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Running title: Temporal trends of workplace SHS exposure

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ABSTRACT

Background: The workplace is one of the major locations outside of the home for nonsmokers' exposure to secondhand smoke (SHS). New policies in many states and localities restrict or prohibit smoking in the worksites and information on current trends in the exposure of nonsmokers to SHS across various occupational groups is therefore needed.

Objective: To evaluate temporal trends in SHS exposure among nonsmoking workers in the United States, and identify those occupations with workers with the highest levels of SHS exposure.

Methods: We combined serum cotinine (sCOT) measurements and questionnaire data from five survey cycles of the National Health and Nutrition Examination Survey (NHANES: 2001–2010). Trends of SHS exposure by occupations were examined by percent changes and least-squares geometric means (LSGMS) of sCOT concentrations computed using sample-weighted multiple regression models.

Results: Between NHANES 2001-02 and 2009-10, LSGMs of sCOT levels had changed –25% (95% CI: –39, –7%) in nonsmoking workers. The largest decrease was identified among food preparation workers –54% (95% CI: –74, –19%), followed by white collar (–40%, 95% CI: –56, –19%) and blue collar workers (–32%, 95% CI: –51, –5%). LSGMs of sCOT remained highest in food preparation workers in all survey cycles, but the gap between occupations narrowed in the latest survey cycle (2009–10). For instance, the gap in LSGMs of sCOT between food preparation and science/education workers dropped above 70% during 2000 to 2010.

Conclusions: During the period from 2001 to 2010, the overall SHS exposure in nonsmoking workers has declined with substantial decline in food preparation/service and blue-collar workers. Although disparities persist in SHS exposure, the gap among occupations has narrowed.

INTRODUCTION

Second-hand smoke (SHS), i.e. exposure of nonsmokers to tobacco smoke, has been shown to cause cancer, respiratory and cardiovascular diseases in nonsmoking adults and serious respiratory problems in children (Schönherr 1928; US-CDC 2013; US-DHHS 2014). The International Agency for Research on Cancer and the National Toxicology Program of the National Institutes of Health have classified SHS as a human carcinogen (IARC 2004; NTP 2014). In 2004, SHS reportedly caused more than 600,000 deaths worldwide (Öberg et al. 2011). In the United States (US), despite the increasing awareness of those adverse impacts of SHS exposure, and the implementation of smoke-free policies in many states, SHS remains a frequent air pollutant and a major preventable cause of premature deaths and disability. According to the 2014 Report of the Surgeon General, 41,000 estimated deaths per year are attributable to SHS (US-DHHS 2014).

Over the past two decades, many studies have addressed exposure to SHS within diverse settings. Measuring air nicotine concentrations, Hammond and colleagues examined tobacco smoke exposure in offices and production areas and found SHS exposure posed substantial risk to workers in worksites without smoking restrictions (Hammond et al. 1995; Hammond 1999). Our understanding of the extent of SHS exposure within the US general population improved when serum cotinine (sCOT), a metabolite of nicotine present in tobacco and tobacco smoke (Hukkanen et al. 2005), was measured in all participants aged 4 and older beginning with the Third National Health and Nutrition Examination Survey (NHANES III). Based on cotinine data collected in NHANES III, for the first time, Pirkle et al. (1996) reported the extent of SHS exposure, and differences among population groups, within the general US population. Subsequently Wortley et al.

(2002) reported variations in SHS exposure across different occupations. These studies revealed that disparities exist in SHS exposure levels across population groups in different environmental settings, i.e., home and the workplace (Pirkle et al. 1996).

As of June 30, 2014, 26 states and the District of Columbia have established comprehensive smoke-free indoor air laws for bars, restaurants and worksites (US-CDC 2015), whereas such policies were few prior to 1980. Several major events influencing smoking and health issues have also occurred over the past 2 decades, such as the availability of nicotine medications in 1996 (MMWR 1997), the tobacco Master Settlement Agreement in 1998 (US-CDC 2014a), and the Family Smoking Prevention and Tobacco Control Act in 2009 (FDA 2009). Implementation of comprehensive smoke-free policies at the state and local levels along with national events could lead to a decline in SHS exposures in the US.

In this study, we combined and examined the sCOT concentrations and associated questionnaire data regarding occupation, tobacco use, and exposure to SHS, collected in five consecutive cycles from the NHANES by the National Center for Health Statistics (NCHS), within the US Centers for Disease Control and Prevention (CDC) during 2001–2010. We evaluated SHS exposure among nonsmoking workers (≥16 years) with no reported smoker(s) at home across a wide range of occupational categories. The findings from this study establish SHS exposure levels during 2000–2010 among US nonsmoking workers for comparison with future evaluations.

METHODS

Study design and participants

The NHANES are a series of cross-sectional health examination surveys representative of the US civilian non-institutionalized population conducted by the NCHS, CDC. The representative samples of participants are obtained through a complex, stratified, multistage probability design with unequal probabilities of selection. Written informed consent was obtained from all participants and the protocol was approved by the NCHS Research Ethics Review Board.

