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Occupational Exposure of Nonsmoking Nightclub Musicians to Environmental Tobacco Smoke

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This study assessed environmental tobacco smoke (ETS) exposures of nonsmoking musicians in nightclub environments using total suspended particulate (TSP), the ultraviolet absorbing fraction of TSP (UVPM), gaseous nicotine, saliva nicotine, saliva cotinine, and perceived smokiness as exposure/dose indicators. Measured exposures were as high or higher than those of other occupational groups studied. TSP ranged from 110 to 1714 μg/m^3 (mean 502, SD 390 μg/m^3). UVPM (mean 221, SD 95 μg/m^3) was associated with gaseous and saliva nicotine concentrations. Paired-sample variation was much higher for TSP than for UVPM. Correlation of TSP with UVPM, gaseous nicotine, and saliva nicotine was poor. Paired-sample gaseous nicotine results were similar, with exposures of 28.0 to 50.0 μg/m^3 (mean 37.1, SD 6.9 μg/m^3), and were high compared with previous studies. These results suggested that nightclub musicians may be exposed to higher concentrations of ETS than some other occupational groups. Saliva nicotine results were consistent with those previously reported with regard to the range of values, large variation observed, and increase in saliva nicotine levels observable after only a few hours of exposure. Saliva nicotine results could not be correlated with other measures of exposure and did not appear to be a reliable biological indicator of absorbed dose. Saliva cotinine levels were comparable to other occupational groups studied, but were lower than previous findings for bartenders and waitresses. Levels ranged from 1.7 to 5.0 ng/mL (mean 3.4, SD 0.9 ng/mL), and increased with number of exposures during the workweek, but did not correlate with other ETS indicators.

Keywords: cotinine, environmental tobacco smoke (ETS), musicians, nicotine, total suspended particulate

Environmental tobacco smoke (ETS), also referred to as secondhand smoke, is a high-profile indoor air quality issue in the United States today. With over 4000 identified chemical constituents, many of which are carcinogenic, toxic, or irritating, ETS is a major contributor to poor indoor air quality,[1,2] and the ubiquitousness of ETS in homes, workplaces, public places, and private establishments has made nonsmoker exposure to tobacco smoke almost unavoidable.[3,4]

In an early study comparing urine and saliva nicotine content of 82 smokers and 56 nonsmokers, Feyerabend et al.[5] detected nicotine in all of the nonsmokers, with half of the measured values falling within the range observed for smokers. Similarly, a later study[6] found detectable levels of cotinine, a metabolite of nicotine, in the blood of 605 out of 663 nonsmokers examined, and reported home and the workplace as the two most frequent ETS exposure locations. In a current Centers for Disease Control and Prevention study testing 23,000 U.S. residents, it was reported that detectable levels of cotinine were found in the blood of all of the first 800 persons tested.[7] Although the subject of ongoing debate, epidemiologic studies associating adverse health effects with ETS exposure persuaded the U.S. Environmental Protection Agency to issue its controversial 1993 decision[4] to categorize ETS as a serious and substantial public health risk. This, in turn, fueled additional pressure by interest groups to restrict smoking in public places such as restau-

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rants, grocery stores, retail operations, aircraft, and hospitals.[8] A myriad of control measures at the federal, state, local, and private industry levels has been implemented,[9,10] including designated smoking areas, improved mechanical ventilation, and outright smoking bans. Meanwhile, the tobacco industry has suggested common courtesy to be the solution to the passive smoking problem.[11]

Research has shown certain occupational groups to be at high risk for ETS exposure. A review of 24 unpublished studies characterizing restaurant ETS exposure found that restaurant ETS was three to five times higher than typical workplaces; that waitresses had the highest mortality rate of any female occupational group in California, including four times the expected lung cancer mortality rate and two and a half times the expected heart disease mortality rate; and that waiters and waitresses had a 50 to 90% increased risk of lung cancer that was most likely attributable to workplace ETS exposure.[12] Siegel[13] concluded that public health protection of restaurant and bar workers necessitates the prohibition of smoking in these facilities. Another study making simultaneous measurements of respirable suspended particulates (RSP) and airborne nicotine in smoking and no-smoking sections of restaurants found that RSP concentration was not a good indicator of ETS, concluded that designated smoking sections in restaurants reduced but did not eliminate ETS exposure, and also found that employees working in no-smoking sections continued to experience ETS exposure.[14]

