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Thirdhand Smoke Awareness, Beliefs, and Protective Behaviors among Pet Owners: A Cross-Sectional Study

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Abstract. Smoking has been acknowledged as a major threat to the environment globally. Second-hand smoke exposure is associated with substantial health risks worldwide. Third-hand smoke (THS) refers to residential tobacco pollutants that persist on indoor surfaces and in dust after smoking has ceased. In addition, substances in third hand smoke can react with atmospheric oxidants in the atmosphere and cause a permanently toxic chemical in the air. Previous research has raised concerns about the potential health risks of prolonged exposure to tobacco-related pollutants in indoor environments. However, pet owners' knowledge of THS, their perceptions of its potential risks to companion animals, and their protective behaviors remain insufficiently understood. Therefore, this research employed a cross-section questionnaire survey to investigate pet owners' knowledge of third hand smoke, beliefs, and their self-reported protective behaviors.

Keywords: Thirdhand Smoke, Pet Owners, Protective Behaviors, Risk Perception, Tobacco Exposure

1. Introduction

Tobacco smoke remains a major global public health concern, affecting not only smokers but also individuals exposed to environmental tobacco smoke. While the health risks of secondhand smoke (SHS) have long been recognized, increasing attention has focused on thirdhand smoke (THS), the residual tobacco pollutants that remain on indoor surfaces, dust, furniture, clothing, and other materials long after smoking has ended [1]. These residues can persist for extended periods and undergo chemical reactions that generate additional toxic compounds, creating continuous exposure through inhalation, dermal contact, and ingestion [2]. Growing evidence suggests that THS is more than an unpleasant odor or cosmetic residue. Experimental studies have demonstrated that THS exposure can induce DNA damage, oxidative stress, inflammation, and other adverse biological effects in both cellular and animal models [2]. Furthermore, THS contaminants are difficult to remove completely from indoor environments, even after smoking has stopped [3], highlighting the importance of preventing long-term environmental exposure. Companion animals may be particularly vulnerable to THS because they spend most of their lives indoors, frequently contact contaminated surfaces, and groom themselves by licking their fur. Recent studies have detected cotinine, a biomarker of nicotine exposure, in dogs living with smokers [4], while tobacco smoke exposure has been associated with oxidative stress and inflammatory changes in indoor cats [5]. A

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recent scoping review further concluded that dogs and cats experience measurable tobacco smoke exposure and may benefit from stronger smoking cessation efforts among pet owners [6].

Despite growing evidence of THS-related health risks, relatively little is known about public awareness of this issue. A systematic review found substantial variation in parents' knowledge, beliefs, and protective behaviors, suggesting that awareness alone does not necessarily translate into healthier practices [7]. Likewise, parents who believed THS was harmful were more likely to maintain smoke-free homes, adopt smoke-free vehicle policies, and attempt smoking cessation [8]. However, nearly all existing studies have focused on parents and children, leaving pet owners largely overlooked despite increasing evidence that companion animals are also at risk.

2. Methods

2.1. Participants and survey design

A cross-sectional online survey was conducted to examine knowledge, beliefs, and protective behaviors related to thirdhand smoke (THS) exposure among pet owners. A total of 101 participants completed the 41-item questionnaire and provided consent for participation. The survey collected demographic information, including age, gender, education, and smoking status, as well as household smoking exposure, prior awareness of THS, and pet-related characteristics. THS-related questions used 5-point Likert scales. Knowledge items (Q16–Q22) assessed understanding of THS persistence, exposure pathways, and health effects. Q18 and Q21 were reverse scored so that higher values consistently represented greater THS knowledge. Belief and attitude items assessed perceived harm, concern, responsibility, and interest in THS education. Q30, which stated that outdoor smoking completely protects pets from THS, showed poor consistency with the other belief items and was therefore analyzed separately as a misconception. The final Belief/Attitude Score included Q23–Q29 and Q31. Protective behavior was assessed using Q32–Q41, with higher scores representing more frequently reported protective responses. Composite scores were calculated as the mean of their respective items.