NHANES data are released in two year cycles. The data included in this study for SHS exposure evaluation were from five consecutive survey cycles: 2001–2002, 2003–2004, 2005–2006, 2007–2008 and 2009–2010. We merged the survey data and calculated new sample weights for each participant, according to NCHS recommendations (CDC-NCHS 2014). We restricted our analyses to participants aged 16 years or older with their occupations available. Sample sizes and characteristics for demographic and socioeconomic covariates were given in Table 1.

For a comparison with sample-weighted sCOT concentrations reported in this study, we cited current cigarette smoking prevalence (defined as having smoked ≥100 cigarettes during their lifetime and currently smoking every day or some days) among working adults in the United States (2004-2010) from the study based on the National Health Interview Survey (NHIS) (MMWR 2011a). Current working adults were defined as the main paid job worked within the last week during the week prior to the interview.

Laboratory Measurements

Blood samples were shipped to CDC's National Center for Environmental Health laboratory on dry ice from the collection site, and the serum samples were produced and stored below -60 ^{o}C until analysis. We analyzed sCOT using high performance liquid chromatography (HPLC) coupled with atmospheric pressure ionization (API) tandem mass spectrometry (MS/MS) (Bernert et al. 2000; Bernert 2008). About 5.95% of serum samples from nonsmoking workers in NHANES 2001-2002 were analyzed with a limit of detection (LOD) of 0.05 ng/mL and the subsequent NHANES 2003–2010 samples were analyzed using an improved method with a LOD of 0.015 ng/mL. The overall intra- and inter-day accuracy and imprecision were below 10%. A previous study reported little difference in statistical estimates as the "dilution" effect attributable to LOD was approximately comparable among different categories (Pirkle et al. 2006). A measured value at or above LOD was classified as "detected" in our analyses. Calibration standards, quality control samples, and laboratory blanks were included in each analytical batch, along with the study samples. Instruments were regularly evaluated to maintain the high sensitivity and reliability of the data. All reported biomarker results met the accuracy and precision specifications of the rigorous quality control/quality assurance program of the Division of Laboratory Sciences, National Center for Environmental Health, CDC (US-CDC 2014b).

Statistical methods

Statistical analyses were performed using SAS® software (version 9.3; SAS Institute Inc., Cary, NC) and SUDAAN® (version 11.0.0; RTI International, , Cary, NC). We first merged the data regarding sCOT concentrations, tobacco and occupation associated questionnaire data, and then calculated new sample weights for each participant according to the recommendations of the NCHS, equaling to 1/5 of the 2-year sample weights provided in the demographic files (US-CDC 2014b). In all of our analyses, statistics were adjusted for the new sampling weights, and unequal selection probabilities and planned oversampling of certain subgroups resulting from the complex multistage probability design of NHANES.

We defined participants as nonsmokers if they had measured sCOT ≤10 ng/mL (Pirkle et al. 1996; Pirkle et al. 2006), and neither self-reported use of cigarettes nor of any other tobacco products within the last five days, including, cigar, pipe and snuff, chewing tobacco, nicotine patch or gum, at the time of the survey. For adolescents aged 16–19 years old, those who self-reported smoking cigarettes within the preceding 30 days were also excluded. In all calculations, nonsmokers who lived with someone who smoked inside the home were excluded based on their responses to the question "Does anyone smoke inside home?", as were those who reported use of any product containing nicotine to help stop smoking based on the responses to the question "Last time used nicotine stop smoking aid".

Occupations were categorized on the basis of the participant's current job which was defined as the main paid job worked within the last week. Occupation codes were based on the 2000 version of the US Census Bureau codes in NHANES 2001-06, and those during 2007-10 were based on the 2002 version. To ensure enough sample size for each occupation, we included those workers even when they had worked less than 35 hours per week based on the responses to the question "Usually work 35 or more hours per week?"

To assess the relationship between sCOT concentration and NHANES release cycle, we conducted temporal trend analysis using sample-weighted multiple linear regression models. We first constructed a "core" linear regression model where the dependent variable was natural log-transformed sCOT concentration, and the independent variable was NHANES data release cycle with the data collected in 2001–02 as the reference group. sCOT was natural log-transformed because of the skewed distributions (Pirkle et al. 1996; Wei et al. 2015; Wei et al. 2016). To examine whether associations between NHANES release cycle and sCOT concentration varied by occupation after adjustment for demographic and socioeconomic covariates (age, gender, race/ethnicity, education and household income) (Table 1 for categories), we added those covariates to the "core" regression model, and then modeled multiplicative interactions between NHANES cycle and occupation by adding their product term to the model.

From the sample-weighted regression analysis, we estimated percent change in sCOT concentration of each occupation category by NHANES cycle as $[\exp(\beta) - 1] \times 100\%$ with 95% confidence intervals (CIs) estimated as [exp(upper/lower limits on β) – 1] ×100%, where β and upper/lower limits are the estimated regression coefficient and 95% CIs for β, respectively. We estimated least squares geometric means (LSGMs) of sCOT concentration by release cycle as exp(least-squares means) with 95CIs as exp(upper/lower limits on least-squares means), where the least-squares means are the cycle-specific mean of sCOT concentration after adjustment for covariates. For concentrations below the LOD for sCOT, as recommended for the analysis of NHANES data, the value of the LOD divided by the square root of 2 was used in the statistical analyses. Statistics were presented only on measurements with sufficient frequency of detection (> 60%) to avoid undue influence on the estimates caused by imputed values in the analyses. In all analysis, a null hypothesis probability level of < 0.05 was considered to be statistically significant.