Bars, nightclubs, and lounges can constitute extreme ETS exposure settings,[13,15] but these establishments are likely to escape ETS regulation in many areas because they represent traditional havens where smokers may congregate. Studies of ambient air quality in such locations have consistently shown elevated levels of particulates, carbon monoxide, and other constituents characteristic of ETS[16,17] to which workers in these establishments are occupationally exposed. While studies of nightclub, bar, and restaurant patrons and employees have been conducted, the only occupational group studied to date has been bar staff such as bartenders, waiters, and waitresses; however, nightclub musicians represent another occupational group with the potential for substantial ETS exposure.[1] Also at risk are their support personnel, i.e., equipment handlers, sound engineers, and equipment technicians. In many if not most instances, musicians are considered general contractors and are not held under the law to be employees of the nightclub at which they perform. They are therefore not eligible for benefits, such as health insurance, normally associated with an employee/employer relationship. Since performing is a secondary job for many nightclub musicians who may be covered by health insurance at their primary place of employment, their ETS-related health care costs as an occupational group may be unrecognized. No study has been reported that characterizes ETS exposures of musicians in nightclub environments; therefore, the purpose of this study was to perform such a characterization using a combination of environmental and biological exposure indicators.

MATERIALS AND METHODS

Nine caucasian nonsmoking musicians (eight male, one female) from three Oklahoma City bands were identified as potential study subjects. The candidates were informed of the nature and objectives of the study and were asked to sign letters of informed consent. Prior to any exposure measurements, each volunteer was asked to complete a questionnaire that characterized his or her smoking history, current smoking status, and potential ETS exposures. All nine subjects, aged 21 to 40 years, described themselves as nonsmokers, and only one indicated any ETS exposure other than that associated with nightclub performances. Indications of recurring smoke-related health problems were negative from both the questionnaire results and direct physical examination.

Permission was obtained to conduct unobtrusive sampling and other study activities at three nightclubs offering live music and dancing in the Oklahoma City metropolitan area. Site selection considerations included the bands' play schedules, club structure and layout, and type of ventilation system. Subjective observations made during data collection suggested that although audience sizes were typically smaller on Thursday nights than on Friday or Saturday nights, there was no apparent difference in audience makeup (i.e., fraction of smokers) by club, night of week, or band performing. Each club operated at or near maximum rated capacity for at least some period during each performance sampled.

During data collection, pre- and postexposure interviews, questionnaires, and physical examinations were administered to the study subjects by a licensed physician. The interviews ascertained any known outside ETS exposure that might impact the study results and gave each participant the opportunity to provide a subjective ETS exposure assessment. The questionnaire design was modeled after that used by Cummings et al.[6] Each study site received a prestudy assessment of its room characteristics, heating/ventilating/cooling (HVAC) system, and smoke removal system, if any, to evaluate their potential impact on ETS exposure levels. The assessment included determinations of room layout, room volume, stage and ceiling height, stage area and features, HVAC system type and operating modes, maximum legal room occupancy, presence of any smoke removal systems, and availability of fresh (outside) air via doors and windows.

