Secondhand Smoke Exposure and Validity of Self-Report in Low-Income Women and Children in India

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abstract

BACKGROUND: There is limited validation of self-reported measures for secondhand smoke (SHS) exposure in low- and middle-income countries. We evaluated the validity of standard self-reported measures among women and children in urban India.

METHODS: Structured questionnaires were administered, and household air and hair samples were analyzed for nicotine concentration.

RESULTS: In total, 141 households of 70 child and 71 adult participants were included. Air nicotine was detected in 72 (51%) homes, and 35 (75%) child and 12 (56%) adult participants had detectable hair nicotine. Correlation between air and hair nicotine was significant in children ($r = 0.5$; $P = .0002$) but not in adults ($r = -0.1$; $P = .57$). Poor correlation was found between self-reported measures of exposure and both air and hair nicotine. No questions were significantly correlated with hair nicotine, and the highest-magnitude correlation with air nicotine was for how often someone smoked inside for adults ($r = 0.4$; $P = .10$) and for home preparation of mishri (a smokeless tobacco product prepared for consumption by roasting) for children ($r = 0.4$; $P = .39$). The highest value for sensitivity by using air nicotine as the gold standard was for whether people smelled other families preparing mishri (47%; 95% confidence interval: 31–62) and prepared mishri in their own homes (50%; 95% confidence interval: 19–81).

CONCLUSIONS: These results raise caution in using or evaluating self-reported SHS exposure in these communities. More appropriate questions for this population are needed, including mishri preparation as a source of SHS exposure.

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Secondhand smoke (SHS) exposure from tobacco is an important cause of lung disease in children and nonsmoking adults.¹ An accurate assessment of SHS exposure is needed for population-based prevalence estimates, epidemiologic studies in which researchers investigate associations with disease, and clinicians during patient examinations.² Self-reported measures and questionnaires are the most commonly used methods for assessing SHS exposure levels in populations of interest. These methods are noninvasive, inexpensive, and easy to administer, providing a useful resource to a wide range of professionals for a variety of purposes.² Additionally, clinicians and health care professionals often use questionnaire methods for ascertaining exposure among their patients.³

Of importance, however, is ensuring that the questions included in reported measurement tools are valid for the target population. Misclassification of SHS exposure may lead to incorrect prevalence estimates in surveillance studies and biased or confounded estimates of risk in epidemiologic studies, and it is frequently cited as a major limitation of studies in which researchers evaluate SHS exposure.² In the clinic setting, patients who are not identified as being exposed to SHS may miss out on important interventions from their providers.

In some studies, environmental and biological samples are collected to confirm reported measures of exposure.^{4,5} However, in large population surveys, biochemical validation of responses is often not feasible for logistical as well as financial reasons. Additionally, the collection of biological samples, such as blood, urine, and saliva, may be deemed invasive or culturally insensitive in some situations.⁶ The measurement of exposure to SHS is particularly difficult because individuals may be exposed in

a variety of environments, and accurately reporting intensity and duration of exposure is often challenging.⁷ A variety of self-report methods have been used to collect SHS exposure information, from daily diaries to directly observed methods.² In children, caregivers are often responsible for reporting exposure, which is a challenge if children are not in the presence of their caregivers full-time or if the caregivers are the source and reluctant to accurately report.⁸ Children are a particularly vulnerable population, elevating the importance of accurate classification in this group. The validation of self-reported measures is necessary because accuracy of self-report may vary across populations and cultures. As long as a majority of our tobacco-use and exposure data are collected via self-reported measures, the ongoing validation of questions will be an important exercise.⁹

To date, there is limited evidence of the validation of reported measures for SHS exposure in India, which is home to the second-largest number of smokers in the world using a wide variety of tobacco products. Valid questions may be especially important for low-income individuals, providing value to researchers and clinicians evaluating tobacco use and associated morbidities in this particularly vulnerable population.^{2,9} Questions used in the Global Tobacco Surveillance System surveys, which have been administered in India, are validated for understanding and comprehension of questions, but routine validation with biomarkers is not conducted (as is the case with the NHANES in the United States).^{10,11} The purpose of this present study is to evaluate the validity of reported measures of exposure to tobacco use in India, specifically women's ability to report personal SHS exposure and caregiver ability to report SHS exposure for children <5 years of age.