RESULTS

Among the five consecutive survey cycles (2001–2010), 9568 respondents were identified as nonsmoking workers after excluding those who reported smokers in their home. The sample size characteristics of demographic and socioeconomic categories in the combined dataset are given in Table 1.

Table 2 presents the 7 occupation groups based on the similarities in current work types. Among them, sCOT was detected in 52.1–88.6% of all samples. Relative to the overall population of nonsmoking workers, sCOT was more frequently detected (>80%) in workers preparing and serving foods workers. Nonsmoking workers in science and education group generally had lower detection rate of sCOT (52.1–69.8%) compared with other groups.

LSGM of sCOT in all nonsmoking workers was significantly lower in 2009–10 than in 2001–02 (p = 0.008) after adjustment for occupation, age, gender, race/ethnicity, education, and household income (Fig. 1A –All nonsmoking workers). Compared with 2001–02, LSGMs of sCOT were 40% (95% CI: –56, –19%), 24% (95% CI: –42, –1%), 54% (95% CI: –74, –19%) and 32% (95% CI: –51, –5%) lower in 2009–10 for nonsmoking workers categorized in white collar (Fig. 1B), health related (Fig. 1D), food preparation/service (Fig. 2C), and blue collar (Fig. 2D) occupation groups, respectively (Figures 1 and 2, and Table 3). During the same period from 2001 to 2010, LSGMs of sCOT changed –20% (95% CI: –37, 2%), –12% (95% CI: –33, 17%) and –20% (95% CI: –39, 6%) among nonsmoking workers categorized in science and education (Fig. 1C), sales/finance/business related (Fig. 2A), and office administrative support (Fig. 2B) occupation groups, respectively, but these percentage changes were not statistically different.

During the period 2000–01, nonsmoking workers categorized in food preparation and service had the highest LSGM of sCOT (0.088 ng/mL, 95%CI: 0.055, 0.140 ng/mL) among all groups, which was approximately 158% higher than workers in science and education category (0.0.034 ng/mL, 95%CI: 0.029, 0.041 ng/mL). During the period 2009–2010, the difference in LSGM of sCOT between those two groups decreased to 46%, suggesting SHS exposure gap has narrowed over time.

Figures 3A and 3B show the relationship between sample-weighted GMs of sCOT concentrations by occupation groups and by current cigarette smoking prevalence among working adults who reported having smoked ≥100 cigarettes during their lifetime and currently smoking every day or some days. Among those 20 detailed occupational categories, participants who worked in fields such as education, training and library had the lowest GM of sCOT (0.026 ng/mL), followed by those working in the areas of science, technology and engineering (0.028 ng/mL). Conversely, participants preparing and serving foods had the overall highest GM of sCOT (0.077 ng/mL), followed by those doing construction and extraction jobs (0.060 ng/mL). These data also suggest an association between nonsmoking workers' sCOT concentrations as an indicator of SHS exposure and the prevalence of smoking among adult workers. The overall data show a positive correlation between those two groups with squared correlation coefficient (R^2) of 0.80.

DISCUSSION

Compared to the results found in NHANES III (1988 to 1994) by Wortley et al. (2002), the overall sCOT in the 2001–02 survey decreased approximately 78% among the US nonsmoking workers after excluding those who self-reported home exposure to cigarette smoke. During the period from 2001 to 2010, a further significant decrease in the LSGM of sCOT concentration was detected (– 25%, 95CI: –39, –7%). This finding is consistent with survey data showing an overall slightly declining trend of cigarette use prevalence among working adults during the same time period (MMWR 2011a). It has been noticed that the largest decrease in sCOT has occurred in the 2009-10 survey. However, available data could not allow us to evaluate the impact of specific influential factors on this decrease. Generally, these decreases may be attributable to tobacco control progress made during the period, including the increasing number of states (including the District of Columbia) with comprehensive smoke-free laws that prohibit smoking in indoor areas of worksites, restaurants, and bars (MMWR 2011b).

We observed differences in sample-weighted GMs of sCOT concentrations among some occupations. For example, the sCOT concentrations in workers in the food preparation and service sector (0.041 – 0.088 ng/mL) was nearly twice of that for workers in educational and science related sectors (0.028 – 0.034 ng/mL). Those findings are similar to those previously reported for the NHANES III (1988 to 1994) population (Wortley et al. 2002) in which food preparation and service sectors also had high mean sCOT concentrations (0.24–0.47 ng/mL), although the overall mean sCOT concentrations for nonsmoking workers were far higher during the late 1980 – 1990 period studied by Wortley et al. than we have found in more recent surveys. Again, this probably reflects substantial public health accomplishments in reducing SHS exposure over the past two decades. Although current lower SHS exposures are encouraging, especially the narrowing of gaps between occupations over the period from 2001 to 2010, consistent differences among groups remain. For example, construction, extraction, production, transportation and material moving workers had the highest sample weighted sCOT levels after food servers in our study, whereas education, training and library sector workers had the lowest SHS exposure. Although farming, fishing and forestry workers tended to have relatively lower sCOT concentrations than might be expected, both in our study and in the earlier report by Wortley et al., this might reflect a predominately outdoor setting for work in those categories.

