflecting bronchial hyperresponsiveness-related symptoms. Consequently, within the context of a given study, one could entertain inclusion of both a "sensitive" symptom-based definition reflective of bronchial hyperresponsiveness-related symptoms, and a "stricter" (i.e., more specific) definition based on physician diagnosis, in order to allow a

broader assessment of the spectrum of asthma. The advantages of using more than one definition, reflecting different asthma endpoints or characteristics, were illustrated in Study II. As noted in the Introduction, Pekkanen and Pearce have recommended using different asthma definitions depending on study aims, i.e., prevalence versus etiologic studies.[33] Study II examined associations of asthma prevalence with occupational exposures in a cross-sectional survey of healthcare professionals, using both the 8-item predictor and reported asthma as outcome variables. In Study I, the 8-item predictor for $PC_{20} \leq 4$ mg/ml had shown the best combination of sensitivity and specificity (i.e., the highest Youden´s index) of the different asthma measures examined. Hence, its use for purposes of examining prevalence in Study II was justified. The more specific outcome, on the other hand (i.e., reported asthma) was better suited for examining the various associations with occupational risk factors and, indeed, in Study II tended to show stronger associations than BHR-related symptoms.

Other limitations of Study I should be noted. Like most occupational asthma surveys we were unable to distinguish between pre-existing asthma and work-related asthma, and a case definiton of *work-related asthma* was not specifically validated. However, the final questionnaire (Appendix A) does include items regarding time of asthma onset (relative to entry into the healthcare profession), worsening of asthma and/or respiratory symptoms with work, amelioration when away from work and work absences due to asthma and/or respiratory symptoms. Combining these questions with the validated asthma and bronchial hyperresponsiveness predictor in future studies could allow a better approximation to a usable probabilistic definition of work-related asthma. In the context of a longitudinal cohort study, an approach that combined asthma with onset after start of employment and symptom patterns in relation to work proved useful for studying asthma in laboratory animal workers.[77] A limitation with our questionnaire, however, is that these items reflect symptom patterns occurring in the previous 12 months, i.e., current job scenarios. Hence, persons with a

definite history of reported asthma, but who no longer labor in a job that provokes their symptoms, could be missed. On the other hand, serial administration of these same questionnaire items in the context of a future longitudinal study of HCWs could overcome this limitation.

As is the case with methacholine challenge, a similar issue arises for the RAST antibody panel, where some asymptomatic persons may have significantly elevated titers of these antibodies, in the absence of a clinical diagnosis of atopy.[78] However, the good specificity (86%) shown by the questionnaire items for allergens known to be strongly related to asthma (dust mite and animals) suggests that this effect was small.

After revisions, the final validated questionnaire was formatted in two versions, and is available for public use. The hard copy version of the booklet is designed for use in conjunction with the Cardiff TeleformTM software (Cardiff Software, Inc., Vista, CA), which allows direct optical scanning of completed data entry forms into a database, markedly reducing the need for manual data entry or double entry. In addition, a web-based version of the questionnaire was prepared using Active Server Pages (ASP). Questionnaire items, skip patterns, and general appearance of the questions are identical in both versions, except that, depending on their answers, online responders may see fewer items overall (i.e., skip patterns allowed the viewing of fewer screens). Completion of the online version of the survey leads to direct data entry, also reducing the need for time-consuming manual data entry. Follow-up data quality control routines are in place for both data entry methods.

The availability of two different modes of survey return is a helpful feature of the questionnaire. However, selection of one or both modes should be done thoughtfully since responder profiles may differ, as noted in Study III. The two key findings in that study were: 1) among healthcare professionals (when given a choice of response method), younger age and male gender are determinants of greater likelihood of responding over the internet, and 2)

the pattern of missing values may vary by method of response. Knowledge of these findings can be helpful in survey design and implementation when taken in the context of the expected profile of a study population, together with other issues, such as available budget. For example, if one were conducting a survey among healthcare professional groups dominated by one or other gender (e.g., nurses and occupational therapists, where ~90% in Texas are female) or younger age groups (e.g., surveys conducted in medical or nursing schools), the findings in Study III could help guide choice of method of response. In addition, knowing that certain key questionnaire items (e.g., sex, age, smoking) are more susceptible to not being answered via the web could lead to choice of traditional mail surveys and/or using a different approach to measurement of these variables in order to increase the likelihood of a participant responding to a particular questionnaire item. However, these generalizations may be short-lived, since profiles of internet users and familiarity with its use as an everyday tool are rapidly changing. Consequently, our findings may need to be reevaluated in the future, in light of these changing trends.

Overall, our questionnaire appeared to be easily completed by participants, making it applicable for use in other healthcare worker groups, including dental professionals, housekeeping personnel, security, facilities maintenance, etc. However, there are caveats to expanded use of this questionnaire, depending on the intended subgroup of healthcare workers. The education level of the study population was quite high in the validation study; thus care should be taken before using this questionnaire in a broader cross-section without further cognitive testing and validation. An unexplored issue is whether HCWs, because they are likely to be more familiar with asthma as a disease, respond differently to questions about asthma than general populations. Or even whether subgroups of HCWs (i.e., physicians versus therapists, nurses, etc.) differ in their interpretation of what the term ‘asthma’ means to each. In Study II, this might have been one factor in the different prevalences of reported

asthma (physicians, lowest; nurses, highest) and BHR-related symptoms (physicians, lowest; occupational therapists, highest). In addition, certain items in the job history section might require modification, in order to incorporate a greater number of choices for job title and practice settings, since this information is later integrated into the JEM for classification of occupational exposures for each individual participant.

7.2. Study II

In Study II we found an approximately two-fold or greater increased likelihood of asthma after entry into a healthcare profession for tasks involving instrument cleaning and disinfection, general cleaning products used on indoor building surfaces, use of powdered latex gloves, and the administration of aerosolized medications. Significant associations were likewise found between BHR-related symptoms and use of surface cleaners, aerosolized medication administration, adhesives or solvents as products in patient care, as well as with a history of sustaining an acute exposure to a chemical or gas at work. Study findings are consistent with previously reported associations between asthma and occupational exposures in healthcare settings, but also identify new relationships warranting further evaluation.

As noted in the Discussion section of Paper # 2, among the strengths of the study was the development and use of an externally developed JEM to assign occupational exposures, which merits additional commentary, particularly in relation to validity. The process followed for its development consisted of many detailed steps, beginning with use of the NOES database, constructed in the early 1980s.[67] This large database was then reduced to a smaller set, limited to the health services industry and a list of asthmagens. The hospital walk-throughs provided an opportunity to add new chemicals and products to this list. Those brand name products that we identified in our walk-throughs were then broken down into their component active ingredients, and further into their potential as respiratory irritants

and/or sensitizers. All three hospitals, although intentionally different in terms of their patient populations (a tertiary referral general hospital, a pediatric hospital and a cancer hospital), were fully accredited by the U.S. Joint Commission on Accreditation of Healthcare Organizations (JCAHO). JCAHO has stringent standards for infection control, including general cleaning/disinfection and instrument cleaning procedures, which are generally applicable to all hospitals. During the walkthroughs we also found that many of the chemical products overlapped. Although there could be some variation in the brand name products across hospitals (e.g., for general cleaning and medical instrument cleaning), the active ingredients used in these products were similar (e.g., quaternary ammonium compounds, bleach, citric-based cleaners, glutaraldehyde, paraffinic hydrocarbons, etc.) (Appendix C). More recently, JCAHO has incorporated standards for worker protection/employee health into its inspections, so policies and procedures such as those governing protective clothing, including gloves, would be similar across hospitals. It is reasonable to assume that the "inventory" found during our walk-throughs would therefore be generalizable to other U.S. hospitals with JCAHO accreditation (of which there are approximately 6000). It is less clear, however, whether our findings can be extrapolated to hospitals outside the United States. In recent years other countries have begun to apply JCAHO standards to their own hospitals as a means of quality assurance. If the same standards are applied there, then this could add to the generalizability of our findings, as well as provide a means by which preventive programs can be implemented and evaluated.

The end result of these initial efforts was a reduced list of approximately 28 chemicals that were then incorporated into the questionnaire for Study I. Principal factor analysis conducted on these chemicals during Study I indicated that they could be grouped into logical domains (e.g., cleaning agents, sterilizing agents, aerosolized medications, etc.). This knowledge then guided the development of the final JEM structure where exposure categories

focused more on tasks than on physicochemical characteristics of the compounds, in contrast to the asthma risk factor JEM developed by Kennedy et al.[72] The value of examining risk of asthma by tasks has been shown recently in studies of cleaners in Barcelona, and adds another perspective to assessing exposure.[79]

Another strength of the JEM development process was that coding was performed by a multidisciplinary team of five occupational health professionals. In many prior studies, fewer persons are usually involved, often centering on one or two industrial hygienists, engineers and/or chemists.[80-82] In our case there was one occupational physician (with over 18 years of experience working in a hospital employee health service) and four industrial hygienists (one of whom was also a chemist, another a hospital-based safety specialist, and a third with expertise in exposure modeling). Taken collectively, all of the steps described above for the development of our JEM added important content validity.

Use of a carefully constructed JEM can be a less expensive method of assigning exposures as compared to more costly, time-consuming approaches, such as individualized industrial hygiene reviews. Since the JEM is constructed externally, i.e., "blinded", to the questionnaire responses, differential misclassification of exposure is less likely.[83] However, limitations associated with the use of JEMs have also been identified, including the potential for misclassification of exposure, the loss of statistical power, and the lack of formal validation of most JEMs. [60,64,65,83] More recently, studies have shown the value of favoring specificity of the exposure assignment over sensitivity.[84,85] When combined with increasingly specific disease definitions, the associations found between JEM-assigned exposures and disease outcomes may gain strength.[84] This has been especially true in recent studies of work-related asthma.[72,84,85] Other features of a JEM that seem to increase validity include limiting the JEM to specific exposures (e.g., carcinogens, asthmagens), industries or

worker populations (e.g., healthcare workers), and using semiquantitative scales to assign probability of exposure.[64,66,72]

In order to enhance validity, several of these features were incorporated into the development and coding of our JEM. The occupational exposure categories were limited to asthma risk factors and to HCWs as a worker population. The coding categories were originally designed to reflect increasing probability of exposure (i.e., a semiquantitative approach) and specificity. However, in the end the two 'exposed' codes ("low" and "high" probability of exposure) were collapsed into a single 'exposed' category and compared to the referent code '0', which deviated from our *a priori* ideas. After consensus was reached by the five experts, the number of occupation-practice setting combinations assigned to the "low probability" code was very small for almost all considered exposures (in some cases, even none). As a result, this intermediate exposure group as such appeared to be too small for meaningful analyses, including a dose-response analysis. Although a high specificity of the exposure estimate is important, particularly in cases with low prevalence of exposure, in our study the prevalence of exposure differed considerably for the different asthma risk factors, and in many cases was not low. On the other hand, the experts had been instructed to code a '0' in situations where exposure seemed very unlikely. This ultimately resulted in a "clean" reference group and a high sensitivity of the exposure definition. We ran some additional analyses in which the reference category was redefined by collapsing the non-exposed with the low-exposed group (data not shown). This reanalysis revealed that all associations still pointed in the same direction as those presented in Paper # 2, and that the main associations remained significant. Therefore, it is unlikely that another grouping strategy for the occupational exposures would have altered the main findings of Study # 2.

Much discussion also exists regarding appropriate ways of validating JEMs. Methods described refer primarily to criterion or construct validity and include:

- comparison of JEM-based exposure predictions to quantitative measures of exposure;[80,86]
- comparison of risk estimates generated by the use of two or more different JEMs;[82]
- comparison of JEM–based exposure predictions with expert review;[60]
- testing a known causal association (e.g., asbestos and lung cancer) using JEM-based exposure predictions;[60,64,87]
- comparison of JEM-based exposure predictions to self-reported occupational history;[87]
- comparison of an *a priori* developed JEM to a population-specific JEM and to self-reported exposures;[45,82,88]

In our case, quantitative measurements of exposure were neither available for current chemical products nor for those identified in the original NOES. Likewise, to our knowledge there are no other JEMs of similar characteristics to ours, limiting comparability. Although the JEM developed by Kennedy and colleagues does center on asthma risk factors, it was originally designed for use in general populations.[72] Hence, the number of HCW categories on the job axis of their JEM would be too few to assure sufficient variability of exposure across all cells. On the other hand, the confirmation of previously described causal associations between certain occupational exposures (e.g., powdered latex glove use) and asthma in our study does lend construct validity to our JEM.

In addition to the possibility of recall bias generally associated with self-reported exposures, this bias may be differential, i.e., asthmatics and non-asthmatics may recall differently, as has been noted.[85,89] We found some limited evidence of this when we compared our original JEM codings to self-reported exposures derived from the questionnaires in the full study population of 3650 persons (Table 1). Overall, differences

were not dramatic, with overlapping of virtually all of the confidence intervals for agreement. However, based on the point estimates, asthmatics tended to show a slightly stronger level of agreement with the JEM than non-asthmatics for patient-care related cleaning, instrument cleaning, and administration of aerosolized medications; there was little difference with respect to latex glove use. When examining senstitivity and specificity, however, the former was slightly higher among asthmatics and the latter in nonasthmatics; in a few instances, the confidence intervals did not overlap. These results (although mentioned in Paper 2) were not included in the main papers because: a) they would have lengthened the paper unnecessarily, and were not directly related to the study objectives, and b) more importantly, our comparisons were not on an identical category-by-category basis in all cases. For example, in the questionnaire we asked about glutaraldehyde, but not about medical instrument cleaning, whereas in the JEM the closest category was "medical instrument cleaning". Thus, comparisons were admittedly a bit crude (which explains the various low kappa scores for some of the comparisons), but they do evidence a tendency towards differential recall bias when exposure classification is based on self-reported exposures. This further justified use of the JEM in our study, and provided some limited criterion validity as well.

Finally, this JEM also has the advantage that it can be expanded to include other groups of HCWs, as long as the same methodology is followed. As of the writing of this thesis, our group is undertaking a new project, of similar characteristis as the present project, directed at two recently identified possibly at-risk HCW groups, dental professionals and radiology technologists.[81-86]

In summary, this new JEM does show evidence of content, criterion and construct validity. However, further validation is desirable (especially criterion) and will be addressed in future studies as its use is expanded to include other HCW groups and asthma risk factors.

Table 1. Comparison of Asthma-related self-reported exposures in the longest held job with occupational exposure assessed by a job-exposure matrix (JEM) among Texas healthcare workers (n= 3650)[a].

	HCWs with a prior physician diagnosis of asthma or wheezing in the previous 12 months				HCWs without a prior physician diagnosis of asthma or wheezing in the previous 12 months			
Exposures	**Sensitivity (95% CI)[b]**	**Specificity (95% CI)[b]**	**Kappa[c] (95% CI)**	**Phi[d]**	**Sensitivity (95% CI)[b]**	**Specificity (95% CI)[b]**	**Kappa[c] (95% CI)**	**Phi[d]**
Cleaning agents								
Patient care	79 (75-83)	71 (29-96)	0.07 (0.00-0.14)	0.51	69 (65-72)	71 (42-92)	0.04 (0.01-0.07)	0.40
Instrument cleaning								
Glutaraldehyde	71 (67-75)	73 (69-78)	0.44 (0.39-0.50)	0.45	60 (57-63)	82 (79-84)	0.42 (0.38-0.46)	0.44
Building surfaces	87 (84-89)	37 (30-44)	0.25 (0.18-0.33)	0.32	80 (77-82)	47 (43-51)	0.27 (0.23-0.32)	0.30
Latex gloves								
< 1992	90 (86-93)	30 (22-39)	0.24 (0.14-0.33)	0.33	86 (84-89)	36 (30-41)	0.24 (0.18-0.31)	0.31
1992 – 2000	90 (86-93)	27 (20-35)	0.19 (0.10-0.28)	0.29	88 (85-91)	33 (28-38)	0.23 (0.17-0.29)	0.31
Aerosolized medications	74 (68-80)	74 (67-80)	0.48 (0.39-0.56)	0.48	67 (62-71)	78 (74-81)	0.45 (0.39-0.51)	0.45
Adhesives/glues/vapors/gases								
Patient care	54 (50-57)	64 (57-71)	0.13 (0.07-0.18)	0.18	42 (39-44)	70 (67-73)	0.10 (0.06-0.13)	0.13
On surfaces	53 (45-60)	51 (48-55)	0.03 (-0.03-0.08)	0.04	40 (35-44)	63 (60-65)	0.02 (-0.02-0.06)	0.03
Gases/vapors (nonspecific)	55 (46-64)	73 (68-78)	0.28 (0.18-0.37)	0.30	43 (37-49)	79 (76-82)	0.23 (0.16-0.30)	0.26

[a] Actual sample varies by exposure. [b] Expressed as a percentage. [c] Cohen's unweighted Kappa statistic. [d] Chance-independent agreement.

8. CONCLUSIONS

8.1. Study I

- Although some questionnaires exist for the evaluation of asthma and exposures in the workplace, none have undergone formal validation in a healthcare worker population. Evaluation of the performance of this new questionnaire for the study of asthma in healthcare workers indicates good validity and reliability for the asthma definitions and for the characterization of nonoccupational exposures and other asthma risk factors. The validity and reliability of assessment of occupational exposures was only moderate and similar to previous studies based on self-report, supporting the desirability of using alternative methods of occupational exposure classification.
- Use of this validated questionnaire in epidemiological studies of healthcare workers should improve the quality of asthma research in this large sector of the employed workforce.
- Although the instrument was specifically designed for use in the healthcare sector, the rigorous methodological approach to questionnaire validation employed in this study could also be adapted for studies of other worker populations.

8.2. Study II

- Healthcare-related occupations are among the top 30 fastest growing occupations in the U.S. Healthcare settings present an opportunity for exposure to several respiratory irritants and sensitizers, and our findings indicate that the contribution of occupational exposures to asthma in HCWs is not trivial.

- An approximately two-fold increased likelihood of asthma after entry into a healthcare profession was observed for tasks involving instrument cleaning and disinfection, general cleaning products used on indoor building surfaces, use of powdered latex gloves, and the administration of aerosolized medications.
- Risk of asthma associated with use of powdered latex gloves was not observed after the year 2000, suggesting that the various recommendations and guidelines established for control of latex exposure in U.S. healthcare settings are having a beneficial effect.
- Significant associations were likewise found between BHR-related symptoms and use of surface cleaners, aerosolized medication administration, adhesives or solvents as products in patient care, as well as with a history of sustaining an acute exposure to a chemical or gas at work.
- Study findings are consistent with previously reported associations between asthma and occupational exposures in healthcare settings, and identify new relationships warranting further evaluation. For previously described associations confirmed by this study, the collective evidence is sufficiently strong to justify moving from descriptive studies to the implantation and evaluation of appropriate controls. For newly described findings, additional, more focused studies appear to be warranted.

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10. APPENDICES

Appendix A.

Final Study Questionnaire

THE UNIVERSITY *of* TEXAS

HEALTH SCIENCE CENTER AT HOUSTON

SCHOOL OF PUBLIC HEALTH

A Survey of Asthma in Health Professionals

A study funded by the U.S. Centers for Disease Control and Prevention and the National Institute for Occupational Safety and Health (CDC/NIOSH)

A Survey of Asthma In Health Professionals

You have been randomly selected from among your licensed Texas colleagues. All answers are confidental.