METHODS

The current study was nested within ongoing research investigating the association between SHS exposure and tuberculosis in Pune, India. Eligible participants were recruited from low-income communities served by Sassoon General Hospital and Byramjee Jeejeebhoy Medical College (SGH/BJMC). Child and adult patients who presented at SGH/BJMC were recruited to participate in the study. Additionally, for each participant recruited from SGH/BJMC, 1 additional control participant, matched for age and sex, was randomly recruited from the same neighborhood as the patient participant. In the home, field staff administered a structured questionnaire to the participant or primary caregiver to assess reported measures of personal tobacco use or exposure to SHS. Because all children were <5 years of age, no personal tobacco use questions were administered to them. The research team placed 1 passive air-nicotine monitor in the common living space of each home for a period of ~7 days. For quality-control purposes, a 10% sample of blank monitors and a 10% sample of duplicate monitors were included. Additionally, a hair sample was taken from each consenting participant. Approximately 100 strands were cut near the hair root from the back of the scalp, and 3 cm of hair were analyzed, representing the previous 3 months' growth and exposure.¹² Samples were analyzed at the Johns Hopkins University Bloomberg School of Public Health Secondhand Smoke Exposure Assessment Laboratory in Baltimore, Maryland.

Reported Measures

Structured questionnaires were developed to assess reported measures of tobacco exposure. Included questions were sourced from recommended questions in published literature, questions

TABLE 1 Questions Assessing Self-Reported Exposure to SHS Among Adult Women and Primary Caregivers of Children <5 Years of Age in India

Question	Source Reference
Children	
Over the past 7 d, has your child been around SHS from tobacco? Do you remember smelling cigarette, bidi, hookah, and/or waterpipe smoke when your child was present?	AAP ¹³ ; Avila-Tang et al ² 2013
Over the past 7 d, did you and your child visit other people's homes? If yes, did you smell cigarettes, bidis, or hookah?	AAP ¹³
Over the past 7 d, did you and your child visit markets, restaurants, or other public places? If yes, did you smell cigarettes, bidis, or hookah?	AAP ¹³
Over the past 7 d did you and your child use public transportation (bus or auto rickshaw)? If yes, did you smell cigarettes, bidis, or hookah?	AAP ¹³
Over the past 7 d did you and your child visit your place of work? If yes, did you smell cigarettes, bidis, or hookah?	AAP ¹³
Does anyone who currently lives in your home use mishri?	N/A
If someone who currently lives in your home uses mishri, over the past 7 d, about how many times has mishri been prepared in your home?	N/A
How many people who currently live in your home smoke cigarettes or bidis?	AAP ¹³
Not including yourself, which of the following people living in your home currently smoke cigarettes or bidis (all that apply):	AAP ¹³
Your spouse or significant other	
Your child age <18 y	
Other adults in the home	
Does anyone who lives in your home currently use a hookah or waterpipe to smoke tobacco?	AAP ¹³
Over the past 3 mo, has anyone smoked anywhere inside your home?	AAP ¹³
Where do people smoke when they are at your home?	AAP ¹³
Inside only	
Inside and outside	
Outside only	
Depends on the season	
No one (including visitors) smokes at my home	
How often does anyone, including visitors, smoke cigarettes or bidis inside your home?	AAP ¹³
Daily	
Weekly	
Monthly	
Sometimes but not every month	
Never	
Which best describes how cigarette and/or bidi smoking is handled in your home (includes proximate outdoor spaces)?	AAP ¹³
No rules	
Smoking is permitted anywhere	
Smoking is permitted in some places or at some times	
No one is allowed to smoke anywhere	
In general, how often can you smell other people or families preparing mishri when you are inside your own home?	N/A
Adults	
Do you currently smoke tobacco on a daily basis, less than daily, or not at all?	GATS ¹⁰
The next questions are about using smokeless tobacco, such as mishri, gutka, khaini, betel, or pan with tobacco. Smokeless tobacco is tobacco that is not smoked but is sniffed through the nose, held in the mouth, or chewed. Do you currently use smokeless tobacco on a daily basis, less than daily, or not at all?	GATS ¹⁰
Which of the following best describes the rules about smoking inside of your home? Smoking is allowed inside of your home, smoking is generally not allowed inside of your home but there are exceptions, smoking is never allowed inside of your home, or there are no rules about smoking in your home.	GATS ¹⁰
Do you currently work outside of your home? Do you usually work indoors or outdoors? Are there any indoor areas at your work place? Which of the following best describes the indoor smoking policy where you work? Smoking is allowed anywhere, smoking is allowed only in some indoor areas, smoking is not allowed in any indoor areas, or there is no policy.	GATS ¹⁰
Do you currently work outside of your home? Do you usually work indoors or outdoors? Are there any indoor areas at your work place? During the past 30 d, did anyone smoke in indoor areas where you work?	GATS ¹⁰
During the past 30 d, did you visit any restaurants? Did anyone smoke inside of any restaurants that you visited in the past 30 d?	GATS ¹⁰
During the past 30 d, did you use any public transportation? Did anyone smoke inside of any public transportation that you used in the past 30 d?	GATS ¹⁰
In general, how often can you smell other people or families preparing mishri when you are inside your own home?	GATS ¹⁰