These persistent disparities in SHS exposure for workers in certain occupations may reflect differences in strength and impacts of smoke-free policies across different occupational sectors. For example, blue-collar and service workers continue to encounter workplaces without smoke-free policies, whereas comprehensive coverage percentages for other occupations, such as white-collar workers, are far higher (ANR 2015). The potential importance of such policies in reducing SHS exposures in the workplace is well known (King et al. 2014). This may be particularly important for food servers whose exposure depends not only on coworkers' behaviors in a non-restricted workplace, but also to an important extent on other important factors such as their unavoidable proximity to smoking customers.

As in the home, public areas, social settings etc., workplace SHS exposure is impacted by the behavior of smokers in the vicinity of nonsmoking workers, such as the number of cigarettes smoked and the smoking rates. Recent data indicate that blue-collar workers continue to have higher smoking rates than do other workers despite the overall decline in cigarette smoking rates among US adults (Chin et al. 2012; Chiu et al. 2010; Plescia et al. 2005). Fujishiro *et al.*, 2012 have also reported that blue-collar workers are more likely to be heavy smokers compared to white-collar workers. Thus, factors such as higher smoking rates and a "smoking friendly atmosphere" in the workplace are likely to be important contributors to higher SHS exposure levels among nonsmoking blue-collar workers.

Our results are also consistent with other national surveys. Based on NHIS data, the prevalence of current cigarette smoking was about 19.3 % overall among adult U.S. workers in 2010 with substantial differences in smoking prevalence across occupation groups. However, workers in the construction, extraction, and food trades had smoking prevalence rates approximately 50% greater than the mean (MMWR 2011b). The exposure of nonsmokers in the workplace might be expected to approximately parallel the extent of smoking to which they are exposed, and our finding of relatively higher nonsmoker serum cotinine levels in these same groups is consistent with this expectation. Conversely, smoking prevalence was reportedly < 9% among workers in education, training and library services in the NHIS survey, and this agrees well with the low serum cotinine GMs we found among nonsmoking workers in these categories, which were among the lowest identified in our study. These findings suggest that cigarette smoking prevalence is one of the most influential factors affecting the SHS exposure levels among nonsmoking workers.

The goal of reduction and eventual elimination of SHS exposure in the workplace will require not only universal coverage of smoke-free policies, but also strong policy enforcement. King et al. (2014) found significantly fewer reports of exposure to SHS in workplaces with smoke-free policies (16.4%) than in workplaces lacking such policies (51.3%), but their findings also indicate that enforcement of these restrictions is not always reliable. In a study on workplace SHS exposure in the US trucking industry (Chiu et al. 2010), only 23% of nonsmokers and 10% of smokers reported that the smoke-free policies were always enforced. Plescia et al. (2005), in a study addressing SHS exposure among workers in North Carolina, reported that 3% of workers had violated the company smoke-free policy. Even one person violating a smoke-free policy can result in multiple nonsmokers being exposed to SHS. Thus, the current limited comprehensive smoke-free policies at workplaces and lapses in their enforcement continue to complicate the issue of SHS exposures of nonsmokers in the workplace, and suggest that individual employers should strive for working environments which are 100% SHS free to finally accomplish the goal of comprehensive smoke-free workplaces (Calvert et al. 2013; NIOSH-CIB 2014), and that additional challenges must be overcome to eventually eliminate health risks from SHS exposure among US workers.

Our findings should be interpreted in the context of several limitations. First, the sCOT concentrations reflect the integrated contributions from all potential exposure sources, e.g. inhalation, dermal absorption and ingestion (McGuffey et al. 2014; Wei et al. 2014), and can be further complicated by factors such as the activities and exposure durations in different environments the participants had visited each day. Although we excluded those participants with self-reported smokers inside their homes, it didn't rule out potentially important exposures to outside SHS that penetrated inside through doors and windows, nor the possibility of SHS exposure from visits to the home by smokers. Second, it is not currently feasible to differentiate the workplace SHS exposure, using sCOT concentrations, from other sources, such as public areas and social settings. Thus, this study only indirectly evaluated workplace SHS exposure by assuming that non-workplace SHS exposures occurred at comparable levels across different occupations. Third, this study used a sCOT cutpoint of ≤10 ng/mL in combination with responses to tobacco use questions as the criteria to select nonsmokers. Benowitz et al. (2009) proposed an overall cutpoint of 3 ng/mL, and race/ethnicity-specific cutpoints of 1–6 ng/mL, based on NHANES data collected during 1999-2004. A lower cutpoint than ≤10 ng/mL could exclude more misclassified smokers from nonsmokers, however, it may also exclude participants who were self-identified nonsmokers with heavy exposure to SHS. Fourth, the occupation of each participant was identified using the self-reported information on his/her current job. Because of a low response rate for the question of total hours worked per week, we included workers that reported less than 35 working hours per week to ensure adequate sample sizes for each occupation. Meanwhile, during the 2001-06 survey period, occupation codes were based on the 2000 US Census Bureau codes, while those during the 2007-10 survey period were based on the 2002 US Census Bureau codes. For instance, during the earlier survey periods (2000-2004), workers were categorized in 41 occupational groups while during the periods 2005-10, workers were coded in 23 occupational groups. Thus, variations could exist when we grouped subjects into similar work categories. Fifth, although the majority of samples were analyzed using the improved method (LOD of 0.015ng/mL), the less sensitive method (LOD of 0.05ng/mL) used for the

