Fragranced consumer products and effects on asthmatics: an international population-based study

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Abstract
Asthma is an international concern, with risks linked to air pollutants. Fragranced consumer products, such as air fresheners and cleaning supplies, have been associated with health problems such as asthma attacks and breathing difficulties. This study investigates the health and societal effects of fragranced products on asthmatics in four countries: United States, Australia, United Kingdom, and Sweden. Nationally representative population surveys (n = 1137; 1098; 1100; 1100) found that, across the four countries, 26.0% of adults (n = 1151) are asthmatic, reporting medically diagnosed asthma (15.8%), an asthma-like condition (11.1%), or both. Among these asthmatics, 57.8% report adverse health effects, including asthma attacks (25.0%), respiratory problems (37.7%), and migraine headaches (22.6%), from exposure to fragranced products. In particular, 36.7% of asthmatics report health problems from air fresheners or deodorizers, 18.1% from the scent of laundry products coming from a dryer vent, 32.9% from being in a room cleaned with scented products, 38.7% from being near someone wearing a fragranced product, and 37.5% from other types of fragranced products. For 24.1% of asthmatics, health problems from fragranced products are potentially disabling. Further, 20.6% of asthmatics have lost workdays or lost a job, in the past year, due to fragranced product exposure in the workplace. Fragrance-free environments received widespread support. More than twice as many individuals, both asthmatics as well as non-asthmatics, would prefer that workplaces, health care facilities and professionals, airplanes, and hotels were fragrance-free rather than fragranced. This study provides evidence that asthmatics can be profoundly, adversely, and disproportionately affected by exposure to fragranced consumer products. Moreover, the study points to a relatively straightforward and cost-effective approach to reduce risks; namely, to reduce exposure to fragranced products.

Keywords Asthma · Asthma-like condition · Asthmatic · Fragranced consumer products · Indoor air quality · Fragrance · Health effects · Volatile organic compounds

Introduction
Fragranced consumer products—such as air fresheners, cleaning supplies, laundry detergents, scented candles, essential oils, colognes, soaps, and personal care products—are widely used throughout society (Steinemann 2016). Fragranced products emit numerous volatile organic compounds (VOCs) including asthmagens (Weinberg et al. 2017) and hazardous air pollutants (e.g., Nazaroff and Weschler 2004). Fragranced products have been implicated as an important source of human exposure to VOCs (e.g., Hoang et al. 2017; Gokhale et al. 2008; Wallace 2001), as well as indoor air pollution (e.g., Geiss et al. 2011; Edwards et al. 2001; Goodman et al. 2017) and urban outdoor air pollution (McDonald et al. 2018).

A “fragranced consumer product” (or “fragranced product”) is a product that contains an added fragrance or that is largely comprised of fragrance (Steinemann 2016). A single “fragrance” in a product is typically a complex mixture of dozens of compounds (Steinemann 2015), many derived from petrochemicals (Sell 2006). However, no law in any country requires full disclosure of all ingredients in a fragrance. Further, no law requires full disclosure of all ingredients in a
Exposure to fragranced products has been associated with adverse health effects in the general population and in vulnerable sub-populations. Studies in the United States (US), Australia (AU), United Kingdom (UK), and Sweden (SE) found that, on average, 32.2% of the general population (34.7%, 33.0%, 27.8%, and 33.1%, respectively) report health problems when exposed to fragranced products such as air fresheners, laundry supplies, cleaning products, personal care products, and household items (Steinemann 2016, 2017a, 2018a, b). Health problems include respiratory difficulties, migraine headaches, asthma attacks, mucosal symptoms, skin rashes, and neurological problems, among others. Among vulnerable sub-populations, 75.8% of individuals with autism (83.7%, 82.9%, 84.6%, and 51.8%, respectively) and 81.3% with chemical sensitivity (78.9%, 82.1%, 77.3%, and 86.9%, respectively) report adverse health effects from exposure to fragranced products (Steinemann 2018d, 2019).