N/A, not applicable.

recommended by the American Academy of Pediatrics (AAP), and questions from the Global Adult

Tobacco Survey (GATS) (Table 1).^{2,10,13} Small adjustments were made to account for cultural

relevance and nuances in language. All questionnaires were translated into Marathi, the local language of the

TABLE 2 Air-Nicotine and Hair-Nicotine Concentrations Among Adult Women (*n* = 71) and Children (*n* = 70) in Low-Income Communities in Pune, India

	Children <5 y	Adult Women	All
Air nicotine	<i>n</i> = 70	<i>n</i> = 71	<i>n</i> = 141
Air nicotine (µg/m ³), median (IQR)	0.027 (0.02–0.06)	0.009 (0.001–0.04)	0.026 (0.02–0.05)
Air nicotine (µg/m ³), minimum, maximum	0.007, 2.0	0.001, 2.02	0.001, 2.02
Air nicotine detectable, <i>n</i> (%)	28 (40)	43 (61)	72 (51)
Air nicotine, geometric mean (SD)	0.04 (3.0)	0.02 (4.2)	0.03 (3.8)
Hair nicotine	<i>n</i> = 56	<i>n</i> = 45	<i>n</i> = 101
Hair nicotine (ng/mg), median (IQR)	1.7 (0.3–4.2)	0.2 (0.03–4.2)	0.9 (0.2–4.2)
Hair nicotine (ng/mg), minimum, maximum	0.03, 19.8	0.03, 34.03	0.03, 34.03
Hair nicotine, geometric mean (SD)	1.0 (7.1)	0.5 (12.0)	0.7 (9.3)
Hair nicotine detectable, <i>n</i> (%)	42 (75)	25 (56)	67 (66)

state of Maharashtra, where Pune is located.

Specific questions on the preparation of mishri, a smokeless tobacco product, were incorporated in the questionnaire after the study began. Although mishri is a smokeless product, it is prepared for consumption by using a roasting process, which we were alerted to by participants before the formal incorporation of these questions into the survey. To prepare mishri, tobacco is placed on a hot, metal plate and roasted until the tobacco is pyrolyzed, resulting in a toasted or burnt product that is subsequently powdered for use.^{14,15}

Ethics approval was granted by the SGH/BJMC Institutional Review Board in Pune, India, and the Johns Hopkins University Institutional Review Board. All adult participants or their primary caregivers gave written, informed consent before participation in the parent study.