5.95% of samples collected from nonsmoking workers in the survey cycle from 2001 to 2002 would cause lower detection rates in these samples, and could result in potential variations across the categories. Finally, although we excluded all those participants who self-reported use of cigarettes or other tobacco products including cigars, pipes, snuff, chewing tobacco, patches or gum, some participants who were light or occasional smokers with serum cotinine ≤10/mL could be included if these participants were misclassified as nonsmokers based on their responses to tobacco use questions. Participants with occasional use of other tobacco-related products such as e-cigarettes and with serum cotinine levels ≤10/mL could also be included because questionnaire data to identify and exclude users of these tobacco products during the study period of 2001–10 were not available.

CONCLUSIONS

Our analysis of serum cotinine concentrations among US nonsmoking workers aged 16 years or older shows their SHS exposure declined 25% during the period from 2001 to 2010. Despite this progress, serum cotinine concentrations suggest that disparities in exposure to SHS persist for nonsmokers in certain worker groups (i.e., food preparing/serving workers). Overall, temporal trends suggest the exposure gaps among occupational groups have narrowed in the last decades.

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Table 1–Sample size characteristics of all nonsmoking workers in combined dataset (NHANES 2001-10).

NHANES 2001-2010[a]	Sample size	Unweighted percent, %
All	9568	100.0
Gender		
Male	4690	49.0
Female	4878	51.0
Age (years)		
16-19	938	9.80
20-59	7245	75.7
60+	1385	14.5
Race/ethnicity		
Non-Hispanic White	4280	44.7
Non-Hispanic Black	1802	18.8
Mexican American	2264	23.7
Others	1222	12.8
Ratio of family income to poverty (PIR)		
PIR<1.0	1669	17.5
1.0<=PIR<2.0	1886	19.7
2.0<=PIR<3.0	1410	14.7
PIR>=3.0	4603	48.1
Education		
Below high school	1689	17.6
High school/ general educational development	1718	18.0
Some college or associates degree	2592	27.1
College graduate or higher	2626	27.4
Non-reported	943	9.90

[a] The combined dataset were from five consecutive survey cycles: 2001–2002, 2003–2004, 2005–2006, 2007–2008 and 2009–2010.

Table 2–Occupation category based on the similarity in current jobs of participants from NHANES 2001–10.

Category	Occupation types
White collar	Executive, administrators, and managers, and other management related occupations
Science and education	Engineering, architecture, computer, mathematical, life, physical, social sciences, education, teaching, training and library occupations.
Health related	Health diagnosing, assessing, treating, related healthcare practitioner, technical support, and personal care and service
Sales, finance, business related	Sales supervisors and proprietors, sales representatives, finance, business, commodities, sales workers, retail, personal services and other sales related
Office, administrative support	Secretaries, stenographers, and typists, information clerks, records processing, material recording, scheduling, and distributing clerks, miscellaneous administrative supporting workers
Food preparation and service	Waiters and waitresses, cooks and miscellaneous food preparing and serving workers.
Blue-collar	Workers doing cleaning and building service, vehicle and mobile equipment mechanics and repairers, other mechanics and repairers, construction trades, extractive and precision production, textile, apparel, and furnishings machine operators, machine operators, assorted materials, fabricators, assemblers, inspectors, and samplers, motor vehicle operators, other transportation and material moving, construction laborers, freight, stock, and material movers, hand, and other helpers, equipment cleaners, hand packagers and laborers

Table 3–Association between serum cotinine concentrations (ng/ml) and NHANES release cycle by occupation category. Estimates were computed from sample-weighted linear regression model of interactions between release cycle and occupations, after adjustment for age, gender, race/ethnicity, education and PIR (Ratio of family income to poverty).