Air sampling to characterize ETS exposure involved both area and personal sampling. Total suspended particulate (TSP) was selected rather than respirable suspended particulate (RSP), because the nonrespirable but inhalable fraction of TSP would contribute to the musicians' exposure to nicotine and other ETS constituents. Area TSP sampling was conducted using three-piece 37-mm polystyrene cassettes with tared 1 μm pore size polytetrafluorethylene (PTFE) filters. The filters were placed in a desiccator and conditioned overnight at 50% relative humidity over a saturated sodium dichromate solution,[18] then weighed on a microbalance. Two concurrent stage-area TSP samples were taken at 2.8 L/min flow rate for the duration of each performance, with air pumps calibrated immediately before and after sampling using a bubble tube primary standard. The exposed filters were again humidity conditioned overnight and reweighed, then shipped to Tulane University for analysis of the ultraviolet absorbing fractions of the particulate matter (UVPM).[18]

Personal air samples for gaseous nicotine exposure were taken using specially treated passive (diffusion) nicotine samplers.[19,20] Passive monitors were selected over active monitoring due to the subjects' need to be unencumbered while performing. Each subject was assigned two monitors, which were worn for the duration of the study (due to the detection limits of the sampling and analytical method); thus, the sample results represented aggregate, or time-weighted average (TWA), exposures for each person over the entire study period. The monitors were opened on the subjects' arrival at the sites, and were capped and sealed between study nights. The samplers were procured from and analyzed by Dr. Brian Leaderer of Yale University's John B. Pierce Laboratory.

ETS byproduct retention was evaluated by obtaining saliva samples from each subject before, during, and after each performance. Saliva samples were selected because they were relatively noninvasive and convenient compared to blood and urine sampling,

and because saliva cotinine has been shown to provide a good estimate of ETS byproduct retention.[21,22] Two sterile cotton wads were placed in the subject's mouth for a period of three to five minutes, removed to a 10-cc syringe, and the saliva expunged into sterile vacuum tubes. Following an established methodology,[23] a sample volume of at least 1 mL was obtained. The saliva samples were frozen after each night's collection and subsequently placed in dry ice for shipment to a commercial analytical laboratory where nicotine and cotinine content were assayed via gas chromatography. Following each performance, each subject provided an independent, subjective assessment of the ETS level present, i.e., the smokiness of the club atmosphere.

Sampling was limited to Thursday, Friday, and Saturday nights due to the performance schedules of the participating bands. There was little control over scheduling of bands for performances at particular locations on particular nights of the week, with the result that data could be collected for only two nights of the week at each club, i.e., either Thursday–Friday (Clubs 2 and 3) or Friday–Saturday (Club 1), except that at one club a single data point was obtained for the third night as well (Club 3). This incomplete block data structure precluded statistical analysis using analysis of variance techniques; however, data were obtained for all three clubs for Friday night, allowing some formal statistical comparison of means between clubs. The study took place between late February and early May, and cool weather caused all of the clubs to operate with doors and windows closed, so that air sample results may be taken to represent worst case ETS exposure conditions.

RESULTS AND DISCUSSION

Results indicated the subjects were exposed to levels of secondary smoke as high or higher than other occupational groups previously studied, including bartenders and waitresses. Individual retention of ETS byproducts, as measured by saliva nicotine and cotinine levels, was lower than anticipated. Perceived ETS exposure, as reported by the subjects, was not consistent with other ETS-indicator measurements. Locational attributes were largely insignificant; however, there was evidence that ETS exposure and retention were impacted by the type and operation of the differing HVAC and air cleaning systems employed at each club.

TSP Analysis

TSP concentrations were somewhat higher than the RSP concentrations measured in other public house ETS studies, ranging from 110 to 1714 μg/m³ of air sampled (Table I), with a mean of 502 μg/m³ (SD=390 μg/m³), compared with 75 to 1320 μg/m³ RSP reported in other works.[9,11] This was expected, since RSP represents a mass fraction of TSP, the fraction comprised of particles smaller than 10 μm aerodynamic equivalent diameter.

Variability between paired TSP samples was high, with greater than 100% difference in the results of 7 of 15 paired samples (Table II). This was not surprising, because TSP collection gathers all airborne particulates and the gravimetric analysis does not distinguish between ETS and other particulates. Thus, large non-ETS dust particles unevenly sampled by the two devices may contribute a large mass to one filter and thereby skew the measurement results. Although mean TSP for all samples collected on Thursdays was 337 μg/m³, on Fridays was 515 μg/m³, and on Saturdays was 579 μg/m³, there was no consistent pattern indicating an effect of day of week when TSP levels for Thursday–Friday or Friday–Saturday were compared by club sampled.