Statistical Analysis

Descriptive statistics for air-nicotine and hair-nicotine values were calculated, including median (interquartile range [IQR]), range, and whether values were over the limit of detection for the laboratory analysis. Binary variables were generated for each objective marker, with below the limit of detection as the reference category. Air- and hair-nicotine concentrations were categorized into undetectable, low-detectable, and high-detectable levels of nicotine, with the low- and

high-detectable levels delineated by the median value among those with detectable nicotine for each type of measurement. Correlation between air- and hair-nicotine values was estimated by using the Spearman rank test for log-transformed continuous concentrations, tetrachoric correlation for binary measures of nicotine, and polychoric correlation for categorical measures of nicotine. Linear regression was performed on log-transformed air- and hair-nicotine values as independent and dependent variables of interest, respectively. Percent agreement and sensitivity and specificity were calculated by using binary, detectable air- and hair-nicotine concentrations as the gold standard. Statistical analysis was conducted in R (version 3.3.0).¹⁶

RESULTS

In total, 142 households consisting of 70 pediatric participants and 71 adult participants were included in this analysis. Air-nicotine measurements are included for all households; however, 9 (13%) child participants and 25 (35%) adult participants refused hair sample collection. Additionally, 7 (10%) child participants did not have sufficient hair for a sample to be taken. Participants primarily resided in unplanned, low-income, urban communities (*n* = 63; 45%), and 50 (36%) reported an income below the poverty line. None of the adult women reported any current tobacco smoking; however, 19 (26%)

reported current smokeless-tobacco use.

Detectable levels of air nicotine were found in 72 (51%) of the included homes (Table 2). A larger proportion of hair samples, compared with air samples, were found to have detectable levels of nicotine, including those of 35 (75%) pediatric participants and 12 (56%) adult participants. The correlation between log-transformed air- and hair-nicotine values was statistically significant in children (*r* = 0.5; *P* = .0002); however, no association was found in the adults (*r* = −0.1; *P* = .57). This correlation among children did not hold with results that were dichotomized into detectable and undetectable (*r* = 0.2; *P* = .28) levels of exposure; however, it was significantly correlated for the categorical exposure variables (*r* = 0.4; *P* = .02). In linear regression among pediatric participants, each 10% increase in air-nicotine concentration resulted in a 26% increase (95% confidence interval [CI]: 17%–41%) in the geometric mean hair-nicotine concentration.

Among all participants, a poor correlation was found between self-reported measures of exposure for both air- and hair-nicotine values (Table 3). No survey questions were significantly correlated with detectable hair-nicotine levels, and the highest-magnitude correlation with air nicotine was found for how often someone smoked inside the home in adult homes (*r* = 0.4; *P* = .10) and for reported mishri preparation

TABLE 3 Percent Agreement and Correlation for Reported Measures of Exposure to SHS and Air- and Hair-Nicotine Concentrations in Children ($n = 70$) and Adult Women ($n = 71$) in Low-Income Communities in Pune, India

