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Open fire ovens and effects of in-home lavash bread baking on carbon monoxide exposure and carboxyhemoglobin levels among women in rural Armenia

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Abstract

Lavash is a traditional flatbread commonly baked at home by women in Armenia and other Middle Eastern and Caucasus countries. The baking process follows centuries' old recipes and is done primarily in open fire ovens. Data are limited regarding the impact of baking on indoor air quality and health outcomes. This study aimed at assessing the effects of lavash baking on household air pollution and cardiovascular outcomes among women who bake lavash in rural Armenia. A convenience sample of 98 bakers, all women, never-smokers, representing 36 households were enrolled. Carbon monoxide (CO) concentrations and carboxyhemoglobin (COHb) levels were monitored before, during, and/or after baking. As expected, exposure to concentrations of CO peaking at/or above 35-ppm during baking was more likely to occur in homes with fully enclosed and poorly ventilated baking rooms, compared to those with three or fewer walls and/or one or more windows. Bakers in homes where CO concentrations peaked at/or above 35-ppm were more likely to have an increase in post-baking COHb levels compared to those in homes with lower CO concentrations.

KEYWORDS

carbon monoxide, carboxyhemoglobin, indoor air quality, lavash, open fire ovens, ventilation

1 | INTRODUCTION

With an estimated 3 billion people worldwide relying on solid fuels for cooking and heating, indoor air pollution has become an increasingly compelling health problem, contributing to 3.5 million premature deaths (95%UI: 2.6-4.4 million) and 4.3% (95% UI: 3.4%-5.3%) of global disability-adjusted life years in 2010 alone.[1] Cancers, cardiovascular disease, low birthweight, and acute and chronic respiratory conditions including pneumonia, asthma, and chronic obstructive pulmonary disease (COPD) are among the health conditions linked to the combustion of wood, coal, charcoal, dung, crop waste, grasses, and other biofuels.[2] Smoke from cooking in poorly ventilated living areas can result in small particle concentrations exceeding up to several hundred times the recommended air quality limits.[3,4] Women and children are at high risk for adverse effects from smoke exposure due to prolonged exposures at home and/or increased metabolic rate.[5-7] There is also accumulating evidence for poor maternal and child health outcomes, including stillbirth and low birthweight, related to household indoor air pollution in developing countries.[8-11]

Lavash is a traditional Armenian flatbread, commonly baked by women in countries across the Caucasus and Middle East. The baking process follows centuries' old recipes and is done primarily in home-based clay pot ovens. Tondirs, also called tandoors, are cylindrical pits dug into the ground and fired by solid fuels with a top opening for access and ventilation. Keeping them lit for long periods is a common practice to maintain high temperatures. Most of the 3 million people in rural Armenia bake their lavash bread at home.[12] However, data are lacking on the effect of these common baking practices on the quality of household air and health outcomes.

Carbon monoxide (CO) is an odorless and tasteless gas formed during the incomplete combustion of carbon-containing products. The gas has a stronger affinity with hemoglobin than oxygen and according to global estimates may be responsible for over half of all air-related fatal poisonings in the industrialized world.[13] Recent studies show that reduction in household air pollution, with decreases in CO levels measured as a surrogate of particulate exposure, can lower the incidence of childhood pneumonia.[14-17] Little is known about the effect of traditional bread baking on the concentrations of CO, particulates in household air, and the health effects associated with this process.

This manuscript presents results of a pilot study conducted to assess the effect of traditional lavash bread baking on CO concentrations in household air, COHb levels, and cardiovascular parameters among lavash bakers in Armenian villages.

Practical Implications

- Concentrations of CO during the baking process peaking at/or above the 35-ppm level associated with increased COHb levels in a non-smoking population.
- This finding has important clinical, prevention, and policy implications for populations who cook and heat their homes with solid fuels over the open fire ovens.

2 | METHODS

Human Subjects Institutional Review Board approval for this study was issued by the Yerevan State Medical University Ethics Committee, Yerevan, Armenia, protocol No 8, 06.18.2015.