2.2. Statistical analysis

Descriptive statistics were used to summarize participant characteristics and survey responses. Internal consistency of the composite measures was evaluated using Cronbach's alpha. Welch's independent-samples t-tests were used for two-group comparisons, while Kruskal–Wallis tests were used for exploratory comparisons across demographic variables with multiple categories. Pearson correlations examined associations among Knowledge, Belief/Attitude, and Protective Behavior Scores; Spearman correlations were used for ordinal pet-related variables. Multiple linear regression examined whether Knowledge and Belief/Attitude Scores were independently associated with Protective Behavior. HC3 robust standard errors were used because the Behavior Score showed a substantial ceiling effect. Statistical significance was evaluated at $p < .05$. Because several behavior items referred specifically to actions following smoking, analyses involving the Protective Behavior Score were interpreted cautiously given the large proportion of never-smokers in the sample.

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3. Results

3.1. Participant showed moderate prior awareness but generally high knowledge of thirdhand smoke

A total of 101 participants were included in the analysis. Nearly half of the sample was under 18 years of age (47.5%), and 64.4% identified as female. Most participants reported that they had never smoked (83.2%), although 32.7% reported that someone smoked inside their household. Prior awareness of thirdhand smoke (THS) was nearly evenly divided, with 50.5% reporting that they had heard of THS before participating in the survey (Table 1).

Table 1. Sample characteristics

Characteristic	n	%
Age: Under 18	48	47.5
Age: 18–24	21	20.8
Age: 25–34	25	24.8
Age: 35 or older	7	6.9
Gender: Female	65	64.4
Gender: Male	32	31.7
Gender: Other / prefer not to say	4	4.0
Never smoked	84	83.2
Household indoor smoking	33	32.7
Previously heard of THS	51	50.5
Owns one pet	75	74.3
Pet often/always indoors	82	81.2

Participant demographics, smoking characteristics, prior thirdhand smoke (THS) awareness, and pet-related characteristics. Values are presented as n (%) (N = 101).

Overall THS knowledge was relatively high (M = 4.16, SD = 0.57), and the seven-item knowledge scale showed acceptable internal consistency (Cronbach's α = .74; Table 2). Item-level responses indicated particularly high knowledge that THS can remain on clothing and furniture and may negatively affect human and animal health. Knowledge concerning whether regular household cleaning can completely eliminate THS was comparatively lower (Figure 1). Participants who had previously heard of THS had significantly higher knowledge scores (M = 4.27, SD = 0.51) than those who had not (M = 4.04, SD = 0.60), Welch's t (95.55) = 2.08, p = .040, Cohen's d = 0.41. Prior awareness, however, was not associated with belief/attitude scores (p = .728; Table 3).

Table 2. Descriptive statistics and reliability of study measures

Scale	Items	Mean	SD	Cronbach's alpha
THS Knowledge	7	4.16	0.57	0.74
THS Belief/Attitude	8	4.06	0.59	0.72
Protective Behavior	10	4.54	0.66	0.9

Descriptive statistics and internal consistency of the THS knowledge, belief/attitude, and protective behavior scales. Cronbach's α indicates internal consistency.

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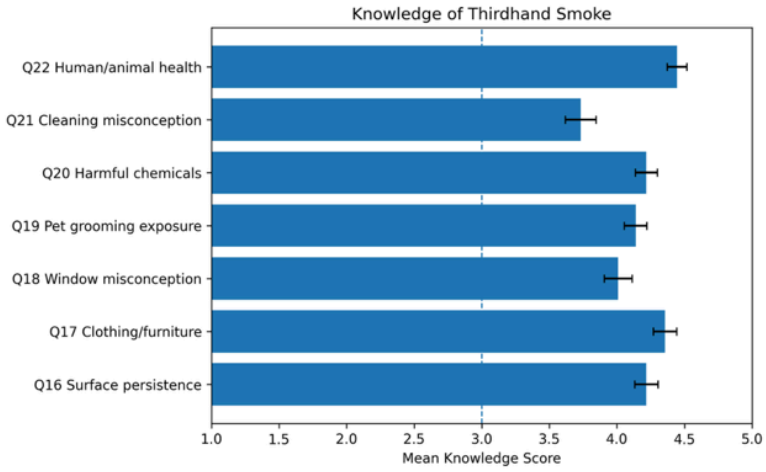


Figure 1. Knowledge of thirdhand smoke

Mean scores for individual THS knowledge items. Q18 and Q21 were reverse scored so that higher values consistently indicate greater THS knowledge. Error bars represent SEM; the dashed line indicates the neutral midpoint (3).