	n (%)	Air Nicotine		Hair Nicotine			
		Percent Agreement	Correlation	P ^a	Percent Agreement	Correlation	P ^a
Children (n = 70)							
Over the past 7 d, has your child been around SHS?	25 (36)	54	0.06	.76	45	0.1	.70
Over the past 7 d, did your child visit other people's homes, and did you smell cigarettes, bidis, or hookah?	9 (13)	—	—	—	29	−0.2	.55
Over the past 7 d, did your child visit markets, restaurants, or other public places, and did you smell SHS?	13 (19)	—	—	—	33	0.03	.79
Over the past 7 d, did your child use public transportation (bus or autorickshaw), and did you smell SHS?	13 (19)	—	—	—	39	1.0	.80
Over the past 7 d, did your child visit your place of work, and did you smell SHS?	2 (3)	—	—	—	24	—	—
Does anyone who currently lives in your home use mishri?	22 (32)	59	0.20	.46	46	0.2	.51
Has mishri been prepared in the home in past 7 d?	7 (11)	63	0.4	.15	33	0.4	.35
How many people who currently live in your home smoke cigarettes or bidis (at least 1 person smokes)?	23 (32)	48	−0.20	.46	44	0.09	.74
Not including yourself, which of the following people living in your home currently smoke cigarettes or bidis?							
Your spouse or significant other	12 (17)	56	0.01	.80	34	−0.05	.78
Your child age <18 y	0 (—)	—	—	—	—	—	—
Other adults in the home	11 (16)	51	−0.2	.44	36	0.3	.47
Does anyone who lives in your home currently use a hookah or waterpipe to smoke tobacco?	3 (4)	54	−0.9	.79	30	0.9	.79
Over the past 3 mo, has anyone smoked anywhere inside your home?							
Where do people smoke when they are at your home (outside or none versus inside)?	18 (26)	56	0.06	.76	32	−0.3	.30
Where do people smoke when they are at your home (none versus inside or outside)?	15 (21)	57	0.09	.72	32	−0.2	.60
Where do people smoke when they are at your home (none versus inside or outside)?	24 (34)	56	0.1	.69	43	0	.80
How often does anyone, including visitors, smoke cigarettes or bidis inside your home (less than or equal to monthly versus daily or weekly)?	8 (11)	63	0.3	.32	32	0.02	.80
Household smoking rules (not allowed versus sometimes or no rules)	24 (34)	56	0.1	.69	45	0.2	.55
Adults (n = 71)							
Current smoking (daily or less than daily)	0 (—)	40	—	—	43	—	—
Current smokeless tobacco (daily or less than daily)	19 (27)	—	—	—	73	1.0	.80
Household smoking rules (not allowed versus sometimes or no rules)	12 (17)	51	0.4	.10	51	0.2	.59
Smoking policy at work (allowed versus not allowed; among the 22 who reported working outside of the house)	7 (32)	—	—	—	47	0.1	.77
Past 30 d SHS exposure at work (n = 22)	6 (27)	—	—	—	53	1.0	.79
Past 30 d SHS exposure at restaurants (n = 14)	5 (38)	—	—	—	63	0.4	.58
Past 30 d SHS exposure on public transportation (n = 37)	16 (43)	—	—	—	54	0.2	.70
How often smell other people preparing mishri (less than or equal to monthly versus daily or weekly)	33 (46)	49	0.001	.80	50	0.2	.66
All participants (n = 141)							
Household smoking rules (not allowed versus sometimes or no rules; n = 141)	38 (27)	53	0.1	.49	47	0.1	.64
How often smell other people preparing mishri (less than or equal to monthly versus daily or weekly; n = 94)	39 (41)	47	−0.02	.79	51	0.2	.61

TABLE 3 Continued

	Air Nicotine			Hair Nicotine		
	<i>n</i> (%)	Percent Agreement	Correlation	<i>r</i> ^a	Percent Agreement	Correlation
Combining exposure questions (no smoking allowed in house and don't smell others' preparing mishri; <i>n</i> = 94)	50 (53)	52	0.03	.78	54	0.2
						.61

—, not applicable.

^a These values are statistically significant at $P < .05$.

in the home for pediatric participants ($r = 0.4$; $P = .39$). Sensitivity and specificity for self-reported exposure questions were low, especially for hair-nicotine comparisons. The highest value for sensitivity by using air nicotine as the gold standard was for whether people smelled other families using mishri on at least a weekly basis (47%; 95% CI: 31–62) and whether they reported preparing mishri in their own homes (50%; 95% CI: 19–81; Table 4). Higher values for sensitivity by using hair nicotine as the gold standard was found for women; however, caution should be used in interpretation because of the low sample size resulting from sample refusal.

DISCUSSION

We report high levels of SHS exposure, a low correlation between reported measures of exposure and air- and hair-nicotine values, and low sensitivity of reported measures of exposure to SHS in low-income Indian households. Importantly, a high proportion of participants reported exposure to the preparation of mishri, and these questions were more highly associated with gold-standard measures of exposure than many traditional SHS exposure questions. Other studies in which researchers evaluate the validity of SHS exposure questions have primarily been conducted in high-income countries, and the existing assessment of SHS exposure in India has been limited to SHS produced by burning cigarettes or bidis (thin, hand-rolled cigarettes wrapped in a leaf¹⁷) and may be overlooking the importance of mishri as an exposure source.^{2,10,18–20}

Hair-nicotine concentrations among the children in this study were higher than those in other studies reporting hair-nicotine concentrations in young children. The median level of hair nicotine found in children in this present study (1.7 ng/mg; IQR:

