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ABSTRACT

Background

Secondhand smoke exposure (SHSe) is associated with numerous adverse health effects and is a major burden for those who do not smoke. SHSe has been primarily characterized via questionnaire, but exposure levels can also be estimated using a specific biomarker, such as cotinine (COT).

Data and methods

Urinary COT measurements and questionnaire data from three cycles (2007 to 2013) of the Canadian Health Measures Survey were combined and analyzed as indicators of regular SHSe for nonsmokers aged 6 to 79 years. Exposure extent was examined by demographic and socioeconomic variable, dwelling type, and exposure location.

Results

Among Canadian nonsmokers, 22% reported having been regularly exposed to smoke; of those, 26% had detectable COT. The range of SHSe significantly differed by age group and exposure location. While the most frequently reported location category was "outside their home" (16%), the most important contributor to elevated COT was exposure "at home". The creatinine-adjusted COT geometric mean (C_COT-GM) for the nonsmokers aged 6 to 79 reporting regular home exposure was 3.7 µg/g, but the C_COT-GM was almost three times higher for those living in an apartment than for those in a single-detached home. Some discrepancy appeared between self-reported SHSe and detectable COT estimates for the assessed subpopulations.

Interpretation

Surveillance by questionnaire and biomonitoring both have their own advantages and are fundamental in identifying the subpopulations most susceptible to SHSe. Using a biomarker provides a quantitative estimate of relative exposure that can be compared over time and with other studies, and this is of particular interest for effective public health interventions.

Keywords

Secondhand smoke exposure, questionnaire, biomonitoring, urinary cotinine, population, self-report, Canadian Health Measures Survey

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What is already known on this subject?

- There is no risk-free level of secondhand smoke exposure (SHSe), which has been mainly assessed by questionnaire.
- Cotinine is a specific biomarker of SHSe.
- Quantitative biomonitoring SHSe estimates have not been available at the national level for the Canadian population.

What does this study add?

- This study provided baseline smoke exposure levels in Canada, which can be used for comparisons over time or with other studies.
- This study identified differences in smoke exposure between various subpopulations, using biomonitoring and questionnaire approaches.
- This study found based on a biomarker (cotinine) that Canadian nonsmokers living in apartments and aged 6 to 19 were the subpopulations with the highest SHSe. SHSe discrepancies by age groups were also identified for respondents who reported no exposure.

Exposure to tobacco smoke has been associated with adverse health effects, and there is no risk-free level of secondhand smoke exposure (SHSe).[1-3] As a result, steps are being taken to reduce the prevalence of tobacco use and SHSe.[4]

Secondhand smoke (SHS) is a mixture of exhaled and sidestream smoke from burning tobacco, the composition of which changes by interaction over time with compounds found in the surroundings.[5,6] Indoor smoke chemicals are especially important because of their lasting presence in dwellings where smoking is allowed and also in those that are adjacent.[3,7-11]

SHSe may occur from living, working or socializing with a smoker; being exposed to smoke in enclosed areas; or being in close proximity to a smoker in outdoor areas.[3] It occurs in various environments, with the home being the most common for children and adolescents.[12]

Self-reported information surveys are commonly used to assess the prevalence of SHSe; however, socially undesirable behaviours are particularly prone to underreporting. Tobacco specific biomarker studies provide increased objectivity in evaluating SHSe,[13,14] but they are more intrusive for participants and costly to conduct. Biomarker studies often measure cotinine (COT), which is the major metabolite of nicotine and has excellent specificity for SHSe[13,15,16] in the absence of nicotine medication usage.[17] However, caution should also be exercised with biomonitoring results: urinary COT estimates are not necessarily equal to exposure levels, as they can be influenced by interindividual factors.

Data from the Canadian Health Measures Survey (CHMS) offer a unique opportunity to estimate nationwide SHSe using both questionnaire and biomonitoring approaches. The main objectives were, first, to characterize the subpopulations of Canadian nonsmokers who are regularly exposed to smoke, by location, socioeconomic variable and dwelling type; second, to identify determinants of higher SHSe; and, lastly, to provide, with the biomonitoring data, relative levels of SHSe for temporal trends and future comparisons.

Methods

Data collection

The CHMS is a nationally representative survey conducted by Statistics Canada, in partnership with Health Canada and the Public Health Agency of Canada. The CHMS excludes full-time members of the Canadian Forces and residents of Crown lands, Indian reserves, institutions and certain remote regions. Together, these exclusions make up about 4% of the target population. Data collection was completed in two steps: an in-person household interview and a visit by the respondent to a mobile examination centre (MEC). The data are from the first (2007 to 2009), second (2009 to 2011) and third (2012 to 2013) CHMS cycles. No significant statistical differences between each cycle were observed for the exposure estimates assessed by questionnaire and biomonitoring.