START HERE

Trouble Breathing

Questions 1 and 2 ask you about trouble breathing EVER IN YOUR LIFE.

1. **Have you ever had trouble with your breathing?** *(Mark an X for the single best answer)*
   - ☐ Yes
   - ☐ No → **Go to Question 2**
   - ☐ Don't Know → **Go to Question 2**

   1.1 ***If YES*****, what kind of trouble did you have?**
   - ☐ Continuously, as if breathing is not quite right
   - ☐ Repeatedly, however gets completely better
   - ☐ Only rarely

   1.2 ***If YES*****, was this trouble with your breathing brought on by your work environment?**
   - ☐ Yes
   - ☐ No
   - ☐ Don't Know

2. **Have you ever had asthma?** *(Mark an X for the single best answer)*
   - ☐ Yes
   - ☐ No → **Go to Question 5 on Page 3**
   - ☐ Don't Know → **Go to Question 5 on Page 3**

   2.1 ***If YES*****, has your asthma been confirmed by a doctor?**
   - ☐ Yes
   - ☐ No → **Go to Question 3**
   - ☐ Don't Know → **Go to Question 3**

   2.1.1 ***If YES*****, at what age was your asthma confirmed by a doctor?**

   ☐☐ YEARS OLD

For Office use Only ☐☐☐☐☐☐☐☐

For Office use Only ☐☐☐☐☐☐☐☐

Asthma

Questions 3 and 4 ask you about asthma in THE LAST 12 MONTHS.

3. Have you had an attack/episode of asthma in the last 12 months? *(Mark an X for the single best answer)*

- ☐ Yes
- ☐ No → **Go to Question 4**
- ☐ Don't Know → **Go to Question 4**

3.1 ***If YES*, how many attacks of asthma have you had in the last 12 months?** *(Enter approximate number of asthma attacks)*

☐☐☐ ATTACKS

3.2 Have you had an attack/episode of asthma while you were at work in the last 12 months?

- ☐ Yes
- ☐ No → **Go to Question 3.3**
- ☐ Don't Know → **Go to Question 3.3**

3.2.1 ***If YES*, do you know what triggered the last attack/episode of asthma while you were at work?**

- ☐ Yes
- ☐ No → **Go to Question 3.3**

3.2.1.a ***If YES*, what was the trigger?**

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

3.3 Have you had to miss any days of work due to asthma in the last 12 months?

- ☐ Yes
- ☐ No → **Go to Question 4**
- ☐ Don't Know → **Go to Question 4**

3.3.1 ***If YES*, how many days of work did you have to miss due to asthma?** *(Enter approximate number of days)*

☐☐☐ DAYS

4. Are you currently taking any medications for asthma, including inhalers, aerosols or tablets?

- ☐ Yes
- ☐ No

Wheezing, Whistling or Shortness of Breath

Questions 5 to 7 ask you to think about your breathing in THE LAST 12 MONTHS.

5 . Have you had wheezing or whistling in your chest at any time in the last 12 months? ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No → **Go to Question 6 on Page 4**
- ☐ Don't Know → **Go to Question 6 on Page 4**

5.1 ***If YES*****, Have you had wheezing or whistling in your chest when you did not have a cold in the last 12 months?**

- ☐ Yes
- ☐ No

5.2 Have you had wheezing or whistling in your chest while you were at home (indoors or outdoors) at any time in the last 12 months?

- ☐ Yes
- ☐ No

5.3 Have you had wheezing or whistling in your chest while you were at work at any time in the last 12 months?

- ☐ Yes
- ☐ No

5.4 While you were away from work at any time in the last 12 months, was your wheezing or whistling: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged

5.5 After returning to your work at any time in the last 12 months, was your wheezing or whistling: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged

5.6 If you were away from work for 5 or more consecutive days of absence at any time in the last 12 months, was your wheezing or whistling: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged
- ☐ Not Applicable

5.7 When you returned to your work after 5 or more consecutive days of absence at any time in the last 12 months, was your wheezing or whistling: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged
- ☐ Not Applicable

5.8 Have you had to miss days of work due to wheezing or whistling at any time in the last 12 months?

- ☐ Yes
- ☐ No → **Go to Question 6 on Page 4**

5.8.1 ***If YES*****, how many days of work did you miss in the last 12 months?** ***(Enter approximate number of days)***

☐☐☐ DAYS

6 . **Have you had an attack/episode of <u>shortness of breath</u> at any time in the last 12 months?** ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No → **Go to Question 7**
- ☐ Don't Know → **Go to Question 7**

6.1 Have you had an attack/episode of shortness of breath that came on <u>following strenuous activity</u> at any time in the last 12 months?

- ☐ Yes
- ☐ No

6.2 Have you had an attack/episode of shortness of breath while you were <u>at home</u> (indoors or outdoors) at any time in the last 12 months?

- ☐ Yes
- ☐ No

6.3 Have you had an attack/episode of shortness of breath while you were <u>at work</u> at any time in the last 12 months?

- ☐ Yes
- ☐ No

6.4 While you were <u>away from work</u> at any time in the last 12 months, was your shortness of breath: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged

6.5 <u>After returning to your work</u> at any time in the last 12 months, was your shortness of breath: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged

6.6 If you were <u>away from work for 5 or more consecutive days</u> of absence at any time in the last 12 months, was your shortness of breath: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged
- ☐ Not Applicable

6.7 When you <u>returned to your work after 5 or more consecutive days</u> of absence at any time in the last 12 months, was your shortness of breath: worse, better, or unchanged?

- ☐ Worse
- ☐ Better
- ☐ Unchanged
- ☐ Not Applicable

6.8 Have you had to <u>miss days of work due to shortness of breath</u> in the last 12 months?

- ☐ Yes
- ☐ No → **Go to Question 7**

6.8.1 ***If YES*, how many days of work did you miss in the last 12 months?** ***(Enter approximate number of days)***

☐☐☐ DAYS

7. **Have you been <u>awakened during the night</u> by an attack/episode of any of the following symptoms in the last 12 months?** ***(Indicate YES or NO for each symptom)***

Yes	No	
☐	☐	Cough
☐	☐	Shortness of breath
☐	☐	Chest tightness

Pets, Animals, Allergies

Questions 8 to 13 ask you about pets, animals, allergies and family medical history.

8. Do you currently have any of the following pets in your home? ***(Indicate Yes or No for each)***

Yes	No	
☐	☐	Dog
☐	☐	Cat
☐	☐	Other pet

9. Have you ever lived with any of the following pets in your home? ***(Indicate Yes or No for each)***

Yes	No	
☐	☐	Dog
☐	☐	Cat
☐	☐	Other pet

10. Have you ever had any of the following medical conditions? ***(Indicate Yes or No for each)***

Yes	No	
☐	☐	Nasal or sinus allergies, including hay fever
☐	☐	Eczema or any kind of skin allergy
☐	☐	Frequent heartburn
☐	☐	More than 6 respiratory infections in one year
☐	☐	Allergies to chemicals
☐	☐	Allergies to medicines
☐	☐	Allergies to animals
☐	☐	Allergies to dust or dust mite
☐	☐	Allergies to latex or latex-containing products (ace bandages/adhesive tape/condoms/gloves)

11. When you are near animals (cats/dogs/horses), feathers (pillows/quilts/duvets), or in a dusty part of the house, do you ever:

Yes	No	
☐	☐	Get itchy or watery eyes?
☐	☐	Get a feeling of tightness in your chest?

12. When you are near trees, grass, or flowers, or when there is a lot of pollen around, do you ever:

Yes	No	
☐	☐	Get itchy or watery eyes?

13. Have any of your immediate family members (parents/siblings/children) had any of the following medical conditions? ***(Indicate Yes, No or Don't Know for each condition)***

Yes	No	Don't Know	
☐	☐	☐	Asthma
☐	☐	☐	Hay fever, eczema, or skin allergies

House or Apartment

Questions 14 and 15 ask you to describe the house or apartment you are currently living in.

14. In your house or apartment do you use any of the following: ***(Indicate Yes or No for each item)***

Yes	No	
☐	☐	Gas for cooking or heating?
☐	☐	Fireplace?
☐	☐	Air-conditioning (central or window unit)?

15. Does your house or apartment have any of the following characteristics: ***(Indicate Yes or No for each characteristic)***

Yes	No	Don't Know	
☐	☐	☐	Are there drapes or curtains in any room in your house or apartment?
☐	☐	☐	Is there wall-to-wall carpeting in any room in your house or apartment?
☐	☐	☐	Is your home sprayed for pest control at least every 3 months?
☐	☐	☐	Are there large visible areas of mold, mildew, or recent water damage?
☐	☐	☐	Was your house or apartment originally built before 1973?

Occupational History

Questions 16 to 22 ask you about your CURRENT or MOST RECENT Job.

16. In which month and year did you begin your current or most recent job?

Month / Year

17. In which month and year did you stop working at this job?

Month / Year ☐ Not Applicable

18. How many hours per week did/do you usually work on this job, including overtime?

HOURS

19. During this time, were/are you a student in this job? ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No

20. What kind of business or industry is/was this? ***(Mark an X for the single best answer)***

- ☐ Hospital
- ☐ Private practice
- ☐ Outpatient clinic
- ☐ Nursing home
- ☐ Health department
- ☐ Public school
- ☐ Health insurance agency
- ☐ Research
- ☐ Medical sales
- ☐ Academia
- ☐ Home health
- ☐ Dental office
- ☐ Other (specify):

21. What is/was your job title? ***(Mark an X for the single best answer)***

- ☐ LVN
- ☐ RN
- ☐ Nurse practitioner
- ☐ Physician
- ☐ Dentist
- ☐ Dental assistant
- ☐ Allied health professional
- ☐ Respiratory therapist
- ☐ Occupational therapist
- ☐ Physical therapist
- ☐ Physician's assistant
- ☐ Dental hygienist
- ☐ Nurse aid
- ☐ Other (specify):

22. While working at this job, indicate how often, on average, you handled or were exposed to any of the following products? ***(Mark an X for the single best answer for each item)***

	More than once a day	Every day	At least once a week	At least once a month	Never
Disinfectants/sterilants	☐	☐	☐	☐	☐
Cleaning agents	☐	☐	☐	☐	☐
Latex gloves/products	☐	☐	☐	☐	☐
Aerosolized medications	☐	☐	☐	☐	☐
Adhesives/removers/glues	☐	☐	☐	☐	☐
Gases/vapors	☐	☐	☐	☐	☐

Occupational History *(continued)*

Questions 23 to 30 ask you about your LONGEST HELD Job.

23. Is your current or most recent job also your longest held job?

☐ Yes → **Go to Question 31 on Page 9**
☐ No

24. In which month and year did you begin your longest held job?

☐☐/☐☐☐☐
Month Year

25. In which month and year did you stop working at this job?

☐☐/☐☐☐☐
Month Year

26. How many hours per week did you usually work on this job, including overtime?

☐☐☐ HOURS

27. During this time, were you a student in this job? ***(Mark an X for the single best answer)***

☐ Yes
☐ No

28. What kind of business or industry was this? ***(Mark an X for the single best answer)***

☐ Hospital
☐ Private practice
☐ Outpatient clinic
☐ Nursing home
☐ Health department
☐ Public school
☐ Health insurance agency
☐ Research
☐ Medical sales
☐ Academia
☐ Home health
☐ Dental office
☐ Other (specify):

☐☐☐☐☐☐☐☐☐☐

29. What was your job title? ***(Mark an X for the single best answer)***

☐ LVN
☐ RN
☐ Nurse practitioner
☐ Physician
☐ Dentist
☐ Dental assistant
☐ Allied health professional
☐ Respiratory therapist
☐ Occupational therapist
☐ Physical therapist
☐ Physician's assistant
☐ Dental hygienist
☐ Nurse aid
☐ Other (specify):

☐☐☐☐☐☐☐☐☐☐

30. While working at this job, indicate how often, on average, you handled or were exposed to any of the following products? ***(Mark an X for the single best answer for each item)***

	More than once a day	Every day	At least once a week	At least once a month	Never
a. Disinfectants/sterilants	☐	☐	☐	☐	☐
b. Cleaning agents	☐	☐	☐	☐	☐
c. Latex gloves/products	☐	☐	☐	☐	☐
d. Aerosolized medications	☐	☐	☐	☐	☐
e. Adhesives/removers/glues	☐	☐	☐	☐	☐
f. Gases/vapors	☐	☐	☐	☐	☐

Accidental Chemical Spill or Gas Release

Question 31 asks you about exposure to an accidental chemical spill or gas release.

31. Were you ever involved in an accidental chemical spill or gas release? ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No → **Go to Question 32 on Page 10**
- ☐ Don't Know → **Go to Question 32 on Page 10**

31.1 Did this accidental chemical spill or gas release occur at work? ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No

31.2 When did this accidental chemcial spill or gas release occur?

☐☐/☐☐☐☐

Month Year

31.3 What were you exposed to? (*Please be as specific as possible)*

☐☐☐☐☐☐☐☐☐☐☐☐☐☐

31.4 How were you exposed? ***(Indicate Yes or No for each route of exposure)***

Yes	No	
☐	☐	Breathing
☐	☐	Through direct contact with skin
☐	☐	Swallowing/ingestion

31.5 During this accidental chemical spill or gas release, how long were you exposed? ***(Mark an X for the single best answer)***

- ☐ Less than 1 hour
- ☐ 1 to 8 hours
- ☐ 9 to 24 hours
- ☐ More than 24 hours
- ☐ Don't Know/Don't Remember

31.6 Did you have to receive medical attention because of this accident/exposure? ***(Mark an X for the single best answer)***

- ☐ Yes
- ☐ No
- ☐ Don't Know/Don't Remember

31.7 In the first 24 hours following this accident/exposure, did you experience any of the follwing symptoms: ***(Indicate Yes or No for each symptom)***

Yes	No	
☐	☐	Shortness of breath?
☐	☐	Wheezing?
☐	☐	Cough?
☐	☐	Tightness in your chest?

If you answered <u>YES to ANY</u> symptoms in Q31.7, continue answering the questions on this page.

If you answered <u>NO to ALL</u> items in Q31.7, Go to Question 32 on Page 10.

31.7.1 How soon after the accident/exposure did these symptoms occur?

- ☐ Less than 1 hour
- ☐ 1 to 24 hours
- ☐ 25 hours to 1 week
- ☐ More than 1 week
- ☐ Don't Know/Don't Remember

31.7.2 How long did these symptoms last?

- ☐ Less than 1 week
- ☐ 1 week to 1 month
- ☐ More than 1 month to 3 months
- ☐ More than 3 months
- ☐ Don't Know/Don't Remember

Jobs

Question 32 asks you about jobs that you have EVER had.

32. Think about all of the jobs you have ever had. To the best of your knowledge have you ever been in contact with any of the following materials at least once a month for a period of 6 months or longer? *(Indicate Yes or No for each one)*

Yes	No	
☐	☐	Bleach
☐	☐	Cleaners for room and counter tops
☐	☐	Cleaners/abrasives
☐	☐	Cleaners for restrooms and toilets
☐	☐	Detergents
☐	☐	Disinfectants

Yes	No	
☐	☐	Cidex™ (glutaraldehyde)
☐	☐	Cidex OPA™ (ortho-phtaldehyde)
☐	☐	Chloramines
☐	☐	Adhesives or glues

Yes	No	
☐	☐	Ammonia
☐	☐	Pesticides
☐	☐	Paints (acrylics, stains/varnishes)
☐	☐	Tobacco smoke (including passive)
☐	☐	Solvents like toluene, xylene, benzene, hexane, mineral spirits, paint thinners
☐	☐	Toner for copiers or printers

Yes	No	
☐	☐	Anesthetics
☐	☐	Antibiotics
☐	☐	Antiseptics
☐	☐	Bronchodilators
☐	☐	Iodine (Povidone iodine, Betadine™)
☐	☐	Nebulized drugs (like pentamadine or ribavirin)
☐	☐	Talc

Yes	No	
☐	☐	Acetaldehyde
☐	☐	Alkalis
☐	☐	Ethylene oxide
☐	☐	Formalin/formaldehyde
☐	☐	Nitric oxide

Hobbies

Question 33 asks you about hobbies that you have EVER had.

33. Have you ever been regularly involved in any of the following hobbies or activities for a period of 3 months or longer? *(Indicate Yes or No for each one)*

Yes	No	
☐	☐	Refinishing furniture
☐	☐	Auto repair
☐	☐	Building radios or other electronic equipment
☐	☐	Metal work including soldering metal (such as jewelry making)
☐	☐	Painting with acrylics or oil paints
☐	☐	Gardening/Farming
☐	☐	Sculpting
☐	☐	Woodworking
☐	☐	Hobbies involving use of glues or adhesives
☐	☐	Other hobbies/activities (Please specify):

Demographics

34. What is your date of birth?

☐☐/☐☐/☐☐☐☐

Month Day Year

35. What is your gender?

- ☐ Male
- ☐ Female

36. Do you consider yourself Spanish/Hispanic/Latino? ***(Mark an X for the single best answer)***

- ☐ No, not Spanish/Hispanic/Latino
- ☐ Yes, Mexican, Mexican American, Chicano
- ☐ Yes, Puerto Rican
- ☐ Yes, Cuban
- ☐ Yes, other Spanish/Hispanic/Latino (specify):

☐☐☐☐☐☐☐☐☐☐

37. What is your race? ***(Mark an X for the single best answer)***

- ☐ White
- ☐ Black
- ☐ Asian, Asian-American or Pacific Islander
- ☐ American Indian or Alaska Native
- ☐ Another race (specify):

☐☐☐☐☐☐☐☐☐☐

38. What is your standing height?

☐/☐☐

Feet Inches

39. How much do you weigh?

☐☐☐

Pounds

40. What is the highest grade or level of education that you have completed? ***(Mark an X for the single best answer)***

- ☐ High school graduate or GED
- ☐ Some college or vocational/technical training
- ☐ 4 year college graduate (Bachelor's Degree)
- ☐ Graduate/Medical/Law school

41. How many years have you worked as a health care professional ***(include years as a healthcare student)*****?**

☐☐ YEARS

42. Have you smoked at least 100 cigarettes during your life?

- ☐ Yes
- ☐ No

43. Do you smoke cigarettes now?

- ☐ Yes → **Go to Question 43.1**
- ☐ No

43.1 ***If YES*****, how many cigarettes do you smoke per day?**

- ☐ less than 1/2 pack a day
- ☐ 1/2 to 1 pack a day
- ☐ >1 to 2 packs a day
- ☐ >2 to 3 packs a day
- ☐ more than 3 packs a day

Thank you for completing this survey.

Please return this survey in the envelope provided to:

PO Box 20186

Houston, TX 77225-0186

THE UNIVERSITY *of* TEXAS
HEALTH SCIENCE CENTER AT HOUSTON
SCHOOL OF PUBLIC HEALTH

Thank you for completing
A Survey of Asthma in Health Professionals
Please return this survey in the envelope provided to:
PO Box 20186
Houston, TX 77225 - 0186

Appendix B.