Thirty villages, 10 from each of three geographical areas, were selected as a convenience sample. The study sample was representative of 21 rural communities in seven administrative regions in Armenia. Doctors from regional medical centers announced the study to local people and invited bakers to participate. A convenience sample of 36 households with at least two women bakers per household, a primary baker and a dough roller, were then selected for the study. The selections considered the presence of an operational tondir oven and ongoing lavash bread baking at home. The three geographical areas included lowland, pre-mountain, and highland areas to adjust for the effects of elevation and climate on COHb in the analyses.[18] Stratification into elevation areas was conducted according to the Republic of Armenia National Statistical Council rule #756, 11.27.1998.[12] Using power calculations for random effects multivariate models with three covariates and partial correlations between 0.3 and 0.4, a total sample size of 100 women had power between 0.85 and 0.95 to observe statistically significant mean differences ($P \le .5$) between the maximum CO concentrations and the primary independent covariates, including demographics, house/baking room characteristics, and geographical location. For associations between categorical covariates and the two CO concentration (≥35 parts per million [ppm] vs <35 parts per million [ppm]), power was between 0.80 and 0.95, to detect statistically significant odds ratios between 3.2 and 4.5.

Although lavash bread baking is a year-round process and its frequency ranges from daily to every couple of weeks, the study was conducted between May and August in 2015 and in 2016 to enable the study team access to houses located at higher elevations. The team visited each house early during the day, at the start of the bread-baking process. Participants consented after the study procedures were explained. The study team recorded household characteristics including the architectural features of the baking rooms including the number of windows, doors, walls, and type of ventilation system. The exact location/elevation of the houses was confirmed using the Global Positioning System (GPS) coordinates. Information on the village's name, street, and house number was also confirmed, whenever applicable.

Participants in the study completed a questionnaire and provided information on age, marital status, education, number of children, children's ages, and lavash baking frequency, defined as the number of baking days per month. Lifetime smoking history and secondhand tobacco exposure information were collected along with personal history of chronic and/or infectious diseases, respiratory health concerns and cardiovascular symptoms including history of hypertension, dizziness, nausea, and/or headache, all within the 30-days period prior to the study. The female head of each household, in most cases the main baker, was also asked about the type of fuel used for baking. All reported using commonly available firewood but no dung.

2.1 | CO concentration measurements

CO concentrations were measured using a Lascar CO data logger (EL-USB-CO; Lascar Electronics), pre-calibrated by the manufacturer, with 0-1000 ppm measurement range, ±7 ppm accuracy, and −10 to +40°C operating temperature range. Indoor temperature and atmospheric pressure in the baking rooms were recorded before and after the first hour of baking using commonly accepted methods that included a laboratory thermometer with 1°C scale and aneroid barometer (manufacturer #34812). CO monitors, one per house, were placed within one meter of the oven, at approximately the height of the bakers' breathing zone. The main bakers typically sit closest to the pit on the ground throughout the baking process, placing dough and removing bread from the oven while rollers are positioned within a maximum of two-arm distance of the main baker to enable handing of the dough and bread (Figure 1). CO readings were taken continuously from the start of the oven for 1 hour. One hour was reported as the average baking duration for most of the bakers in the study.

The US Environmental Protection Agency's (EPA) National Ambient Air Quality Standard of 35 ppm peak CO concentration averaged per hour was used as a cutoff concentration, to study the association of increase in CO exposure (=>35 ppm) with all variables in the study.[19]

2.2 | Clinical measurements

Baseline systolic (SBP) and diastolic blood pressure (DBP), heart rate (HR), and peripheral blood oxygen saturation (SpO2) were recorded for each of the study participants before the start of the baking process. These parameters were also measured after one hour of baking, allowing for 10-15 minutes of rest.

All participants in the study were asked to provide a blood sample. Venous blood was drawn on-site by a certified phlebotomist, within 10-15 minutes after the baking process, and sent, on ice, in vacutainer tubes with heparin for COHb and total hemoglobin (tHb) analysis to the clinical laboratory at the “Arabkir” Joint Medical Centre—Institute of Child and Adolescent Health (ICAH), in Yerevan, Armenia. The shipping time varied from 30 minutes to 3 hours depending on the distance from the laboratory.