For increased statistical power and for detailed information on SHSe, data from the three cycles were combined. The overall response rate was 52.9%, resulting in 16,606 respondents aged 6 to 79. Statistics Canada obtained ethics approval from the Health Canada and Public Health Agency of Canada Research Ethics Board for conducting the CHMS. All respondents provided informed consent or assent before participating.[18]

Household interview

Through household interviews, the CHMS gathered information on smoking behaviours, SHSe and use of medications. Respondents aged 12 to 79 were asked if they had

smoked cigars or a pipe or used snuff or chewing tobacco in the past month, and if they had smoked cigarettes daily, occasionally or not at all. Those who responded "not at all" were considered nonsmokers. All respondents aged 6 to 11 were assumed to be nonsmokers.

For each household, respondents were asked if they had been exposed to tobacco smoke in the past month inside their own home every day, almost every day, at least once a week, at least once in the past month, or never. Those who responded "every day" or "almost every day" were considered to be regularly exposed to SHS in their home. Respondents were also asked if in the past month they had been regularly (daily or almost every day) exposed to SHS (a) in a car or other private vehicle, (b) in public locations, or (c) at their place of work (respondents older than 12 only) . Respondents who answered "yes" to any of these locations were considered to be regularly exposed to smoke outside their home. Parents and guardians were invited to attend and assist respondents aged 6 to 11 with the questionnaire, but they were asked to leave for respondents aged 12 to 19.

Urinary free cotinine analysis

Spot urine samples were collected on average 17 days after household interviews using mid-stream in cycle 1, then first catch starting in cycle 2. In addition, from cycle 2 onwards, guidelines provided to respondents instructed them to avoid urinating at least two hours prior to their MEC visit. Standardized procedures were used at the MEC from biospecimen collection to shipping. The testing laboratory (Institut national de santé publique du Québec) is accredited under ISO 17025. COT was extracted from urine for the three cycles as previously described.[19] In cycle 3, COT from respondents aged 12 to 79 was analyzed using a slightly modified method.[20] The limit of detection (LOD) was set at 1.1 ng/ml for all three cycles.

Statistical analysis

Respondents were excluded from the analyses if they reported that they currently smoked cigarettes daily or occasionally (n = 2,349), did not have a valid COT result (n = 187), had incomplete self-reported data (n = 248), reported smoking cigars or a pipe or using snuff or chewing tobacco in the past month (n = 452), reported using a medication with nicotine (n = 92), or reported being a nonsmoker but had a COT above 50 ng/ml (n = 358).[13] Some respondents met more than one exclusion criterion. Only nonsmokers reporting regular SHSe from any location and whose COT was between 1.1 ng/ml and 50 ng/ml were included in the analysis.

To evaluate quantitative SHSe estimates, COT concentrations were adjusted with urine creatinine, and geometric means (C_COT-GM) and 90th percentiles (C_COT-P90) were calculated. Nonsmokers were categorized by sex and, where possible, by detailed age group: 6 to 11 (children), 12 to 19 (adolescents), 20 to 59 (adults) and 60 to 79 (seniors). They were further categorized by socioeconomic variable (ethnicity, education and income) and dwelling type. Ethnicity was defined based on respondents' choice among a list of cultural backgrounds: those who indicated "White" were classified as such; all others were classified as "non-White". Education was dichotomized based on the highest household education level: less than or at least a postsecondary graduation. Total household income was classified by tertile: low (less than $50,000), middle ($50,000 to $89,999) and high ($90,000 or more). Two dwelling types were considered in this study—single-detached home and apartment. Low-rise and high-rise dwellings, including condos, were collapsed into the "apartment" category. For each category of nonsmokers, SHSe was characterized based on three locations: (a) only in their home, (b) only outside their home (i.e., only in private vehicles, public places and workplaces) and (c) in multiple locations (i.e., in their home and in at least one outside location).

The data were analyzed with SAS 9.3 and SUDAAN 11.0.1 software. Analyses used the CHMS Canadian representative survey weights. To account for the survey design, coefficients of variation and 95% confidence intervals (CIs) were calculated using the bootstrap technique.[21,22] Differences between estimates were tested using Student's t-test for statistical significance established at the $p < 0.05$ level. The results are presented with two significant numbers.