Job-Exposure Matrix for Asthma Risk Factors among Healthcare Workers

LEVEL Description (Major chemical class)	Cleaning agents/disinfectants			Powdered latex gloves			Aerosolized medications	Adhesives/removers/glues/organic solvents/gases/vapors			Sensitizing metals
LEVEL Description (Chemical subclass)	Patient-care cleaning and disinfection -PT	Instrument cleaning and disinfection -IN	Building surfaces cleaning & disinfection -BD					On Patients	On Surfaces	Misc.	
	CLPT	CLIN	CLBD	LX1992	LX2000	LX2001	AM	ADPT	ADBD	ADMC	SM
				Pre 1992	1992-2000	Post 2000		Pt Care	Surface	Misc	
OCCUPATION X PRACTICE SETTING											
MD-ALL (Physicians)											
MD-Hospital - Surgical Specialty	2	0	0	2	2	2	0	2	0	2	0
MD-Hospital - Other Specialties	2	0	0	2	1	0	0	0	0	1	0
MD-Private practice	2	0	0	2	0	0	0	0	0	0	0
MD-Outpatient clinic - Surgical Specialty	2	0	0	2	2	2	0	2	0	2	0
MD-Outpatient clinic - Other Specialties	2	0	0	2	1	0	0	0	0	1	0
MD-Nursing home	2	0	0	2	2	0	0	0	0	0	0
MD-Health department	2	0	0	0	0	0	0	0	0	0	0
MD-Public school	2	0	0	0	0	0	0	0	0	0	0
MD-Health insurance agency	0	0	0	1	0	0	0	0	0	0	0
MD-Research	2	0	0	0	0	0	0	0	0	0	0
MD-Academia	2	0	0	2	1	0	0	0	0	0	0
RN-ALL (Registered Nurses)											
RN-Hospital	2	1	2	2	2	0	1	2	0	0	0
RN-Private practice	2	1	2	0	0	0	0	2	0	0	0
RN-Outpatient clinic	2	1	2	1	1	0	1	2	0	0	0
RN-Nursing home	2	0	2	2	2	0	2	2	0	0	0
RN-Health department	1	0	1	0	0	0	0	0	0	0	0
RN-Public school	2	0	2	0	0	0	2	2	0	0	0
RN-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
RN-Research	1	0	0	1	1	0	0	0	0	0	0
RN-Medical sales	0	0	0	0	0	0	0	0	0	0	0
RN-Academia	0	0	0	0	0	0	0	0	0	0	0
RN-Home health	2	0	2	2	2	0	1	2	0	0	0
RN-Dental office	0	0	2	1	1	1	0	0	0	0	0
LVN-ALL (Licensed Vocational Nurses)											
LVN-Hospital	2	1	2	2	2	0	1	2	0	0	0
LVN-Private practice	2	1	0	0	0	0	0	2	0	0	0
LVN-Outpatient clinic	2	1	2	1	1	0	1	2	0	0	0
LVN-Nursing home	2	0	2	2	2	0	1	2	0	0	0
LVN-Health department	1	0	1	0	0	0	0	0	0	0	0
LVN-Public school	2	0	2	0	0	0	2	2	0	0	0
LVN-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
LVN-Research	1	0	0	1	1	0	0	0	0	0	0
LVN-Medical sales	0	0	0	0	0	0	0	0	0	0	0
LVN-Academia	0	0	0	0	0	0	0	0	0	0	0
LVN-Home health	2	0	2	2	2	0	1	2	0	0	0
LVN-Dental office	0	0	2	1	1	1	0	0	0	0	1
NP-ALL (Nurse Practitioners)											
NP-Hospital	2	1	2	2	1	0	1	2	0	0	0
NP-Private practice	2	1	0	2	0	0	0	2	0	0	0
NP-Outpatient clinic	2	1	2	2	1	0	1	2	0	1	0
NP-Nursing home	2	0	2	2	2	0	1	2	0	0	0
NP-Health department	1	0	1	0	0	0	0	0	0	0	0
NP-Public school	2	0	2	0	0	0	2	2	0	0	0
NP-Health insurance agency	0	0	0	1	0	0	0	0	0	0	0
NP-Research	2	0	0	0	0	0	0	0	0	0	0
NP-Medical sales	0	0	0	0	0	0	0	0	0	0	0
NP-Academia	2	0	0	2	1	0	0	0	0	0	0
NP-Home health	2	0	0	2	2	0	1	2	0	0	0
NP-Dental office	0	0	2	1	1	1	0	0	0	0	0
NA-ALL (Nurse aide)											
NA-Hospital	2	2	2	0	1	0	0	0	0	0	0
NA-Private practice	2	0	2	0	0	0	0	0	0	0	0
NA-Outpatient clinic	2	2	2	0	0	0	0	0	0	0	0
NA-Nursing home	2	0	2	0	0	0	0	0	0	0	0

LEVEL Description (Major chemical class)	Cleaning agents/disinfectants			Powdered latex gloves			Aerosolized medications	Adhesives/removers/glues/organic solvents/gases/vapors			Sensitizing metals
LEVEL Description (Chemical subclass)	Patient-care cleaning and disinfection -PT	Instrument cleaning and disinfection -IN	Building surfaces cleaning & disinfection -BD					On Patients	On Surfaces	Misc.	
	CLPT	CLIN	CLBD	LX1992	LX2000	LX2001	AM	ADPT	ADBD	ADMC	SM
				Pre 1992	1992-2000	Post 2000		Pt Care	Surface	Misc	
NA-Health department	1	0	1	0	0	0	0	0	0	0	0
NA-Public school	2	0	2	0	0	0	0	0	0	0	0
NA-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
NA-Research	0	0	0	0	0	0	0	0	0	0	0
NA-Medical sales	0	0	0	0	0	0	0	0	0	0	0
NA-Academia	0	0	0	0	0	0	0	0	0	0	0
NA-Home health	2	0	2	0	1	0	0	0	0	0	0
NA-Dental office	0	0	2	0	0	0	0	0	0	0	0
RT-ALL (Respiratory therapists)											
RT-Hospital	2	2	2	2	2	0	2	2	0	2	0
RT-Private practice	2	2	2	2	2	0	2	0	0	0	0
RT-Outpatient clinic	2	2	2	2	2	0	2	2	0	2	0
RT-Nursing home	2	2	0	2	2	0	2	2	0	0	0
RT-Public school	2	2	0	0	0	0	0	0	0	0	0
RT-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
RT-Research	2	2	0	2	2	0	2	0	0	0	0
RT-Medical sales	0	0	0	0	0	0	0	0	0	0	0
RT-Academia	2	2	0	2	2	0	2	0	0	0	0
RT-Home health	2	2	0	2	2	0	2	2	0	0	0
OT-ALL (Occupational therapists)											
OT-Hospital	2	0	2	0	0	0	0	2	2	0	0
OT-Private practice	2	0	2	0	0	0	0	2	2	0	0
OT-Outpatient clinic	2	0	2	0	0	0	0	2	2	0	0
OT-Nursing home	2	0	2	0	0	0	0	2	2	0	0
OT-Health department	0	0	1	0	0	0	0	0	0	0	0
OT-Public school	2	0	2	0	0	0	0	0	0	0	0
OT-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
OT-Research	1	0	1	0	0	0	0	1	2	0	0
OT-Medical sales	0	0	0	0	0	0	0	0	0	0	0
OT-Academia	1	0	1	0	0	0	0	1	2	0	0
OT-Home health	2	0	1	0	0	0	0	1	2	0	0
OT-Dental office	0	0	2	0	0	0	0	0	0	0	0
OTHER - DENTAL (Dentist, dental assistant, Lab Techs)											
DENTAL-Hospital	2	2	1	2	2	0	0	2	0	0	2
DENTAL-Private practice	2	2	2	2	2	2	0	2	0	0	2
DENTAL-Outpatient clinic	2	2	2	2	2	0	0	2	0	0	2
DENTAL-Nursing home	2	2	0	2	2	0	0	2	0	0	2
DENTAL-Health department	2	0	0	2	2	2	0	2	0	0	2
DENTAL-Public school	2	0	0	0	0	0	0	0	0	0	0
DENTAL-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
DENTAL-Research	2	0	0	2	2	2	0	2	0	0	2
DENTAL-Medical sales	0	0	0	0	0	0	0	0	0	0	0
DENTAL-Academia	2	0	0	2	2	0	0	2	0	0	2
DENTAL-Home health	2	2	2	2	2	2	0	2	0	0	2
OTHER - DENTAL (Dental Hygienist)											
DENTAL-Hospital	2	2	1	2	2	0	0	0	0	0	0
DENTAL-Private practice	2	2	2	2	2	2	0	0	0	0	0
DENTAL-Outpatient clinic	2	2	2	2	2	0	0	0	0	0	0
DENTAL-Nursing home	2	2	2	2	2	0	0	0	0	0	0
DENTAL-Health department	2	1	2	2	2	2	0	0	0	0	0
DENTAL-Public school	2	2	2	0	0	0	0	0	0	0	0
DENTAL-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
DENTAL-Research	2	0	0	2	2	2	0	0	0	0	0
DENTAL-Medical sales	0	0	0	0	0	0	0	0	0	0	0
DENTAL-Academia	2	0	0	2	2	0	0	0	0	0	0
DENTAL-Home health	2	0	0	2	2	2	0	0	0	0	0

LEVEL Description (Major chemical class)	Cleaning agents/disinfectants			Powdered latex gloves			Aerosolized medications	Adhesives/removers/glues/organic solvents/gases/vapors			Sensitizing metals
LEVEL Description (Chemical subclass)	Patient-care cleaning and disinfection -PT	Instrument cleaning and disinfection -IN	Building surfaces cleaning & disinfection -BD					On Patients	On Surfaces	Misc.	
	CLPT	CLIN	CLBD	LX1992	LX2000	LX2001	AM	ADPT	ADBD	ADMC	SM
				Pre 1992	1992-2000	Post 2000		Pt Care	Surface	Misc	
DENTAL-Dental office	2	2	2	2	2	2	0	0	0	0	0
PA-ALL (Physician Assistant)											
PA-Hospital	2	1	2	2	1	0	1	2	0	2	0
PA-Private practice	2	1	0	2	2	0	0	2	0	1	0
PA-Outpatient clinic	2	1	2	2	0	0	1	2	0	2	0
PA-Nursing home	2	0	2	2	2	0	1	2	0	0	0
PA-Health department	1	0	1	0	0	0	0	0	0	0	0
PA-Public school	2	0	2	0	0	0	1	1	0	0	0
PA-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
PA-Research	2	0	0	1	1	0	0	0	0	0	0
PA-Academia	2	0	0	2	1	0	0	0	0	0	0
PT-ALL (Physical therapists)											
PT-Hospital	2	0	0	0	0	0	0	2	2	0	0
PT-Private practice	2	0	0	0	0	0	0	2	2	0	0
PT-Outpatient clinic	2	0	0	0	0	0	0	2	2	0	0
PT-Nursing home	2	0	0	0	0	0	0	2	2	0	0
PT-Health department	0	0	0	0	0	0	0	0	0	0	0
PT-Public school	2	0	0	0	0	0	0	1	0	0	0
PT-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
PT-Research	1	0	0	0	0	0	0	1	0	0	0
PT-Medical sales	0	0	0	0	0	0	0	0	0	0	0
PT-Academia	1	0	0	0	0	0	0	1	0	0	0
PT-Home health	2	0	0	0	0	0	0	1	0	0	0
PT-Dental office	0	0	2	0	0	0	0	0	0	0	0
OTHER - Allied Health Professionals/ /Other											
OTHER-Hospital	1	2	0	0	0	0	0	0	0	0	0
OTHER-Private practice	1	1	1	0	0	0	0	0	0	0	0
OTHER-Outpatient clinic	1	2	1	0	0	0	0	0	0	0	0
OTHER-Nursing home	1	1	1	0	0	0	0	0	0	0	0
OTHER-Health department	0	1	1	0	0	0	0	0	0	0	0
OTHER-Public school	0	0	1	0	0	0	0	0	0	0	0
OTHER-Health insurance agency	0	0	0	0	0	0	0	0	0	0	0
OTHER-Research	0	0	0	0	0	0	0	0	0	0	0
OTHER-Medical sales	0	0	0	0	0	0	0	0	0	0	0
OTHER-Academia	0	0	0	0	0	0	0	0	0	0	0
OTHER-Home health	0	0	1	0	0	0	0	0	0	0	0
OTHER-Dental office	0	0	2	0	0	0	0	0	0	0	0

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
OCCUPATION X PRACTICE SETTING		
MD-ALL (Physicians)	http://online.onetcenter.org/link/summary/29-1069.99	**Check primary specialty area (separate tab). Note that the O-net link provided indicates that there are other O-net links to specific physician specialties.**
MD-Hospital	Tasks largely determined by specialty area - check primary specialty area (separate tab). This job may be combined with several of the other practice settings (hospital/private practice/outpatient/nursing home, etc.).	
MD-Private practice	Examine, diagnose and treat outpatients. MDs in surgical specialties and selected medical specialties (pulmonary, GI) may perform minor surgical procedures in the office, as well as some endoscopies.	
MD-Outpatient clinic	Examine, diagnose and treat outpatients. MDs in surgical specialties and selected medical specialties (pulmonary, GI) may perform minor surgical procedures in the office, as well as some endoscopies.	
MD-Nursing home	Examine, diagnose and treat (makes rounds) on inpatients. MDs in surgical specialties and selected medical specialties (pulmonary, GI) may perform minor surgical procedures, as well as some endoscopies (less likely).	
MD-Health department	Greater emphasis on program development/administrative tasks, but some MDs also staff and care for patients in a clinical setting (STD clinics, for example).	
MD-Public school	Unlikely scenario. Similar to RN/LVN in this position. A few school-based clinics are now appearing in Texas, but they are more likely to be staffed by NPs or PAs. Tasks would be similar.	
MD-Healh insurance agency	Administrative/case management work.	
MD-Research	Varies widely, from no patient contact to frequent contact in clinical trials.	
MD-Academia	Teaching and research, but may also involve direct patient care activities.	
MD-Other		
RN-ALL (Registered Nurses)	http://online.onetcenter.org/link/summary/29-1111.00	**Check primary specialty area (separate tab).**
RN-Hospital	Involved in direct patient care (hospitalized patients), by specialty areas. Take vital signs, administer medications, daily patient skin care, assist physicians in their procedures. Some (higher level) may do purely administrative work.	
RN-Private practice	Generally will assist physicians in their offices. Take vital signs, administer medication, maintain charts, call patients, etc.	
RN-Outpatient clinic	Involved in direct patient care (ambulatory patients), by specialty areas. Some (higher level) may do purely administrative work.	
RN-Nursing home	Involved in direct patient care, geriatric patients. Similar to hospital environment, but more general patient care tasks (vital signs, administer medication, daily patient skin care)	

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
RN-Health department	A greater emphasis on administrative tasks, some home visits and direct patient care, but less intensive than in hospitals or private office, outpatient clinic settings.	
RN-Public school	Daily interaction with students. Take vital signs, some limited administration of medications (including asthma inhaler administration, oral medication). Conduct health promotion activities.	
RN-Healh insurance agency	Mostly administrative and case management. Little or no direct patient care.	
RN-Research	May involve some direct patient care (taking blood samples, administering study medication, vital signs, etc.), depending on study protocol.	
RN-Medical sales	No direct patient care. Interacts with physicians, purchasing representatives of hospitals, etc.	
RN-Academia	Teaching and research, but may also have direct patient care duties.	
RN-Home health	Involved in direct patient care at the home of the patient. Take vital signs, administer medication, maintain charts, patient skin care.	
RN-Dental office	Rare, but would have tasks similar to dental assistants.	
RN-Other		
LVN-ALL (Licensed Vocational Nurses)	http://online.onetcenter.org/link/summary/29-2061.00	**Check primary specialty area (separate tab).**
LVN-Hospital	Involved in direct patient care (hospitalized patients), by specialty areas. Take vital signs, administer medications, daily patient skin care, assist physicians in their procedures. Some (higher level) may do purely administrative work.	
LVN-Private practice	Generally will assist physicians in their offices. Take vital signs, administer medication, maintain charts, call patients, etc.	
LVN-Outpatient clinic	Involved in direct patient care (ambulatory patients), by specialty areas. Some (higher level) may do purely administrative work.	
LVN-Nursing home	Involved in direct patient care, geriatric patients. Similar to hospital environment, but more general patient care tasks (vital signs, administer medication, daily patient skin care)	
LVN-Health department	A greater emphasis on administrative tasks, some home visits and direct patient care, but less intensive than in hospitals or private office, outpatient clinic settings.	
LVN-Public school	Daily interaction with students. Take vital signs, some limited administration of medications (including asthma inhaler administration, oral medication). Conduct health promotion activities.	
LVN-Healh insurance agency	Mostly administrative and case management. Little or no direct patient care.	
LVN-Research	May involve some direct patient care (taking blood samples, administering study medication, vital signs, etc.), depending on study protocol.	
LVN-Medical sales	No direct patient care. Interacts with physicians, purchasing representatives of hospitals, etc.	

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
LVN-Academia	Teaching and research, but may also have direct patient care duties.	
LVN-Home health	Involved in direct patient care at the home of the patient. Take vital signs, administer medication, maintain charts, patient skin care.	
LVN-Dental office	Rare, but would have tasks similar to dental assistants.	
LVN-Other		
NP-ALL (Nurse Practitioners)	http://online.onetcenter.org/link/summary/29-1111.00	**The O-net link is the same as for RNs (I wasn't able to find a separate one). However, advanced practice nursing (i.e., nurse practitioners) is practiced by RNs who have specialized formal, post-basic education and who function in highly autonomous and specialized roles. These nurses can diagnose and treat and, therefore, share many of the same tasks as physicians and physician assistants, mostly in primary specialties (family medicine, emergency medicine, geriatrics, etc.).Check primary specialty area (separate tab).**
NP-Hospital	Primarily driven by specialty area. Similar tasks to physicians, except major surgery (they may, however, do some minor surgery procedures and assist surgeons in the operating room).	
NP-Private practice	Similar to physician tasks, working under physician supervision (in Texas).	
NP-Outpatient clinic	Similar to physician tasks, working under physician supervision (in Texas).	
NP-Nursing home	Similar to physician tasks, working under physician supervision (in Texas).	
NP-Health department	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Public school	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Healh insurance agency	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Research	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Medical sales	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Academia	Similar to MDs in this position (related to more primary care specialties).	
NP-Home health	Combines the role of an MD and an RN/LVN in this position.	
NP-Dental office	Similar to RNs and LVNs in this position. However, less likely to be in this role.	
NP-Other		
NA-ALL (Nurse aide)	http://online.onetcenter.org/link/summary/31-1012.00	
NA-Hospital	Basic patient care tasks: feed, bathe, dress, groom, or move patients, or change linens.	
NA-Private practice	Basic outpatient care tasks: place patient in exam room, take vital signs.	
NA-Outpatient clinic	Basic outpatient care tasks: place patient in exam room, take vital signs.	