Relatively little prior population-based research has investigated links between fragranced products and asthma. In two national studies, upon which this international study builds, 64.3% and 55.6% of asthmatics in the US and AU, respectively, report adverse health effects from fragranced products (Steinemann 2018c; Steinemann et al. 2018). Two studies in the US, conducted in 2002–2003 and 2005–2006, found that 29.7% and 37.2%, respectively, of asthmatics report adverse health effects from air fresheners or deodorizers (Caress and Steinemann 2009). A study of workers in California found that 3.8% of 7163 confirmed work-related asthma cases from 1993 to 2012 were associated with fragranced product exposure (Weinberg et al. 2017).

This present study investigates the effects of exposure to fragranced products on asthmatic adults in four countries (US, AU, UK, SE). It assesses the types and severity of health effects associated with different types of fragranced product exposures; societal effects such as access to public places, lost workdays and lost jobs; and preferences for fragrance-free environments. It extends the prior national studies of asthma and SE, offering greater breadth and depth of analysis. Results from this study reveal important and under-explored associations between fragranced products and asthmatics and suggest a relatively straightforward way to reduce adverse effects by reducing exposure.

**Methods**

Nationally representative population-based cross-sectional studies, using the same survey instrument, were conducted of adults ages 18–65 in the United States, Australia, United Kingdom, and Sweden. Sample populations were representative of the general populations according to age, gender, and region (n = 1137; 1098; 1100; 1100; respectively; confidence limit = 95%, margin of error = 3% for all studies). The surveys drew upon large web-based panels (with over 5,000,000; 200,000; 900,000; 60,000 people, respectively) held by Survey Sampling International (SSI). For the panels, SSI uses multi-source samples to develop a blend that reflects the heterogeneity of the study population. For the surveys, recruitment followed a three-step randomization process to identify potential participants [see Electronic Supplementary Materials (ESM-Survey Methods and ESM-SSI Methodologies)]. The survey instrument, a questionnaire in each country’s native language, was developed and tested over a 2-year period before full implementation in June 2016 (US, AU, UK) and June 2017 (SE). The survey response rate was 94%, 93%, 97%, and 92% (respectively), and all responses were anonymous. The research study received ethics approval from the University of Melbourne. Survey methods are detailed in the Electronic Supplementary Material (ESM-Survey Methods).

Descriptive statistics and cross-tabulations determined percentages according to each response and sub-population; see Electronic Supplementary Material (ESM-Data). Prevalence odds ratios (PORs) measured the strength of associations to determine whether one sub-population is proportionally more affected than another. Chi-squared analyses compared proportions among countries to determine whether a statistically significant difference exists. All POR and chi-squared analyses were performed using a 95% confidence interval (CI) or a 95% confidence level, respectively.

To promote comparability, the survey replicated questions from previous studies of asthma/asthma-like conditions and fragrance sensitivity (Steinemann 2016, 2017a, 2018a, b, c, 2019; Steinemann et al. 2018; Caress and Steinemann 2009), as follows.

For asthma/asthma-like conditions, the survey asked, “Has a doctor or health care professional ever told you that you have asthma or an asthma-like condition?” If the respondent answered yes, the survey then asked to specify whether “asthma” or an “asthma-like condition” or both.

For fragrance sensitivity, defined as adverse effects from exposure to fragranced consumer products (Caress and Steinemann 2009), the survey asked, “Do you experience any health problems when exposed to (fragranced product)”? If the respondent answered yes, the survey then asked the respondent to specify which health problems they experienced. An individual was considered to characterize fragrance sensitivity if they reported one or more types of health problems from...
exposure to one or more types of fragranced consumer products.

Fragranced products were categorized as follows: (a) air fresheners and deodorizers (e.g., sprays, solids, oils, disks), (b) personal care products (e.g., soaps, hand sanitizer, lotions, deodorant, sunscreen, shampoos), (c) cleaning supplies (e.g., all-purpose cleaners, disinfectants, dishwashing soap), (d) laundry products (e.g., detergents, fabric softeners, dryer sheets), (e) household products (e.g., scented candles, restroom paper, trash bags, baby products), (f) fragrance (e.g., perfume, cologne, after-shave, essential oils), and (g) other.

