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Brief Report

Thirdhand Smoke Knowledge, Attitudes, and Behavior: Development of Reliable and Valid Self-report Measures

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Abstract

Introduction: This study sought to provide essential tobacco control tools by testing the reliability and validity of new self-report scales developed to assess thirdhand smoke (THS) (ie, toxic tobacco residue) related knowledge, attitudes, and behavior (KAB).

Aims and Methods: Items for the KAB scales were adapted from established secondhand smoke (SHS) measures, reviewed to support face validity, and tested in a longitudinal online survey evaluating THS health messages. Participants were California adults at risk of THS exposure. For 7 months, the three KAB scales were completed monthly, and data from the first (n = 1086), third (n = 315), and seventh (n = 301) month surveys were used in these analyses.

Results: All three scales demonstrated consistent reliability and single-factor loading at all three timepoints for knowledge (α_{range}: .87–.90), attitude (α_{range}: .84–.87), and behavior (α_{range}: .80–.86). Similarly, analyses supported scale convergent validity (scale correlations r_{range}: .45–.85; all p values <.001), discriminant validity between smokers and nonsmokers (knowledge Cohen's d_{range}: .57–.61, all p values <.001; attitude Cohen's d_{range}: .78–.82, all p values <.001; behavior Cohen's d_{range}: .90–.99, all p values <.001), and predictive validity (range R^2_{KAB}: .41–.48; all p values <.001).

Conclusions: KAB scales about THS provide new opportunities for tobacco control advocates and scholars to identify gaps in knowledge, misperceptions, and obstacles to behavior change in order to guide the design of novel tobacco control policies and interventions.

Implications: Numerous scales have been vetted as reliable and valid measures for assessing SHS-related KABs. Currently, standard measures of THS KABs are not available. This study tested three THS scales to fill this gap. The present findings provide tobacco control advocates, scholars, and practitioners tools for assessing KABs related to THS. This information is critical to development, implementation, and evaluation of novel tobacco control strategies.

Introduction

Thirdhand smoke (THS) is the toxic residue left in environments after the secondhand smoke (SHS) has cleared. THS remains on surfaces and in dust and is readmitted back into the air long after the smoking stopped.[1] Research has documented the presence of THS in indoor environments and the risks of THS exposure for people, especially children.[1–3] Although extensive scholarly research exists on THS, few studies have explored applied and social scientific approaches to understanding and assessing THS.

For decades, knowledge, attitudes, and behavior (KAB) have been recognized as important determinants of health.[4] Within tobacco

prevention research, numerous scales measuring tobacco use and SHS-related KABs have been established.[5–11] However, reliable and valid scales to measure THS are limited with few scales proposed to assess THS-related KABs. The first was designed to assess perceived risks of exposure to children.[12] Two additional THS-related scales have been proposed, one assessing perceptions based on where smoking is allowed,[13] and the other assessing beliefs about THS via two factors (general beliefs and persistence in the built environment).[14] The present study seeks to build on this literature through the development of measures to more broadly assess THS-related KABs.

Psychometrically sound KAB measures assessing THS perceptions would provide useful tools for tobacco control advocates and scholars in designing, implementing, and evaluating modern tobacco control strategies addressing toxic THS residue. As global discussions of a tobacco endgame grow,[15] novel approaches that go beyond current efforts are needed. The present study responds to this need by testing the reliability and validity of self-report scales to assess THS-related KABs constructs.

Methods

Procedures and Participants

This was a longitudinal study that employed a panel design using a convenience sample of California adults. Data were collected as part of a larger 7-month social media intervention designed to increase THS-related KABs (see [16]). Adults of low to middle socioeconomic status with interest in children, travel, pets, cars, apartments, or real estate were recruited through Facebook. These characteristics were used to target adults most at risk of THS exposure (eg, living in multiunit housing, purchasing a used cars, buying a house, traveling) as well as those most at risk of harm from THS exposure (eg, children, pets). Via Facebook's advertising program, these characteristics produced an estimated sampling frame of 24 million users. Recruitment occurred during October 2019 with a $4500 advertising budget. The recruitment message received 2959 link clicks with 1755 survey attempts recorded in Qualtrics. Excluding participants who did not provide e-mail addresses for follow-up (n = 612) and duplicates (n = 56), 1087 unique participants were included in the intervention. Participants were incentivized with a chance of winning a $50 (15 winners) or $150 (10 winners) Amazon gift card. The intervention ended in May 2020.