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
NA-Nursing home	Basic patient care tasks: feed, bathe, dress, groom, or move patients, or change linens.	
NA-Health department	Greater emphasis on clerical tasks, but may work in some public health clinic setting (basic outpatient care tasks: place patient in exam room, take vital signs).	
NA-Public school	Unlikely setting. Tasks would be very general: clerical, take vital signs.	
NA-Healh insurance agency	No direct patient care. Clerical tasks.	
NA-Research	Unlikely setting. Tasks would be very general: clerical, take vital signs, maybe interview study participants.	
NA-Medical sales	Similar to RN/LVN in this position.	
NA-Academia	Unlikely setting.	
NA-Home health	Basic patient care tasks: feed, bathe, dress, groom, or move patients, or change linens.	Also, check this link: http://online.onetcenter.org/link/summary/31-1011.00
NA-Dental office	Similar to RN/LVN in this position.	
NA-Other		
RT-ALL (Respiratory therapists)	http://online.onetcenter.org/link/summary/29-1126.00	
RT-Hospital	Daily patient contact, both on the general ward as well as in intensive care settings. High number of patient contacts. Likely to clean and disinfect instruments like bronchoscopes, assist physicians in bronchoscopy procedures.	
RT-Private practice	Less common. May be more focused on conducting pulmonary function test. Much lower frequency of aerosolized medication administration than in hospital setting.	
RT-Outpatient clinic	Daily patient contact, high number of patient contacts. Likely to clean and disinfect instruments like bronchoscopes, assist physicians in bronchoscopy procedures.	
RT-Nursing home	Daily patient contact, high number of patient contacts. Not as likely to clean and disinfect instruments like bronchoscopes, or assist physicians in bronchoscopy procedures.	
RT-Public school	Unlikely scenario. Tasks would be similar to those of a nurse aide in this setting.	
RT-Healh insurance agency	Similar to RN/LVN in this setting.	
RT-Research	Unlikely scenario, probably limited to respiratory studies in which aerosolized medications could be given, pulmonary function tests performed.	
RT-Medical sales	Similar to RN/LVN in this setting.	
RT-Academia	Teaching and research. May be involved in direct patient care, but on a lesser scale than RT-hospital/RT-outpatient clinic.	
RT-Home health	Daily patient contact, checks pulmonary function, administers aerosolized medications.	
RT-Other		
OT-ALL (Occupational therapists)	http://online.onetcenter.org/link/summary/29-1122.00	**Additional links: http://online.onetcenter.org/link/summary/31-2012.00 (Occupational therapist aides) , http://online.onetcenter.org/link/summary/31-2011.00 (Occupational therapist assistants)**
OT-Hospital	Most likely work setting, together with outpatient clinics. Tasks will involve hospitalized (i.e., sicker) patients.	

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
OT-Private practice	Less likely to be free-standing, more likely to be in the context of a physical medicine/rehab physician's private practice.	
OT-Outpatient clinic	Similar to hospital setting tasks, except that patients are less ill.	
OT-Nursing home	Similar to hospital setting tasks, except that patients are less ill. Lower patient load than in hospitals.	
OT-Health department	Unlikely setting. More likely to be in the context of vocational rehabilitation.	
OT-Public school	Unlikely setting. More likely to be in the context of vocational rehabilitation.	
OT-Healh insurance agency	Case management. Some patient contact (assessment of vocational skills,etc.).	
OT-Research	Mostly research specific to occupational therapy projects.	
OT-Medical sales	Similar to RN/LVN in this role.	
OT-Academia	Teaching and research. May involve some direct patient care.	
OT-Home health	Unlikely setting. More likely to be in the context of assessment of patient skills. Possibly some limited interventions, similar to outpatient clinic setting, but on a lesser scale.	
OT-Dental office	Unlikely setting. Tasks would be similar to a dental assistant.	
OT-Other		
OTHER - DENTAL (Dentist, dental assistant or dental hygienist)	http://online.onetcenter.org/link/summary/29-1021.00	**Additional links: http://online.onetcenter.org/link/summary/29-2021.00 (Dental hygienists), http://online.onetcenter.org/link/summary/31-9091.00 (Dental assistants) and http://online.onetcenter.org/link/summary/51-9081.00 (Dental laboratory technicians)**
DENTAL-Hospital	Same general tasks as in private practice/outpatient clinic setting, but performed on hospitalized (and potentially sicker) patients.	
DENTAL-Private practice	Tasks consistent with those described in O-Net, on outpatients.	
DENTAL-Outpatient clinic	Tasks consistent with those described in O-Net, on outpatients.	
DENTAL-Nursing home	Same general tasks as in private practice/outpatient clinic setting, but performed on older (and potentially sicker) patients.	
DENTAL-Health department	Tasks consistent with those described in O-Net, on outpatients.	
DENTAL-Public school	Less common scenario. Would involve more preventive dentistry.	
DENTAL-Healh insurance agency	More administrative tasks.	
DENTAL-Research	Tasks consistent with those described in O-Net, on outpatients, although specific to a given set of research protocols (i.e., less general).	
DENTAL-Medical sales	Similar to RN/LVN.	
DENTAL-Academia	Teaching and research. May involve some (or a lot of) direct patient care.	
DENTAL-Home health	Similar to dental-nursing home, but on a wider range of patient ages.	
DENTAL-Dental office	Tasks consistent with those described in O-Net, on outpatients.	

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
DENTAL-Other		
PA-ALL (Physician Assistant)	http://online.onetcenter.org/link/summary/29-1071.00	
PA-Hospital	Similar to NP (nurse pratcitioners) in this setting.	
PA-Private practice	Similar to NP (nurse pratcitioners) in this setting.	
PA-Outpatient clinic	Similar to NP (nurse pratcitioners) in this setting.	
PA-Nursing home	Similar to NP (nurse pratcitioners) in this setting.	
PA-Health department	Similar to NP (nurse pratcitioners) in this setting.	
PA-Public school	Similar to NP (nurse pratcitioners) in this setting.	
PA-Healh insurance agency	Similar to NP (nurse pratcitioners) in this setting.	
PA-Research	Similar to NP (nurse pratcitioners) in this setting.	
PA-Academia	Similar to NP (nurse pratcitioners) in this setting.	
PA-Other		
PT-ALL (Physical therapists)	http://online.onetcenter.org/link/summary/29-1123.00	**PTs have a lot of direct patient care activities, and in some hospital/clinic settings, They also go to the bedside in inpatient settings to conduct some of their tasks, so this involves possible exposure to whatever else may be in the patient room. PTs and OTs work side by side in the same department. Additional O-net links: http://online.onetcenter.org/link/summary/31-2022.00 (Physical therapist aides) and http://online.onetcenter.org/link/summary/31-2021.00 (Physical therapist assistants).**
PT-Hospital	Most likely work setting, together with outpatient clinics. Tasks will involve hospitalized (i.e., sicker) patients.	
PT-Private practice	Less likely to be free-standing, more likely to be in the context of a physical medicine/rehab physician's private practice.	
PT-Outpatient clinic	Similar to hospital setting tasks, except that patients are less ill.	
PT-Nursing home	Similar to hospital setting tasks, except that patients are less ill. Lower patient load than in hospitals.	
PT-Health department	Unlikely setting. More likely to be in the context of evaluation of home needs (assistive devices, etc.).	
PT-Public school	Unlikely setting. More likely to be in the context of evaluation of home needs (assistive devices, etc.).	
PT-Healh insurance agency	Case management. Some patient contact (assessment of home needs,etc.).	
PT-Research	Mostly research specific to physical therapy projects.	
PT-Medical sales	Similar to RN/LVN in this role.	
PT-Academia	Teaching and research. May involve some direct patient care.	
PT-Home health	Unlikely setting. More likely to be in the context of assessment of patient physical limitations. Possibly some limited interventions, similar to outpatient clinic setting, but on a lesser scale.	
PT-Dental office	Unlikely setting. Tasks would be similar to a dental assistant.	
PT-Other		

LEVEL Description	O'Net Link and GLD description of practice setting	Comments - GLD
OTHER - Allied Health Professionals/ Physical Therapists/Other	Several O-net links (NOTE -this is an INCOMPLETE list): http://online.onetcenter.org/link/summary/21-1091.00 (Health educators) , http://online.onetcenter.org/link/summary/21-1014.00 (Mental health counselors) , http://online.onetcenter.org/link/summary/29-2071.00 (Medical records and health information technicians), http://online.onetcenter.org/link/summary/21-1023.00 (Mental health and substance abuse social workers), http://online.onetcenter.org/link/summary/29-1031.00 (Dietitians and nutritionists), http://online.onetcenter.org/link/summary/29-2099.99 (Health technologists and technicians, all others), http://online.onetcenter.org/link/summary/31-9099.99 (Health care support workers, all others), http://online.onetcenter.org/link/summary/29-2034.01 (Radiologic technologists), http://online.onetcenter.org/link/summary/29-2034.02 (Radiologic technicians), http://online.onetcenter.org/link/summary/29-2011.00 (Medical and clinical laboratory technologists, and http://online.onetcenter.org/link/summary/29-2012.00 (Medical and c	**What is common to this OTHER category is a lower probability of exposure to our major asthmagen classes (except maybe some general cleaners exposure to developer fluids among radiology technicians/technologists and/or exposure to fixatives and solvents among medical and clinical lab workers).**
OTHER-Hospital	Tasks will involve hospitalized (i.e., sicker) patients.	
OTHER-Private practice	Similar to hospital setting tasks, except that patients are less ill.	
OTHER-Outpatient clinic	Similar to hospital setting tasks, except that patients are less ill.	
OTHER-Nursing home	Similar to hospital setting tasks, except that patients are less ill. Lower patient load than in hospitals.	
OTHER-Health department	Unlikely setting, except maybe radiology technicians, pharmacy personnel and some basic laboratory techicians.	
OTHER-Public school	Unlikely setting.	
OTHER-Healh insurance agency	Unlikely setting. Case management.	
OTHER-Research	Mostly research specific to the focus of individual projects.	
OTHER-Medical sales	Similar to RN/LVN in this role.	
OTHER-Academia	Teaching and research. May involve some direct patient care, within the scope of the field.	
OTHER-Home health	Similar to hospital setting tasks, except that patients are less ill. Lower patient load than in hospitals. Physical therapists are more likely to be involved in this role. Rarely some radiology technicians perform mobile x-ray testing services in the home.	
OTHER-Dental office	Unlikely setting. Tasks would be similar to a dental assistant.	
OTHER-Other		

Primary specialty area	GLD Comments - physicians and nurses
Central services	Mainly refers to physician services provided to all other hospital physicians. Includes primarily imaging services (radiology, nuclear medicine) and laboratory services (including pathology and forensic). Some radiologists perform invasive procedures on patients (interventional radiology). Pathologists will use fixatives like formalin and solvents like toluene to prepare specimens. Unfortunately, we are not able to distinguish between the two within this category. Nurses in this category will assist physicians. Some nurses may also take and develop x-rays (radiographs), which
Gynecology	Physicians in this specialty perform surgery and should be considered similar to the surgical specialties, although they may spend less time in the operating room (since they tend to be in clinic a lot as well). However, when in the operating room, their tasks and potential exposures would be similar to those of surgeons.
Medical specialties	Very broad category. Includes internal medicine and all of its subspecialties, as well as family practice and general medicine. Family practitioners often perform some minor surgery in their offices, as well as some limited endoscopies (flexible sigmoidoscopy, for example). Some internal medical subspecialties (pulmonary, GI, cardiology, neurology, rheumatology, nephrology) perform a large volume of procedures (endoscopies, cardiac catheterizations, lumbar punctures, joint aspirations, renal biopsies) which require sterile technique (i.e., patient disinfection, prepping of area, etc.). Most of these now do not involve as much use of powdered latex gloves as before (but they still involve use of non-powdered latex gloves). Nurses in these specialties will assist the physicians, make rounds with them or perform nursing tasks as ward nurses in specific specialty wards (e.g., oncology wards, cardiac cath suites,etc.).
Mental health	Physicians and nurses in this specialty area are not likely to perform any invasive or minor surgery procedures. Also not likely to administer aerosolized medications.
Pediatrics	Physicians and nurses in this specialty area are similar to the medical specialties group, except that their patient population is younger. Just like medical specialties, however, pediatrics can be divided into subspecialties (in fact, pretty much the same: pediatric cardiology, pediatric pulmonology, etc.). The procedures (endoscopies, catheterizations,etc.) associated with certain medical subspecialties will also be performed by these pediatric subspecialists).
Surgical specialties	Physicians in this specialty will spend long hours in the operating room, typically at least 3-4 days per week. Nurses in these specialties may assist the surgeons in the operating room (e.g., scrub nurses) will also go on rounds with the surgeon and see patients in follow-up in the outpatient clinic.
Other	

Appendix C.

Summary descriptive table of chemical products and active ingredients identified in hospital walkthroughs

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
3M Spray-mount adhesive	Aerosol	2-methylpentane/ Isohexane	AD	No	Yes	PT/OT	AD	AD	AD	107-83-5	Pediatric	MSDS	resp. irritant		
		Acetone	AD	No	Yes	PICU	AD	AD		67-64-1	Pediatric	MSDS	irritating to nose, throat, resp. tract		
3M Super 74 Foam Fast Adhesive	Aerosol	Acetone	AD	No	Yes	Rehab Svc	AD	AD	AD	67-64-1	Cancer	MSDS	irritating to nose, throat, resp. tract		
Acetone Alcohol Swab Sticks	Solid	Acetone	AD	No	Yes	Nursing	AD,CL,DS	CL,DS		67-64-1	General	MSDS	irritating to nose, throat, resp. tract		
Acetone Pads	Solid	Acetone	AD	No	Yes	MICU	AD	AD		67-64-1	General	MSDS	irritating to nose, throat, resp. tract		
Nail Polish Remover Pads	Solid	Acetone	AD	No	Yes	FICU	AD	AD		67-64-1	General	MSDS	irritating to nose, throat, resp. tract	irritant of skin, eyes, mucous membrane, upper resp. tract -- extreme exposure = pulmonary edema	
Velcro Adhesive		Acetone	AD	No	Yes	PT/OT	AD	AD	AD	67-64-1	Pediatric	MSDS	irritating to nose, throat, resp. tract	Velcro Adhesive hazardous if inhaled	
Velcro Adhesive		Acetone	AD	No	Yes	OT	AD	AD	AD	67-64-1	General	MSDS	irritating to nose, throat, resp. tract	Velcro Adhesive hazardous if inhaled	
Cast?????		Aliphatic petroleum hydrocarbons	AD	No	Yes	PT/OT		OT		8002-05-9	Pediatric	NIOSH Pocket Guide	irritating to eyes, nose, throat		
Ammonia Inhalants		Ammonia	AD	No	Yes	FICU	GV	OT		7664-41-7	General	NIOSH Pocket Guide	irritation to eyes, nose, throat, chest pain, difficulty breathing		
Ammonia Inhalants		Ammonia	AD	No	Yes	PICU	GV	OT		7664-41-7	Pediatric	NIOSH Pocket Guide	irritation to eyes, nose, throat, chest pain, difficulty breathing		
		Carbon Dioxide	AD	No	Yes	Resp. Care	GV			124-38-9	Pediatric	NIOSH Pocket Guide	difficulty breathing		
C02/02 mixture		Carbon Dioxide	AD	No	Yes	Resp. Care	GV		GV	124-38-9	Pediatric	NIOSH Pocket Guide	difficulty breathing		
Stomahesive Protective Powder and Paste (ContraTec)		Cellulose, carboxymethyl ether, sodium salt	AD	No	Yes	P3 Med. Unit		AD	AD	9004-32-4	Cancer	MSDS	may cause resp. tract irritation-low hazard for usual industrial handling		
Silicone Hardener Cement		Chromium oxide	AD	No	Yes	PT/OT		AD	AD	1308-38-9	Pediatric	MSDS	causes resp. tract irritation		
3M Spray-mount adhesive	Aerosol	Cyclohexane	AD	No	Yes	PT/OT	AD		AD	110-82-7	Pediatric	NIOSH Pocket Guide	irritates resp. system		
Sharpies	Solid	Diacetone-alcohol	AD	No	Yes	FICU		AD	OT	123-42-2	General	NIOSH Pocket Guide	irritates eye, skin, nose, throat		
Flouri-methane		Dichloromethane (methylene chloride)	AD	No	Yes	PT/OT	AD			75-09-2	Pediatric	MSDS	resp. tract irritation, high concentration causes nervous system effects		
North Coast Solvent		Dichloromethane (methylene chloride)	AD	No	Yes	Rehab Svc	AD			75-09-2	Cancer	MSDS	resp. tract irritation, high concentration causes nervous system effects		
3M Spray-mount adhesive	Aerosol	Dimethyl ether	AD	No	Yes	PT/OT	AD		AD	115-10-6	Pediatric	MSDS	vapor reduces oxygen available for breathing		
3M Super 74 Foam Fast Adhesive	Aerosol	Dimethyl ether	AD	No	Yes	Rehab Svc		AD	AD	115-10-6	Cancer	MSDS	vapor reduces oxygen available for breathing		
Adhesive Remover		Dipropylene glycol methyl ether	AD	No	Yes	Rehab Svc	AD		AD	34590-94-8	Cancer	MSDS	irritant to nose	Irritant to nose and throat	
Adhesive Remover		Dipropylene glycol methyl ether	AD	No	Yes	FICU	AD		AD	34590-94-8	General	MSDS	irritant to nose	Irritant to nose and throat	
Collodion		Ethanol	AD	No	Yes	PICU		GV		64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose		
Mastisol		Ethanol	AD	No	Yes	PICU		AD		64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose		
Velcro Adhesive		Ethyl Acetate	AD	No	Yes	PT/OT		AD	AD	141-78-6	Pediatric	NIOSH Pocket Guide	irritates, eyes, skin, nose, throat	Velcro Adhesive hazardous if inhaled	
Velcro Adhesive		Ethyl Acetate	AD	No	Yes	OT	AD		AD	141-78-6	General	NIOSH Pocket Guide	irritates, eyes, skin, nose, throat	Velcro Adhesive hazardous if inhaled	
Stomahesive Protective Powder and Paste (ContraTec)		Gelatins	AD	No	Yes	P3 Med. Unit		AD	AD	9000-70-8	Cancer	MSDS	may cause resp tract irritation		
		Heptane Isomers	AD	No	Yes	PT/OT	AD			64742-49-0	Pediatric	MSDS	high vapor/aerosol concentrations are irritating to resp tract		
Skin Bond		Hexane	AD	No	Yes	P3 Med. Unit, Med. ICU	AD		AD	110-54-3	Cancer	NIOSH Pocket Guide	irritation nose	High concentrations can displace oxygen, aspiration hazard	