Exposure contexts included the following: air fresheners or deodorizers used within indoor environments, scented laundry products coming from a dryer vent, being in a room after it was cleaned with scented cleaning products, being near someone wearing a fragranced product, and exposure to other types of fragranced consumer products.

Health effects were categorized as follows: (a) migraine headaches, (b) asthma attacks, (c) neurological problems (e.g., dizziness, seizures, head pain, fainting, loss of coordination), (d) respiratory problems (e.g., difficulty breathing, coughing, shortness of breath), (e) skin problems (e.g., rashes, hives, red skin, tingling skin, dermatitis), (f) cognitive problems (e.g., difficulties thinking, concentrating, or remembering), (g) mucosal symptoms (e.g., watery or red eyes, nasal congestion, sneezing), (h) immune system problems (e.g., swollen lymph glands, fever, fatigue), (i) gastrointestinal problems (e.g., nausea, bloating, cramping, diarrhea), (j) Cardiovascular problems (e.g., fast or irregular heartbeat, jitteriness, chest discomfort), (k) musculoskeletal problems (e.g., muscle or joint pain, cramps, weakness), and (l) other.

Societal effects included the following: ability to access restrooms, businesses, and other locations that use air fresheners or other fragranced products; loss of workdays or lost jobs due to illness from fragranced product exposure in the workplace; disabling health effects from exposure to fragranced products; and preferences for fragrance-free workplaces, health care facilities, health care professionals, airplanes, and hotels.

**Results**

Main findings are provided in this section, with summaries in Tables 1, 2, and 3. Complete data and statistical analyses for each country individually, and across the four countries, are provided as Electronic Supplementary Material (ESM-Data).

**Study populations, prevalence, and fragranced product use and exposure**

Of the general population surveyed in four countries, 26.0% of adults \( (n = 1151) \) are asthmatic (26.8% US; 28.5% AU; 25.3% UK; 23.2% SE), reporting medically diagnosed asthma (15.8%), an asthma-like condition (11.1%), or both (Table 1). Across the four countries, no statistically significant difference was found in the prevalence of asthma/asthma-like conditions \( (p = 0.087, \chi^{2}\text{-test}) \).

Among asthmatics, 99.8% are exposed to fragranced products at least once a week from their own use (99.1%), others’ use (93.2%), or both (see ESM-Data). Among non-asthmatics,
98.9% are exposed to fragranced products at least once a week from their own use (98.0%), others’ use (89.7%), or both. Across the four countries, no statistically significant difference was found in the use and exposure to fragranced products among asthmatics ($p = 0.99$, chi-square test) or between asthmatics and non-asthmatics ($p = 0.92$, chi-square test).

### Health problems reported from fragranced consumer products

Among asthmatics, 57.8% report fragrance sensitivity (64.3% US, 55.6% AU, 54.0% UK, 57.3% SE); that is, adverse health effects from exposure to fragranced products. The most common adverse health effects were respiratory problems (37.7%), mucosal symptoms (25.4%), asthma attacks (25.0%), migraine headaches (22.6%), and skin problems (17.1%) (Table 2). Among non-asthmatics, 23.1% report fragrance sensitivity (Table 2). Across all types of health effects, asthmatics are proportionally more affected than non-asthmatics (POR 4.56; 95% CI 3.96–5.26).

Severity of health effects from exposure to fragranced products was investigated using criteria for disability according to each country’s legislation (ADAAA 2008; DDA 1992; EA 2010; DA 2008). Among all asthmatics, 24.1% across the four countries (40.3% US, 15.0% AU, 20.1% UK, 20.8% SE) report that effects from fragranced products are potentially disabling, which represents 40.9% of fragrance-sensitive asthmatics (Table 2 and ESM-Data). Among non-asthmatics, 6.4% report potentially disabling effects (Table 2). While both asthmatics and non-asthmatics can be severely affected by fragranced products, asthmatics are proportionally more affected (POR 4.72; 95% CI 4.09–5.45).