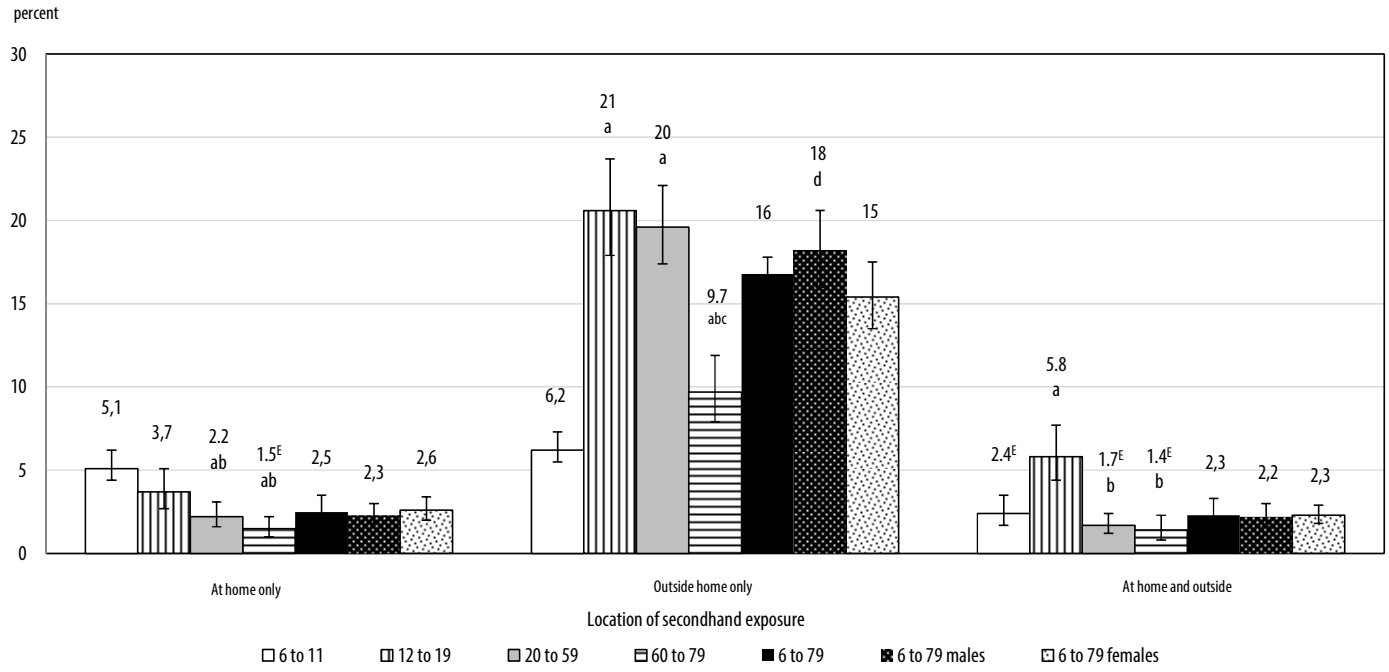
Results

The SHSe distribution by reported frequency in any location for nonsmokers aged 6 to 79 from 2007 to 2013 was 22% for regular exposure (every day or almost every day), 9.5% for exposure at least once a week, 19% for exposure at least once a month, and 50% for never. Among nonsmokers who reported being exposed regularly to SHS, 26% had detectable COT.

By age group, and based on questionnaire data, the prevalence of nonsmokers regularly exposed to SHS was 14% for children (ages 6 to 11), 33% for adolescents (ages 12 to 19), 24% for adults (ages 20 to 59) and 13% for seniors (ages 60 to 79). However, the prevalence of nonsmokers regularly exposed to SHS with detectable COT was 60% for children, 37% for adolescents, and 21% for adults and seniors.

The percentages of nonsmokers were sorted into three locations by sex and age group (Figure 1). Nonsmokers were more likely to report exposure "outside their home" (16%) than in their home (2.5%) or "in their home and outside" (2.3%). Children (5.1%) and adolescents (3.7%) were significantly more likely to report having been exposed to smoke in their home than adults (2.2%) and seniors (1.5%). In contrast, children reported significantly less SHSe "outside their home", compared to other age groups. Adolescents (21%) and adults (20%) reported about double the frequency of exposure "outside their home", compared to seniors (9.7%). The proportion of adolescents who answered that they had been exposed "in their home and outside" was 5.8%, the highest proportion among all age groups. By questionnaire, the only difference observed between sexes was that males (18%) reported significantly higher exposure "outside their home" than females (15%).

Figure 1
Percentage of nonsmokers aged 6 to 79 reporting regular exposure to secondhand smoke, overall, by sex and age group, Canada, 2007 to 2013



[E] use with caution
Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Significantly different ($p < 0.05$) from estimate for respondents aged 6 to 11 (a), aged 12 to 19 (b), aged 20 to 59 (c), and between sexes (d).
Source: Statistics Canada, Canadian Health Measures Survey.