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
3M Super 74 Foam Fast Adhesive	Aerosol	Isoparaffinic hydrocarbons	AD	No	Yes	Rehab Svc	AD		AD	64742-48-9	Cancer	MSDS	high vapor/aerosol concentrations are irritating to eye and resp tract		
Adhesive Remover		Isoparaffinic hydrocarbons	AD	No	Yes	FICU	AD		AD	64742-48-9	General	MSDS	high vapor/aerosol concentrations are irritating to eye and resp tract		
Adhesive Remover		Isoparaffinic hydrocarbons	AD	No	Yes	Rehab Svc	AD		AD	64742-48-9	Cancer	MSDS	high vapor/aerosol concentrations are irritating to eye and resp tract		
Adhesive Remover		Isopropanol	AD	No	Yes	FICU	AD		AD	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Adhesive Remover		Isopropanol	AD	No	Yes	Rehab Svc	AD		AD	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
No-Flame Flameproofing Solution Spray	Aerosol	Isopropanol	AD	No	Yes	Rehab Svc		AD,DS		67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat		
		Mercury	AD	No	Yes	Resp. Care	GV	GV		7439-97-6	Pediatric	NIOSH Pocket Guide	cough, chest pain, dyspnea, bronchitis pneumonitis		
		Mercury	AD	No	Yes	FICU	GV	GV		7439-97-6	General	NIOSH Pocket Guide	cough, chest pain, dyspnea, bronchitis pneumonitis		
		Mercury	AD	No	Yes	Nursing	GV	GV		7439-97-6	General	NIOSH Pocket Guide	cough, chest pain, dyspnea, bronchitis pneumonitis		
Cytolyt Solution		Methanol	AD	No	Yes	Resp. Care	AD			67-56-1	Cancer	NIOSH Pocket Guide	irritation upper resp system		
All Kare Adhesive Remover (ConvaTec)		Methylbenzene	AD	No	Yes	PT/OT		AD	AD	128-37-0	Pediatric	MSDS	causes resp irritation		
EZ Paint Thinner	Liquid	Mineral spirits	AD	No	Yes	OT		AD		8052-41-3	General	MSDS	may cause resp irritation		
EZ Paint Thinner	Liquid	Mineral spirits	AD	No	Yes	OT		AD		8052-41-3	General	MSDS	may cause resp irritation		
Paint Thinner	Liquid	Mineral spirits	AD	No	Yes	OT		AD		8052-41-3	General	MSDS	may cause resp irritation		
Paint Thinner	Liquid	Mineral spirits	AD	No	Yes	Rehab Svc		AD		8052-41-3	Cancer	MSDS	may cause resp irritation		
Paint Thinners	Liquid	Mineral spirits	AD	No	Yes	OT		AD		8052-41-3	General	MSDS	may cause resp irritation		
Paint Thinner-Startex Chem. Co.		Mineral spirits	AD	No	Yes	PT/OT		AD		8052-41-3	Pediatric	MSDS	may cause resp irritation		
Cold Spray	Aerosol	n-butane	AD	No	Yes	OT		AD		106-97-8	General	MSDS	relatively non-toxic, simple hydrocarbon may irritate the eyes, mucous membranes and resp system at high concentrations		
Sharpies	Solid	n-butanol	AD	No	Yes	FICU	AD		OT	71-36-3	General	MSDS	causes resp irritation		
Dry Erase Markers	Solid	N-Butyl Acetate	AD	No	Yes	FICU		AD		123-86-4	General	MSDS	may cause resp irritation	no hazards reported	
3M Spray-mount adhesive	Aerosol	Neohexane	AD	No	Yes	PT/OT		AD	AD	75-83-2	Pediatric	MSDS	may cause resp irritation		
Spray-Ment	Aerosol	N-hexane	AD	No	Yes	PT/OT		AD		110-54-3	Pediatric	MSDS	causes resp irritation		
		Nitric Oxide (in Balanced N - 800 ppm)	AD	No	Yes	Resp. Care		AD		10102-43-9	Pediatric	TLV Book	irritant		
3M Super 74 Foam Fast Adhesive	Aerosol	n-Pentane	AD	No	Yes	Rehab Svc		AD	AD	109-66-0	Cancer	TLV Book	weak irritant		
Velcro Adhesive		Phenol	AD	No	Yes	OT	AD		AD	108-95-2	General	TLV Book	irritant	Velcro Adhesive hazardous if inhaled	
Velcro Adhesive		Phenol	AD	No	Yes	PT/OT	AD		AD	108-95-2	Pediatric	TLV Book	irritant	Velcro Adhesive hazardous if inhaled	
Redux Paste		Silica quartz	AD	No	Yes	PICU		AD	AD	14808-60-7	Pediatric	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis	not an inhalation hazard	
Redux Paste		Silica quartz	AD	No	Yes	Resp. Care		AD	AD	14808-60-7	Pediatric	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis	not an inhalation hazard	
Barge Cement		Toluol (toluene)	AD	No	Yes	PT/OT		AD		108-88-3	Pediatric	NIOSH Pocket Guide	irritation eyes, nose		
Cast?????		Trichloroethane	AD	No	Yes	PT/OT		OT		71-55-6	Pediatric	MSDS	irritant		
EZ Paint Thinner	Liquid	Trimethyl benzene	AD	No	Yes	OT	AD			95-63-6	General	TLV Book	irritant		
School glue (labeled non-toxic)	Liquid	Vinyl acetate monomer	AD	No	Yes	PT/OT		AD	AD	108-05-4	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, nose, throat, hoarseness, cough, loss of smell		
Silicone Hardener Cement		Xylenes	AD	No	Yes	PT/OT		AD	AD	1330-20-7	Pediatric	TLV Book	irritant		

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
		Ribavirin (Nebulized Agent)	AM	No	Yes	Resp. Care		AM		36791-04-5	Pediatric	cal dept health svcs online datasheet	irritant		
3M Quat Disinfectant Cleaner Concentrated		Acetic acid	BD	Yes	Yes	General Ward		DS	DS	64-19-7	Pediatric	MSDS	irritation of eyes, nose, throat, can affect resp. response		
Glass Cleaner Concentrate		Acetic Acid	BD	Yes	Yes	FICU	CL	CL	CL	64-19-7	General	MSDS	irritation of eyes, nose, throat, can affect resp. response		
Shineline Multi-Surfaced Cleaner		Acetic acid	BD	Yes	Yes	Rehab Svc		CL	CL	64-19-7	Cancer	MSDS	irritation of eyes, nose, throat, can affect resp. response		
Vinegar	Liquid	Acetic Acid	BD	Yes	Yes	Rehab Svc	CL	CL		64-19-7	Cancer	MSDS	irritation of eyes, nose, throat, can affect resp. response		
3M Glass Cleaner	Liquid	2-Butoxyethanol	BD	No	Yes	General Ward	CL	CL	CL	111-76-2	Pediatric	MSDS	resp. irritant		
3M Sharpshooter Extra Strength No Rinse Cleaner		2-Butoxyethanol	BD	No	Yes	General Ward	CL	CL	CL	111-76-2	Pediatric	MSDS	resp. irritant	Very toxic by inhalation	
3M Trouble shooter (to remove oil and wax buildup)		2-Butoxyethanol	BD	No	Yes	PICU	AD	AD	CL	111-76-2	Pediatric	MSDS	resp. irritant	Very toxic by inhalation	
Blue Glass Cleaner		2-Butoxyethanol	BD	No	Yes	Bldg. Svc.	CL	CL	CL	111-76-2	Cancer	MSDS	resp. irritant		
Disinfectant Cleaner (Pink - Spartan Foamy Q & A)		2-Butoxyethanol	BD	No	Yes	Housekeeping, Bldg. Svc.	CL	CL	DS	111-76-2	Cancer	MSDS	resp. irritant	Very toxic by inhalation	
Expo Cleaner for Dry Erase Surfaces		2-Butoxyethanol	BD	No	Yes	Nursing		CL	CL	111-76-2	General	MSDS	resp. irritant		
Foamy Q&A		2-Butoxyethanol	BD	No	Yes	Bldg. Svc.	CL	CL		111-76-2	Cancer	MSDS	resp. irritant	Very toxic by inhalation	
Glance & Multi-Surface Cleaner		2-Butoxyethanol	BD	No	Yes	Resp. Care	CL	CL	CL	111-76-2	Pediatric	MSDS	resp. irritant	skin irritant but not resp.	
Glass Cleaner		2-Butoxyethanol	BD	No	Yes	MICU	CL	CL	CL	111-76-2	General	MSDS	resp. irritant	many different formulations for Glass Cleaner -- irritant	
Simple Green Environmental Friendly Cleaner		2-Butoxyethanol	BD	No	Yes	Med. ICU	CL	CL	CL	111-76-2	Cancer	MSDS	resp. irritant	does not possess health risks assoc. w/undil. Butyl cellosolve	
Spartan Glass Cleaner (Blue)		2-Butoxyethanol	BD	No	Yes	Housekeeping		CL	CL	111-76-2	Cancer	MSDS	resp. irritant	Spartan Glass Cleaner, avoid inhalation	
Spritz		2-Butoxyethanol	BD	No	Yes	MICU	CL	CL		111-76-2	General	MSDS	resp. irritant	skin & eye irritant/inhalation=breathing difficulties	
Wax Stripper		2-Butoxyethanol	BD	No	Yes	Nursing, FICU, MICU	AD	AD	CL	111-76-2	General	MSDS	resp. irritant	Note=many other formulations for wax strippers, most contain 2-butoxyethanol and many other ingred. (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
Yellow Glass Cleaner (Various Scents)		2-Butoxyethanol	BD	No	Yes	Bldg. Svc.	CL	CL	CL	111-76-2	Cancer	MSDS	resp. irritant	May be irritating to respiratory tract	
Blue Glass Cleaner		Acetic acid anhydride	BD	No	Yes	Bldg. Svc.	CL	CL	CL	108-24-7	Cancer	MSDS	harmful if inhaled	May be fatal if inhaled - irritating to N, T, RT, possible pulm. edema	
Glass Cleaner		Ammonia	BD	No	Yes	MICU	CL	CL	CL	7664-41-7	General	NIOSH Pocket Guide	irritation to eyes, nose, throat, chest pain, difficulty breathing	many different formulations for Glass Cleaner -- irritant	
Wax Stripper		Ammonia	BD	No	Yes	Nursing, FICU, MICU	AD	AD	CL	7664-41-7	General	NIOSH Pocket Guide	irritation to eyes, nose, throat, chest pain, difficulty breathing	Note=many other formulations for wax strippers, most contain 2-butoxyethonal and many other ingred. (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
Blue Glass Cleaner		Ammonium hydroxide	BD	No	Yes	Bldg. Svc.	CL	CL	CL	1336-21-6	Cancer	MSDS	vapor intense irritant, may produce severe tracheitis, bronchitis and chemical pneumonia		
Glance & Multi-Surface Cleaner		Ammonium hydroxide	BD	No	Yes	Resp. Care		CL	CL	1336-21-6	Pediatric	MSDS	vapor intense irritant, may produce severe tracheitis, bronchitis and chemical pneumonia	skin irritant but not resp.	
Wax Stripper		Ammonium hydroxide	BD	No	Yes	Nursing, FICU, MICU	CL	CL	CL	1336-21-6	General	MSDS	vapor intense irritant, may produce severe tracheitis, bronchitis and chemical pneumonia	Note=many other formulations for wax strippers, most contain 2-butoxyethonal and many other ingredients (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
M9 Odor Eliminator	Aerosol	Butylparaben	BD	No	Yes		CL	CL	DS	94-26-8	Cancer	MSDS	harmful if swallowed or inhaled, causes irritation to skin, eyes, resp. tract		
Comet	Powder	Calcium carbonate	BD	No	Yes	Nursing		CL	CL	1317-65-3	General	NIOSH Pocket	irritation of resp. system		

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
												Guide			
Lysol disinfectant		Carbon Dioxide	BD	No	Yes	Nursing	DS		DS	124-38-9	General	NIOSH Pocket Guide	difficulty breathing	may cause tem. Eye irritation. Persons w/history of resp. disorders may be at increased risk from exposure.	
M9 Odor Eliminator	Aerosol	Citric acid	BD	No	Yes		CL	CL	DS	77-92-9	Cancer	MSDS	causes resp. tract irritation		
SparCreme Liquid Cleaner		Citric acid	BD	No	Yes	PICU	CL		CL	77-92-9	Pediatric	MSDS	causes resp. tract irritation	SparCreme Liquid Cleaner inhalation irritant, may aggravate other pulmonary conditions	
Spartan Crème Liquid Cream	Cream	Citric Acid	BD	No	Yes	PICU		CL	CL	77-92-9	Pediatric	MSDS	Pulmonary function may be reduced by inhalation of (silicosis) which may aggravate other pulmonary conditions and diseases and which increases susceptibility to pulmonary tuberculosis		
ServiceMaster Scrub N Shine		Diatomaceous earth, calcined	BD	No	Yes	Hse. Keep	CL		CL	68855-54-9	General	MSDS	harmful if inhaled, irritation to skin, eyes, resp tract	Dust may cause coughing & mild, temp irritation of RT	
Wax Stripper		Diethanolamine	BD	No	Yes	Nursing, FICU, MICU	CL		CL	111-42-2	General	MSDS	causes resp irritation, irritates eyes, skin, nose, throat,	Note=many other formulations for wax strippers, most contain 2-butoxyethonal and many other ingredients (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
Glass Cleaner Concentrate		Diethylene Glycol N-Butyl Ether	BD	No	Yes	FICU	CL		CL	112-34-5	General	MSDS	may cause resp tract irritation		
Precise QTB		Diethylene Glycol N-Butyl Ether	BD	No	Yes	Med. ICU	DS			112-34-5	Cancer	MSDS	may cause resp tract irritation		
M9 Odor Eliminator	Aerosol	Dimethyl declyamine oxide	BD	No	Yes		CL	CL	DS	2605-79-0	Cancer	MSDS	expected to be irritating to resp. tract		
All Purpose Cleaner		Dipropylene glycol methyl ether	BD	No	Yes	Nursing	CL		CL	34590-94-8	General	MSDS	irritant to nose		
3M Crème Cleanser	Dream	Dodecyl benzenesulfonic acid	BD	No	Yes	PICU, General Ward	CL			27176-87-0	Pediatric	MSDS	may cause irritation of resp tract with sore throat, coughing, SOB delayed lung edema		
3M Heavy Duty Multi-Surface Cleaner Concentrate		Dodecyl benzenesulfonic acid	BD	No	Yes	General Ward	CL		CL	27176-87-0	Pediatric	MSDS	may cause irritation of resp tract with sore throat, coughing, SOB delayed lung edema	allergic reactions, resp. irritant	
3M Multi-surface cleaner concentrate - yellow		Dodecyl benzenesulfonic acid	BD	No	Yes	PICU	CL		CL	27176-87-0	Pediatric	MSDS	may cause irritation of resp tract with sore throat, coughing, SOB delayed lung edema		
Husky 430 Crème cleanser	Cream	Dodecyl benzenesulfonic acid	BD	No	Yes	MICU		CL		27176-87-0	General	MSDS	may cause irritation of resp tract with sore throat, coughing, SOB delayed lung edema		
3M Quat Disinfectant Cleaner Concentrated		Ethanol	BD	No	Yes	General Ward		DS	DS	64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose		
Concept Country Green Disinfectant and Deodorant		Ethanol	BD	No	Yes	OT	DS		DS	64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose		
Lysol disinfectant		Ethanol	BD	No	Yes	Nursing	DS		DS	64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose	may cause tem. Eye irritation. Persons w/history of resp. disorders may be at increased risk from exposure.	
Staphene Disinfectant Spray	Aerosol	Ethanol	BD	No	Yes	Nursing	DS		DS	64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose	eye/skin irritant (not toxic by inhalation, by def. of resp.)	
3M Desk Cleaner		Ethanolamine	BD	No	Yes	General Ward	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system		
3M Heavy Duty Multi-Surface Cleaner Concentrate		Ethanolamine	BD	No	Yes	General Ward	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system	allergic reactions, resp. irritant	
3M Multi-surface cleaner concentrate - yellow		Ethanolamine	BD	No	Yes	PICU	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system		
3M Sharpshooter Extra Strength No Rinse Cleaner		Ethanolamine	BD	No	Yes	General Ward, PICU	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system		
3M Stainless Steel Cleaner	Aerosol	Ethanolamine	BD	No	Yes	General Ward	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system		
3M Trouble shooter (to remove oil and wax buildup)		Ethanolamine	BD	No	Yes	PICU	CL		CL	141-43-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, resp system		
Wax Stripper		Ethanolamine	BD	No	Yes	Nursing, FICU,	CL		CL	141-43-	General	NIOSH	irritates eyes, skin, resp system	Note=many other formulations for	

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
						MICU				5		Pocket Guide		wax strippers, most contain 2-butoxyethonal and many other ingredients (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
M9 Odor Eliminator	Aerosol	Ethylparaben	BD	No	Yes		CL	CL	DS	120-47-8	Cancer	MSDS	may cause resp tract irritation		
Disinfectant Cleaner (Pink - Spartan Foamy Q & A)		Glycolic acid (hydroacetic acid)	BD	No	Yes	Housekeeping, Bldg. Svc.	CL		DS	79-14-1	Cancer	MSDS	causes chemical burns to resp tract	NA	
Foamy Q&A		Glycolic acid (hydroacetic acid)	BD	No	Yes	Bldg. Svc.	DS			79-14-1	Cancer	MSDS	causes chemical burns to resp tract	inhalation may irritate the throat and resp. system	
Pink Disinfectant Cleaner (Spartan Foamy Q & A)		Glycolic acid (hydroacetic acid)	BD	No	Yes	Bldg. Svc.	CL		DS	79-14-1	Cancer	MSDS	causes chemical burns to resp tract	NA	
Tile Brite		Glycolic acid (hydroacetic acid)	BD	No	Yes	FICU		CL	CL	79-14-1	General	MSDS	causes chemical burns to resp tract	irritant	
SparClean restroom disinfectant		Hydrochloric Acid, Hydrogen Chloride	BD	No	Yes	General Ward		DS	DS	7647-01-0	Pediatric	NIOSH Pocket Guide	irritates nose, throat, larynx, cough, chocking		
Spartan Sparkling		Hydrochloric Acid, Hydrogen Chloride	BD	No	Yes	General Ward, PICU	CL		CL	7647-01-0	Pediatric	NIOSH Pocket Guide	irritates nose, throat, larynx, cough, chocking	Vapor or mist can cause irritation to nose, sore throat, trouble breathing	
Johnson Stainless Steel Cleaner	Aerosol	Isoparaffinic hydrocarbons	BD	No	Yes	PT/OT	CL		CL	64742-48-9	Pediatric	MSDS	high vapor/aerosol concentrations are irritating to eye and resp tract		
3M Desk Cleaner		Isopropanol	BD	No	Yes	General Ward	CL	CL	CL	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat		
3M Glass Cleaner	Liquid	Isopropanol	BD	No	Yes	General Ward	CL		CL	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat		
3M Heavy Duty Multi-Surface Cleaner Concentrate		Isopropanol	BD	No	Yes	General Ward	CL		CL	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat	allergic reactions, resp. irritant	
3M Multi-surface cleaner concentrate - yellow		Isopropanol	BD	No	Yes	PICU	CL		CL	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
All Purpose Cleaner		Isopropanol	BD	No	Yes	Nursing	CL	CL	CL	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Bactistat CHG (personnel used to wash hands)	Liquid	Isopropanol	BD	No	Yes	PICU, General Ward, PT/OT	DS		DS	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat		
Blue Glass Cleaner		Isopropanol	BD	No	Yes	Bldg. Svc.	CL		CL	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Damp Mop (scrubbing machines)		Isopropanol	BD	No	Yes	Bldg. Svc.	CL		CL	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Expo Cleaner for Dry Erase Surfaces		Isopropanol	BD	No	Yes	Nursing	CL	CL	CL	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
Germicidal Cloth		Isopropanol	BD	No	Yes	FICU	CL, DS			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	eye & skin irritant	
Glass Cleaner		Isopropanol	BD	No	Yes	MICU	CL		CL	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
No-Flame Flameproofing Solution Spray	Aerosol	Isopropanol	BD	No	Yes	Rehab Svc		AD,DS		67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat		
Spartan Glass Cleaner (Blue)		Isopropanol	BD	No	Yes	Housekeeping	CL	CL	CL	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	Spartan Glass Cleaner, avoid inhalation	
Supersani Germicidal Cloth Wipes	Solid	Isopropanol	BD	No	Yes	Med. ICU, Resp. Care	DS	DS	DS	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Wax Stripper		Isopropanol	BD	No	Yes	Nursing, FICU, MICU	CL		CL	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	Note=many other formulations for wax strippers, most contain 2-butoxyethonal and many other ingredients (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
Yellow Glass Cleaner (Various Scents)		Isopropanol	BD	No	Yes	Bldg. Svc.	CL		CL	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
M9 Odor Eliminator	Aerosol	Methylparaben	BD	No	Yes		CL	CL	DS	99-76-3	Cancer	MSDS	may causes resp irritation		
3M Stainless Steel	Aerosol	Mineral oil	BD	No	Yes	General Ward	CL	CL	CL	8042-	Pediatric	MSDS	may cause resp irritation		