Participants agreed to receiving an invitation to complete short surveys each month for 7 months (ie, for seven waves). The initial survey contained THS KAB measures as well as demographic items. In the follow-up surveys, the KAB items were included with other intervention measures. For the present analyses, data provided in waves 1 (n = 1087), 3 (n = 315), and 7 (n = 301) are included to explore stability over time. In all three waves, most participants had at least smoked a puff of a cigarette in their lifetime (range: 53%–57%), identified as female (range: 82%–83%), were employed at least part-time (range: 49%–55%), identified as non-Hispanic White (range: 76%–83%), and reported at least some college education (range: 82%–86%); participant age varied minimally across waves (M_{range} = 42–43, SD_{range} = 18.3–18.9). See Supplementary Table S1 for within-wave demographics.

Measures

Items for the THS KAB scales were developed after extensive review of existing SHS-[5–11] and THS-related[12–14] KAB measures. To begin, THS-relevant domains were identified based on where THS can be found (eg, house dust, hotel rooms, cars), who is most at risk of exposure (eg, children, pets), and how THS exposure can be prevented (eg, enforce indoor smoking ban, disclose smoking history). To establish construct validity, items were presented within domains as being post-SHS experiences in order to separate THS from SHS exposure. To establish initial face validity, the identified items were reviewed by the research team (ie, RR, GM, LG, and HW) with consensus required for inclusion. To assure that items would be understood by participants of different educational backgrounds and language proficiency, items were examined for low-literacy level following the recommendations of limited text, consistency, common words, and active verbs.[17] In the end, eight items were included for knowledge, seven for attitude, and five for behavior (conceptualized to include items assessing behavioral intention and actual behavior). For all three scales, response options were on a 5-point Likert scale from strongly agree to strongly disagree. All scale items are listed in Table 1.

Data Analysis

To be included in analyses, participants needed to have no more than six missing item responses across the 20 items that comprised all three scales. Across the three waves, only six participants (0.4%) had insufficient data and were excluded from a within-wave analysis. For participants with fewer than six missing responses, hot deck imputation[18] in Stata V 15[19] was used, replacing missing values via variable matching based on within-wave gender and smoking status. Reported analyses were performed in SPSS V 27.[20] To assess reliability, Cronbach's α coefficients were examined to determine internal consistency followed by test–retest reliability to examine consistency over time. Convergent validity was established through examining the correlations among the three scales within each wave. Split-plot analyses of variance and independent samples t test were used to explore discriminant validity with smoking status as the independent variable and the KABs as the dependent variables. Finally, predictive validity was established via linear regression modeling with knowledge and attitude as the independent variables and behavior as the dependent variable.

Results

Reliability

Tables 1 and 2 present the reliability and content validity analyses of the three scales at waves 1 and 7 (wave 3 analyses are available in Supplementary Table S2). At each of the three waves, the three scales demonstrated moderate to high reliability: knowledge (8 items; α range: .87–.90); attitude (7 items; α range: .84–.87); behavior (5 items; α range: .80–.86). The internal consistency of the three scales was supported by principal component factor analyses showing high first-factor saturation. Analyses at all three timepoints supported single-factor loadings and explained variance consistently above 50%: knowledge (eigenvalue range: 4.37–4.50; variability range: 52%–61%); attitude (eigenvalue range: 3.62–3.97; variability range: 52%–57%); behavior (eigenvalue range: 2.80–3.22; variability range: 56%–64%). The removal of any items did not improve the reliability of any of the measures. The range of scale total score means and SDs supported approximately normal distributions for knowledge (M_{range} = 4.37–4.50; SD_{range} = 0.58–0.64),