Category	Release cycle	LSGMs (95% CIs)	% Change	*p* -value	Sample size	Detection Rate, %
White collar	2001-02	0.046 (0.035, 0.060)	(*ref*)	.	137	65.0
	2003-04	0.045 (0.038, 0.053)	-2 (-30, 35)	0.881	144	73.6
	2005-06	0.038 (0.028, 0.050)	-18 (-45, 24)	0.339	154	69.5
	2007-08	0.036 (0.030, 0.042)	-22 (-44, 8)	0.132	181	72.4
	2009-10	0.027 (0.024, 0.031)	-40 (-56, -19)	0.001	240	66.7
Science and education	2001-02	0.034 (0.029, 0.041)	(*ref*)	.	190	52.1
	2003-04	0.035 (0.027, 0.045)	2 (-25, 39)	0.890	129	69.8
	2005-06	0.033 (0.028, 0.041)	-2 (-25, 27)	0.848	221	69.7
	2007-08	0.033 (0.028, 0.040)	-3 (-25, 25)	0.810	216	62.0
	2009-10	0.028 (0.024, 0.032)	-20 (-37, 2)	0.068	257	60.3
Health related	2001-02	0.043 (0.037, 0.049)	(*ref*)	.	176	67.6
	2003-04	0.042 (0.032, 0.055)	-1 (-28, 35)	0.949	168	72.0
	2005-06	0.037 (0.031, 0.045)	-12 (-30, 10)	0.261	219	74.4
	2007-08	0.042 (0.035, 0.051)	-1 (-23, 26)	0.906	224	79.5
	2009-10	0.032 (0.026, 0.040)	-24 (-42, -1)	0.045	250	66.0
Sales, finance, business related	2001-02	0.034 (0.027, 0.041)	(*ref*)	.	288	64.2
	2003-04	0.056 (0.041, 0.076)	66 (13, 142)	0.010	243	81.5
	2005-06	0.042 (0.034, 0.052)	25 (-8, 68)	0.148	286	78.0
	2007-08	0.041 (0.034, 0.050)	23 (-8, 64)	0.168	293	75.4
	2009-10	0.030 (0.025, 0.036)	-12 (-33, 17)	0.385	297	68.0
Office, administrative support	2001-02	0.039 (0.033, 0.046)	(*ref*)	.	289	67.5
	2003-04	0.040 (0.031, 0.050)	2 (-24, 38)	0.876	252	74.2
	2005-06	0.038 (0.032, 0.045)	-2 (-23, 25)	0.870	273	70.7
	2007-08	0.035 (0.030, 0.041)	-10 (-29, 13)	0.360	263	72.6
	2009-10	0.031 (0.025, 0.039)	-20 (-39, 6)	0.125	238	66.4
Food preparation and service	2001-02	0.088 (0.055, 0.140)	(*ref*)	.	125	80.0
	2003-04	0.081 (0.060, 0.110)	-8 (-48, 63)	0.784	114	85.1
	2005-06	0.059 (0.042, 0.084)	-33 (-63, 21)	0.184	123	82.9
	2007-08	0.077 (0.050, 0.120)	-12 (-54, 69)	0.697	132	88.6
	2009-10	0.041 (0.030, 0.054)	-54 (-74, -19)	0.007	132	80.3
Blue-collar	2001-02	0.049 (0.036, 0.067)	(*ref*)	.	479	75.0
	2003-04	0.063 (0.047, 0.083)	28 (-16, 96)	0.250	389	83.8
	2005-06	0.044 (0.038, 0.051)	-10 (-36, 27)	0.547	511	86.5
	2007-08	0.038 (0.032, 0.044)	-23 (-46, 10)	0.146	551	80.8
	2009-10	0.033 (0.030, 0.037)	-32 (-51, -5)	0.026	632	77.2

Abbreviations: LSGM – least squares geometric mean. 95% CIs: 95% confidence intervals; ref – reference.

Figure Legends

Figure 1– Association between serum cotinine concentrations (ng/ml) and NHANES release cycle for (A) all nonsmoking workers (B) white collar, (C) science and education, and (D) health related. Estimates in Figure (A) are from regression models where the independent variable was NHANES release cycles, after adjustment for occupation, age, gender, race/ethnicity, education and PIR (Ratio of family income to poverty). Estimates in Figures (B, C, D) are from regression models of interactions between NHANES release cycles and occupation groups (Table 2), after adjustment for age, gender, race/ethnicity, education and PIR. Data points represent LSGMS and error bars indicate the 95% confidence intervals. Corresponding numeric data are provided in Table 3.

Figure 2– Association between serum cotinine concentrations (ng/ml) and NHANES release cycle by occupation for (A) sales, finance, business related, (B) office, administrative support, (C) food preparation and service, and (D) blue-collar. Estimates are from regression models of interactions between NHANES release cycles and occupation groups (Table 2), after adjustment for age, gender, race/ethnicity, education and PIR (Ratio of family income to poverty). Data points represent LSGMS and error bars indicate the 95% confidence intervals. Corresponding numeric data are provided in Table 3.

Figure 3–Association between sample weighted geometric means of serum cotinine levels among nonsmoking workers (NHANES 2001-2010) and age-adjusted current cigarette smoking prevalence among working adults (NHIS 2004-2010), respectively. Vertical and horizontal error bars indicate the 95% confidence intervals for sample weighted geometric means of serum cotinine levels and current cigarette smoking prevalence, respectively. Current cigarette smokers are working adults who reported having smoked ≥100 cigarettes during their lifetime and currently smoking every day or some days.

Figure 1.

