
Associations between hookah tobacco smoking knowledge and hookah smoking behavior among US college students

Erin Nuzzo¹, Ariel Shensa¹, Kevin H. Kim², Michael J. Fine^{1,3}, Tracey E. Barnett⁴, Robert Cook⁵ and Brian A. Primack^{1,6*}

¹Division of General Internal Medicine, Department of Medicine, ²Department of Psychology in Education, University of Pittsburgh School of Education, ³Center for Health Equity Research and Promotion, VA Pittsburgh Healthcare System, Pittsburgh, PA 15213, USA, ⁴Department of Behavioral Science and Community Health, ⁵Department of Epidemiology, University of Florida, Gainesville, FL 32610, USA and ⁶Division of Adolescent Medicine, Department of Pediatrics, University of Pittsburgh School of Medicine, Pittsburgh, PA 15213, USA.

*Correspondence to: B. A. Primack. E-mail: bprimack@pitt.edu

Received on February 24, 2012; accepted on August 8, 2012

Abstract

Hookah tobacco smoking is increasing among US college students, including those who would not otherwise use tobacco. Part of hookah's appeal is attributed to the perception that hookah is less harmful than cigarettes. The aims of this study were to assess knowledge of harmful exposures associated with hookah smoking relative to cigarette smoking and to determine associations between this knowledge and hookah smoking outcomes. Students ($N = 852$) at the University of Florida were randomly sampled via e-mail to obtain information on demographics, hookah smoking behavior and knowledge of five exposures (e.g. tar and nicotine). Multivariable logistic regression models assessed independent associations between knowledge and hookah smoking outcomes. Of the five factual knowledge items asked, 475 (55.8%) of the respondents answered none correctly. In multivariable models, correct responses to any knowledge items were not associated with lower odds of hookah smoking or susceptibility to hookah smoking in the future. Although college students are largely unaware of the toxicant exposures associated with hookah smoking, there is little association between knowledge and hookah smoking behavior.

Introduction

A hookah (also known as a waterpipe or narghile) is an apparatus increasingly used among adolescents and young adults in the United States to smoke tobacco. Convenience and random samples of college students indicate 20–40% ever use and 5–20% current use (past 30 days' use) of hookah to smoke tobacco [1–4]. Moreover, whereas cigarette smoking often decreases during the course of college [5], hookah use may actually increase during the same time period [6]. Hookah use is also increasing among secondary school students. Barnett *et al.* [7] reported that 17% of a state-wide sample of Florida adolescents had ever smoked tobacco from a hookah, with similar results among secondary school students in Arizona and California [8, 9].

Many hookah tobacco smokers perceive hookah smoking as having a low potential for harm and addictiveness [3, 4, 10, 11], yet studies suggest that it exposes the user to high levels of toxicants and carcinogens. In fact, the World Health Organization [12] reports that one hookah tobacco smoking session exposes the user to about 100 times the smoke volume of a single cigarette. Other research confirms that, compared with a single cigarette, one hookah session is associated with substantially more exposure to tar, nicotine, carbon

monoxide and heavy metals [13–16]. These findings are not ambiguous; for example, it is estimated that, compared with a single cigarette, a hookah smoking session contains about 40 times the tar [15, 16].

Many individuals who smoke hookah tobacco are otherwise not exposed to combustion products of tobacco. For example, between 30% and 50% of college-aged hookah tobacco smokers do not also use cigarettes [17–19]. Although the precise nature of the relationship between cigarette and hookah smoking remains unknown, it is possible that those who find hookah smoking to be pleasant and social may eventually try cigarettes as well. Moreover, because hookah tobacco smoke contains nicotine, which is addictive, hookah smoking may lead to increased use of cigarettes or other tobacco products.

One reason for the popularity of hookah smoking, even among populations that do not otherwise use tobacco, may be the lack of knowledge of toxicant exposures associated with the practice. For example, Primack *et al.* [3] surveyed a random sample of 647 college students and found that, in fully adjusted multivariable models, 1-year water-pipe smoking was associated with low perceived harm [odds ratio (OR)=2.5, 95% confidence interval (95% CI) 1.7–3.8] and addictiveness (OR=4.6, 95% CI 3.0–7.1) compared with cigarette smoking. Consistent with the health belief model linking knowledge with behavior [20], these data suggest that educational interventions designed to increase knowledge regarding hookah tobacco smoking may be valuable in reducing hookah tobacco smoking.