FIGURE 1 Lavash bread baking in Armenia and positioning of main baker (right) versus dough roller (left)

2.3 | Statistical analysis

2.3.1 | Participants' characteristics

Age was normally distributed and divided into five categories for descriptive purposes (≤40, 41-50, 51-60, 61, and older). Exposure to secondhand smoke, history of dizziness, nausea, headache, and hypertension were classified as “YES” or “NO.”

2.3.2 | Baking room characteristics

Architectural characteristics of each baking room were recorded based on number of windows (0, 1, 2, or more), number of doors (0-1, 2), and number of walls (1-3, 4).

2.3.3 | Change in Clinical Outcomes

A range of 1%-3% was selected as a normal, non-smoker baseline reference for COHb levels in the blood given the negative smoking history reported by all members of the study group.[20,21]

A 2% or greater drop in SpO2 was considered a clinically meaningful difference with values between −1 and +1 indicating no change. For differences in pre- and post-baking HR, SBP, and DBP, a 10% or greater change in either direction was selected as clinically meaningful cutoff points. No change was indicated for values between −9 and +9.9.

2.3.4 | Analyses

Descriptive statistics were calculated for study variables using frequencies (percent) and means (±standard deviation, SD). Outliers were checked for accuracy and possible data entry errors. Distributions of continuous variables were evaluated for normality by graphical observation and the Shapiro-Wilk test. Collinearity among fixed effect variables was examined using the variance inflation factor (VIF) method. To determine whether there were associations between categorical variables at baseline, Fisher's exact tests for small sample sizes were used.

Mixed effects models were used to account for the correlation of women within a bakery house. The models included a random intercept with the house ID variable as the subject. A standard variable component covariance was used for all models. Categorical outcome models included either a logit link with a binary distribution or a general logit link with a multinomial distribution. Odds ratios (OR) and 95% confidence intervals (95% CI) are presented. Changes scores for SBP, DBP, HR, SpO2, and COHb were used to assess change over baking time. Because there was wide variability among the original values for measured variables, analyses were run for both untransformed and log-transformed dependent variables to assure normal distribution assumptions were met. Adjusted untransformed means with *P*-values and geometric means (back-transformed from a log-transformed variable) with p-values are both presented in the tables. Adjusted models included continuous age and secondhand smoking. The geographical location of baking houses was assessed in adjusted models but did not alter results and conclusions.

Corrections for multiple comparisons were not used.[22-24] Correcting for multiple testing in this study could potentially result in too many false negatives and important areas for future research would be missed. The data analysis was generated using SAS software, version 9.4.[25] All data were analyzed using two-tailed tests with α <0.05 or ≤0.10 due to the relatively small sample size of some categories.

3 | RESULTS

A total of 98 lavash bread bakers (n = 36 houses) were enrolled in the study. Three of the bakers, a 40- and a 62-year-old from one house, and a 63-year-old from another house (both houses located in the lowland terrain area), baked bread in open-air tondirs with CO concentrations below the detection levels, and their data were excluded from the analyses. Data for 95 bakers and 34 houses were included in the analyses.

The majority of study participants were 50 years or younger (62.1%), and a majority reported a history of secondhand exposure to cigarette smoke (65.3%). The mean age (SD) of bakers and rollers was 49.7 (10.7) and 47.4 (13.4) years, respectively, with a wide range in age for the participants (23-84). Categorical age, continuous age, and secondhand smoking were not associated with participants' job type (Table 1). Geographical area and baking house characteristics were also not associated with the job role. Although the majority of participants reported a history of headaches (66.3%) with 77% of bakers vs 60% of the rollers reporting this symptom, the association by job type was not statistically significant at the 0.05 level (*P*-value = .12). Symptoms of dizziness, nausea, and hypertension showed no association by job type.