TABLE I. TSP and UVPM Concentrations by Club and Day of Week

	Club 1		Club 2		Club 3		
	Friday	Saturday	Thursday	Friday	Thursday	Friday	Saturday
TSP[A]							
	297	1461	110	537	708	717	1137
	300	382	160	389	530	488	
	149	590	174	168		1004	
	383	501	343	675		866	
	293	254				124	
	1714	877					
	443	119					
	222	118					
		349					
Mean	475	517	197	442	619	640	1137
SD	509	427	102	217	126	346	
UVPM[A]							
	206	190	215	442	294	358	223
	181	204	167	385	268	306	
	183	269	42	168		362	
	189	171	301	138		383	
	184	164				208	
	154	73					
	181	228					
	240	38					
		173					
Mean	190	168	181	281	281	324	223
SD	25	72	108	153	19	71	

[A]Concentration units are μg/m³

UVPM Analysis

Much less variation was seen in the UVPM results than in the TSP results. As shown in Figure 1, UVPM and TSP results were not well correlated (correlation coefficient 0.17). UVPM concentrations were consistent with those reported by Rando for laboratory ETS studies.[18] Consistency of results between paired samples was good; only 4 of the 15 paired UVPM results exhibited differences of more than 35%, compared with differences of more than 100% in 7 of the 15 paired TSP results (Table II).

UVPM concentrations had an overall mean of 221 μg/m³ (SD 95 μg/m³). Contrasting UVPM levels were not apparent when compared by day of the week (Table I). UVPM means by location for Friday night only were: Club 1, 190 μg/m³; Club 2, 283 μg/m³; and Club 3, 324 μg/m³. When pooled over all sample nights, Club 1 had a mean of 178 μg/m³, Club 2, 232 μg/m³, and Club 3, 300 μg/m³. Differences in UVPM levels at the three locations were thought to be related to the facility layout and types of HVAC and smoke removal systems in use (see Site Influence section).

Gaseous Nicotine Analysis

Gaseous nicotine sample results are presented in Table III. Results were similar for paired samples, generally varying by less than 20%, with levels ranging from 28.0 to 50.0 μg/m³ and a mean of 37.1 μg/m³ (SD 6.9 μg/m³). These levels were high compared to previous studies, which suggested a significant ETS exposure potential for the study participants.

Because gaseous nicotine samples were taken as cumulative exposures for each band member, they were by definition TWAs.

TABLE II. Results of Concurrent TSP and UVPM Samples

Band Code	Day of Week	TSP Conc (μg/m³)	TSP Ratio	UVPM Conc (μg/m³)	UVPM Ratio
3	Fri	717	1.47	358	1.17
		488		306	
2	Fri	297	1.01	206	1.14
		300		181	
3	Sat	1461	2.48	269	1.07
		590		204	
3	Sat	501	1.31	190	1.57
		382		171	
3	Thu	708	1.34	294	1.10
		530		268	
3	Fri	1004	1.16	362	1.06
		866		383	
2	Thu	110	1.46	215	1.28
		160		167	
2	Fri	537	1.38	442	1.15
		389		385	
2	Fri	149	2.57	183	1.03
		383		189	
2	Sat	254	3.45	164	2.25
		877		73	
3	Fri	1714	5.84	154	1.19
		293		184	
3	Thu	174	1.97	42	7.15
		343		301	
3	Fri	168	4.01	168	1.21
		675		138	
1	Fri	443	2.00	81	1.32
		222		240	
1	Sat	118	2.97	38	4.58
		349		173	

To compare gaseous nicotine, TSP, and UVPM measurements for each band, TWA TSP and UVPM exposures were calculated from TSP and UVPM results and the associated sample period durations. As shown in Table IV, gaseous nicotine data were consistent with UVPM, but not with TSP. This finding supports the proposition that UVPM analysis is a better indicator of ETS than TSP analysis.[18]