However, no study to date has directly assessed knowledge related to specific exposures associated with hookah tobacco smoking (e.g. tar, nicotine and carbon monoxide) and how this knowledge is related to hookah tobacco smoking behavior. The aims of this study were (i) to assess knowledge of specific toxicant exposures associated with hookah tobacco smoking among US college students and (ii) to determine the independent associations between this knowledge and hookah tobacco smoking outcomes (i.e. current use and susceptibility to future use). For the second aim, our *a priori*

hypotheses based on the health behavior model were that correct identification of one hookah tobacco smoking session as containing more tar [Hypothesis 1a (H1a)], nicotine (H1b), carcinogens (H1c), carbon monoxide (H1d) and heavy metals (H1e) compared with a single cigarette would be associated with lower odds for current hookah smoking and lower odds for susceptibility to hookah smoking in the future (H2a–e, respectively, for each toxicant exposure). We additionally hypothesized that an increase in an individual's overall summary knowledge of toxicant exposures associated with one hookah tobacco smoking session, compared with a single cigarette, would be associated with significantly lower odds for current use of hookah tobacco (H1f) and susceptibility to hookah tobacco use in the future (H2f).

Methods

Participants and procedures

We obtained from the registrar of the University of Florida, a random sample of 2400 e-mail addresses for first- and second-year undergraduate and graduate students for the 2010–11 school year. First- and second-year undergraduate and graduate students were the focus of this study, as previous studies [1, 3] have shown that it is these populations, entering a new environment, who are most susceptible to the uptake of new activities, such as hookah tobacco smoking. In September 2010, we invited all of these individuals to participate in an online study for a \$10 Amazon.com gift card. Of the 2339 individuals who received the invitation (61 e-mails were returned), 852 (36%) responded to the survey. The study procedures were IRB-approved by both the University of Florida and the University of Pittsburgh. To our knowledge, these participants were not exposed to any previous hookah smoking prevention initiatives or education campaigns

Measures

We assessed respondents' demographics, hookah tobacco smoking behavior, susceptibility to hookah use, and knowledge of toxicant exposure.

Demographics

Demographic items assessed age, sex, race, enrollment status (undergraduate versus graduate), and residence type (on-campus versus off-campus).

Hookah tobacco smoking

Before the items assessing hookah tobacco use, the survey contained these instructions in bold type: 'The following questions ask about smoking tobacco from a hookah (also known as a water-pipe or narghile). These questions only ask about smoking tobacco, not marijuana'. The first item then asked, 'Have you ever smoked tobacco from a hookah, even a puff?' with yes or no responses. Those who responded 'yes' then received the question, 'Have you smoked tobacco from a hookah in the past year, even a puff?' with yes or no responses. Finally, those who responded 'yes' to this item were asked, 'Within the past 30 days, on how many days did you smoke tobacco from a hookah?' Response choices were none; 1–2 days; 3–5 days; 6–10 days; 11–20 days and 21–30 days. Our primary outcome was current smoking of hookah tobacco, defined as having smoked at least 1 day in the past 30 days. We used similar items to assess cigarette smoking ever, in the past year, and in the past 30 days.

Susceptibility to hookah tobacco

We assessed our secondary outcome, susceptibility to hookah tobacco use, using the item, 'Do you intend to smoke tobacco from a hookah sometime in the rest of your life?' with response categories of definitely yes; probably yes; probably no and definitely no. We created a dichotomous variable defining participants as 'not susceptible' if they indicated 'definitely no' and 'susceptible' if they marked any other response. Similar measures of susceptibility have been validated for cigarette smoking and are commonly utilized in the literature [21, 22].

Knowledge about hookah tobacco use

In order to assess knowledge, participants were first instructed to 'Please answer the following questions to the best of your knowledge. In this question, we'd

like you to compare smoking a single cigarette with a single hookah tobacco session'. This was followed by five items, such as 'Which has more tar?' and 'Which has more nicotine?' All items are shown in Table II. For each term, Likert-type responses included definitely cigarette; probably cigarette; don't know; probably hookah and definitely hookah. For each of these questions, the correct answer is hookah, based upon established research [13–16]. Therefore, we counted each individual's response as correct if he or she indicated 'probably hookah' or 'definitely hookah' and as incorrect if he or she indicated 'probably cigarette' or 'definitely cigarette'. A response of 'don't know' was categorized separately. We developed a summary knowledge score equal to the number of correct responses that individual had out of five.