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
Cleaner										47-5					
Misty "Painless Stainless"	Aerosol	Mineral oil	BD	No	Yes	OT	CL	CL		8042-47-5	General	MSDS	may cause resp irritation		
3M Crème Cleanser	Cream	Nonoxynol	BD	No	Yes	PICU, General Ward		CL		9016-45-9	Pediatric	MSDS	irritant MSDS and CCinfo		
3M Quat Disinfectant Cleaner Concentrated		Nonoxynol	BD	No	Yes	General Ward	DS		DS	9016-45-9	Pediatric	MSDS	irritant MSDS and CCinfo		
Husky 430 Crème cleanser	Cream	Nonoxynol	BD	No	Yes		CL	CL		9016-45-9	General	MSDS	irritant MSDS and CCinfo		
		nonyl phenol ethoxylate	BD	No	Yes	Hse. Keep		CL		127087-87-0	General	MSDS	may cause irritation MSDS and CCinfo		
Damp Mop (scrubbing machines)		nonyl phenol ethoxylate	BD	No	Yes	Bldg. Svc.	CL		CL	127087-87-0	Cancer	MSDS	may cause irritation MSDS and CCinfo	May be irritating to respiratory tract	
Staphene Disinfectant Spray	Aerosol	Ortho-benzyl-para-chlorophenol	BD	No	Yes	Nursing		DS	DS	120-32-1	General	Toxicology Program online datasheet	irritant		
Wex-cide		Ortho-benzyl-para-chlorophenol	BD	No	Yes	Bldg. Svc.		DS		120-32-1	Cancer	Toxicology Program online datasheet	irritant		
Brite N Tile		Phosphoric Acid	BD	No	Yes	MICU	CL	CL	CL	7664-38-2	General	NIOSH Pocket Guide	irritation eyes, skin upper resp		
Disinfectant Cleaner (Pink - Spartan Foamy Q & A)		Phosphoric Acid	BD	No	Yes	Housekeeping, Bldg. Svc.		DS	DS	7664-38-2	Cancer	NIOSH Pocket Guide	irritation eyes, skin upper resp	Corrosive to Resp. Tract. Mist cause irritant to nose, throat, RT	
Foamy Q&A		Phosphoric Acid	BD	No	Yes	Bldg. Svc.		DS,CL		7664-38-2	Cancer	NIOSH Pocket Guide	irritation eyes, skin upper resp	inhalation may irritate the throat and resp. system	
Lime Off		Phosphoric Acid	BD	No	Yes	Nursing		CL	CL	7664-38-2	General	NIOSH Pocket Guide	irritation eyes, skin upper resp	Skin=severe irritation, inhalation = slight toxic, eyes = chemical burn	
Lime Away	Liquid	Phosphoric Acid	BD	No	Yes	Nursing		CL	CL	7664-38-2	General	NIOSH Pocket Guide	irritation eyes, skin upper resp	if inhaled, vapors cause irritation, burning taste, sneezing, coughing, difficulty breathing	
Pink Disinfectant Cleaner (Spartan Foamy Q & A)		Phosphoric Acid	BD	No	Yes	Bldg. Svc.		DS	DS	7664-38-2	Cancer	NIOSH Pocket Guide	irritation eyes, skin upper resp	Corrosive to Resp. Tract. Mist cause irritant to nose, throat, RT	
Tile Brite		Phosphoric Acid	BD	No	Yes	Nursing		CL	CL	7664-38-2	General	NIOSH Pocket Guide	irritation eyes, skin upper resp	irritant	
3M Sharpshooter Extra Strength No Rinse Cleaner		Potassium hydroxide	BD	No	Yes	General Ward, PICU		CL	CL	1310-58-3	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, resp system, cough sneezing		
Vesphene II SE		Potassium hydroxide	BD	No	Yes	FICU	DS			1310-58-3	General	NIOSH Pocket Guide	irritation eyes, skin, resp system, cough sneezing	Mists may irritate nasal passages and lungs	
Wax Stripper		Potassium hydroxide	BD	No	Yes	Nursing, FICU, MICU	CL		CL	1310-58-3	General	NIOSH Pocket Guide	irritation eyes, skin, resp system, cough sneezing	Note=many other formulations for wax strippers, most contain 2-butoxyethonal and many other ingredients (often w/o NH3) -- many contain NH4/or K OH -- skin irritation and burns	
3M Deodorizer (Country Garden)	Aerosol	Propylene glycol monomethyl ether	BD	No	Yes	General Ward		CL		107-98-2	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, nose	upper resp. irritant	
3M Deodorizer (Country Garden)	Aerosol	Propylene glycol monomethyl ether	BD	No	Yes	PICU	CL			107-98-2	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, nose	upper resp. irritant	
3M Heavy Duty Multi-Surface Cleaner Concentrate		Propylene glycol monomethyl ether	BD	No	Yes	General Ward	CL		CL	107-98-2	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, nose	allergic reactions, resp. irritant	
3M Multi-surface cleaner concentrate - yellow		Propylene glycol monomethyl ether	BD	No	Yes	PICU	CL		CL	107-98-2	Pediatric	NIOSH Pocket Guide	irritation eyes, skin, nose		
All Purpose Cleaner		Propylene glycol monomethyl ether	BD	No	Yes	Nursing		CL	CL	107-98-2	General	NIOSH Pocket Guide	irritation eyes, skin, nose		
3M Cleaner Disinfectant - green	Liquid	Quaternary ammonium compounds	BD	No	Yes	PICU, General Ward	DS		DS	7173-51-5	Pediatric	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
3M Cleaner Disinfectant - green	Liquid	Quaternary ammonium compounds	BD	No	Yes	PICU, General Ward		DS,CL	DS	68424-85-1	Pediatric	Chem Online	occ. Asthma prolonged use		benzyl-C12-C16-alkyldimethyl, chlorides

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
3M Cleaner Disinfectant - green	Liquid	Quaternary ammonium compounds	BD	No	Yes	PICU, General Ward		DS	DS	32426-11-2	Pediatric	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
3M Quat Disinfectant Cleaner Concentrated		Quaternary ammonium compounds	BD	No	Yes	General Ward		DS	DS	68424-85-1	Pediatric	Chem Online	occ. Asthma prolonged use		benzyl-C12-C16-alkyldimethyl, chlorides
3M Quat Disinfectant Cleaner Concentrated		Quaternary ammonium compounds	BD	No	Yes	General Ward		DS	DS	32426-11-2	Pediatric	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
3M Quat Disinfectant Cleaner Concentrated		Quaternary ammonium compounds	BD	No	Yes	General Ward	DS		DS	7173-51-5	Pediatric	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
DIBS Powder (Walter Marsh)	Powder	Quaternary ammonium compounds	BD	No	Yes	Nursing		DS		63449-41-2	General	Chem Online	occ. Asthma prolonged use		Dimethyl ethylbenzyl ammonium chloride, n-alkyl
DIBS Powder (Walter Marsh)	Powder	Quaternary ammonium compounds	BD	No	Yes	Nursing		DS		63449-41-2	General	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Enviro 40, Spritz detergent disinfectant		Quaternary ammonium compounds	BD	No	Yes	Med ICU, Resp Care	DS		DS	63449-41-2	Cancer	Chem Online	occ. Asthma prolonged use		Ammonium, alkyl (C14-16) Dimethylbenzyl-, chloride
Enviro 40, Spritz detergent disinfectant		Quaternary ammonium compounds	BD	No	Yes	OT, Nursing, Resp. Care		DS	DS	63449-41-2	General	Chem Online	occ. Asthma prolonged use		Ammonium, alkyl (C14-16) Dimethylbenzyl-, chloride
Enviro 40, Spritz detergent disinfectant		Quaternary ammonium compounds	BD	No	Yes	PICU	DS		DS	63449-41-2	Pediatric	Chem Online	occ. Asthma prolonged use		Ammonium, alkyl (C14-16) Dimethylbenzyl-, chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Nursing		DS		7173-51-5	General	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Rehab Svc		DS		7173-51-5	Cancer	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	PICU, PT/OT	DS			7173-51-5	Pediatric	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Rehab Svc	CL			63449-41-2	Cancer	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Nursing	DS			63449-41-2	General	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	PICU, PT/OT	DS			63449-41-2	Pediatric	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Nursing		DS		32426-11-2	General	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	PICU, PT/OT		DS		32426-11-2	Pediatric	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
Gen Kleen IV		Quaternary ammonium compounds	BD	No	Yes	Rehab Svc		DS		32426-11-2	Cancer	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
Germicidal Cloth		Quaternary ammonium compounds	BD	No	Yes	FICU	DS			68391-01-5	General	Chem Online	occ. Asthma prolonged use	eye & skin irritant	N-Alkyl Dimethylbenzyl Ammonium Chloride
Odo Ban Disinfectant (Clean Control Corporation)		Quaternary ammonium compounds	BD	No	Yes	Mid. ICU	DS		DS	63449-41-2	Cancer	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Precise QTB		Quaternary ammonium compounds	BD	No	Yes	Med. ICU	DS			68391-01-5	Cancer	Chem Online	occ. Asthma prolonged use		N-Alkyl Dimethylbenzyl Ammonium Chloride
Precise QTB		Quaternary ammonium compounds	BD	No	Yes	Med. ICU		DS		68956-79-6	Cancer	Chem Online	occ. Asthma prolonged use		C12-18-alkyl[(ethylphenyl)methyl]dimethyl, chloride
Quat Disinfectant Cleaner		Quaternary ammonium compounds	BD	No	Yes	PICU	DS		DS	7173-51-5	Pediatric	Chem Online	occ. Asthma prolonged use		Didecyl dimethyl ammonium chloride
Quat Disinfectant Cleaner		Quaternary ammonium compounds	BD	No	Yes	PICU		DS	DS	32426-11-2	Pediatric	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride
Quat Disinfectant Cleaner		Quaternary ammonium compounds	BD	No	Yes	PICU	DS		DS	68424-85-1	Pediatric	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
ServiceMaster III Disinfectant		Quaternary ammonium compounds	BD	No	Yes	Nursing		DS	DS	32426-11-2	General	Chem Online	occ. Asthma prolonged use		octyl decyl dimethyl ammonium chloride

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ServiceMaster III Disinfectant		Quaternary ammonium compounds	BD	No	Yes	Nursing		DS	DS	68424-95-3	General	Chem Online	occ. Asthma prolonged use		di-C8-10-alkyldimethyl, chlorides
ServiceMaster III Disinfectant		Quaternary ammonium compounds	BD	No	Yes	Nursing		DS	DS	68424-85-1	General	Chem Online	occ. Asthma prolonged use		benzyl-C12-C16-alkyldimethyl, chlorides
Spartan Sparkling		Quaternary ammonium compounds	BD	No	Yes	General Ward, PICU	DS		CL	63449-41-2	Pediatric	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
Spartan Yellow Cleaner		Quaternary ammonium compounds	BD	No	Yes	Housekeeping		DS,CL	CL	139-08-2	Cancer	Chem Online	occ. Asthma prolonged use		Ammonium, benzyldimethyltetradecyl-, chloride
Spritz detergent disinfectant		Quaternary ammonium compounds	BD	No	Yes	Resp. Care, OT	DS		DS	63449-41-2	General	Chem Online	occ. Asthma prolonged use		Dimethyl ethylbenzyl ammonium chloride, n-alkyl
Staphene Disinfectant Spray	Aerosol	Quaternary ammonium compounds	BD	No	Yes	Nursing		DS	DS	68391-01-5	General	Chem Online	occ. Asthma prolonged use		N-Alkyl dimethyl benzyl ammonium chloride
Supersani Germicidal Cloth Wipes	Solid	Quaternary ammonium compounds	BD	No	Yes	Med. ICU, Resp. Care	DS		DS	63449-41-2	Cancer	Chem Online	occ. Asthma prolonged use		Dimethyl benzyl ammonium chloride, n-alkyl
ServiceMaster Scrub N Shine		Silica gel	BD	No	Yes	Hse. Keep		CL	CL	7631-86-9	General	NIOSH Pocket Guide	pneumoconiosis	High concent. may cause coughing & mild temp irrit. to RT	
3M Crème Cleanser	Cream	Silica quartz	BD	No	Yes	PICU, General Ward		CL		14808-60-7	Pediatric	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis		
Husky 430 Crème Cleanser	Cream	Silica quartz	BD	No	Yes	FICU		CL		14808-60-7	General	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis		
SparCreme Liquid Cleaner		Silica quartz	BD	No	Yes	PICU		CL	CL	14808-60-7	Pediatric	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis	SparCreme Liquid Cleaner inhalation irritant, may aggravate other pulmonary conditions	
Spartan Crème Liquid Cream	Cream	Silica quartz	BD	No	Yes	PICU		CL	CL	14808-60-7	Pediatric	NIOSH Pocket Guide	cough, dyspnea, sneezing decreases pulmonary function silicosis		
3M Desk Cleaner		Sodium carbonate	BD	No	Yes	General Ward		CL	CL	497-19-8	Pediatric	MSDS	irritant		
Comet	Powder	Sodium carbonate	BD	No	Yes	Nursing		CL	CL	497-19-8	General	MSDS	irritant		
Tide	Powder	Sodium carbonate	BD	No	Yes	Rehab Svc	CL		CL	497-19-8	Cancer	MSDS	irritant		
Vesphene II SE		Sodium hydroxide	BD	No	Yes	FICU		DS,CL		1310-73-2	General	MSDS	irritant		
Bleach	Liquid	Sodium Hypochlorite	BD	No	Yes	PT/OT	DS			7681-52-9	Pediatric	MSDS	irritant		
Bleach	Liquid	Sodium Hypochlorite	BD	No	Yes	FICU, Hse. Keep		DS,CL		7681-52-9	General	MSDS	irritant		
Bleach	Liquid	Sodium Hypochlorite	BD	No	Yes	Med. ICU, Rehab svc, Resp. Care	DS			7681-52-9	Cancer	MSDS	irritant	May cause anaphylaxis, edema extreme exposure - pulmonary edema	
Ultra-Bleach - Germicidal		Sodium Hypochlorite	BD	No	Yes	Housekeeping		DS, CL	DS	7681-52-9	Cancer	MSDS	irritant		
3M Quat Disinfectant Cleaner Concentrated		Sodium Metasilicate/ Sodium Silicate	BD	No	Yes	General Ward		DS,CL	DS	6834-92-0	Pediatric	MSDS	spray irritant		
Spartan Yellow Cleaner		Sodium Metasilicate/ Sodium Silicate	BD	No	Yes	Housekeeping		CL	CL	6834-92-0	Cancer	MSDS	spray irritant		
Spritz		Sodium Metasilicate/ Sodium Silicate	BD	No	Yes	MICU		CL		6834-92-0	General	MSDS	spray irritant	skin & eye irritant/inhalation=breathing difficulties	
Tide	Powder	Sodium Metasilicate/ Sodium Silicate	BD	No	Yes	Rehab Svc		CL	CL	6834-92-0	Cancer	MSDS	spray irritant		
Tide	Powder	Sodium sulfate (2:1)	BD	No	Yes	Rehab Svc		CL	CL	7757-82-6	Cancer	MSDS	mild irritant		
Brite N Tile		Sulfuric Acid	BD	No	Yes	MICU		CL	CL	7664-93-9	General	NIOSH Pocket Guide	irritation eyes, skin, nose, throat, pulmonary edema, bronchitis, emphysema		
Knock Out II		Sulfuric Acid	BD	No	Yes	MICU		DS,CL		7664-93-9	General	NIOSH Pocket Guide	irritation eyes, skin, nose, throat, pulmonary edema, bronchitis, emphysema	irritation to the nose/nasal passages and lungs	
ServiceMaster III Disinfectant		Urea	BD	No	Yes	Nursing		DS	DS	57-13-6	General	MSDS	irritant		
Coffee Breaker		Urea peroxide	BD	No	Yes	Nursing		DS,CL		124-43-6	General	MSDS	extreme irritant	respiratory tract irritation	
Cidex	Liquid	Glutaraldehyde	IN	Yes	Yes	Resp. Care	DS		DS	111-30-	Pediatric	MSDS	harmful if inhaled		

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										8					
Rapicide		Glutaraldehyde	IN	Yes	Yes			DS	D	111-30-8	Cancer	MSDS	harmful if inhaled		
Rapicide - disinfectant and sterilizer		Glutaraldehyde	IN	Yes	Yes	Resp. Care	DS		DS	111-30-8	Cancer	MSDS	harmful if inhaled	Moderate to strong irritant, chest tightness, insuf. Resp. sensitizer	
Hydrocollator Stainless Steel Cleaner (Chattanooga Products	Aerosol	Carbon Dioxide	IN	No	Yes	PT/OT	CL	CL	CL	124-38-9	Pediatric	NIOSH Pocket Guide	difficulty breathing		
Transeptic Cleansing Solution		Isopropanol	IN	No	Yes	PT/OT	CL		CL	67-63-0	Pediatric	NIOSH Pocket Guide	Cough, choking	May cause anaphylaxis, edema extreme exposure - pulmonary edema	
Hydrocollator Stainless Steel Cleaner (Chattanooga Products	Aerosol	Mineral oil	IN	No	Yes	PT/OT		CL	CL	8008-20-6	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat		
Manu-Clean		Sodium dodecyl benzene sulfonate	IN	No	Yes	Resp. Care		CL		25155-30-0	General	MSDS	may be harmful if inhaled if		
Organisol	Solid	Sodium dodecyl benzene sulfonate	IN	No	Yes	Resp. Care		CL		25155-30-0	Pediatric	MSDS	spray or mist irritant		
Gluco-Chlor		Sodium Hypochlorite	IN	No	Yes	FICU		DS,CL		7681-52-9	General	MSDS	Burns eyes, mucous membranes of the resp. tract, mouth, throat, esophagus and stomach.	This product can be irritating to the respiratory tract if inhaled as a mist or if the material is vaporized	
Gluco-Chlor		Sodium Hypochlorite	IN	No	Yes	FICU	DS			1782-50-5	General	NIOSH Pocket Guide	irritation eye, skin, mucous membrane pneumonitis	Mists may irritate nasal passages and lungs	
Organisol	Solid	Sodium sesquicarbonate	IN	No	Yes	Resp. Care		CL		533-98-0	Pediatric	MSDS	Burns eyes, mucous membranes of the resp. tract, mouth, throat, esophagus and stomach.	This product can be irritating to the respiratory tract if inhaled as a mist or if the material is vaporized	
Enzol Enzymatic Cleaner		Subtilisin	IN	No	Yes	Resp. Care		CL	CL	9014-82-0	Cancer	TLV Book	irritant		
Toner	Powder	Carbon Black	OT	No	Yes	Resp. Care	OT			1333-86-4	Pediatric	NIOSH Pocket Guide	cough, irritates eyes		
Toner	Powder	Carbon Black	OT	No	Yes	P3 Med. Unity		OT		1333-86-4	Cancer	NIOSH Pocket Guide	cough, irritates eyes		
Elastomer Putty (Roylan - 50/50 mix)		Cyclotetrasiloxane, octamethyl-	OT	No	Yes	Rehab Svc		OT		556-67-2	Cancer	MSDS	may be fatal if inhaled, may cause resp tract irritation, aspiration may lead to pulmonary edema		
Elastomer Putty (Roylan - 50/50 mix)		Dimethicone	OT	No	Yes	Rehab Svc		OT		63148-62-9	Cancer	MSDS	may cause resp tract irritation		
Orthoplast splints		isoprene	OT	No	Yes	PT/OT		OT		78-79-5	Pediatric	MSDS	may cause resp irritation		
Orthoplast splints		isoprene	OT	No	Yes	Rehab Svc		OT		78-79-5	Cancer	MSDS	may cause resp irritation		
Orthoplast splints		isoprene	OT	No	Yes	OT		OT		78-79-5	General	MSDS	may cause resp irritation		
		Methyl Sulfoxide	OT	No	Yes	MICU	OT	OT		67-68-5	General	MSDS	may cause resp irritation, can produce delayed pulmonary edema		DMSO
Glucose Solution		Sodium Phenylsulfonate	OT	No	Yes	Nursing		OT		515-42-4	General	MSDS	mucous membrane irritant only in dry powder form	mucous membrane irritant	
Surgilube surgical lubricant	Cream	Acetic Acid	PT	Yes	Yes	P3 Med. Unit		CL		64-19-7	Cancer	MSDS	irritation of eyes, nose, throat, can affect resp. response		
EZ Surgical Scrub Pads	Solid	Chlorohexidine	PT	Yes	No	PICU	DS		DS	55-56-1	Pediatric				
Skin Prep		Chlorohexidine	PT	Yes	No	FICU		DS		55-56-1	General				
DuoDerm CGF Border Dressing (Border Control gel)	Cream	1,3-Butanediol, polymer with alpha-butyl- omega –hdroxypoly [oxy(methyl-1,2-ethanediyl)] and 1,3-diisocyanatomethyl-benzene	PT	No	Yes	P3 Med. Unit		DS		68400-67-9	Cancer	MSDS	may aggravate resp. conditions		
Acetone Alcohol Swab Sticks	Solid	Acetone	PT	No	Yes	Nursing	AD,CL,DS	CL,DS		67-64-1	General	MSDS	irritating to nose, throat, resp. tract		
		Benzoin	PT	No	DK	Nursing	DS,CL	DS,CL		119-53-9	General	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Benzoin Swabsticks	Solid	Benzoin	PT	No	DK	FICU	DS,AD	DS,AD	DS	119-53-9	General	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Benzoin Swabsticks	Solid	Benzoin	PT	No	DK	MICU	DS,AD	DS,AD	DS	119-53-9	General	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	