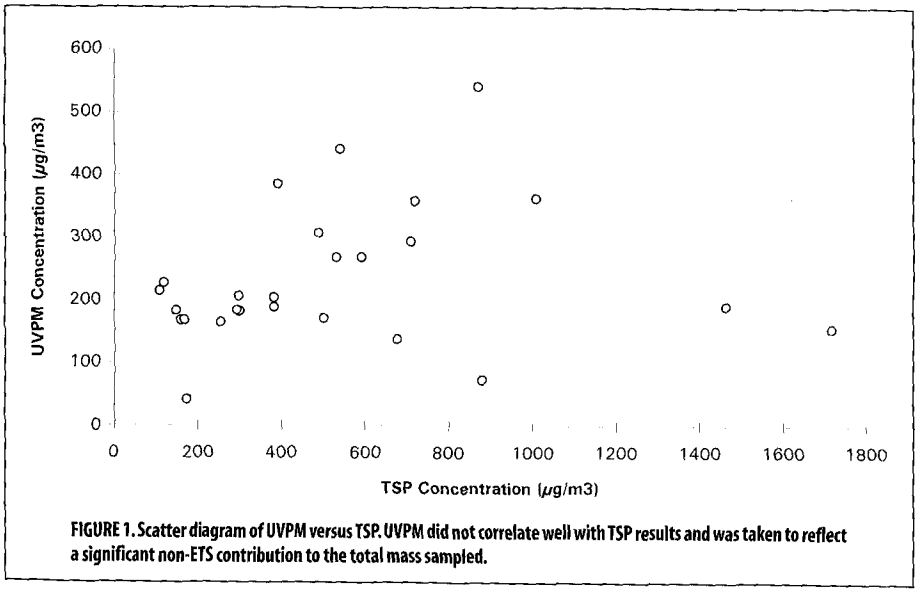

FIGURE 1. Scatter diagram of UVPM versus TSP. UVPM did not correlate well with TSP results and was taken to reflect a significant non-ETS contribution to the total mass sampled.

Saliva Nicotine

Saliva nicotine and cotinine were used as indicators of the subjects' absorbed ETS dose. Because nicotine has a short biological half-life compared with cotinine (2.5 hours versus 28 hours), it served as the short-term indicator of dose. Saliva nicotine results (Table V) were consistent with previously reported results with regard to the range of values, the large variation observed, and the increase in saliva nicotine levels observable after only a few hours of exposure.[24] There was no consistent relationship between night of week played and the nightly saliva nicotine mean for each band, but there did appear to be differences related to the club played. Mean end-of-night saliva nicotine for Friday night performances (the only night for which data were available for all three clubs) was twice as high for Clubs 2 and 3 with 115 ng/mL and 97 ng/mL, respectively, than for Club 1 with 50 ng/mL. Associated differences were also seen for UVPM, with 283 and 324 μg/m³ for Clubs 2 and 3, and 190 μg/m³ for Club 1 (Table VI). This was likely due to differences in the club ventilation systems (see Site Influence section).

Saliva Cotinine

Due to unforseen difficulties with the contract analytical laboratory, saliva cotinine analyses were limited to consolidated samples of saliva from band members for 15 nights of exposure. Initial saliva analyses employed a method with a 1 ng/mL detection limit, and indicated continine above 1 ng/mL in only 2 of 141 samples. Subsequently, the remaining end-of-period saliva samples were pooled by exposure night and analyzed by a different method having a 0.1 ng/mL detection limit, and showed cotinine concentrations ranging from 1.7 to 5.0 ng/mL in the pooled samples (Table VII). Since nicotine (the precursor of cotinine) was found in all of the individual samples, these results suggested that the analytical laboratory erred in the choice or execution of the first analytical technique. The net result was that cotinine data for individuals was not available for comparison with other findings.