Methods of analysis

We described demographics of the respondent sample by computing overall counts and percentages. We then summarized demographic data according to our primary and secondary outcome measures. For the secondary outcome, we only included non-smokers, because the concept of susceptibility has been validated and is generally utilized among non-users [21, 22]. We assessed statistical significance for these bivariable analyses using chi-square tests. We computed internal reliability of the five knowledge items using Cronbach's α [23].

We used multivariable logistic regression models to assess independent associations between each of our individual knowledge items and current hookah smoking (H1a–e) and susceptibility to hookah in the future (H2a–e). We used similar models to determine independent associations between the summary score and current hookah smoking (H1f) and susceptibility to hookah use in the future (H2f). All multivariable models controlled for all measured covariates. Although not all covariates were associated with outcomes in bivariable analyses, we had determined *a priori* to include all covariates in analyses. For each multivariable model, we conducted additional analyses to test interaction terms between

the independent variable and each of the sociodemographic covariates. Statistical analyses were performed with Stata 11.1 (Stata Corp, College Station, TX, USA), and two-tailed P -values <0.05 were considered to be significant.

Results

Compared with the 2400 survey recipients, the 852 respondents were younger (20.6 years versus 21.1 years, $P = 0.04$), more commonly female (47% versus 40%, $P < 0.001$) and more commonly white (71% versus 59%, $P < 0.001$). As a group, respondents were more often aged <20 years (67%), male (53%) and white (71%). About three-fourths (76%) were undergraduate students and most students (62%) lived off-campus (Table I).

Overall, 331 (39%) of survey respondents had ever smoked hookah tobacco, 283 (28%) had done so within the past year and 116 (14%) were current hookah tobacco smokers. Cigarette smoking, which was less prevalent than hookah smoking, was reported by 288 (34%) ever, 182 (21%) in the past year and 88 (10%) in the past 30 days. However, among current hookah users, hookah smoking was less frequent than cigarette smoking: mean hookah smoking frequency was 3–5 times per month, whereas mean cigarette smoking frequency was 6–10 times per month.

Among the 725 non-hookah smokers for whom susceptibility data were available, 369 (51%) were defined as susceptible to hookah tobacco smoking in the future.

In bivariable analyses, current hookah tobacco smoking was associated with younger age ($P = 0.004$) and undergraduate student status ($P = 0.007$). Although susceptibility to hookah tobacco use was not significantly different among individuals of various demographic backgrounds, there was a non-significant trend toward higher susceptibility among older students ($P = 0.06$, Table I).

In bivariable analyses, the summary score was not significantly associated with current use ($P = 0.65$) or susceptibility to use ($P = 0.15$). Of the five factual knowledge items, students answered a mean of

1.0 (SD = 1.4) correctly. More than half (55.8%) of the survey population answered no items correctly (Table II). There was, however, a significant association between a ‘don’t know’ response to various individual knowledge items and both current hookah tobacco use and susceptibility to hookah tobacco use ($P = 0.02$ to >0.001 , Table II). Cronbach’s α for the five item scale was 0.80.

In multivariable models, there were no significant associations established between correct or incorrect answers and current hookah tobacco use or susceptibility to hookah tobacco use. Overall knowledge was not associated with current hookah tobacco use (AOR = 1.06, 95% CI 0.92–1.22; Table III) or susceptibility to hookah tobacco use (AOR = 0.94, 95% CI 0.85–1.05). There was, however, for all knowledge items but tar, an association between a ‘don’t know’ response and hookah tobacco smoking behavior. Admission by survey participant that he or she did not know the answer to a knowledge item was associated with a significantly lower adjusted OR of current hookah tobacco use for nicotine, carcinogens and carbon monoxide (AOR = 0.34, 95% CI 0.17–0.68, AOR = 0.43, 95% CI 0.25–0.75 and AOR = 0.50 95% CI 0.31–0.82, respectively) and a significantly lower adjusted OR of susceptibility to hookah tobacco use in the future for nicotine, carcinogens and heavy metals (AOR = 0.49, 95% CI 0.34–0.72, AOR = 0.58, 95% CI 0.41–0.82 and AOR = 0.69, 95% CI 0.49–0.97, respectively).