0.3–4.2) is higher than was found by Al-Delaimy et al²¹ among children living in homes with 2 smokers (median 1.46 ng/mg; IQR: 0.75–2.75) but less than those living in homes with >2 smokers (median 2.02 ng/mg, IQR: 1.08–4.41) in New Zealand. Kim et al²² report median hair-nicotine concentrations of 0.80 ng/mg (IQR: 0.27–2.24) among children living in homes with smokers across 31 countries, including in Latin America, Asia, Eastern Europe, and the Middle East. In a study reporting among children living in households with a smoker in Asia, median hair-nicotine concentrations were found to be 0.87 ng/mg, which increased to 1.21 ng/mg (IQR: 0.36–3.43) when restricting to children <6 years of age.²³ Because all of the child participants in this present study were <5 years of age, it is unlikely that personal tobacco use, either smoked or smokeless, significantly contributed to hair nicotine concentrations. However, the case may be that thirdhand tobacco smoke, or airborne nicotine that has settled and been ingested orally through hand-to-mouth behavior in young children or through dermal absorption, may contribute to exposure.²⁴ For young children, Avila-Tang et al⁵ suggest a cutoff of 0.2 ng/mg for children exposed to SHS.

Few researchers have evaluated the validity of reported measures of tobacco exposure in Indian populations. Self-reported tobacco use among Indian youth in slums in India found low sensitivity (36.3%) for self-reported tobacco use, although SHS exposure was not considered.²⁵ Researchers in a second study evaluated reported measures of exposure to SHS with blood cotinine among industrial workers in India. Although cotinine, a short-term biomarker for exposure to SHS, was used instead of hair nicotine, the results of the study also indicate that reported measures perform poorly in assessing exposure to SHS among

TABLE 4 Sensitivity and Specificity of Reported Measures of Exposure to SHS as Compared With Air- and Hair-Nicotine Concentrations in Children ($n = 70$) and Adult Women ($n = 71$) in Low-Income Communities in Pune, India

	n (%)	Gold Standard									
		Air Nicotine					Hair Nicotine				
		Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)		
Children (n = 70)											
Over the past 7 d, has your child been around SHS?	25 (36)	38 (21–58)	66 (49–80)	44 (24–65)	60 (44–74)	36 (22–52)	71 (42–92)	79 (54–94)	27 (14–44)		
Over the past 7 d, did your child visit other people's homes, and did you smell cigarettes, bidis, or hookah?	9 (13)	—	—	—	—	12 (4–26)	79 (49–95)	62 (24–91)	23 (12–37)		
Over the past 7 d, did your child visit markets, restaurants, or other public places?	13 (19)	—	—	—	—	17 (7–31)	85 (55–98)	78 (40–97)	24 (13–39)		
Over the past 7 d, did your child use public transportation (bus or autorickshaw)?	13 (19)	—	—	—	—	19 (9–34)	100 (66–100)	100 (52–100)	28 (16–43)		
Over the past 7 d, did your child visit your place of work?	2 (3)	—	—	—	—	0 (0–13)	100 (66–100)	—	24 (13–38)		
Does anyone who currently lives in your home use mishri?	22 (32)	39 (22–59)	72 (56–85)	50 (28–72)	63 (48–77)	34 (20–51)	79 (49–95)	82 (57–96)	29 (15–46)		
Has mishri been prepared in the home in past 7 d?	7 (11)	19 (6–38)	95 (82–99)	71 (29–96)	61 (48–74)	11 (3–25)	100 (28–100)	100 (28–100)	28 (16–43)		
How many people who currently live in your home smoke cigarettes or bidis (at least 1 person smokes)?	23 (32)	25 (11–45)	63 (47–78)	32 (14–55)	55 (40–70)	34 (20–51)	71 (42–92)	78 (52–94)	27 (14–44)		
Not including yourself, which of the following people living in your home currently smoke cigarettes or bidis?											
Your spouse or significant other	12 (17)	17 (6–36)	83 (68–93)	42 (15–72)	59 (45–71)	19 (9–34)	79 (49–95)	73 (39–94)	24 (13–40)		
Your child age <18 y	0 (—)	0 (0–17)	100 (87–100)	—	59 (46–70)	0 (0–12)	100 (68–100)	—	25 (14–38)		
Other adults in the home	11 (16)	10 (2–27)	80 (65–91)	27 (6–61)	56 (42–69)	17 (7–31)	93 (66–100)	88 (47–100)	27 (15–42)		
Does anyone who lives in your home currently use a hookah or waterpipe to smoke tobacco?	3 (4)	0 (0–17)	93 (80–98)	0 (0–81)	57 (44–69)	7 (1–19)	100 (68–100)	100 (19–100)	26 (15–40)		
Over the past 3 mo, has anyone smoked anywhere inside your home?	18 (26)	28 (13–47)	76 (60–88)	44 (22–69)	60 (45–73)	24 (12–39)	57 (29–82)	62 (35–85)	20 (9–36)		
Where do people smoke when they are at your home (outside or none versus inside)?	15 (21)	24 (10–44)	80 (65–91)	47 (21–73)	60 (46–73)	19 (9–34)	71 (42–92)	67 (35–90)	23 (11–38)		
Where do people smoke when they are at your home (none versus inside or outside)?	24 (34)	38 (21–58)	68 (52–82)	46 (26–67)	61 (45–75)	36 (22–52)	64 (35–87)	75 (51–91)	25 (12–42)		
How often does anyone, including visitors, smoke cigarettes or bidis inside your home (less than or equal to monthly versus daily or weekly)?	8 (11)	17 (6–36)	93 (80–98)	62 (24–91)	61 (48–73)	12 (4–26)	86 (57–98)	71 (29–96)	24 (13–39)		
Household smoking rules (not allowed versus sometimes or no rules)	24 (34)	38 (21–58)	68 (52–82)	46 (26–67)	61 (45–75)	38 (24–54)	64 (35–87)	76 (53–92)	26 (12–43)		
Adults (n = 71)											
Current smoking (daily or less than daily)	0 (—)	—	100 (82–100)	—	40 (28–52)	0 (0–20)	100 (75–100)	—	43 (28–59)		
Current smokeless tobacco (daily or less than daily)	19 (27)	—	—	—	—	52 (31–72)	100 (76–100)	100 (66–100)	62 (44–79)		