There were more participants and more houses observed where maximum detected CO concentrations were at or above the 35 ppm cutoff (56.8% and 61.9%, respectively), compared to those with concentrations below 35 ppm (Table 2). A higher proportion of bakers was observed in homes with higher maximum CO concentrations than in houses with lower concentrations (39% vs 34%, respectively), but there was no statistical association found between those variables. Older mean age was observed among participants from homes with lower peak CO concentrations detected (mean age 51.4 vs 45.8, respectively, *P* = .038 and *P* = .023 for log-transformed data). Participants' CO exposure displayed differences by house location and baking room characteristics. Women in houses located in highland areas were much more likely to have higher concentrations compared with women in houses located in lowland areas (OR = 4.5, 95% CI: 1.5-14.0). Bakes and rollers in houses with baking rooms surrounded by four walls (compared to those with two or three walls) and houses with no windows (compared to those with three or fewer) had more than four times the likelihood of a maximum concentrations above the cutoff limit of 35 ppm (OR = 4.4, 95% CI: 1.4-14.0 and OR = 4.5, 95% CI: 1.5-12.6, respectively).

Higher proportions of headaches, dizziness, nausea, and hypertension were reported among participants from bakehouses with CO concentrations ≥35 ppm compared with lower concentrations (Table 3). After adjusting for age and smoking, all odds ratios were elevated (2.2-3.8), but dizziness was not statistically significant (*P* = .12). These associations were not observed in analyses with log-transformed continuous data.

Participants working in bakehouses with higher peak concentrations (≥35 ppm) were much more likely to have had a 3% or higher change in COHb levels from the start to the finish of the baking process (OR 6.8, 95% CI 1.6-28.6) (Table 4). The mean changes (SD) (both untransformed and log-transformed) also exhibited a significant association with the higher CO concentration (2.2 [2.2] vs 1.1 [1.7], respectively *P*-values = .001-.006). Bakers (71%) were more likely to have had a 3% or higher change in COHb levels than rollers (45%); adjusted OR = 2.9, 95% CI = 1.1-7.6, (data not shown in tables).

The mean change (SD) in heart rate between the start and finish of the baking process was greater among women in the houses with the higher peak CO concentrations 4.9 (12.0) vs −0.6 (9.6) for lower concentrations (*P* = .039 for untransformed means and .14 for transformed means). Although the association with HR change data was not statistically significant, 33% of women exposed to the higher peak CO had a change ≥10% compared with 20% of women exposed to the lower CO. Changes in other clinical outcomes were not found to be associated with peak CO concentration.

4 | DISCUSSION

This pilot study of Armenian lavash bread bakers found that concentrations of CO peaking at or above the 35 ppm level during the baking process were statistically significantly associated with increases in COHb levels over the normal range, in a never-smoking population and after controlling for age, history of secondhand smoke exposure, and elevation. This increase in COHb levels in a population with no other potential sources of CO exposure was also confirmed in analyses with log-transformed CO concentration data not included in this text. These results altogether raise concerns for the safety and well-being of in-home bakers and food prepared but also other members of their households and populations relying on open fire sources for home cooking and/or heating. This study included women only, as lavash bread baking is a process traditionally done by women in Armenia and women are the primary food preparers in many developing countries.[26] Women are the primary childcare providers in developing countries and spend most time of all household members at home, making them and their children particularly vulnerable to health effects of exposure to indoor air pollutants. As this was a pilot study only, limited furthermore by the size of the studied population, the findings warrant further investigation; however, the associations found with a common cooking practice performed on a day-to-day basis have important clinical and disease prevention implications.