### Fragranced product exposures, societal access, and workplace effects

Among asthmatics, 36.7% report health problems from air fresheners and deodorizers, 18.1% from the scent of laundry products coming from a dryer vent, 32.9% from being in a room recently cleaned with scented products, 38.7% from being near someone wearing a fragranced product, and 37.5% from other types of fragranced consumer products (see Table 3).

Fragranced product exposures are associated with loss of societal access: 26.4% of asthmatics are unable or reluctant to use the restrooms in a public place if it has an air freshener, deodorizer, or scented product; 21.9% are unable or reluctant to wash their hands with soap in a public place if the soap is fragranced; 31.6% enter a business and then want to leave as quickly as possible if they smell air fresheners or a fragranced product.

### Table 2  Types of health problems from exposure to fragranced consumer products for asthmatics and non-asthmatics

| Types of health problems from exposure to fragranced consumer products                                      | Asthmatics | Non-asthmatics |
|----------------------------------------------------------------------------------------------------------|------------|----------------|
| Total (n) asthmatic/non-asthmatic individuals                                                              | 1151       | 3284           |
| Health problems from fragranced products (n, %) (fragrance sensitivity)                                   | 666        | 760            |
| Asthmatic individuals: US (64.3%), AU (55.6%), UK (54.0%), SE (57.3%)                                      | 57.8%      | 23.1%          |
| Non-asthmatic individuals: US (23.8%), AU (23.9%), UK (19.0%), SE (25.8%)                                 |            |                |
| Types of health problems from exposure to fragranced consumer products:                                     |            |                |
| Migraine headaches                                                                                        | 22.6%      | 9.1%           |
| Asthma attacks                                                                                             | 25.0%      | 0.7%           |
| Neurological problems (e.g., dizziness, seizures, head pain, fainting, loss of coordination)              | 10.2%      | 3.3%           |
| Respiratory problems (e.g., difficulty breathing, coughing, shortness of breath)                           | 37.7%      | 9.4%           |
| Skin problems (e.g., rashes, hives, red skin, tingling skin, dermatitis)                                   | 17.1%      | 6.3%           |
| Cognitive problems (e.g., difficulties thinking, concentrating, or remembering)                           | 9.8%       | 2.4%           |
| Mucosal symptoms (e.g., watery or red eyes, nasal congestion, sneezing)                                    | 25.4%      | 9.0%           |
| Immune system problems (e.g., swollen lymph glands, fever, fatigue)                                       | 6.5%       | 1.2%           |
| Gastrointestinal problems (e.g., nausea, bloating, cramping, diarrhea)                                     | 8.6%       | 2.2%           |
| Cardiovascular problems (e.g., fast or irregular heartbeat, jitteriness, chest discomfort)                  | 7.9%       | 1.5%           |
| Musculoskeletal problems (e.g., muscle or joint pain, cramps, weakness)                                    | 6.5%       | 1.1%           |
| Other                                                                                                     | 1.6%       | 2.1%           |
| Health problems from fragranced consumer products are potentially disabling                                | 24.1%      | 6.4%           |

Asthmatics: US (40.3%), AU (15.0%), UK (20.1%), SE (20.8%)
Non-asthmatics: US (8.7%), AU (6.0%), UK (6.8%), SE (41%)
product; and 32.9% have been prevented from going someplace because they would be exposed to a fragranced product that would make them sick (see Table 3).

Exposures are also associated with lost workdays and lost jobs: 20.6% of asthmatics have lost workdays or lost a job, in the past year, due to illness from fragranced product exposure in the workplace. Accordingly, fragrance-free workplaces and other indoor environments receive a strong majority of support among both asthmatic and non-asthmatics, as detailed below (see Table 3).

For fragrance-free workplace policies: Among asthmatics, 56.7% would support a fragrance-free policy in the workplace (compared to 17.7% that would not). Among non-asthmatics, 44.7% would support a fragrance-free workplace (compared with 21.4% that would not). Thus, over three times as many asthmatics, and two times as many non-asthmatics, would support fragrance-free workplace policies (than not).