TABLE 4 Continued

	n (%)	Gold Standard									
		Air Nicotine					Hair Nicotine				
		Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)		
Household smoking rules (not allowed versus sometimes or no rules)	12 (17)	23 (12–39)	93 (76–99)	83 (52–98)	44 (31–58)	24 (9–45)	85 (62–97)	67 (30–93)	47 (30–65)		
Smoking policy at work (allowed versus not allowed)	7 (32)	—	—	—	—	22 (3–60)	83 (36–100)	67 (9–99)	42 (15–72)		
Past 30 d SHS exposure at work	6 (27)	—	—	—	—	22 (3–60)	100 (42–100)	100 (9–100)	46 (19–75)		
Past 30 d SHS exposure at restaurants	5 (38)	—	—	—	—	67 (9–99)	60 (15–95)	50 (7–93)	75 (19–99)		
Past 30 d SHS exposure on public transportation	16 (43)	—	—	—	—	40 (16–68)	69 (39–91)	60 (26–88)	50 (26–74)		
How often smell other people preparing mishri (less than or equal to monthly versus daily or weekly)	33 (46)	47 (31–62)	54 (34–72)	61 (42–77)	39 (24–57)	44 (24–65)	65 (41–85)	61 (36–83)	48 (29–68)		
All participants (n = 141)											
Household smoking rules (not allowed versus sometimes or no rules; n = 141)	38 (27)	31 (20–43)	77 (65–86)	58 (41–74)	51 (41–61)	33 (22–45)	74 (56–87)	71 (52–86)	36 (25–48)		
How often smell other people preparing mishri (less than or equal to monthly versus daily or weekly; n = 94)	39 (41)	41 (29–54)	58 (39–75)	64 (47–79)	35 (22–49)	39 (24–57)	70 (47–87)	68 (45–86)	41 (26–58)		

—, not applicable.

nonsmokers.¹⁸ Correlation between hair- and air-nicotine concentrations are consistently found to be higher in younger children compared with older children or adults.²² In a study among women and children in 31 countries living in households with at least 1 smoker, the correlation between household air and hair nicotine was 0.36 ($P < .001$) for children and 0.25 ($P < .001$) for adults.²³ Our results are consistent with these findings.