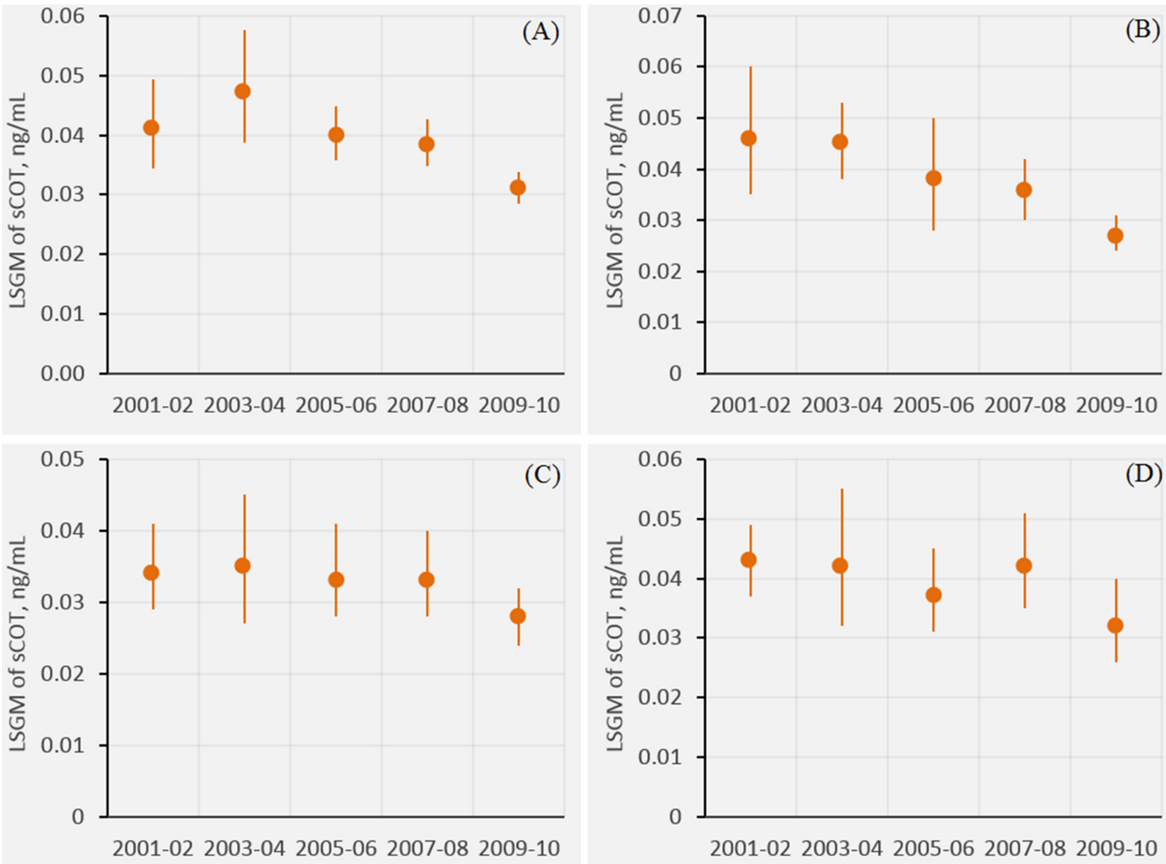


Figure 2.