Saliva cotinine levels (Table VII) were low compared with those reported for other occupational groups, including bartenders and waitpersons.[3,15] For 15 study nights, the mean cotinine level was 3.4 ng/mL (SD 0.9 ng/mL) with values ranging from 1.7 to 5.0 ng/mL. Because individual nicotine intake and metabolism may vary for a given exposure, and because saliva volumes from each band member were not equal in the pooled samples, the analytical results were difficult to interpret and at best provided only an approximate indication of absorbed dose.

As expected from previous studies, subjects' cotinine levels increased with number of performances per week.[25] The effect was noticeable after two exposure periods. The study found measurable cotinine levels in all subjects at the beginning of the exposure period, indicating their residual retention of tobacco smoke byproducts. It also indicated that absence of ETS exposure during nonperformance days allowed individuals to return to very low levels of ETS byproduct retention. It is not clear from this study whether more habitual exposure, e.g., performances five or six nights per week, would result in baseline cotinine levels comparable to occasional smokers.

TABLE III. Gaseous Nicotine Concentrations by Band

Subject Code	Nicotine (µg/m³)	Exposure Time (hrs)	TWA (µg/m³)	Paired Monitor Ratio
LC001	0.88	18.5	33.0	
LC002[A]				
LC003	0.75	18.5	28.2	1.03
LC004	0.77		28.9	
LC005	0.91	18.5	34.2	1.18
LC006	1.07		40.2	
LC007	0.93	18.5	34.9	1.14
LC008	1.06		39.8	
SA001	0.90	22.5	27.8	1.01
SA002	0.91		28.1	
SA003	1.00	22.5	30.9	1.63
SA004	1.63		50.3	
SA005	1.38	22.5	42.6	1.05
SA006	1.31		40.4	
ST003	1.94	29.5	45.7	1.08
ST004	1.80		42.4	
ST005	1.65	29.5	38.8	1.13
ST006	1.87		44.0	

[A]Monitor number LC002 was destroyed during usage.

TABLE IV. Gaseous Nicotine versus TSP and UVPM by Band

Band Code	Nicotine (µg/m³)	TSP (µg/m³)	UVPM (µg/m³)
1	34	399	177
2	36	346	221
3	42	631	236

Smoke Assessment

Subjects characterized their smoke exposure as light, moderate, or heavy (1, 2, or 3, respectively). For 12 of 17 study nights, band members were in complete agreement as to their secondhand smoke exposure. Where differences were exhibited, no more than one person's assessment disagreed with those of the other members, and in no instance did subjects report "light" and "heavy" for the same exposure period.

Perceived smokiness assessments showed no relation to measured saliva nicotine, TSP, or UVPM, so that perceived smokiness rating did not appear to be a good indicator of atmospheric ETS. Personal bias was apparent in the subjective smoke assessment, in that subjects routinely performing in non-nightclub environments had consistently higher smoke ratings than those who more regularly performed in nightclubs.

Site Influence

Club 1 was located in a hotel and had a floor area of 4320 ft², a room volume of 64,800 ft³, and a rated occupancy of 350 persons. Access was limited to a single entrance that did not lead directly outdoors, and windows and fire exit doors were closed so that no fresh air was available through open doors or windows. Ceiling fans were used, and all HVAC and air supply and removal ducts were located in the ceiling. A relatively new two-zone HVAC system provided heating and cooling with a 20% fresh air fraction. In addition, a separate system operating on a timer exhausted 6000 ft³/min to the outdoors for 10 min. each hour from 9:00 p.m. to 1:00 a.m. Building engineers estimated the combined fresh air ventilation rate for the systems to be 2.5 to 3 air changes per hour (ACH). The room featured a multilevel design with 10- to 20-ft ceiling heights throughout.

Club 2 was a stand-alone structure with a single-level layout of 4500 ft² area, 45,000 ft³ volume, and a rated capacity of 300 persons. Access was via a set of double doors on each of three sides of the building. Ceiling height averaged 10 ft for the seating areas, but was approximately 25 ft in the stage and dance floor area where air samples were taken. Ceiling fans were present throughout, and three ceiling-mounted electrostatic precipitators (ESPs) were used to enhance smoke removal in the seating area. The HVAC system dated from the 1950s and did not provide ducted fresh air, so that the fresh air ventilation rate was dependent on the number and duration of entryway usages and was impossible to accurately estimate.