The percentages of nonsmokers with detectable COT, overall, by sex, age group and location, are shown in Tables 1-1 and 1-2. The majority (71%) of nonsmokers reporting exposure "at their home" had biomarker levels consistent with SHSe. In contrast, only 12% of those reporting exposure "outside their home" had detectable COT. Comparisons of biomonitoring data between age groups revealed that adults were significantly less exposed "in their home" than children.

Seniors exposed "outside their home" had the lowest percentage of detectable COT (5.1%), about two times lower than adults and four times lower than children and adolescents. Adults (12%) were also significantly less exposed "outside their home" than children (23%). Among those declaring no SHSe, adults and seniors had significantly lower proportions of detectable COT than children and adolescents suggesting and supported by the combined age group category that the younger aged 6-19 had higher exposure (almost double) that was not reported by the older age group (20-79). For the exposure categories "at home only" and "outside home only" the combined child and adolescent group was significantly more exposed than nonsmokers aged 20 to 79. Males had significantly greater detectable COT proportions than females when reporting exposure "at home and outside" as well as when reporting no regular exposure.

As shown in Tables 2-1 and 2-2, C_COT-GMs were compared for exposure "at home" and "at home and outside". For people aged 6 to 79, the results were 3.7 µg/g and 4.6 µg/g, respectively. A significantly higher C_COT-GM was observed for the younger age group (6 to 19, compared with 20 to 79) "at home". No significant differences were observed by sex. An examination of dwelling types revealed that the C_COT-GM for nonsmokers reporting exposure "at home" was almost three times higher for those living in an apartment than for those in a single-detached home (8.4 µg/g CI: 4.9 to 14, n = 219, vs. 3.0 µg/g, CI: 1.8 to 4.8, n = 70). C_COT-P90s provide an indication of the relative SHSe and were about eight times lower for exposure "outside the home" compared to the other two location categories.

To further characterize the Canadians exposed to smoke, their proportions were evaluated by self-reported location and sociodemographic variable (Tables 3-1, 3-2 and 3-3). For education level, nonsmokers with lower educational attainment reported more SHSe for all three location categories, but the percentages were significant only for exposure "at home" and for combined exposure "at home and outside". In contrast, in terms of detectable COT, nonsmokers with lower educational attainment had a significantly greater exposure only for "outside their home". For ethnicity, White respondents were

Table 1-1
Percentage of nonsmokers aged 6 to 79 with detectable urinary cotinine concentrations, overall, by age group, sex and reported regular secondhand exposure location, Canada, 2007 to 2013 — Part 1

	Self-reported secondhand smoke exposure locations							
	At home only				Outside home only			
	Number	Estimate (%)	CI lower bound	CI higher bound	Number	Estimate (%)	CI lower bound	CI higher bound
Total, 6 to 79 years	376	71	59	81	1,849	12	9.6	15
Male, 6 to 79 years	190	77	60	90	889	14	11.0	19
Female, 6 to 79 years	186	67	50	80	960	10 [E]	6.6	15
Total, 6 to 19 years	262	84 [d]	74	90	713	19 [d]	14.0	25
Total, 20 to 79 years	114	65	48	79	1,136	11	7.6	15
Total, 6 to 11 years	139	86	75	92	149	23	16.0	31
Total, 12 to 19 years	123	82	67	91	564	18 [E]	13.0	25
Total, 20 to 59 years	76	62 [a]	43	79	899	12 [a,E]	8.1	16
Total, 60 to 79 years	38	75	55	88	237	5.1 [a,b,c, E]	2.7	9.3

[E] use with caution

Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Number = the number of individuals self-reporting regular or no exposure by location. CI = confidence interval. Significantly different ($p < 0.05$) from estimate for respondents aged 6 to 11 (a), aged 12 to 19 (b), aged 20 to 59 (c), aged 6 to 19 vs 20 to 79 (d), and between sexes (g).
Source: Statistics Canada, Canadian Health Measures Survey.

Table 1-2
Percentage of nonsmokers aged 6 to 79 with detectable urinary cotinine concentrations, overall, by age group, sex and reported regular secondhand exposure location, Canada, 2007 to 2013 — Part 2

	Self-reported secondhand smoke exposure locations							
	At home and outside				Not exposed			
	Number	Estimate (%)	CI lower bound	CI higher bound	Number	Estimate (%)	CI lower bound	CI higher bound
Total, 6 to 79 years	312	83	75	88	10,674	4.6	3.7	5.7
Male, 6 to 79 years	145	90 [g]	82	95	4,983	5.4 [E]	4.3	6.7
Female, 6 to 79 years	167	77	64	85	5,691	3.9	2.9	5.3
Total, 6 to 19 years	215	87	77	93	4,377	7.2 [d]	5.7	9.1
Total, 20 to 79 years	97	80	67	88	6,297	3.9	3.0	5.1
Total, 6 to 11 years	60	92	84	96	2,111	7.1	5.4	9.2
Total, 12 to 19 years	155	85	75	92	2,266	7.3	5.3	10.0
Total, 20 to 59 years	68	82	68	90	3,938	4.0 [a,b]	3.1	5.3
Total, 60 to 79 years	29	73	47	89	2,359	3.7 [a,b, E]	2.4	5.5