3.2. Greater THS knowledge was associated with stronger ths-related beliefs and attitudes

Participants also reported generally strong THS-related beliefs and attitudes (M = 4.06, SD = 0.59, α = .72; Table 2). Agreement was particularly high for statements that THS is harmful to pets, deserves greater public attention, and should be addressed through veterinarian education (Figure 2). In contrast, agreement with pet-owner responsibility was close to the neutral midpoint. Knowledge and belief/attitude scores were moderately positively correlated, r(99) = .57, p < .001 (Figure 3; Table 3). Thus, participants with greater factual knowledge about THS also tended to express stronger THS-related concern and supportive attitudes. An unexpected item-level pattern was also observed: greater knowledge was positively associated with agreement with the misconception that smoking outside completely protects pets from THS, r = .34, p < .001.

Table 3. Main inferential analyses

Analysis	Test	Effect	p
Prior THS awareness → Knowledge	Welch's t-test	d = 0.41	0.040
Prior THS awareness → Belief/Attitude	Welch's t-test	d = 0.07	0.728
Knowledge ↔ Belief/Attitude	Pearson correlation	r = 0.57	< .001
Knowledge ↔ Protective Behavior	Pearson correlation	r = 0.29	0.003
Belief/Attitude ↔ Protective Behavior	Pearson correlation	r = 0.40	< .001
Knowledge → Protective Behavior (adjusted)	Multiple regression (HC3)	b = 0.11	0.514
Belief/Attitude → Protective Behavior (adjusted)	Multiple regression (HC3)	b = 0.40	0.002

Group comparisons, correlations, and multiple regression analyses of THS knowledge, beliefs/attitudes, and protective behavior. Regression estimates use HC3 robust standard errors.

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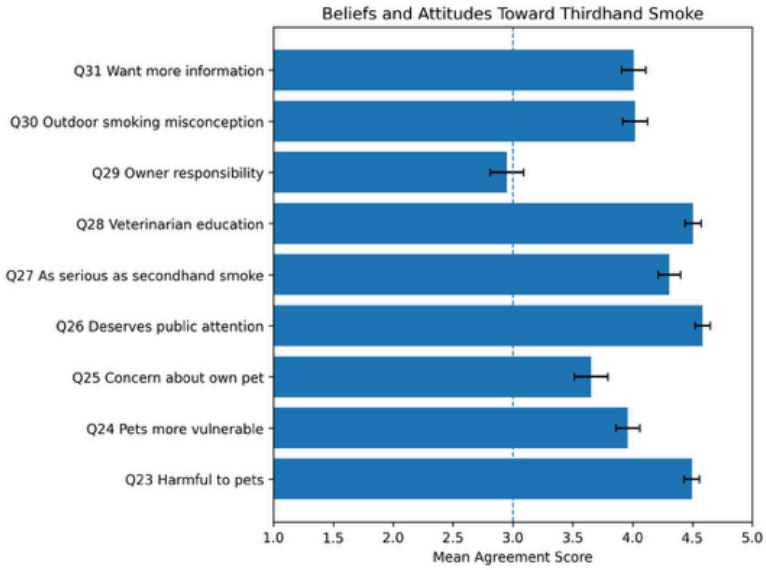


Figure 2. Beliefs and attitudes toward thirdhand smoke

Mean agreement scores for nine THS belief/attitude items (Q23–Q31); Q30 was excluded from the composite score. Error bars indicate SEM; the dashed line marks the neutral midpoint (3).