Club 3 was also a stand-alone structure with a single-level layout having a 2250 ft² area, 56,250 ft³ volume with 25-ft ceilings throughout, and a rated capacity of 155 persons. Entry was via a single doorway. The site had no specific smoke removal equipment in place, and the HVAC system did not provide ducted fresh air.

Facility layout and HVAC system design were expected to have some influence on ETS exposure levels. Observations during sample collection suggested that the fraction of smokers in each club was similar at approximately 0.3 to 0.4; thus, at peak capacity the room volume per smoker was 185 ft³/smoker for Club 1, 150 ft³/smoker for Club 2, and 363 ft³/smoker for Club 3. However, smoke was observed to hang in the air above the seating areas rather than mixing completely with the room air, so that the floor area per smoker also represented an indicator of smoke exposure potential. Floor area per smoker was comparable for the three clubs at 12.3 ft²/smoker for Club 1, 15.0 ft²/smoker for Club 2, and 14.5 ft²/smoker for Club 3. To examine the clubs under comparable conditions, TSP and UVPM concentrations measured in

TABLE V. Salivary Nicotine Mean Concentrations[A] by Day of Week, Band, and Club

Variable	Number of Sample Nights	First Sample Mean	Second Sample Mean	Third Sample Mean	Row Means
Day of week					
Thursday	3	50.2	84.9	58.2	64.5
Friday	9	57.6	69.5	78.1	68.4
Saturday	5	49.1	76.6	64.6	63.4
Band					
1	4	49.0	53.5	64.0	55.5
2	5	75.7	117.1	95.5	96.1
3	8	28.7	54.4	61.8	48.3
Club					
1	8	43.3	60.9	53.9	52.7
2	4	55.6	107.7	102.9	88.7
3	5	59.0	71.8	84.1	71.6
Study Sample Means		**First Sample**	**Second Sample**	**Third Sample**	**Overall Mean**
		52.0	77.4	73.7	67.7

[A]Reported as ng/mL. Salivary nicotine concentration data from individual musicians are pooled over band and club to examine day-of-week differences, over day and club to evaluate band differences, and across day and band to examine club differences.

TABLE VI. Friday Night TSP, UVPM, and SN(3rd) Concentration Means by Club and Smoke Removal System

Club	Smoke Removal System	TSP Study Mean (μg/m³)	UVPM Study Mean (μg/m³)	SN(3rd) Study Mean[A] (ng/mL)
1	exhaust system	475	190	50
2	three ESPs[B]	442	283	115
3	none	640	324	97

[A]SN(3rd) represents the end-of-night salivary nicotine sample
[B]Electrostatic precipitators

TABLE VII. Salivary Cotinine Values from Pooled End-of-Night Samples

Day of Week	Band	Club	Continine Concentration (ng/mL)
Saturday	3	1	3.7
Thursday	3	3	3.3
Friday	3	3	5.0
Thursday	2	2	2.5
Friday	2	2	3.6
Friday	2	1	1.8
Saturday	2	1	3.1
Friday	3	1	4.1
Saturday	3	1	3.3
Thursday	3	2	3.0
Friday	3	2	4.6
Friday	1	1	4.4
Saturday	1	1	3.9
Friday	1	3	1.7
Saturday	1	3	3.1

each club were pooled over band and calculated as the TWA of all samples for Friday night performances. Using the Wilcoxon 2-sample test, it was determined that the UVPM means between Clubs 1 and 3 were approaching significant differences with a p-value of 0.07, but TSP means for the same locations were not significantly different (p=0.88). This was in agreement with the result noted above that UVPM was consistent with saliva nicotine and gaseous nicotine measurements, whereas TSP was not.