Although we tested interaction terms between the independent variable and each of the sociodemographic covariates for each multivariable model, no significant interaction terms were noted.

Discussion

We found a substantial knowledge gap among a random sample of college students: the vast majority of individuals were unaware of the toxin load associated with hookah tobacco smoking. The sizable lack of knowledge of hookah toxicant exposures identified in this study is consistent with results from other studies, which have shown that most individuals view hookah tobacco smoking as

Table I. Respondent demographic characteristics by hookah tobacco smoking outcomes

Characteristic	Whole sample ^a (<i>N</i> = 852 [%])	Current hookah tobacco user ^b (<i>N</i> = 852 [%])			Susceptibility to hookah tobacco use ^c (<i>n</i> = 725 ^d [%])		
		Yes ^a (<i>n</i> = 116)	No ^a (<i>n</i> = 736)	<i>P</i> -value ^e	Yes ^a (<i>n</i> = 369)	No ^a (<i>n</i> = 356)	<i>P</i> -value ^e
Age (years)				0.004			0.06
18	37	39	36		33	40	
19	30	40	29		32	26	
20	6	8	6		7	4	
≥21	27	14	29		28	30	
Sex				0.29			0.84
Female	47	42	47		48	48	
Male	53	58	53		52	52	
Race				0.65			0.28
White	71	75	70		73	67	
Black	9	5	9		9	10	
Asian/Pacific Islander	13	12	13		12	15	
Other	7	8	7		7	7	
Enrollment status				0.007			0.55
Undergraduate	76	86	75		75	73	
Graduate	24	14	25		25	27	
Residence				0.12			0.75
On-campus	38	44	37		36	37	
Off-campus	62	56	63		64	63	

^aRepresent column percentages. Percentages are based on the total for each category and may not total 100 due to rounding.

^bHaving smoked tobacco from a hookah in the last 30 days at least once.

^cAll participants who did not state that they were definitely not planning on smoking hookah tobacco in the future.

^dOnly hookah non-smokers were included in these analyses. The total *n* = 725 instead of 736 because 11 non-smokers had missing data for the susceptibility item.

^eFor chi-square analyses.

less harmful or less addictive than cigarettes [3, 4, 10, 11].

However, we also found that there was little association between correct or incorrect knowledge and hookah tobacco smoking outcomes, contrary to what was predicted based on the health belief model. Correct identification of one hookah tobacco smoking session as containing more tar, nicotine, carcinogens, carbon monoxide and heavy metals compared with a single cigarette was not associated with lower odds for current hookah smoking (H1a–e, respectively, for each toxicant exposure) or lower odds for susceptibility to hookah smoking in the future (H2a–e). Additionally, there was no significant association between summary knowledge and current hookah tobacco smoking (H1f) or susceptibility to hookah tobacco use in the future (H2f).

Although this study did not demonstrate a link between knowledge and hookah tobacco use, previous studies have found that active hookah users are more likely than non-hookah users to perceive hookah smoking as less harmful or less addictive than cigarettes [3, 11, 24]. This apparent discrepancy between findings regarding knowledge and perceptions may stem from the fact that, for an individual, general knowledge does not necessarily translate into a belief that one is personally at higher risk [25]. People may tend to underestimate the risks to their own health; for example, previous research has shown that cigarette smokers tend to be overly optimistic about their personal risk of illness even when knowledgeable of the actual risks [26, 27]. These results suggest that, while our study demonstrates a definite knowledge gap,

Table II. Individualized and summary knowledge items by hookah tobacco smoking outcomes