[E] use with caution

Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol E. Number = the number of individuals self-reporting regular or no exposure by location. CI = confidence interval. Significantly different ($p < 0.05$) from estimate for respondents aged 6 to 11 (a), aged 12 to 19 (b), aged 20 to 59 (c), aged 6 to 19 vs 20 to 79 (d), and between sexes (g).
Source: Statistics Canada, Canadian Health Measures Survey.

significantly more exposed than non-White respondents based on self-declared SHSe "at home and outside". However, the results using the C_COT-GM were conflicting—exposure was significantly greater for non-White respondents. Nonsmokers living in the highest-income households reported significantly lower exposure "at home" and "at home and outside". A significantly lower proportion of detectable COT supported the estimated exposure in the latter location category. The relative SHSe estimated with C_COT-GM was significantly lower for the highest-income households, compared to the lowest-income households, when exposed at multiple locations.

Discussion

A better understanding of SHSe is required to improve interventions and minimize negative effects. The present study characterizes the extent of Canadian SHSe as estimated by questionnaire and biomonitoring for different subpopulations. Wong et al.[19] published a paper on SHSe based on cycle 1 of the CHMS. Their overall estimated SHSe was similar to that found in this study; however, by pooling three cycles of data, this study obtained additional details on tobacco smoke exposure. The increase in sample size made it possible to subdivide the adult group into younger and older adults and enabled the quantitative estimation of SHSe. Identifying susceptible subpopulations is of particular interest for public health interventions, especially for children and seniors, who are at even greater risk of SHSe.[1,3,23-25]

Almost one-quarter of nonsmoking Canadians aged 6 to 79 reported regular SHSe and, of those, 26% had detectable COT. The most frequently reported of the three location categories studied was public or other settings "outside their home", yet this location category demonstrated a weak association with measured COT. This suggests that the exposures were brief or of low concentration and thus less likely to be identified by the COT biomarker.

Analysis of the data by location showed that SHSe "at home" was highest for ages 6 to 19, compared to ages 20 to 79, according to the questionnaire, detectable COT proportions and

Table 2-1
Creatinine-adjusted urinary cotinine geometric means and 90th percentiles for nonsmokers by reported location of regular secondhand smoke exposure, age group and sex, Canada, 2007 to 2013 — Part 1

	Self-reported secondhand smoke exposure locations									
	At home only						Outside home only			
	C_COT-GM (µg/g) (95% CI)			C_COT-P90 (µg/g) (95% CI)			C_COT-GM (µg/g) (95% CI)	C_COT-P90 (µg/g) (95% CI)		
	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound	Estimate	Estimate	CI lower bound	CI higher bound
Total, 6 to 79 years	3.7	2.6	5.2	18.0	12	23	…	2.7	2.1	3.3
Total, 6 to 19 years	5.4 [a]	3.9	7.6	28.0 [E]	16	42	…	4.4 [E]	2.5	6.3
Total, 20 to 79 years	3.0 [E]	1.9	4.8	13.0	9.6	16	…	2.5	1.9	3.1
Male, 6 to 79 years	4.5 [E]	3.1	6.5	21.0 [E]	10	31	…	2.6 [E]	1.7	3.6
Female, 6 to 79 years	3.1 [E]	1.9	5.2	16.0	12	20	…	2.9	2.2	3.7

… not applicable
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Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Coefficient of variation > 33.3% when used with the symbol F. C_COT-GM = creatinine-adjusted cotinine geometric mean. C_COT-P90 = creatinine-adjusted cotinine 90th percentile. CI = confidence interval. N/A= not calculated as more than 40% of results less than limit of detection. Significance testing was limited to CRE-GMs by age group, sex and location of exposure. An "a" indicates significant differences ($p < 0.05$).
Source: Statistics Canada, Canadian Health Measures Survey.