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Benzoin Swabsticks	Solid	Benzoin	PT	No	DK	FICU	DS,AD	DS,AD	DS	119-53-9	General	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Benzoin Swabsticks	Solid	Benzoin	PT	No	DK	MICU	DS,AD	DS,AD	DS	119-53-9	General	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Benzoin Tincture Swabs	Solid	Benzoin	PT	No	DK	Med. ICU		DS	DS	119-53-9	Cancer	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Benzoin Tincture Swabs	Solid	Benzoin	PT	No	DK	Resp. Care		DS	DS	119-53-9	Pediatric	MSDS	no info found, should be handled as hazardous, may cause irritation to resp. tract	eye/skin/resp irritant	
Aloe vera-2-in-1 skin conditioner		Benzyl alcohol	PT	No	Yes		CL	CL		100-51-6	Cancer	MSDS	causes resp. tract irritation		
DuoDerm CGF Border Dressing (Border Control gel)	Cream	Cellulose, carboxymethyl ether, sodium salt	PT	No	Yes	P3 Med. Unit		DS		9004-32-4	Cancer	MSDS	may cause resp. tract irritation-low hazard for usual industrial handling		
Aquaphor	Cream	Ceresin	PT	No	Yes	P3 Med. Unit	CL			8001-75-0	Cancer	MSDS	may cause resp. tract irritation-low hazard for usual industrial handling		
Coconut Oil Acid Diethanolamine Condensate (Manu-Clean)	Liquid	Diethanolamine	PT	No	Yes	Resp. Care	CL			68603-42-9	General	MSDS	low hazard, may cause resp irritation	Toxic	
Aloe vera-2-in-1 skin conditioner		Dimethicone	PT	No	Yes		CL	CL		63148-62-9	Cancer	MSDS	may cause resp tract irritation		
CarraFoam Skin Cleaner		Dimethyl ether	PT	No	Yes	PT/OT	CL			115-10-6	Pediatric	MSDS	vapor reduces oxygen available or breathing		
Alcare Plus - foamed alcohol	Aerosol	Ethanol	PT	No	Yes	PICU	DS			64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose		
Alpha Keri Oil		Ethanol	PT	No	Yes	FICU	CL			64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose	hazards not indicated	
Benzoin Tincture Swabs	Solid	Ethanol	PT	No	Yes	Resp. Care		DS	DS	64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose		
Benzoin Tincture Swabs	Solid	Ethanol	PT	No	Yes	Med. ICU		DS	DS	64-17-5	Cancer	NIOSH Pocket Guide	irritates eyes, skin, nose		
Gastrocult		Ethanol	PT	No	Yes	FICU		OT		64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose		
Gastrocult Developer		Ethanol	PT	No	Yes	PICU	OT			64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose	Mild inebriation, nausea, vomiting, impaired visual perception	
Hemoccult Sensa Developer		Ethanol	PT	No	Yes	MICU, FICU	OT			64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Ethanol	PT	No	Yes	Nursing	OT	OT		64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Ethanol	PT	No	Yes	Resp. Care, PICU	OT			64-17-5	Pediatric	NIOSH Pocket Guide	irritates eyes, skin, nose	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Prevacare (non soap alcohol based cleansing prod.)		Ethanol	PT	No	Yes	Med. ICU	CL			64-17-5	Cancer	NIOSH Pocket Guide	irritates eyes, skin, nose		
Skin Prep		Ethanol	PT	No	Yes	FICU	DS			64-17-5	General	NIOSH Pocket Guide	irritates eyes, skin, nose		
DuoDerm CGF Border Dressing (Border Control gel)	Cream	Gelatins	PT	No	Yes	P3 Med. Unit		DS		9000-70-8	Cancer	MSDS	may cause resp tract irritation		
Aloe vera-2-in-1 skin conditioner		Glycerin	PT	No	Yes		CL	CL		110-27-0	Cancer	MSDS	may cause resp irritation		
		Glycerol	PT	No	Yes	Resp. Care	CL			56-81-5	Pediatric	NIOSH Pocket Guide	irritates resp system		
Aquaphor	Cream	Glycerol	PT	No	Yes	P3 Med. Unit	CL			56-81-5	Cancer	NIOSH Pocket Guide	irritates resp system		
Betadine solution	Liquid	Glycerol	PT	No	Yes	PT/OT	DS		DS	56-81-5	Pediatric	NIOSH Pocket	irritates resp system		

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
												Guide			
Betadine solution	Liquid	Glycerol	PT	No	Yes	FICU	DS		DS	56-81-5	General	NIOSH Pocket Guide	irritates resp system		
Elastomer Putty (Roylan - 50/50 mix)		Glycerol	PT	No	Yes	Rehab Svc		OT		56-81-5	Cancer	NIOSH Pocket Guide	irritates resp system		
Glycerin Usp		Glycerol	PT	No	Yes	PICU		CL,DS		56-81-5	Pediatric	NIOSH Pocket Guide	irritates resp system		
		Hydrogen Peroxide	PT	No	Yes	P3 Med. Unit	DS			7722-84-1	Cancer	NIOSH Pocket Guide	irritates nose throat	Mists can irritate nose and throat. High levels = severe lung dam.	
		Hydrogen Peroxide	PT	No	Yes	FICU	DS			7722-84-1	General	NIOSH Pocket Guide	irritates nose throat	Mists can irritate nose and throat. High levels = severe lung dam.	
		Hydrogen Peroxide	PT	No	Yes	MICU	DS			7722-84-1	General	NIOSH Pocket Guide	irritates nose throat	Mists can irritate nose and throat. High levels = severe lung dam.	
		Hydrogen Peroxide	PT	No	Yes	Nursing	DS			7722-84-1	General	NIOSH Pocket Guide	irritates nose throat	Mists can irritate nose and throat. High levels = severe lung dam.	
Gastrocult Developer		Hydrogen Peroxide	PT	No	Yes	PICU	OT			7722-84-1	Pediatric	NIOSH Pocket Guide	irritates nose throat		
Hemoccult Sensa Developer		Hydrogen Peroxide	PT	No	Yes	Nursing	OT	OT		7722-84-1	General	NIOSH Pocket Guide	irritates nose throat	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Hydrogen Peroxide	PT	No	Yes	MICU, FICU	OT			7722-84-1	General	NIOSH Pocket Guide	irritates nose throat	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Hydrogen Peroxide	PT	No	Yes	Resp. Care, PICU	OT			7722-84-1	Pediatric	NIOSH Pocket Guide	irritates nose throat	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hydrogen Peroxide	Liquid	Hydrogen Peroxide	PT	No	Yes	PICU	DS		DS	7722-84-1	Pediatric	NIOSH Pocket Guide	irritates nose throat		
CarraFoam Skin Cleaner		Imidazolidinyl urea	PT	No	Yes	PT/OT	CL			39236-46-9	Pediatric	MSDS	not fully investigated, may cause irritation to resp tract		
		Iodine	PT	No	Yes	Med. ICU	DS			7553-56-2	Cancer	NIOSH Pocket Guide	irritation eye, skin, nose, chest tightness	Iodine vapor severe irritant (chest tight, sore throat) pulm. Edema	
Betadine Ointment	Cream	Iodine	PT	No	Yes	Med. ICU	DS		DS	7553-56-2	Cancer	NIOSH Pocket Guide	irritation eye, skin, nose, chest tightness	Iodine vapor severe irritant (chest tight, sore throat) pulm. Edema	
		Iodine, povidone	PT	No	Yes	MICU	DS			25655-41-8	General	MSDS	causes resp tract irritation		
		Iodine, povidone	PT	No	Yes	MICU	DS			25655-41-8	General	MSDS	causes resp tract irritation		
		Iodine, povidone	PT	No	Yes	FICU	DS			25655-41-8	General	MSDS	causes resp tract irritation		
		Iodine, povidone	PT	No	Yes	PT/OT	DS			25655-41-8	Pediatric	MSDS	causes resp tract irritation		
Acu-dyne Prep Swabs	Solid	Iodine, povidone	PT	No	Yes	PT/OT		DS		25655-41-8	Pediatric	MSDS	causes resp tract irritation		
Betadine Applicators	Solid	Iodine, povidone	PT	No	Yes	FICU	DS			25655-41-8	General	MSDS	causes resp tract irritation		
Betadine solution	Liquid	Iodine, povidone	PT	No	Yes	FICU	DS		DS	25655-41-8	General	MSDS	causes resp tract irritation		
Betadine solution	Liquid	Iodine, povidone	PT	No	Yes	PT/OT	DS		DS	25655-41-8	Pediatric	MSDS	causes resp tract irritation		
EZ Scrub 206		Iodine, povidone	PT	No	Yes	PICU	DS		DS	25655-41-8	Pediatric	MSDS	causes resp tract irritation		
EZ Scrub 206		Iodine, povidone	PT	No	Yes	Nursing	DS		DS	25655-41-8	General	MSDS	causes resp tract irritation		
EZ Surgical Scrub Pads	Solid	Iodine, povidone	PT	No	Yes	PICU	DS		DS	25655-41-8	Pediatric	MSDS	causes resp tract irritation		
Operand Betadine Solution	Liquid	Iodine, povidone	PT	No	Yes	PICU	DS		DS	25655-41-8	Pediatric	MSDS	causes resp tract irritation		
Prepodyne solution		Iodine, povidone	PT	No	Yes	P3 Med. Unit	DS			25655-41-8	Cancer	MSDS	causes resp tract irritation		
Providine Iodine		Iodine, povidone	PT	No	Yes	Med. ICU	DS			25655-	Cancer	MSDS	causes resp tract irritation		

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
10% topical solution										41-8					
		Isopropanol	PT	No	Yes	PT/OT	DS,CL	DS, CL		67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
		Isopropanol	PT	No	Yes	MDA	DS			67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Acetone Alcohol Swab Sticks	Solid	Isopropanol	PT	No	Yes	Nursing	DS	DS		67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
Alcohol Pads	Solid	Isopropanol	PT	No	Yes	Nursing	DS			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Alcohol Swabs and Prep	Solid	Isopropanol	PT	No	Yes	Med. ICU	DS	DS		67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Alcohol Prep Pads	Solid	Isopropanol	PT	No	Yes	FICU	DS			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Alcohol Prep Pads	Solid	Isopropanol	PT	No	Yes	PT/OT	DS			67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Alcohol Prep Pads	Solid	Isopropanol	PT	No	Yes	PT/OT	DS			67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Bactoshield		Isopropanol	PT	No	Yes	Nursing	DS	DS	DS	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
Bactoshield		Isopropanol	PT	No	Yes	FICU	DS	DS	DS	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
Bactoshield		Isopropanol	PT	No	Yes	Med. ICU	DS	DS	DS	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat		
Chloraprep 2%		Isopropanol	PT	No	Yes	Nursing	CL,DS			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
Chlorhexidine Gluconate	Liquid	Isopropanol	PT	No	Yes	MICU	DS			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat		
EZ Surgical Scrub Pads	Solid	Isopropanol	PT	No	Yes	Med. ICU	DS	DS	DS	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Foam Care		Isopropanol	PT	No	Yes	FICU	CL			67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	eye & skin irritant (should not cause resp irritation)	
Hibiclens hand cleaner	Liquid	Isopropanol	PT	No	Yes	Nursing	DS		DS	67-63-0	General	NIOSH Pocket Guide	irritates eyes, nose, throat	skin and eye irritant	
Hibiclens hand cleaner	Liquid	Isopropanol	PT	No	Yes	P3 Med. Unit	CL	DS	DS	67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat	May be irritating to respiratory tract	
Hibiclens/EZ Scrub 206		Isopropanol	PT	No	Yes	PICU	DS	DS	DS	67-63-0	Pediatric	NIOSH Pocket Guide	irritates eyes, nose, throat		
Steris Bactoshield		Isopropanol	PT	No	Yes	Med. ICU	DS			67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat		
Triad antiseptic towelette w/Benzalkonium chloride		Isopropanol	PT	No	Yes		DS	DS		67-63-0	Cancer	NIOSH Pocket Guide	irritates eyes, nose, throat		
Gastrocult Developer		Methanol	PT	No	Yes	PICU	OT	OT		67-56-1	Pediatric	NIOSH Pocket Guide	irritation upper resp system		
Hemoccult Sensa Developer		Methanol	PT	No	Yes	Nursing		OT		67-56-1	General	NIOSH Pocket Guide	irritation upper resp system	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Methanol	PT	No	Yes	MICU, FICU	OT			67-56-1	General	NIOSH Pocket Guide	irritation upper resp system	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions, impaired vision, alcohol intoxications	
Hemoccult Sensa Developer		Methanol	PT	No	Yes	Resp. Care, PICU	OT	OT		67-56-1	Pediatric	NIOSH Pocket Guide	irritation upper resp system	inhalation (& ingestion) coughing, sore throat, shortness of breath, dizziness, vomiting, convulsions,	

Product Name	Product Type	Chemical	New Class	Resp. Sensitizer?	Resp. Irritant?	Dept.	LW Double check	GLD Double check	CML Class	CAS Number	Hospital	Irritant Source	Irritant Comment	Chemical/Product Comment?	2nd ChemName
														impaired vision, alcohol intoxications	
CarraFoam Skin Cleaner		Methyl paraben	PT	No	Yes	PT/OT	CL	CL		99-76-3	Pediatric	MSDS	may cause resp irritation resp tract irritation in high concentrations		
DuoDerm CGF Border Dressing (Border Control gel)	Cream	Methylbenzene	PT	No	Yes	P3 Med. Unit		DS		128-37-0	Cancer	MSDS	causes resp irritation		
Accent Plus Aminolotion (Huntington; Ecolab)		Mineral oil	PT	No	Yes	PICU		CL		8042-47-5	Pediatric	MSDS	may cause resp irritation		
Aloe vera-2-in-1 antifungal ointment	Cream	Mineral oil	PT	No	Yes		CL,DS	CL		8042-47-5	Cancer	MSDS	may cause resp irritation		
DuoDerm CGF Border Dressing (Border Control gel)	Cream	Mineral oil	PT	No	Yes	P3 Med. Unit		DS		8042-47-5	Cancer	MSDS	may cause resp irritation		
CarraFoam Skin Cleaner		Monochlorodifluoro-methane	PT	No	Yes	PT/OT	CL	CL		75-45-6	Pediatric	MSDS	product is relatively non-toxic, may cause minor irritation of mucous membranes & resp. system		
CarraFoam Skin Cleaner		n-butane	PT	No	Yes	PT/OT	CL			106-97-8	Pediatric	MSDS	relatively non-toxic, simple hydrocarbon may irritate the eyes, mucous membranes and resp system at high concentrations		
Surgilube surgical lubricant	Cream	Propylene Oxide	PT	No	Yes	P3 Med. Unit		CL		75-56-9	Cancer	NIOSH Pocket Guide	irritation eyes, skin, nose		
Triad antiseptic towelette w/Benzalkonium chloride		Quaternary ammonium compounds	PT	No	Yes	Med. ICU		DS		8001-54-5	Cancer	MSDS	May cause severe irritation of the resp. tract. w/sore throat, coughing, SOB, delayed lung edema		Benzylalkonium chloride
Elastomer Putty (Roylan - 50/50 mix)		Silica gel	PT	No	Yes	Rehab Svc		OT		7631-86-9	Cancer	NIOSH Pocket Guide	pneumoconiosis		
CarraFoam Skin Cleaner		Sodium lauryl sulfate	PT	No	Yes	PT/OT		DS,CL		151-21-3	Pediatric	MSDS	irritant		
Soap, Dial	Liquid	Sodium lauryl sulfate	PT	No	Yes	Nursing		CL		151-21-3	General	MSDS	irritant		
CarraFoam Skin Cleaner		Sodium metabisulfite	PT	No	Yes	PT/OT		CL		7681-57-4	Pediatric	MSDS	irritation eyes, skin, mucous membrane		
Accent Plus Aminolotion (Huntington; Ecolab)		Stearic Acid	PT	No	Yes	PICU		CL		57-11-4	Pediatric	TLV Book	irritant		
Baby Powder	Powder	Talc	PT	No	Yes	Med. ICU		CL		14807-96-6	Cancer	NIOSH Pocket Guide	Fibrotic pneumoconiosis	eyes=temporary discomfort and irritation	

Appendix D.

Supplemental Paper:

Lai D, Arif AA, Delclos GL.
"A comparative study of three classification procedures: asthma among healthcare professionals in Texas"

Journal of Applied Statistics [submitted]

A Comparative Study of Three Classification Procedures: Asthma among Healthcare Professionals in Texas

Dejian Lai[1], Ahmed A Arif[2] and George L. Delclos[1]

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[1] The University of Texas School of Public Health, Houston, Texas, USA.

[2] Department of Family and Community Medicine, Division of Health Services Research, Texas Tech University Health Science Center, Lubbock, Texas, USA.