TABLE 1 Characteristics of study participants and bakehouses/baking rooms by job type

	Job Type		Unadjusted Values[a]	
Characteristic	Baker	Roller	OR (95%CI)	*P*-value
Number of bakers and rollers (n = 95 women)	n = 35	n = 60		
Number per baking houses (n = 34 houses)	1.0	1.8		
Age in y, mean (SD)	49.7 (10.7)	47.4 (13.4)		
Range in y	23-75	25-84		.40
Age, n (%)				
≤40	5 (14.3)	20 (33.3)	0.2 (0.1-0.8)	.15
41-50	13 (37.1)	21 (35.0)	0.5 (0.2-1.6)	
51-60	13 (37.1)	11 (18.3)	1.0	
61+	4 (11.4)	8 (13.3)	0.4 (0.1-1.9)	
Secondhand smoking exposure, n (%)				
Yes	21 (60.0)	33 (55.0)	1.9 (0.7-5.3)	.19
No	14 (40.0)	27 (45.0)	1.0	
Geographical area, n (%)				
Lowland	11 (31.4)	18 (30.0)		.94
Pre-mountain	11 (31.4)	21 (35.0)	0.9 (0.3-2.6)	
Highland	13 (37.1)	21 (35.0)	1.0 (0.3-3.0)	
Number of walls, n (%)				
1-3	11 (31.4)	18 (30.0)	1.0	.89
4	24 (68.6)	42 (70.0)	0.9 (0.4-2.4)	
Number of Windows, n (%)				
None	16 (45.7)	22 (36.7)	1.7 (0.5-5.3)	.65
1	12 (34.3)	22 (36.7)	1.2 (0.4-4.1)	
2-3	7 (20.0)	16 (26.7)	1.0	
Number of doors, n (%)				
0-1	26 (74.3)	47 (78.3)	1.0	.66
2	9 (25.7)	13 (21.7)	1.3 (0.4-3.5)	
History of dizziness, n (%)				
Yes	13 (37.1)	21 (35.0)	1.1 (0.4-2.9)	.84
No	22 (62.9)	39 (65.0)	1.0	
History of nausea, n (%)				.62
Yes	11 (31.4)	22 (36.7)	0.8 (0.3-2.2)	
No	24 (68.6)	38 (63.3)	1.0	
History of headaches, n (%)				
Yes	27 (77.1)	36 (60.0)	2.3 (0.8-6.3)	.12
No	8 (22.9)	24 (40.0)	1.0	
History of hypertension, n (%)			1.3 (0.5-3.3)	
Yes	15 (42.9)	22 (36.7)	1.3 (0.5-3.3)	.55
No	20 (57.1)	38 (63.3)	1.0	

[a]Odds ratios, 95% confidence intervals, and *P*-values are from unadjusted mixed effects models accounting for correlation among women within a baking house.

Household parameters and poor ventilation characteristics have been shown in several studies to be associated with increases in exposure to indoor air pollution including higher concentrations of particulate matter (PM) and elevated CO concentrations in the air.[27-32] Poor ventilation characteristics of the baking rooms in this study have also been associated with increases in CO concentrations, with peaks at or above the 35 ppm level almost five times more likely in the baking rooms with no windows and surrounded by four walls as compared to those with two to three windows and less than four walls, respectively. The increase in maximum recorded CO

TABLE 2 Characteristics of study participants and participant CO concentration exposure by baking room characteristics and peak CO concentration