Table 2-2
Creatinine-adjusted urinary cotinine geometric means and 90th percentiles for nonsmokers by reported location of regular secondhand smoke exposure, age group and sex, Canada, 2007 to 2013 — Part 2

	Self-reported secondhand smoke exposure locations					
	At home and outside					
	C_COT-GM(µg/g) (95% CI)			C_COT-P90 (µg/g) (95% CI)		
	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound
Total, 6 to 79 years	4.6	3.7	5.8	23 [E]	12.0	34
Total, 6 to 19 years	5.7 [E]	4.1	8.0	24 [E]	8.5	40
Total, 20 to 79 years	4.0 [E]	2.8	5.7	X	…	…
Male, 6 to 79 years	5.8 [E]	4.0	8.4	24	14.0	34
Female, 6 to 79 years	3.8	2.8	5.2	F	…	…

… not applicable
[E] use with caution
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Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol E. Coefficient of variation > 33.3% when used with the symbol F. C_COT-GM = creatinine-adjusted cotinine geometric mean. C_COT-P90 = creatinine-adjusted cotinine 90th percentile. CI = confidence interval. N/A= not calculated as more than 40% of results less than limit of detection. Significance testing was limited to C_COT-GMs by age group, sex and location of exposure. An "a" indicates significant differences ($p < 0.05$).
Source: Statistics Canada, Canadian Health Measures Survey.

C_COT-GM. However, when data were available for all four age groups, the only significant difference observed for exposure "at home" was with detectable COT, the results of which demonstrated that adults were less exposed than children. Children are more likely than adults to live with someone who smokes indoors and have less control in terms of avoiding the smoking behaviour of household members and visitors.[26-28] Similarly to children, people living in apartments have little control over their SHSe since the air entering their apartment can originate somewhere else in the building and can increase their exposure levels.[3,8,11,29] Specifically, their ability to manage the ventilation of the apartment may be limited. In addition, a higher proportion of people might choose to smoke inside because of the distance to an exterior door or the stigma of being seen smoking outside. Apartments also generally tend to be smaller than single-detached homes. This is consistent with the finding that significantly higher C_COT-GMs were observed in apartment residents than in those living in single-detached homes.

For exposure "outside their home", children reported the lowest tobacco exposure relative to all other age groups, while seniors had the lowest percentage of detectable COT. The total clearance of nicotine is decreased in seniors compared to younger adults, and this may explain the difference.[16] According to the biomonitoring data, children and adolescents had similar SHSe "outside their home", and this contrasts with the information obtained from the questionnaire. Discrepancies between self-reported and biomonitoring estimated exposure may reflect differences in aspects that were not captured by the questionnaire, such as the frequency, duration and intensity of exposure, as well as ventilation characteristics. The greater estimated SHSe for children based on detectable COT could be due to exposure in a vehicle, an enclosed space for which a higher COT correlation with SHSe has been observed.[30-32] Other residential settings that better characterize exposure

"outside their home" were not assessed for the 2007 to 2013 period. In addition, depending on their interindividual attributes and their age-related behaviour, children might also be more sensitive to SHSe and therefore have higher COT estimates. However, a study has suggested that higher COT levels in children exposed to smoke versus adults were due to greater SHSe rather than different COT pharmacokinetics.[33]

The only location category where a self-reported difference between the sexes was observed was "outside their home" while for measurable COT, it was the category "at home and outside". In both cases, males had higher measured COT than females, but women have a faster nicotine metabolism than men.[16] The observed discrepancy between the two approaches in terms of location of SHSe may reflect that COT is poorly associated with reported estimates when the specific outside locations are not well defined.

Low socioeconomic status, whether defined by income or level of education, was identified in the literature as of greater risk for SHSe.[3,29,32,34-37] However, this study did not identify a difference for exposure "at their home location". This could be because the sample size is insufficient to detect one, there is

Table 3-1
Questionnaire and biomonitoring estimates for nonsmokers aged 6 to 79 reporting regular exposure to secondhand smoke by reported location of exposure and sociodemographic variable, Canada, 2007 to 2013 — Part 1

	Self-reported secondhand smoke exposure locations									
	At home only									
	Reported %				Detectable cotinine %			C_COT-GM (µg/g)		
Category and sub-categories	Number	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound
Highest household education										
Low education	162	4.6 [a]	3.3	6.5	81	70	89	5.0 [E]	2.9	8.4
High education	214	1.9	1.4	2.5	65	46	80	3.0 [E]	1.9	4.7
Ethnicity										
White	314	2.6	2.2	3.1	76	64	85	4.4	3.3	5.8
Non-White	62	2.2 [E]	1.2	4.0	55 [E]	27	80	F	…	…
Total household income										
Low income (<$50,000)	185	3.2 [E]	2.3	4.5	74	53	88	4.7 [E]	2.5	8.9
Middle income ($50,000 to $89,999)	111	2.9 [E]	2.1	4.1	75	56	88	3.3 [E]	2.1	5.4
High income ($90,000 or more)	80	1.5 [b,c,E]	1.0	2.5	61 [E]	36	81	2.9 [E]	1.8	4.6

… not applicable
[E] use with caution
F too unreliable to be published
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Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Coefficient of variation > 33.3% when used with the symbol F. Low education category = Less than post-secondary graduation. High education category = with a post-secondary graduation. C_COT-GM = creatinine-adjusted cotinine geometric mean (not calculated for exposure outside home). Significant differences ($p < 0.05$) are indicated by (a) between dichotomized categories, by (b) if different from low income and by (c) when different from middle income. CI = confidence interval.
Source: Statistics Canada, Canadian Health Measures Survey.