For health care facilities and health care professionals: Among asthmatics, 62.3% would prefer that health care facilities and professionals were fragrance-free (compared to 18.3% that would not). Among non-asthmatics, 47.5% would prefer that health care facilities and professionals were fragrance-free (compared to 23.4% that would not). Thus, over three times as many asthmatics, and two times as many non-asthmatics, would prefer fragrance-free health care facilities and health care professionals (than not).

For airplane travel: Among asthmatics, if given a choice between flying on an airplane with or without fragranced air pumped throughout the passenger cabin, 68.8% would choose an airplane without fragranced air (compared to 17.3% with fragranced air). Among non-asthmatics, 63.3% would choose an airplane without fragranced air (compared to 15.7% with fragranced air). Thus, nearly four times as many asthmatics as well as non-asthmatics would choose an airplane without fragranced air (than with fragranced air).

For hotels: Among asthmatics, if given a choice between staying in a hotel with or without fragranced air, 65.8% would choose a hotel without fragranced air (compared to 22.7% with fragranced air). Among non-asthmatics, 58.9% would choose a hotel without fragranced air (compared to 21.9% with fragranced air). Thus, nearly three times as many asthmatics as well as non-asthmatics would choose a hotel without fragranced air (than with fragranced air).

Study strengths include the following: (a) sample populations in each country were statistically representative of age, gender, and region; (b) respondents were randomly recruited from large web-based panels developed from multiple sources to reflect population characteristics; and (c) the survey employed questions from large national studies previously conducted and published to promote replicability and comparability.

Study limitations include the following: (a) only adults ages 18–65 were included in the survey, which excludes other age groups; (b) the survey relied on self-reported data; however, self-report is a widely accepted method for survey research; (c) the cross-sectional design of the survey represents...
Discussion

This study adds to the growing scientific evidence that exposure to fragranced consumer products is associated with adverse health and societal effects, especially in vulnerable populations such as asthmatics.

For instance, as estimated across the four countries (USCB 2016; ABS 2016; ONS 2016; SCB 2017), over 10 million adults experience asthma attacks from exposure to air fresheners. In addition, for over 20 million asthmatics, illness from exposure to fragranced products in the workplace was associated with lost workdays and lost jobs. Further, for over 24 million asthmatics, health problems from exposure are potentially disabling.

Given that fragranced products are reported to trigger asthma attacks in an estimated 25% of asthmatics, and additional types of health problems in more than 50% of asthmatics, reducing exposure would appear to be a logical, cost-effective, and medically effective approach to asthma control.

To that end, fragrance-free products offer practical alternatives and can reduce fragrance compound emissions (Goodman et al. 2018). Further, as this study demonstrated, fragrance-free policies and fragrance-free environments are preferred by a majority of the population, both asthmatics and non-asthmatics.

To assist in reducing exposure, an important step would be the required listing of “fragrance” on the label for all types of consumer products (not only for foods, drugs, and cosmetics). Analysis of fragranced consumer products found that 2/3 did not disclose that the product contained fragrance (Steinemann 2015). Further, an “unscented” product may not be “fragrance-free”; it may still contain fragrance but with a masking fragrance to cover the scent (Steinemann 2015).

A further step would be the disclosure of fragrance ingredients. Analysis of fragranced consumer products found that most ingredients (over 90%), even potentially hazardous compounds, were not listed on the product label, safety data sheet, or elsewhere (Nematollahi et al. 2018a, b; Steinemann 2015, 2017b). One approach is the listing of certain fragrance ingredients such as allergens (e.g., EU 2009). However, allergens may not address all major health effects of concern associated with fragranced consumer products, as this study demonstrates.

It should not be surprising that fragranced consumer products can be associated with asthmatic exacerbations and respiratory difficulties, as noted by Weinberg et al. (2017). What is surprising, however, is that a seemingly obvious and effective approach—reducing exposure to reduce adverse effects—is not more widely recognized and implemented. However, results from this study may provide the foundations for more effective approaches to reduce the burden of asthma.

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Compliance with ethical standards The research study received ethics approval from the University of Melbourne. Survey methods are detailed in the Electronic Supplementary Material (ESM-Survey Methods).

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