Knowledge item	Whole sample ^a (N = 852 [%])	Current Hookah tobacco user ^b (N = 852 [%])		P-value ^c	Susceptibility to hookah tobacco use ^c (n = 725 ^d [%])		P-value ^e
		Yes ^a (n = 116)	No ^a (n = 736)		Yes ^a (n = 369)	No ^a (n = 356)	
Which has more tar?				0.01			0.10
Incorrect	53	53	53		56	48	
Correct	21	30	19		19	21	
Don't know	27	17	28		25	31	
Which has more nicotine?				0.001			>0.001
Incorrect	64	77	62		69	54	
Correct	14	14	14		14	15	
Don't know	22	9	24		18	31	
Which has more carcinogens?				0.01			0.004
Incorrect	56	67	55		60	49	
Correct	15	16	15		15	16	
Don't know	28	16	30		25	35	
Which has more carbon monoxide?				0.01			0.14
Incorrect	35	46	34		37	31	
Correct	24	26	24		25	23	
Don't know	40	29	42		38	45	
Which has more heavy metals?				0.55			0.02
Incorrect	42	47	41		46	36	
Correct	22	21	23		21	25	
Don't know	36	33	36		33	39	
Summary score ^f				0.65			0.15
0	56	51	57		57	56	
1	18	17	18		16	19	
2	12	16	11		14	9	
3	7	9	7		7	8	
4	3	4	3		2	3	
5	4	4	5		4	5	
Mean (SD)		1.07 (1.38)	0.95 (1.39)	0.80 ^g	0.93 (1.34)	1.00 (1.45)	0.27 ^g

^aRepresent column percentages. Percentages are based on the total for each category and may not total 100 due to rounding.

^bHaving smoked tobacco from a hookah in the last 30 days at least once.

^cAll participants who did not state that they were definitely not planning on smoking hookah tobacco in the future.

^dOnly hookah non-smokers were included in these analyses. The total n = 725 instead of 736 because 11 non-smokers had missing data for the susceptibility item.

^eFor chi-square analyses.

^fThe number of items scored correct summed.

^gDetermined using *t*-test.

filling this knowledge gap may not have a significant effect on hookah tobacco use and susceptibility.

It is possible that underestimation of risk could be related to the fact that hookah smoking is relatively intermittent in this population; current hookah tobacco smokers only smoked an average of three to five times in the past month. However, this pattern is not very different from cigarette smoking in

college; in this sample, current cigarette users only smoked an average of six to ten times in the past month.

Interestingly, an answer of 'don't know' to many of the knowledge items was associated with significantly 'decreased' odds of either current hookah tobacco smoking or susceptibility to hookah tobacco smoking. In the bivariable analysis, there was

Table III. Bivariable and multivariable associations between individualized and summary knowledge items and hookah tobacco smoking outcomes

Knowledge items	Current hookah tobacco user ^a (N = 852)		Susceptibility to hookah tobacco use ^b (n = 725 ^c)	
	OR (95% CI)	AOR (95% CI) ^d	OR (95% CI)	AOR (95% CI) ^d
Which has more tar?				
Incorrect	1.00	1.00	1.00	1.00
Correct	1.56 (1.00–2.47)	1.52 (0.95–2.44)	0.79 (0.53–1.16)	0.76 (0.51–1.14)
Don't know	0.61 (0.36–1.04)	0.68 (0.39–1.19)	0.70 (0.50–1.00)	0.71 (0.50–1.02)
Which has more nicotine?				
Incorrect	1.00	1.00	1.00	1.00
Correct	0.78 (0.44–1.39)	0.84 (0.46–1.50)	0.72 (0.47–1.11)	0.67 (0.43–1.05)
Don't know	0.32 (0.16–0.60)	0.34 (0.17–0.68)	0.46 (0.32–0.65)	0.49 (0.34–0.72)
Which has more carcinogens?				
Incorrect	1.00	1.00	1.00	1.00
Correct	0.87 (0.51–1.51)	0.89 (0.51–1.56)	0.78 (0.51–1.19)	0.71 (0.46–1.10)
Don't know	0.44 (0.26–0.75)	0.43 (0.25–0.75)	0.57 (0.41–0.79)	0.58 (0.41–0.82)
Which has more carbon monoxide?				
Incorrect	1.00	1.00	1.00	1.00
Correct	0.79 (0.48–1.28)	0.77 (0.47–1.27)	0.91 (0.62–1.34)	0.90 (0.60–1.33)
Don't know	0.50 (0.31–0.79)	0.50 (0.31–0.82)	0.72 (0.51–1.01)	0.76 (0.54–1.09)
Which has more heavy metals?				
Incorrect	1.00	1.00	1.00	1.00
Correct	0.81 (0.48–1.36)	0.86 (0.51–1.46)	0.65 (0.44–0.95)	0.62 (0.42–0.93)
Don't know	0.80 (0.51–1.25)	0.85 (0.54–1.36)	0.65 (0.47–0.91)	0.69 (0.49–0.97)
Summary score ^e	1.06 (0.92–1.21)	1.06 (0.92–1.22)	0.97 (0.87–1.08)	0.94 (0.85–1.05)