Table 3-2
Questionnaire and biomonitoring estimates for nonsmokers aged 6 to 79 reporting regular exposure to secondhand smoke by reported location of exposure and sociodemographic variable, Canada, 2007 to 2013 — Part 2

	Self-reported secondhand smoke exposure locations						
	Outside home only						
	Reported %				Detectable cotinine %		
Category and sub-categories	Number	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound
Highest household education							
Low education	454	18	15	22	22.0 [a,E]	15.0	31.0
High education	1,395	16	15	18	9.0	6.6	12.0
Ethnicity							
White	1,410	17	15	19	12.0	9.4	16.0
Non-White	439	16	14	18	11.0 [E]	7.7	17.0
Total household income							
Low income (<$50,000)	626	16	14	18	18.0 [E]	13.0	26.0
Middle income ($50,000 to $89,999)	542	16	14	19	16.0 [E]	9.5	25.0
High income ($90,000 or more)	681	18	15	21	5.2 [b,c,E]	3.2	8.3

… not applicable
E use with caution
F too unreliable to be published
X suppressed to meet the confidentiality requirements of the *Statistics Act*

Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Coefficient of variation > 33.3% when used with the symbol F. Low education category = Less than post-secondary graduation. High education category = with a post-secondary graduation. C_COT-GM = creatinine-adjusted cotinine geometric mean (not calculated for exposure outside home). Significant differences ($p < 0.05$) are indicated by (a) between dichotomized categories, by (b) if different from low income and by (c) when different from middle income. CI = confidence interval.
Source: Statistics Canada, Canadian Health Measures Survey.

Table 3-3
Questionnaire and biomonitoring estimates for nonsmokers aged 6 to 79 reporting regular exposure to secondhand smoke by reported location of exposure and sociodemographic variable, Canada, 2007 to 2013 — Part 3

	Self-reported secondhand smoke exposure locations									
	At home and outside									
	Reported %				Detectable cotinine %			C_COT-GM (µg/g)		
Category and sub-categories	Number	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound	Estimate	CI lower bound	CI higher bound
Highest household education										
Low education	120	3.9 [a]	2.9	5.5	86	75	92	5.2 [E]	3.6	7.4
High education	192	1.7	1.4	2.1	81	70	88	4.3	3.1	5.9
Ethnicity										
White	262	2.5 [a]	2.1	3.1	82	73	88	4.3 [a]	3.3	5.6
Non-White	50	1.5 [E]	1.0	2.1	X	…	…	7.0 [E]	4.5	11
Total household income										
Low income (<$50,000)	148	3.2	2.5	3.9	84	75	91	6.3	4.8	8.4
Middle income ($50,000 to $89,999)	111	2.5 [E]	1.7	3.7	89	78	95	4.3 [E]	2.7	7.0
High income ($90,000 or more)	53	1.3 [b,c,E]	0.8	1.9	69	46	85	2.8 [b,E]	1.5	5.0

… not applicable
[E] use with caution
F too unreliable to be published
X suppressed to meet the confidentiality requirements of the *Statistics Act*

Notes: Coefficient of variation 16.6% to 33.3% when used with the symbol [E]. Coefficient of variation > 33.3% when used with the symbol F. Low education category = Less than post-secondary graduation. High education category = with a post-secondary graduation. C_COT-GM = creatinine-adjusted cotinine geometric mean (not calculated for exposure outside home). Significant differences ($p < 0.05$) are indicated by (a) between dichotomized categories, by (b) if different from low income and by (c) when different from middle income. CI = confidence interval.

Source: Statistics Canada, Canadian Health Measures Survey.

variability in the data or there is no significant difference in the Canadian population. People with lower income and education are less likely to be covered by smoke-free laws in worksites, restaurants and bars.[34] Biomonitoring results agreed with the literature that people with lower education had increased SHSe "outside their home".

Among those who declared not having been regularly exposed to smoke, 4.6% had detectable COT, but some subpopulations are more prone to this bias, as reported in pregnant women.[29] At first glance, this small percentage might indicate that nonsmokers generally reported their SHSe accurately, but it is worth considering that, for example, 12% of nonsmokers in the most frequently reported location category (outside their home) had detectable COT, as well as the significant differences among age groups underreporting their SHSe. The present study indicated that about twice as many children and adolescents as older nonsmokers who did not report SHSe had evidence of smoke exposure based on detectable COT.