A large proportion of individuals in our study (64%) had detectable levels of hair nicotine. It is difficult to translate hair-nicotine concentrations into precise units of exposure, such as number of cigarettes per day, because of differences in nicotine metabolism across race and age, as well as type of tobacco product exposure.⁵ However, several researchers have published suggested cutoffs and levels of nicotine found in self-reported tobacco users and SHS exposure at the household level. Kintz et al²⁶ suggest a cutoff of 2 ng/mg hair-nicotine concentration for adult smokers. Avila-Tang et al⁵ identified a cutoff of 0.8 ng/mg for nonsmoking adults exposed to SHS. Klein et al²⁷ reported that adult women reporting exposure to SHS had an average hair-nicotine concentration of 3.32 (SE: 0.85), and those not reporting SHS exposure had an average concentration of 1.24 (SE: 0.39). A study among adults in Baltimore, Maryland, reported median hair-nicotine concentrations of 0.23 (IQR: 0.08–0.44) among nonsmokers, 0.36 (IQR: 0.27–3.03) among those self-reported exposure to SHS, and 16.2 (4.0–40.6) among active smokers. In that study, a cutoff of 2.77 ng/mg was calculated for distinguishing between smokers and nonsmokers.²⁸

Studies in Indian populations are challenging in that there is a high prevalence of smokeless-tobacco use, which will also contribute to biological measures of nicotine

exposure. Of our adult participants, >25% reported smokeless-tobacco use, which is slightly higher than prevalence estimates among women reported by the GATS.²⁹ Removing these individuals from hair-nicotine concentration summary statistics lowers the median concentration of hair nicotine. Even so, 12 (38%) of those reporting no smokeless-tobacco use still have detectable levels of hair nicotine, approaching levels seen among women in Asia who live in households with at least 1 smoker (median hair-nicotine concentration of 0.17 ng/mg).²³

Air-nicotine concentrations are subject to similar limitations as hair nicotine in terms of variability in results based on type of tobacco exposure.⁴ Furthermore, the concentrations found are a time-weighted average of the duration a monitor is placed in a home and cannot distinguish between constant low levels of exposure and 1 extremely high level. A lower proportion of air-nicotine monitors were found to be detectable compared with hair-nicotine values. Air-nicotine concentrations in Asian homes of at least 1 smoker have been reported as 0.09 µg/m³, which is slightly higher than the median value of those with detectable levels in this present study (0.048 µg/m³; IQR: 0.02–0.11).²³ However, because hair samples represent the previous 3 months of exposure to tobacco both inside and outside of the home as well as the fact that smokeless-tobacco use among women would register on hair nicotine but not

air-nicotine values, it is expected that a higher proportion of values would be detectable compared with household air nicotine.

Additional research is needed to determine more appropriate questions related to SHS exposure in this vulnerable population with an eye to the importance of the preparation of mishri as an important source of SHS exposure. Microenvironmental models of exposure are recommended for reported measures of exposure, and those currently recommended may not be applicable in this population.³⁰ Child care may often consist of time spent at family or neighboring households compared with day care settings, as is often seen in higher-income countries. Additionally, restaurants or work settings may not be as relevant for individuals living in conditions of extreme poverty, such as the slum areas of urban India. This is indicated by the poor correlation between household air-nicotine and hair-nicotine concentrations; however, there are likely additional locations where significant SHS exposure occurs. Qualitative research identifying these other, potentially important locations are needed. Additionally, given the highly polluted settings in which these individuals live, it may be difficult for individuals to recall tobacco-specific pollution.

CONCLUSIONS

Children and families in low-income, urban, Indian households are highly

exposed to SHS; however, current methods for assessing exposure by using self-reported measures are inadequate. The results of this study should raise caution to those using or evaluating reported measures of exposure to SHS in these communities in population-based, epidemiologic studies and, perhaps more importantly, studies of exposure–disease relationships. Statistical models that include self-reported SHS exposure as the primary exposure of interest or as a control variable for a different relationship of interest may misclassify individual exposure, and readers should be cautious when interpreting the results. When feasible, objective measures of exposure should be used.

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ABBREVIATIONS

AAP: American Academy of Pediatrics
CI: confidence interval
GATS: Global Adult Tobacco Survey
IQR: interquartile range
SGH/BJMC: Sassoon General Hospital and Byramjee Jeejeebhoy Medical College
SHS: secondhand smoke

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