3.3. Stronger THS beliefs were more closely associated with reported protective behavior

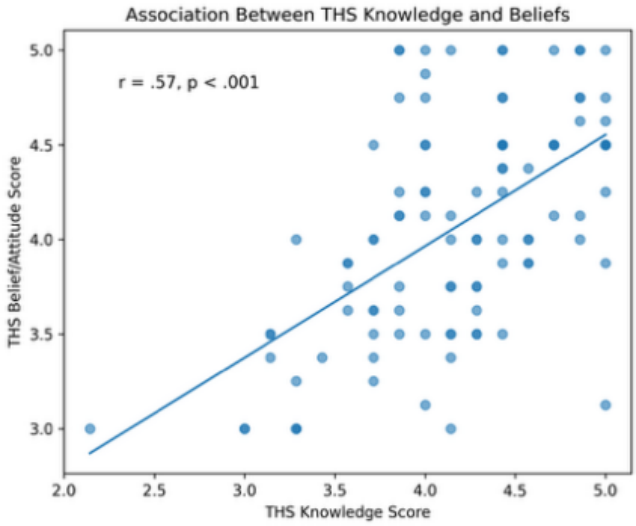


Figure 3. Association between THS knowledge and beliefs/attitudes

The protective behavior scale showed high internal consistency ($\alpha = .90$) and a high overall mean ($M = 4.54$, $SD = 0.66$; Table 2). Knowledge was positively correlated with protective behavior, $r = .29$, $p = .003$, while the association between beliefs/attitudes and protective behavior was somewhat stronger, $r = .40$, $p < .001$ (Figure 3; Table 3). When knowledge and beliefs/attitudes were entered simultaneously into a multiple regression model using HC3 robust standard errors, the model accounted for 16.7% of the variance in protective behavior, $F(2, 98) = 8.90$, $p < .001$. Belief/attitude score remained significantly associated with protective behavior ($b = 0.40$, $SE = 0.12$, $p = .002$), whereas knowledge did not ($b = 0.11$, $SE = 0.16$, $p = .514$). Interpretation of the behavior measure

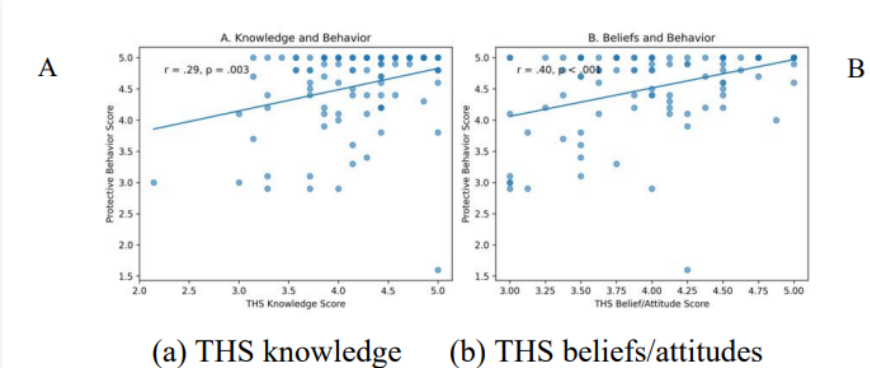
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should be cautious because several items referred specifically to behaviors following smoking, whereas most participants were never smokers.

THS knowledge was positively correlated with belief/attitude scores ($r = .57$, $p < .001$; $N = 101$). The line indicates the linear fit.

4. Discussion

This study suggests awareness of thirdhand smoke (THS) alone is insufficient to promote protective behaviors among pet owners. Participants showed high THS knowledge and concern for pets. While prior awareness correlated with greater knowledge, only beliefs and attitudes—not knowledge—predicted protective behavior when considered together. Understanding THS existence is merely one step toward changing responses to tobacco risks. Public smoking education traditionally focuses on active and secondhand smoke. THS is a complex issue as residues persist in environments after visible smoke disappears. Owners may avoid smoking beside pets but underestimate other exposures (e.g., believing outdoor smoking fully protects pets, a common misconception). General awareness does not equal complete understanding. Practically, public health messages should explain persistent tobacco residues and reduction methods, emphasizing smoke-free homes/cars and residual exposure routes. This is vital as pets interact closely with contaminated surfaces. Veterinarians are supported as key educators; incorporating brief smoking-exposure questions into preventive care can link public health goals with pet health concerns, motivating household tobacco reduction.



(a) THS knowledge (b) THS beliefs/attitudes

Figure 4. Associations with protective behavior

Protective behavior was positively correlated with (A) THS knowledge ($r = .29$, $p = .003$) and (B) beliefs/attitudes ($r = .40$, $p < .001$; $N = 101$). Lines indicate linear fits.

5. Conclusion

These findings highlight the importance of raising pet owners' awareness of thirdhand smoke and its potential health risks to pets. The results indicate an association between pet owners' awareness of thirdhand smoke-related health risks and their protective behaviors, underscoring the potential value of targeted health education. Overall, the findings suggest a need to raise pet owners' awareness of thirdhand smoke. Targeted educational measures may help enhance their understanding of potential risks to companion animals and encourage them to adopt protective behaviors.

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