There was also evidence of a considerable discrepancy between reported SHSe and COT measurements for children. The reasons for this underreported SHSe may be attributable to self-reported estimates potentially introducing recall and social desirability biases. Parents and guardians reported the SHSe of children. Efforts by stakeholders involved in tobacco control, and heavy advertising on the dangers of SHSe for children, may have affected the social perception for this particular subpopulation[38] and may therefore have led to underreporting of proxy smoke exposure. The underreporting could also indicate that parents and guardians do not know to what extent their children are exposed and that these children are perhaps more often exposed in an enclosed environment with a smoker.

In addition to genetic factors, interindividual factors,[16] including age, can influence estimated biomonitored levels, and this may therefore contribute to the discrepancy between urinary COT and self-reporting. One-quarter of the United States (U.S.) population aged older than 3 had a detectable serum COT in the 2013 to 2014 period,[35] compared to about 6% for urinary COT in this study. Generalization and comparison between studies are not recommended without careful consideration.[39,40] The Canadian and U.S. surveys differed in methodology, including in the biological matrix, assay, age groups and data collection periods. Biomarker studies are recognized for their specificity, but their sensitivity can be poor. Low detectable COT levels were observed for the three assessed location categories, but were particularly observed for "outside their home". Unsurprisingly, in an enclosed environment like a home, 71% of nonsmokers reporting exposure "at home" had detectable COT. While the urinary COT analytic method was robust and the LOD was acceptable for studies of low-level SHSe like this study of the Canadian population, methods with even higher sensitivity are now required. A urinary COT cut-off value of 50 ng/ml was presented by Jarvis et al.[41] in the 1980s to distinguish between smokers and nonsmokers. Since then, the threshold for serum COT has been revised downwards and evaluated for different ethnicities.[42] The threshold for urinary COT has not been reassessed, and uncertainties persist. However, a cut-off range of 30 ng/ml to 200 ng/ml has been widely used;[43] therefore, the 50 ng/ml cut-off was considered appropriate for this study. The impact of varying levels by ethnicity is not considered significant for the Canadian population compared to the U.S. The larger C_COT-GM for the White subpopulation observed for the location category that includes exposure both in and outside their home may be

explained by greater exposure in enclosed areas, such as "at home" or in a vehicle.

There have been important developments in the use of questionnaires and biomarkers, but there is still no gold standard assessment of SHSe, posing challenges for direct comparisons with other studies. SHSe assessments are most frequently based on self-reported questionnaires because of their cost efficiency, but these can be prone to biased reporting and complexity, as many items, including specific inferences, must be collected. Indeed, the results of the present study suggest that while self-reporting is fairly accurate, it may be less exact for certain subpopulations (e.g., younger age groups, certain types of dwelling, certain characteristics of the exposure location) when questionnaires are used to estimate SHSe. While the use of a biomarker such as COT generally reduces these uncertainties, providing a more accurate and objective estimate of recent SHSe, it is subject to interindividual differences, as well as variations in sample collection.

Other potential limitations may explain the observed differences between the self-reported and biomonitoring SHSe estimates. The urine sample was collected at a different time than the administration of the questionnaire, and some self-reported assessment issues (e.g., lack of detail, longer recall period than recommended[44]) likely limited the ability to characterize SHSe in this study in ways that better correlate with COT. This biomarker is also a reliable measure of potential SHSe only over the previous few days,[45] and the urine matrix used in this study also complicated the interpretation of the results.[46] It is unlikely that vaping nicotine sources contributed to the COT estimated in this study's population, since the prevalence assessed by questionnaire in 2013 was very low.[47]

This study provides a detailed characterization of regular SHSe in Canada by combining questionnaire and biomonitoring data. Almost one-quarter of Canadians aged 6 to 79 were still regularly exposed, and disparities existed by socioeconomic variable, dwelling type, exposure location and method of assessment.

Researchers' preferred method for evaluating SHSe is by questionnaire. However, this study compares the results of this method with those obtained for the same population through biomonitoring, not only increasing SHSe knowledge but showing possible limitations of each approach.

Since smoking and SHSe are a costly social and public health problem,[48] accurate data will further assist in devising effective interventions aimed at driving down their risks. This study provides, for the first time at the national level, Canadian quantitative exposure estimates for comparison over time or with other studies, the identification of discrepancies for respondents self-reporting no exposure, and insights on SHSe locations for certain highly susceptible populations.

Given that there is no safe level of SHSe,[3] sustained efforts to reduce exposure disparities are warranted, and ongoing surveillance is paramount.

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Supplementary data

Additional tables with unadjusted-creatinine cotinine estimates are available by contacting the authors.

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