Characteristics	Peak CO		Unadjusted Values[a]		Log CO peak
	CO ≥ 35	CO < 35	Odds ratio 95% CI	*P*-value	*P*-value[b]
Participants n (%)	54 (56.8)	41 (43.2)			
Houses (n (%)	21 (61.8)	13 (38.2)			
Average number per house	2.6	3.2			
Age, mean (SD)	45.8 (12.3)	51.4 (12.1)		.038	.023
Range	23-77	30-84			
Median [IQR]	44.5 [35-55]	48.0 [44-56]			
Age, n (%)					
≤40	19 (35.2)	6 (14.6)	1.9 (0.5-7.0)	.10	.15
41-50	15 (27.8)	19 (46.3)	0.5 (0.2-1.5)		
51-60	15 (27.8)	9 (22.0)	1.0		
61+	5 (9.3)	7 (17.1)	0.4 (0.1-1.9)		
Secondhand smoking, n (%)					
Yes	32 (59.3)	30 (73.2)	0.5 (0.2-1.4)	.19	.19
No	22 (40.7)	11 (26.8	1.0		
Baking Role					
Bakers	21 (38.9)	14 (34.1)	1.2 (0.5-3.0	.64	.42
Rollers	33 (61.1)	27 (54.9)	1.0		
Geographical area (n, %)					
Lowland	11 (20.4)	18 (43.9)	**1.0**	**.035**	**<.0001**
Pre-mountain	18 (33.3)	14 (34.1)	2.1 (0.7-6.2)		
Highland	25 (46.3)	9 (21.9)	**4.5 (1.5-14.0)**		
Number windows, n (%)					
0	28 (51.8)	10 (24.4)	**4.4 (1.4-14.0)**	**.004**	**.019**
1	17 (31.5)	17 (41.5)	**1.6 (0.5-4.8)**	**.036**	**.081**
2-3	9 (16.7)	14 (34.1)	**1.0**		
Number doors, n (%)					
0-1	41 (75.9)	32 (78.0)	1.1 (0.4-3.1)	.24	.34
2	13 (24.1)	9 (22.0)	1.0	.82	.54
Number walls, n (%)				**.009**	**.020**
1-3	23 (42.6)	6 (14.6)	**1.0**		
4	31 (57.4)	35 (85.4)	**4.5 (1.5-12.6)**		

Bold values indicate statistically significant level <.05.

[a]Odds ratios, 95% confidence intervals, and *P*-values are from unadjusted mixed effects models accounting for correlation among women within a baking house.

[b]Models were generated using log CO maximum instead of the two-category variable.

concentrations was also associated with smaller area of the baking room (geometric mean). As this study took place during the summer months, with improved ventilation from opened windows as confirmed by the study team, it may have underestimated the actual risk of exposure to CO. Nonetheless, these findings confirm that household characteristics and specifically the ventilation design of the rooms with open fire ovens play an important role in reducing the potential for CO exposure. They also have implications for educational campaigns and recommendations for improved ventilation practices especially in areas where modifications to the baking process are not easily implementable due to consideration for culturally embedded traditional food preparation practices.

Several cases of clinically significant elevated cardiovascular markers were found in this study. There were participants identified with blood pressure measurements indicating hypertension and some with SpO2 and low hemoglobin levels. Although no statistically significant research findings were found with regard to these observations, the study team made special efforts to recommend

TABLE 3 Association of peak CO concentration with participants' cardiovascular symptoms history

Symptoms	Peak CO concentration (ppm) CO ≥ 35	CO < 35	Adjusted[a] Odds ratio 95% CI	P-value	Adjusted log CO max P-value[b]
History of dizziness, n (%)				.12	.12
Yes	23 (42.6)	11 (26.8)	2.2 (0.8-5.8)		
No	31 (57.4)	30 (73.2)	1.0		
History of nausea, n (%)				.07	.28
Yes	23 (42.6)	10 (24.4)	2.5 (0.9 −6.7)		
No	31 (57.4)	31 (75.6)	1.0		
History of headaches n (%)				**.012**	.13
Yes	42 (77.8)	21 (51.2)	**3.8 (1.4-10.5)**		
No	12 (22.2)	20 (48.8)	**1.0**		
History of hypertension n (%)				.050	.32
Yes	25 (46.3)	12 (29.3)	2.7 (1.0-7.0)		
No	29 (53.7)	29 (70.7)	1.0		

Bold values indicate statistically significant level <.05.

[a]Mixed effects models adjusted for age and secondhand smoking exposure and accounting for correlation of women within bakehouses.

[b]Adjusted models were generated using log CO maximum instead of the two-category variable.