Table 1. Principal Component Analyses (PCA) and Reliability, Wave 1

Scales items	Wave 1		
	Factor loading	Corrected item total *r*	Item *m* (*SD*)
Knowledge			
Thirdhand smoke can be found in cars where people have smoked.	.767	.667	4.65 (.72)
Thirdhand smoke can be found in the dust of homes where people have smoked.	.763	.665	4.38 (.89)
Thirdhand smoke can make kids sick.	.762	.672	4.33 (.93)
Thirdhand smoke contains dangerous chemicals.	.747	.647	4.30 (.97)
Thirdhand smoke sticks to surfaces.	.729	.627	4.46 (.80)
Thirdhand smoke is dangerous for pets.	.719	.621	4.30 (.91)
Thirdhand smoke can linger in hotel rooms where guests have smoked.	.667	.552	4.62 (.80)
Thirdhand smoke in my home can reduce its value.	.623	.517	3.95 (1.05)
Scale mean (*SD*)	4.37 (0.64)		
Scale PCA eigenvalue (% of variance)	4.19 (52%)		
Scale Cronbach's α	.865		
Attitude			
Landlords should be required to disclose if a smoker has lived in the rental unit.	.822	.700	4.14 (1.11)
Sellers should be required to disclose if someone has smoked in their home.	.811	.688	4.15 (1.08)
Sellers should be required to disclose if products have been exposed to tobacco smoke.	.786	.675	3.83 (1.19)
Childcare providers should be nonsmokers.	.724	.623	4.00 (1.25)
Hospitals should hire only nonsmokers.	.674	.561	2.98 (1.35)
I support smokefree policies.	.591	.463	4.54 (.93)
It should be illegal to smoke inside vehicles with children present.	.579	.453	4.62 (.90)
Scale mean (*SD*)	4.04 (0.80)		
Scale PCA eigenvalue (% of variance)	3.62 (52%)		
Scale Cronbach's α	.839		
Behavior			
I would buy a car that has been smoked in.	.840	.698	3.65 (1.34)
I would buy furniture from a smoker.	.780	.619	3.93 (1.24)
I would move into a home that has been smoked in.	.773	.607	3.43 (1.31)
In general, I avoid places where people have smoked.	.710	.551	3.19 (1.25)
When I travel, I stay in places that have no-smoking policies.	.617	.454	4.12 (1.15)
Scale mean (*SD*)	3.79 (0.94)		
Scale PCA eigenvalue (% of variance)	2.80 (56%)		
Scale Cronbach's α	.802		

attitude (M_{range} = 4.04–4.20; SD_{range} = 0.75–0.80), and behavior (M_{range} = 3.78–3.86; SD_{range} = 0.94–0.99). Overall, the data supported internally consistency with dominant single-factor loading.

Validity

Given the research demonstrating positive relationships between KABs,[21] convergent validity was established through examining the correlations among the three scales within each wave. Analyses found significant correlations among the three scales at all three timepoints (*r* range: .45–.85; all *p* values <.001). The full test–retest correlation matrix is available in the online supplemental materials (Supplementary Table S3), demonstrating temporal stability over the 7-month period.

Discriminant validity was established following the theoretical premise[4] that smokers, who are actively engaging in the creation of THS, would hold lower THS-related KAB perceptions than nonsmokers. Thus, KAB means were expected to be lower for current smokers than nonsmokers. Split-plot analyses of variance found a small, statistically significant interaction effect between wave (within-subjects) and smoking status (between-subjects) for knowledge ($F[2,114] = 3.87$, $p < .05$) and a smoking status main effect for knowledge ($F[2,114] = 17.73$, $p < .001$), attitudes ($F[1,114] = 19.80$, $p < .001$), and behavior ($F[1,114] = 43.43$, $p < .001$). These effects were explored further via independent samples *t* test, which found smokers, compared with nonsmokers, in all three waves to have significantly lower means on knowledge (*t* range: 4.87–7.93; *d* range: .57–.61; all *p* values <.001), attitude (*t* range: 5.09–9.71; *d* range: .78–.82; all *p* values <.001), and behavior (*t* range: 5.66–11.86; *d* range: .90–.99; all *p* values <.001). The full set of test results is reported in Supplementary Table S4.

Finally, predictive validity was established following theoretical expectations that knowledge and attitude should be associated with within-wave behavior.[4] Predictive validity was supported in all three waves (r^2 range: .41–.48; *F* range: 128.58–376.13; all *p* values <.001) with knowledge being significantly associated with behavior ($\hat{\beta}$ range: .272–.393; all *p* values <.01) and attitude being slightly more associated ($\hat{\beta}$ range: .576–.732; all *p* values <.001). The full regression results are reported in Supplementary Table S5.