AOR, adjusted odds ratio. ^aHaving smoked tobacco from a hookah in the last 30 days at least once.

^bAll participants who did not state that they were definitely not planning on smoking hookah tobacco in the future.

^cOnly hookah non-smokers were included in these analyses. The total $n = 725$ instead of 736 because 11 non-smokers had missing data for the susceptibility item.

^dAdjusted for age, gender, race/ethnicity, graduate student status and housing.

^eThe summary score was the number of items scored correct summed. Associated ORs represent the odds for each 1-point increase in the 5-point scale.

an inconsistent trend among non-hookah smokers or non-susceptible individuals to answer 'don't know', with both groups answering correctly a similar amount. There was no significant difference in incorrect answers between those engaging in hookah tobacco smoking behavior and those abstaining from hookah tobacco smoking behavior in multivariable analyses, however. The cross-sectional design of this study limits our ability to establish causal inferences. It is possible that those with exposure to or interest in hookah tobacco might be more confident, though not necessarily correct, in their knowledge of hookah tobacco smoking, making them less likely to respond 'don't know'. It will be valuable to follow associations between

knowledge and hookah tobacco smoking outcomes in longitudinal samples in order to determine the directionality of these associations. Regardless, the lack of an association between correct or incorrect answers to knowledge items and hookah tobacco smoking behavior suggests that increased knowledge does not act as a strong deterrent to hookah tobacco smoking.

Given the lack of association between correct knowledge and hookah smoking outcomes, it may be valuable to utilize other theoretical frameworks, in addition to the health belief model, to assist with understanding mechanisms underlying hookah tobacco smoking. For example, the theory of reasoned action, an often employed theory when describing

youth tobacco use, predicts that more positive attitudes toward and normative beliefs regarding a behavior increases the likelihood of intending to perform, and ultimately performing, a given behavior [28]. Indeed, many more successful anti-smoking interventions for cigarettes focus on dispelling positive expectations adolescents have for smoking, rather than emphasizing negative consequences of tobacco use [29–31]. It may be beneficial to explore associations between positive attitudes and normative beliefs and hookah smoking behavior in future studies.

Additionally, altering environmental factors, by limiting hookah smoking in public places, may prove successful in decreasing hookah tobacco smoking rates. While clean air laws that ban cigarette smoking in public places are proliferating throughout the United States, few of these laws ban hookah tobacco smoking [32]. Clean air laws have shown success in lowering cigarette smoking, both by limiting opportunities to smoke and by changing attitudes toward smoking [33]. Aiming anti-hookah tobacco smoking campaigns at countering positive attitudes toward hookah smoking and altering public policy may prove more effective than solely educating students about the risks.

Limitations

A potential limitation of this study is that the knowledge items we surveyed were limited to toxicant content; other knowledge items, such as the actual harm and addictiveness of hookah versus cigarettes, were not assessed. However, although there is ample evidence for the specific comparisons that we made between hookah and cigarettes [13–16], no data quantifying specific health risks and addictiveness of hookah yet exist. It will be valuable to integrate more specific biomedical information about the harms of hookah tobacco smoking as this information become available.

This study was also potentially limited in that our e-mail survey had a response rate of 36%. However, systematic reviews have demonstrated 36% is an average response rate for this type of study [34, 35]. A further limitation of this study is that

our respondents were more likely to be younger, Caucasian and female; this bias is a known limitation of this type of research, because previous surveys of college students demonstrate that these students are more likely to respond [36, 37]. This may have artificially skewed the demographics of our hookah tobacco user and hookah tobacco susceptible populations, however, it should not have had an impact on the knowledge data, as these covariates were controlled for in the multivariable analyses. Additionally, the fact that this survey was administered at only one college may limit our ability to generalize these findings. In the future, it would be useful to repeat this survey to other US college locations to ensure findings are reproducible across the general population.