TABLE 4 Change in outcomes of study participants by peak CO concentration

Changes from Start to Finish	Peak CO CO ≥ 35	CO < 35	Adjusted[a] Odds ratio 95% CI	P-value	Adjusted log CO max P-value[b]
COHb 3% change, mean (SD)	2.2 (2.2)	1.1 (1.7)		**.006**/.14[c]	**.003/.001**[c]
Geometric mean 3% (95% CI)	0.6 (0.3-1.2)	0.1 (0.03-1.2)		**.004/.031**[c]	**.011**[B]**/.006**[c]
≥3%	18 (33.3)	3 (7.3)	**6.8 (1.6-28.6)**	**.011**	
<3%	36 (66.7)	38 (92.7)	1.0		
SpO2, mean (SD)	-0.9 (4.7)	-1.4 (4.0)		.39	.42
≤−2%	19 (35.2)	13 (31.7)	1.2 (0.4-3.1)	.80	.85
No change: −1 to 1	27 (50.0)	23 (56.1)	1.0		
≥2%	8 (14.8)	5 (12.2)	1.5 (0.4-6.0)		
HR, mean (SD)	4.9 (12.0)	-0.6 (9.6)			**.039**[B]/.14[c]
≤−10%	9 (16.7)	7 (17.1)	1.4 (0.3-5.4)	.41	.79
No change: −9.9 to 9.9	27 (50.0)	26 (63.4)	1.0		
≥10%	18 (33.3)	8 (19.5)	2.4 (0.6-9.5)		
SBP, mean (SD)	-0.6 (4.0)	2.4 (11.4)		.23	.30
≤−10%	10 (18.5)	3 (7.3)	3.2 (0.6-16.3)	.36	.28
No change: −9.9 to 9.9	34 (63.0)	30 (73.2)	1.0		
≥10%	10 (18.5)	8 (19.5)	1.2 (0.3-4.9)		
DBP, mean (SD)	-0.7 (10.4)	1.2 (11.9)		.33	.91
≤10%	13 (24.1)	11 (26.8)	0.9 (0.2-3.5)	.75	.97
No change ± <10%	27 (50.0)	17 (41.5)	1.0		
≥10%	14 (25.9)	13 (31.7)	0.7 (0.2-2.0)		

Bold values indicate statistically significant level <.05.

[a]Mixed effects models adjusted for age and secondhand smoking exposure and accounting for correlation of women within bakehouses.

[b]Adjusted models were generated using log CO maximum instead of the two-category variable.

[c]Adjusted for age, secondhand smoking exposure, and geographical area.

clinical follow-up for every participant identified with abnormal clinical findings.

As this was a pilot study, the study team did not evaluate the validity of CO exposure as a surrogate measure of particulate exposure. Although still under research, there is a growing body of evidence from exposure studies showing correlation between personal CO and fine particulate matter ($PM_{2.5}$) exposures in the context of household air pollution.[33-36] Epidemiological studies have shown reductions in rates of childhood pneumonia following decreases in indoor air CO levels.[15]

This study did not collect socioeconomic status (SES) information because all participants were similar in their SES. However, lower SES may be associated with increased exposures to indoor air pollution,[16] primarily as a result of the inability to afford, implement, and maintain solutions to reduce exposure such as improved ventilation systems. This study also did not collect information on the type and age of the tondir oven used in the baking process and its' effect on CO concentrations.[32] Most tondir ovens were older (20+ years) and in some cases inherited from previous bread bakers with minimal maintenance over the years. Age and maintenance of the ovens may play important roles in indoor air pollution. Further studies with larger populations are warranted.

5 | CONCLUSIONS

This pilot study found that concentrations of CO exceeding the recommended one-hour exposure limits during the traditional in-home open fire oven baking of the lavash bread were associated with increased COHb levels in a group of non-smoking women in the rural areas of Armenia. In-home lavash bread making is embedded in the middle eastern and Caucasus cultures with recipes passed from generation to generation. Baking is done primarily over open fire sources on a daily or a weekly basis. Although CO was used in this study as a surrogate for exposure to $PM_{2.5,}$ the findings have important clinical, disease prevention and policy implications for populations that cook and heat their homes with open fire and solid fuels. Improved ventilation of the baking rooms has been recommended to all bakers in the study. These results add to the growing body of evidence about the negative effects of indoor air pollution on the health of vulnerable populations.

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CONFLICT OF INTEREST

The authors declare they have no actual or potential competing financial interests.

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