As noted above, Club 1 provided ducted fresh air and also exhausted room air hourly, Club 2 employed ESPs, and Club 3 had no specific smoke removal equipment. Noticeable differences in physical and biological measurements expected to result from the dissimilar HVAC systems are reflected in Table VI, with Club 1 having the lowest UVPM and saliva nicotine levels, followed by Club 2 and then Club 3. This trend was not exhibited for TSP measurements, providing further evidence that TSP analysis is a poor indicator of ETS exposure.

It was noted that UVPM levels at Club 2 were low compared with the associated saliva nicotine measurements. This was thought to be related to the operation of ESPs, which impact only the particulate phase of ETS. This finding suggests that ESP operation may reduce area ambient ETS-related particulates without proportionately reducing the musicians' nicotine retention. It is of interest that the smoke rating for Club 2 was high even though UVPM was reduced by the ESPs. This agrees with work by Hugood[26] and Cain et al.[27] showing that the gas-phase of ETS is objectionable in test subjects.

SUMMARY AND CONCLUSIONS

ETS exposures of nonsmoking musicians in nightclub environments were assessed using five objective and one subjective exposure/dose indicators: TSP, UVPM, gaseous nicotine, saliva nicotine, saliva cotinine, and perceived smokiness. The measured exposures were as high or higher than those reported for other occupational groups previously studied. TSP values ranged from 110 to 1714 μg/m³, with a mean of 502 μg/m³ (SD 390 μg/m³). The UVPM portion of TSP had a mean of 221 μg/m³ (SD 95 μg/m³), and UVPM measurements were associated with gaseous and saliva nicotine concentrations. Comparisons of results for paired samples of TSP and UVPM indicated that paired-sample variation was much higher for TSP than for UVPM. Correlation of TSP with UVPM was poor, as previously discussed (correlation coefficient 0.17); correlation of TSP with gaseous and saliva nicotine was also poor, as is apparent from inspection of Tables IV and VI. These results were consistent with those of other researchers, and suggested that TSP should not be used as the sole indicator of ETS exposure.

Results of paired gaseous nicotine samples were similar. Sample results ranged from 28.0 to 50.0 μg/m³ with a mean of 37.1 μg/m³ (SD 6.9 μg/m³). The measured concentrations were high compared to previous studies, suggesting that nightclub musicians may be exposed to higher concentrations of ETS than some other occupational groups. Saliva nicotine results were also consistent with those previously reported with regard to the range of values, the large variation observed, and the increase in saliva nicotine levels observable after only a few hours of exposure. Consistent with previously reported results, saliva nicotine results could not be correlated with other measures of exposure and did not appear to be a reliable biological indicator of absorbed dose. Saliva cotinine levels were comparable to other occupational groups studied, but were lower than previous findings for bartenders and waitresses. Levels ranged from 1.7 to 5.0 ng/mL with a mean of 3.4 ng/mL (SD 0.9 ng/mL). Cotinine levels increased with number of exposures experienced by the musicians during the workweek. The effect was noticeable after two performances. As found in earlier studies, cotinine levels did not correlate with other ETS indicators. Experience in this work suggests that saliva cotinine analysis should be performed at the 0.1 ng/mL detection level. Subjective evaluation was not a reliable indicator of ETS exposure. A distinct bias was observed as a lowered perception of "smokiness" by musicians accommodated to working in high-ETS environments.

The fraction of smokers in each club was similar, and the floor area per smoker at maximum rated occupancy was comparable for each, so that comparison of ETS exposure potential across clubs was possible. Exposures to ETS-related particulate matter appeared to be influenced by the type of ventilation system used, the amount of fresh (dilution) air provided, and the presence and operating mode of treatment devices such as ESPs. UVPM results indicated a reduced particulate exposure in the facility with an HVAC system designed to provide fresh air and in the facility using ESPs.

These results reflected the complexity of assessing ETS exposure and absorbed dose. Additional work is needed to investigate (a) correlations between total nicotine (gaseous and particulate phases) and UVPM concentrations under various ventilation conditions, (b) exposure, absorption, and clearance of nicotine as reflected by total airborne nicotine (gaseous and particulate phases), and (c) the relationship between perceived and measured exposure.

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