Running Title: Discriminant Analysis on Asthma in Texas

Correspondence and reprint request: Dejian Lai, School of Public Health, RAS 1006, University of Texas, Houston, TX 77030

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Abstract

Statistical discriminant analysis has been widely used in many fields. In this article, we applied and compared three different classification procedures: logistic regression, Fisher linear discriminant function and the second order Bahadur representation to two data sets from two surveys on asthma among healthcare professional in Texas. The first data set contained 102 subjects and the second data set had 2963 subjects. The concordance of the classification from the three statistical procedures with possible asthma identified by physician and airway responsiveness to methacholine challenge was assessed through Cohen's κ statistic via a series of 2×2 contingency tables.

1 Introduction

The incidence and prevalence of asthma, a chronic inflammatory disease of airways, is on the rise in the U.S. and has increased by 75% in the past two decades (Mannino et al., 1998). Estimates of the prevalence of asthma differ based on the definition used and range from 4.5% to as high as 16.4% (Arif et al., 2003). It is estimated that more than 14 million persons in the United States suffer from asthma. Community-based studies have reported asthma incidence rates from 0.5 to 2.5 per 1000 (Kivity et al., 1995; Milton et al., 1998). Questionnaires have long been a cornerstone of asthma epidemiology studies, and much work has gone into standardizing asthma questionnaires for use in the general population, by groups such as the British Medical Research Council (MRC) (1960), American Thoracic Society (ATS) (Ferris, 1978), and the International Union Against Tuberculosis and Lung Disease (IUATLD) (Burney et al., 1989a). However, in the absence of a gold standard, the definitions of asthma used in surveys vary and may not necessarily correspond to the clinical definition of asthma. Relatively few studies have been published with information on formal validation of asthma questionnaires (Burney et al. 1989a, 1989b; Abramson et al 1991; Kongerud et al 1994). Accurate detection of asthma in epidemiological studies is critical for the proper characterization of etiologic risk factors, triggers and the identification of prevention and intervention opportunities. There are many different ways that have been proposed and

revised for the diagnosis of asthma. The current operational definition of asthma was given in the International Consensus Report on the Diagnosis and Treatment of Asthma, which is based on three components: chronic airway inflammation, reversible airflow obstruction and enhanced bronchial reactivity that lead to symptoms of wheezing, breathlessness, chest tightness, cough, and sputum production (Sheffer et al., 1992).

The Southwest Center for Occupational and Environmental Health at The University of Texas School of Public Health recently conducted a two-phase survey of asthma among healthcare professionals in Texas. In the first phase, an initial questionnaire was given to a convenience sample of 102 subjects. A methacholine challenge was administered to the 102 subjects in addition to self-administered questions regarding asthmatic symptoms, environmental risk factors and basic demographic characteristics (Delclos et al 2005). In Delclos et al (2005) logistic regression models were based on 118 subjects (16 subjects in the testing stage were included). However, in the current article, the 16 subjects in the testing stage were excluded. For the second phase, the refined questionnaire was administered to a random sample of healthcare professionals in Texas. The second phase of the study consisted of a cross-sectional group-comparison study design, using a mail survey administered to a sample (n=5600) of four groups (n=1400 per group) of Texas healthcare workers: physicians, nurses, respiratory therapists and occupational therapists. Questionnaires were received from 3528 participants, for an overall response rate of 63%. After removing subjects with missing values, we used 2963 subjects with complete responses for model-based discriminant analysis. In the second phase, no methacholine challenge was given.

For an accurate estimation of prevalence, a proper diagnosis of asthma is necessary. Because of the multivariate nature of the risk factors and unknown etiology of asthma, there is always uncertainty for the diagnosis (Douwes and Pearce 2002). A reasonable diagnosis of asthma for a person by a medical doctor generally requires some period of follow up and sufficient clinical and physiologic information documented during this follow up. One of the

purposes of developing the questionnaire from the surveys was to provide a useful instrument in assessing asthma burden to the healtcare professionals in Texas (Delclos et al 2005). In the questionnaire, in addition to a sequence of questions on symptoms, environmental risk factors and demographic characteristics, subjects were also asked if they had ever been diagnosed as having asthma by a physician (MD asthma) (Delclos et al 2005). Preliminary analysis based on logistic regression identified a subset of eight symptom items that exhibited the best combination of sensitivity and specificity when compared to MD asthma and $PC_{20}4$ and $PC_{20}8$, where $PC_{20}4 = 1$ denotes a $\geq 20\%$ decline in the subject's FEV_1 (forced exposure volume at one second) at $\leq$ 4mg/ml methacholine challenge, $PC_{20}8 = 1$ indicates an FEV_1 fall of least 20% at $\leq$ 8mg/ml for the challenge. The eight symptom items were: *1) Have you ever had trouble with your breathing? 2) have you had an attack of shortness of breath at any time in the last 12 months? 3) Have you had wheezing or whistling in your chest at any time in the last 12 months? 4) Have you been awakened during the night by an attack of cough in the last 12 months? 5) Have you been awakened during the night by an attack of chest tightness in the last 12 months? 6) When you are near animals, feathers or in a dusty part of the house, do you ever get itchy or watery eyes? 7) When you are near animals, feathers or in a dusty part of the house, do you ever get a feeling of tightness in your chest? 8) When you are near tree, grass or flowers, or when there is a lot of pollen around, do you ever get itchy or watery eyes?*

There are many widely used discriminant procedures in the statistical literature (Asparoukhov and Krzanowski 2001). In this article, we applied and compared three discriminant analysis methods for the diagnosis of asthma. These three methods were used in two data sets. The first one was a small data set from our phase I survey with 102 subjects. The second was a large data set from our phase II survey with 2963 complete subjects. In Section 2, the three discriminant techniques studied in this article are briefly reviewed. The results from the three methods on the two data sets are tabulated in a series of 2×2 contingency tables

and the agreement among these three methods is quantified via κ statistic and presented in Section 3. Discussions and concluding remarks are given in Section 4.

2 Discriminant Methods

The three discriminant analysis tools applied to the two data sets were logistic regression (Hosmer and Lemeshow 1989), Fisher linear discriminant function (Anderson 1984) and the second order Bahadur model (Goldstein and Dillon 1978). Logistic regression has been widely used to model binary dependent variable in response to risk factors in many fields (Agresti 2002). In this study, we denoted the dependent variable being 1 as asthma positive and 0 as negative. As noted in the introduction, there is no gold standard for the detection of asthma. For phase I data, we modeled three dependent variables: asthma diagnosed by a physician (MD asthma=1), and two levels of response to methacholine challenge ($PC_{20}4 = 1$ or $PC_{20}8 = 1$). In the phase II survey, methacholine challenge testing was not performed.

Logistic Regression

Logistic regression models the probability of asthma in relation to symptoms (risk factors). In our setting, let y = 1 be MD asthma =1 or $PC_{20}4 = 1$ or $PC_{20}8 = 1$. The eight symptoms variables were described in previous section. Mathematically, logistic regression establishes a generalized linear model:

$$P(y = 1|x_1, x_2, \ldots, x_k) = \frac{e^{\alpha+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_p x_p}}{1 + e^{\alpha+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_p x_p}} \quad (1)$$

where x_j, $j = 1, 2, \ldots, p$, denotes the p dichotomous symptom variables used in our study. In our case, p=8. We used S-plus (Insightful 2003) to estimate the parameters in the model. In general, if we observed $P(y = 1) > 0.5$, we would classify the subject with the given combinations of symptoms as being asthmatic. However, more careful assessment of the threshold value for classification may be needed in some cases as discussed in Section 4.

Fisher Linear Discriminant Function

Fisher linear discriminant function (Anderson 1984) is another widely used technique in classification analysis. The simplest Fisher linear discriminant function applied to the classification of two populations is based on two multivariate normal distributions with equal covariance (Anderson 1984). In our two survey phases, the symptom variables were generally binary, with "yes" or "no" answers. It is then obvious that the application of Fisher linear discriminant function to our data is questionable. Nevertheless, we included this method for comparison to the other two methods in our study. In applying Fisher linear discriminant function, we may assume there was an underlying quantitative process of the symptoms. For example, subjects answering a question on shortness of breath would dichotomize the underlying obstruction of the airway into a "yes" or "no" response according to a subjective feeling.

Let $N(\mu_1, \Sigma)$ and $N(\mu_2, \Sigma)$ be the distribution of the asthmatic and nonasthmatic subjects, respectively, where μ_1 is the vector of proportions of positive responses ($X_j = 1$), μ_2 is the vector of proportions of negative responses ($X_j = 0$) and Σ is the common variance-covariance matrix for both populations. Let $X = (X_1, X_2, \ldots, X_p)$ be the vector of symptoms of an individual. The Fisher linear discriminant function would classify a subject with X as an asthmatic if

$$x'\hat{\Sigma}^{-1}(\hat{\mu}_1 - \hat{\mu}_2) - \frac{1}{2}(\hat{\mu}_1 + \hat{\mu}_2)'\hat{\Sigma}^{-1}(\hat{\mu}_1 - \hat{\mu}_2) \geq \log(k), \tag{2}$$

where x is the observed value of X and the hat on μ_1,μ_2 and Σ denotes the sample version of the parameters and

$$k = \frac{q_0 C(1|0)}{q_1 C(0|1)}$$

where q_1,q_0 are prior probabilities of asthma or absence of asthma, respectively, and $C(1|0)$ is the cost of misclassification of a nonasthmatic as asthmatic and $C(0|1)$ is the cost of misclassification of an asthmatic as nonasthmatic. In our application, we assume k=1, which is a commonly used criterion.

Bahadur Representation

The third method applied to our data sets was the second order Bahadur representation (Bahadur 1961, Goldstein and Dillon 1978). In our application, the symptom variables were all correlated and dichotomous. Let $\theta_j = P(X_j = 1)$, $j = 1, 2, \ldots, p$, where X_j is one of the symptom variables of asthma such as cough, shortness of breath, $X_j = 1$ denotes the presence of the symptom and $X_j = 0$ for absence of the symptom. As mentioned previously, in our study, we identified eight symptoms for our comparative discriminant analysis.

Let X_j be a binary random variable. The standardized version of X_j is given by

$$Z_j = \frac{X_j - \theta_j}{\sqrt{\theta_j(1-\theta_j)}} \tag{3}$$

Define

$$\rho_{jk} = E(Z_j Z_k)$$

$$\vdots$$

$$\rho_{jk\ldots p} = E(Z_j Z_k \ldots Z_p)$$

Bahadur (1961) showed that the joint distribution of $X = (X_1, X_2, \ldots, X_p)$ would be written as (Goldstein and Dillon 1978)

$$f(x_1, x_2, \ldots, x_p) = P(x_1, x_2, \ldots, x_p) P_{[1]}(x_1, x_2, \ldots, x_p), \tag{4}$$

where

$$P(x_1, x_2, \ldots, x_p) = 1 + \sum_{j<k} \rho_{jk} Z_j Z_k + \sum_{j<k<l} \rho_{jk} Z_j Z_k Z_l + \ldots + \rho_{12\ldots p} Z_1 Z_2 \ldots Z_p$$

and

$$P_{[1]}(x_1, x_2, \ldots, x_p) = \prod_{j=1}^{p} \theta^{x_j} (1-\theta_j)^{1-x_j}.$$

Assuming the correlation coefficients with order higher than 2 being zero and using the sample mean and sample Pearson correlation coefficients, we obtain the second (sample) Bahadur representation

$$\hat{f}(x_1, x_2, \ldots, x_p) = (\prod_{j=1}^{p} \hat{\theta}^{x_j}(1-\hat{\theta}_j)^{1-x_j})(1 + \sum_{j<k} \hat{\rho}_{jk}\hat{z}_j\hat{z}_k), \tag{5}$$

where

$$\hat{\theta}_j = \sum_{j=1}^{n} \frac{I(X_j = 1)}{n},$$

$$\hat{z}_j = \frac{x_j - \hat{\theta}_j}{\sqrt{\hat{\theta}_j(1-\hat{\theta}_j)}},$$

and

$$\hat{\rho}_{jk} = \frac{\sum_{j,k} I(X_j = 1, X_k = 1)/n - \hat{\theta}_j\hat{\theta}_k}{\sqrt{\hat{\theta}_j(1-\hat{\theta}_j)\hat{\theta}_k(1-\hat{\theta}_k)}}.$$

Note that I(condition) is an indicator function that takes a value of 1 if the condition is true and 0 otherwise. The probability $\hat{f}$ can be estimated based on the sample values of θ and ρ from the asthmatic and the nonasthmatic group. Let $\hat{f}_1(x_1, x_2, \ldots, x_p)$ and $\hat{f}_0(x_1, x_2, \ldots, x_p)$ be the probability estimated from the asthmatic and the nonasthmatic group, respectively. We would classify a subject with symptom $x = (x_1, x_2, \ldots, x_p)$ into the asthmatic group if

$$\delta\hat{f}_1(x_1, x_2, \ldots, x_p) > (1-\delta)\hat{f}_0(x_1, x_2, \ldots, x_p), \tag{6}$$

where δ is the prior probability of asthma. We assumed a $\delta = 0.5$ in our comparative study of these three classification procedures.

3 Results and Agreement Analysis

We applied the three discriminant methods to the two data sets from our surveys on Texas healthcare professionals. The pairwise comparisons of the classification results were assessed using κ statistic (Fleiss 1981) via a series of 2×2 contingency tables as shown in Table 1.

Table 1 about here

In Table 1, p_{ij}, $i = 0, 1$ and $j = 0, 1$, is the proportion of subjects in category i by method A and in category j by method B. The estimate of the κ statistic is defined in Equation (7). If two methods are in complete agreement, $\kappa = 1$. If $\kappa \geq 0$, the observed agreement is greater than chance, and if observed agreement is less than chance, then $\kappa < 0$. We used StatXact (Cytel 2001) to compute the estimates of the κ statistic and its standard deviation.

$$\hat{\kappa} = \frac{p_o - p_e}{1 - p_e}, \tag{7}$$

where $p_o = p_{00} + p_{11}$ and $p_e = p_{0.}p_{.0} + p_{1.}p_{.1}$.

The results of the κ statistic are shown in Table 2 and Table 3 for phase I and phase II data, respectively.

Tables 2 about Here

Results in Table 2 show that the classification based on logistic regression was highly concordant with a prior physician diagnosis of asthma (MD asthma) for the phase I data. We observed $p_{01} = p_{10} = 2/102$ and the estimate of the κ statistic was 0.8651, with a standard deviation of 0.0659. Methacholine challenge was given during phase I and two indicator variables ($PC_{20}4$ and $PC_{20}8$) were generated from the outcomes as described in Section 2. The concordance between the logistic regression using the methacholine challenge and the MD asthma were low. Similar low concordance was observed between the MD asthma and the direct $PC_{20}4$, $PC_{20}8$ without using logistic regression. The methacholine challenge seemed much more sensitive than the physician's diagnosis. For phase I data, the concordance between MD asthma and the Fisher linear discriminant function was high. The value of κ statistic was 0.7414 with a standard deviation a value of 0.0659. The results from the second order Bahadur representation and MD asthma produced 0.5885 for the κ statistic. For the three pairwise

comparisons among logistic regression, second order Bahadur representation and Fisher linear discriminant function, logistic regression and Fisher's method had a high concordance with κ=0.8061 and standard deviation being 0.0761. Bahadur representation and Fisher linear discriminant function had κ= 0.7253 with a standard deviation 0.0861. The κ statistic for concordance between the logistic model and the Bahadur representation was 0.5885 with standard deviation 0.1025, which was the same as MD asthma compared directly to second order Bahadur representation.

Tables 3 about Here

In phase II of the survey, no methacholine challenge was given. The data set used in this comparative analysis consisted of 2963 subjects without missing values. Table 3 summarizes the κ and corresponding standard deviations for the six pairwise comparisons. Compared to MD asthma, the three statistical classification procedures showed relatively large κ values, although they were lower than those in phase I, ranging from 0.4917 to 0.5826. For the pairwise comparisons among the three statistical procedures, logistic regression produced overly sensitive classification since p_{10}=0. The κ statistics were 0.5224 and 0.7362 when comparing results from logistic regression to the second order Bahadur representation and Fisher linear discriminant functions, respectively. Comparison of the Bahadur representation to Fisher's method resulted in a κ statistic of 0.6749 with a standard deviation of 0.0164.

4 Concluding Remarks

In this study, we applied three widely used statistical classification techniques to data obtained from two surveys on asthma in Texas heathcare professionals. All three procedures showed a high concordance with a prior physician diagnosis of asthma although concordance decreased as sample size increased. The Fisher linear discriminant function used an assumption of normality for the explanatory variables that was clearly not true in our study. However, our

study demonstrated its robustness when applied to dichotomous variables. For the classification based on logistic regression, we used a default cut-off value of 0.5 when classifying a subject as asthmatic or nonasthmatic, which may not be appropriate in other applications. A Bayesian approach (Anderson 1984), together with a cost function of misclassification, may add more insights in classification. However, this was beyond the scope of this study since it is hard to justify a particular cost function in a general setting. Due to the correlation among the dichotomous variable, we would expect use of Bahadur representation to produce better classification results. However, we were unable to confirm or reject this in the absence of a true gold standard to compare with. For simplicity only the second order Bahadur representation was used in this study. Analysis with the higher representation was also beyond the scope of our current study.

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Table 1: The Agreement Table for Two Classification Methods

	Method B		
Method A	0	1	Total
0	p_{00}	p_{01}	$p_{0.}$
1	p_{10}	p_{11}	$p_{1.}$
Total	$p_{.0}$	$p_{.1}$	1

Table 2: Selected Pairwise Comparisons of Three Classifications Procedures with MD Asthma, $PC_{20}4$ and $PC_{20}8$ for Phase 1 Survey of 102 Subjects

Method A	Method B	np_{00}	np_{01}	np_{10}	np_{11}	κ	SD
MD Asthma	Logistic	82	2	2	16	0.8651	0.0659
MD Asthma	Logistic4	63	21	4	14	0.3849	0.0938
MD Asthma	Logistic8	47	37	2	16	0.2542	0.0700
MD Asthma	Bahadur	76	8	5	13	0.5885	0.1023
MD Asthma	Fisher	79	5	3	15	0.7414	0.0864
MD Asthma	$PC_{20}4$	50	34	4	14	0.2254	0.0779
MD Asthma	$PC_{20}8$	45	39	3	15	0.2067	0.0695
$PC_{20}4$	Logistic4	46	8	21	27	0.4207	0.0876
$PC_{20}8$	Logistic8	34	14	15	39	0.4301	0.0895
Logistic	Bahadur	76	8	5	13	0.5885	0.1023
Logistic	Fisher	80	4	2	16	0.8061	0.0761
Bahadur	Fisher	77	4	5	16	0.7253	0.0861

Table 3: Pairwise Comparisons of Three Classifications Procedures with MD Asthma for Phase 2 Survey of 2963 Subjects

Method A	Method B	np_{00}	np_{01}	np_{10}	np_{11}	κ	SD
MD Asthma	Logistic	2433	96	216	218	0.5244	0.0234
MD Asthma	Bahadur	2130	399	89	345	0.4917	0.0192
MD Asthma	Fisher	2331	198	131	303	0.5826	0.0206
Logistic	Bahadur	2219	430	0	314	0.5224	0.0187
Logistic	Fisher	2462	187	0	314	0.7362	0.0180
Bahadur	Fisher	2179	40	283	461	0.6749	0.0164