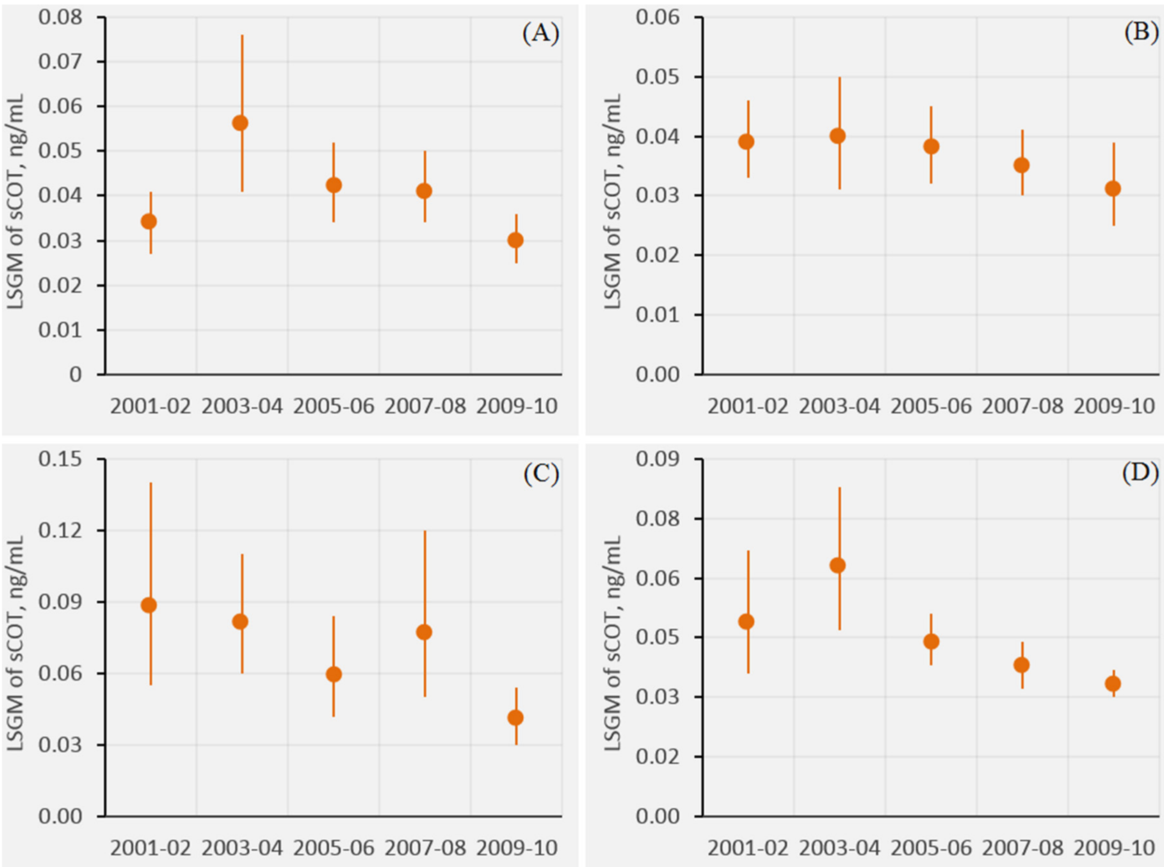
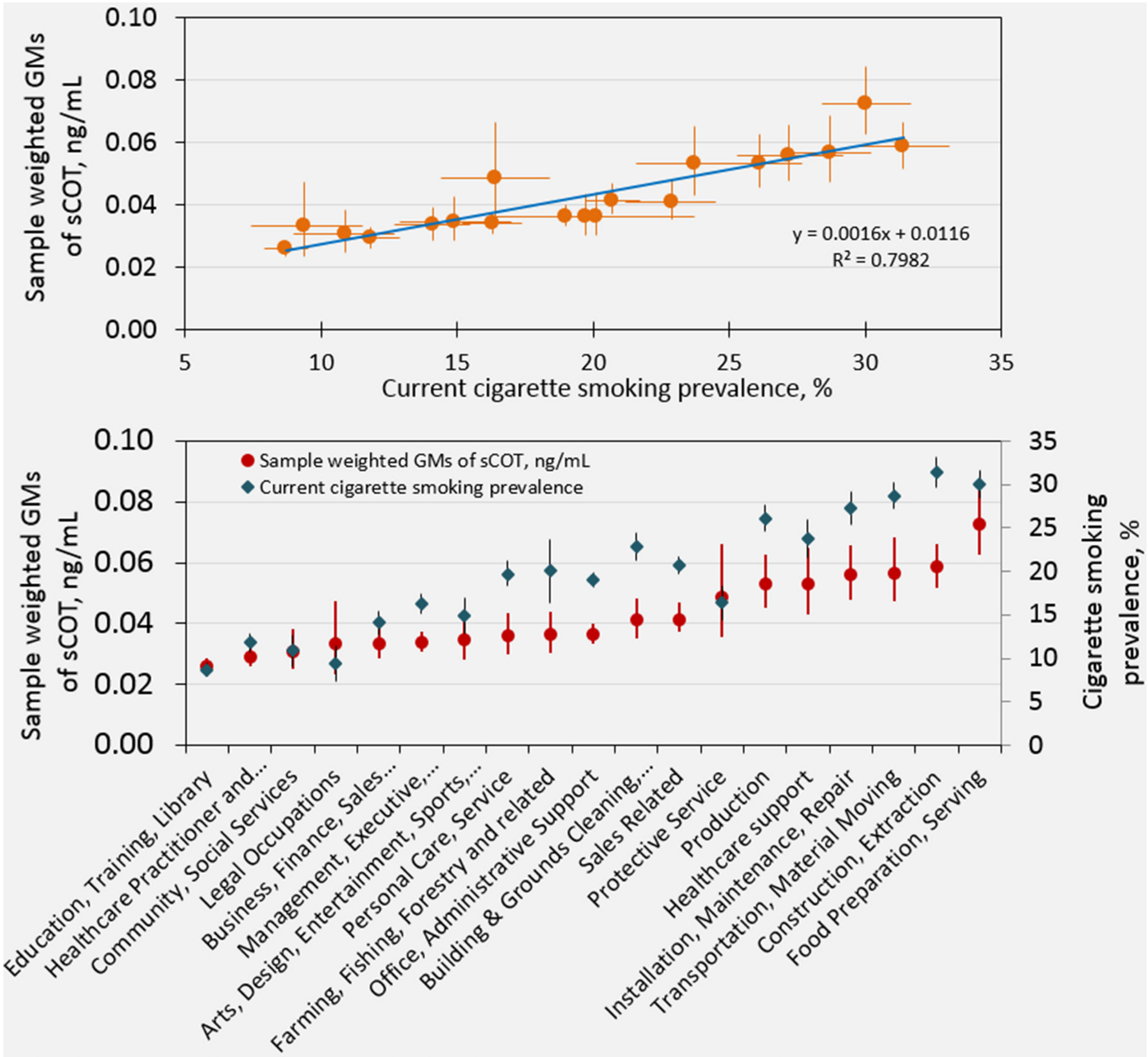

(A)
(B)
(C)
(D)
LSGM of sCOT, ng/mL
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.00
0.15
0.12
0.09
2001-02
2003-04
2005-06
2007-08
2009-10

Figure 3.


Sample weighted GMs of sCOT, ng/mL
Current cigarette smoking prevalence, %
y = 0.0016x + 0.0116
R² = 0.7982
Sample weighted GMs of sCOT, ng/mL
Current cigarette smoking prevalence
Cigarette smoking prevalence, %
Education, Training, Library
Healthcare Practitioner and...
Community, Social Services
Legal Occupations
Business, Finance, Sales...
Management, Executive,...
Arts, Design, Entertainment, Sports,...
Personal Care, Service
Farming, Fishing, Forestry and related
Office, Administrative Support
Building & Grounds Cleaning,...
Sales Related
Protective Service
Production
Healthcare support
Installation, Maintenance, Repair
Transportation, Material Moving
Construction, Extraction
Food Preparation, Serving