Discussion

Research on THS has grown exponentially over the last decade.[3] However, gaps in social scientific tools to understand population perceptions of, and experiences with, THS remain. Results from the present longitudinal study suggest that the developed scales provide reliable measures of KABs related to THS. The findings also provide preliminary evidence of the content, construct, and predictive validity of these measures. These scales build on past

Table 2. Principal Component Analyses (PCA) and Reliability, Wave 7

Scales items	Wave 7		
	Factor loading	Item total *r*	Item *m* (*SD*)
Knowledge			
Thirdhand smoke can be found in cars where people have smoked.	.774	.681	4.72 (.59)
Thirdhand smoke can be found in the dust of homes where people have smoked.	.785	.704	4.53 (.72)
Thirdhand smoke can make kids sick.	.819	.753	4.44 (.80)
Thirdhand smoke contains dangerous chemicals.	.769	.688	4.51 (.85)
Thirdhand smoke sticks to surfaces.	.808	.725	4.56 (.66)
Thirdhand smoke is dangerous for pets.	.782	.710	4.36 (.85)
Thirdhand smoke can linger in hotel rooms where guests have smoked.	.722	.631	4.67 (.67)
Thirdhand smoke in my home can reduce its value.	.685	.594	4.23 (.91)
Scale mean (*SD*)	4.50 (0.58)		
Scale PCA eigenvalue (% of variance)	4.73 (59%)		
Scale Cronbach's α	.896		
Attitude			
Landlords should be required to disclose if a smoker has lived in the rental unit.	.844	.724	4.31 (.97)
Sellers should be required to disclose if someone has smoked in their home.	.843	.726	4.34 (.94)
Sellers should be required to disclose if products have been exposed to tobacco smoke.	.858	.753	4.10 (1.08)
Childcare providers should be nonsmokers.	.687	.605	4.03 (1.17)
Hospitals should hire only nonsmokers.	.691	.602	3.34 (1.34)
I support smokefree policies.	.641	.517	4.62 (.81)
It should be illegal to smoke inside vehicles with children present.	.583	.470	4.64 (.74)
Scale mean (*SD*)	4.20 (0.75)		
Scale PCA eigenvalue (% of variance)	3.86 (55%)		
Scale Cronbach's α	.854		
Behavior			
I would buy a car that has been smoked in.	.840	.732	3.62 (1.35)
I would buy furniture from a smoker.	.844	.737	3.84 (1.31)
I would move into a home that has been smoked in.	.830	.717	3.49 (1.38)
In general, I avoid places where people have smoked.	.740	.595	4.07 (1.14)
When I travel, I stay in places that have no-smoking policies.	.710	.563	4.29 (1.03)
Scale mean (*SD*)	3.86 (0.99)		
Scale PCA eigenvalue (% of variance)	3.16 (63%)		
Scale Cronbach's α	.854		

THS assessment tools,[12–14] providing broader opportunities for the incorporation of self-report measures in THS prevention efforts and research.

In addition, the developed KAB scales provide new opportunities for tobacco control advocates and scholars to identify the gaps in knowledge, misperceptions, and obstacles to behavior change, which increase the likelihood of exposure to THS. This understanding could facilitate the design of novel health promotion materials that would arm at-risk populations with information to better protect themselves from THS exposure. Similarly, this understanding also could highlight specific policy initiatives that perpetuate involuntary THS exposure, such as the impact of grandfather clauses on smokefree policies or the lack of tobacco use disclosure in real estate transactions. Over time, results from repeated use will allow tobacco control advocates to better track and monitor THS perceptions. Such measures are especially timely regarding global tobacco endgame goals[15] that require broadening the scope of tobacco control efforts.

Some limitations of this study should be acknowledged. First, although the sampling frame was broad, only California residents were included. There are likely biases in the sample stemming from the lack of representation. Given the sample was recruited from Facebook, participants are likely more reflective of middle age and young adult social media users; recruitment from other social media platforms, especially those with higher male representation and older participants, might find different results. Similarly, panel designs typically contain high attrition rates with less representation in subsequent groups than the first. Finally, across all three scales, item means were relatively high, suggesting the items do not discriminate at lower levels of KABs. Future research should seek to address these limitations by including items that are more difficult, such as less known prevention behaviors, and by including national and international populations.

Conclusion

Numerous scales have been vetted as reliable and valid measures for assessing SHS-related KABs. Currently, standard measures of KABs related to THS are minimally available. This study sought to reduce the scarcity through the development and testing of three THS scales. The present findings provide tobacco control advocates, scholars, and practitioners tools for assessing KABs related to THS. This information is critical to the development, implementation, and evaluation of novel tobacco control strategies.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interests

None declared.

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