Conclusion

In conclusion, while there was a definite gap in college student's knowledge of exposure to toxicants associated with hookah tobacco smoking, there was little association between such knowledge and hookah tobacco smoking outcomes in our study. Although educational interventions may ultimately have value, our findings suggest that focusing solely on improving knowledge related to toxicant exposures may not substantially change important hookah tobacco smoking behaviors. Instead, a multifaceted approach that addresses attitudes and environmental factors, in addition to knowledge, much like that used to successfully address cigarette tobacco smoking, may be more effective.

Funding

The National Institutes of Health (R01-CA140150 to B.P.); the Steven Manners Memorial Fund at the University of Pittsburgh Center for Social and Urban Research.

Conflict of interest statement

None declared.

References

- Eissenberg TE, Ward KD, Smith-Simone S *et al.* Waterpipe tobacco smoking on a U.S. College campus: prevalence and correlates. *J Adolescent Health* 2008; **42**: 526–9.
 - Smith SY, Curbow B, Stillman FA. Harm perception of nicotine products in college freshmen. *Nicotine Tob Res* 2007; **9**: 977–82.
 - Primack BA, Sidani J, Agarwal AA *et al.* Prevalence of and associations with waterpipe tobacco smoking among U.S. University students. *Ann Behav Med* 2008; **36**: 81–6.
 - Smith-Simone S, Maziak W, Ward KD *et al.* Waterpipe tobacco smoking: knowledge, attitudes, beliefs, and behavior in two U.S. samples. *Nicotine Tob Res* 2008; **10**: 393–8.
 - National Institutes on Health. 2006. *College Students and Adults Ages 19-45. Monitoring the Future: National Survey Results on Drug use 1975-2006*. vol. 2. Washington, DC: US Department of Health and Human Services, 2006.
 - Jackson D, Aveyard P. Waterpipe smoking in students: prevalence, risk factors, symptoms of addiction, and smoke intake. Evidence from one British university. *BMC Public Health* 2008; **8**: 174.
 - Barnett TE, Curbow BA, Weitz JR *et al.* Water pipe tobacco smoking among middle and high school students. *Am J Public Health* 2009; **99**: 2014–9.
 - Primack BA, Walsh M, Bryce C *et al.* Water-pipe tobacco smoking among middle and high school students in Arizona. *Pediatrics* 2009; **123**: e282–8.
 - Smith JR, Edland SD, Novotny TE *et al.* Increasing hookah use in California. *Am J Public Health* 2011; **101**: 1876–9.
 - Smith JR, Novotny TE, Edland SD *et al.* Determinants of hookah use among high school students. *Nicotine Tob Res* 2011; **13**: 565–72.
 - Aljarrah K, Ababneh ZQ, Al-Delaimy WK. Perceptions of hookah smoking harmfulness: predictors and characteristics among current hookah users. *Tob Induc Dis* 2009; **5**: 16.
 - World Health Organization. 2005. *Waterpipe Tobacco Smoking: Health Effects, Research Needs and Recommended Actions by Regulators*. Geneva, Switzerland: TobReg Advisory Note, World Health Organization, 2005.
 - Astora K. Hooked on hookah? What you don't know can kill you. *TRDRP Newsletter* 2005; **7**: 8–9, 13.
 - Barnett TE, Curbow BA, Soule EK *et al.* Carbon monoxide levels among patrons of hookah cafes. *Am J Prev Med* 2011; **40**: 324–8.
 - Shihadeh A, Saleh R. Polycyclic aromatic hydrocarbons, carbon monoxide, "tar", and nicotine in the mainstream smoke aerosol of the narghile water pipe. *Food Chem Toxicol* 2005; **43**: 655–61.
 - Cobb CO, Shihadeh A, Weaver MF *et al.* Waterpipe tobacco smoking and cigarette smoking a direct comparison of toxicant exposure and subjective effects. *Nicotine Tob Res* 2011; **13**: 78–87.
 - Smith-Simone SY, Curbow BA, Stillman FA. Differing psychosocial risk profiles of college freshmen waterpipe, cigar, and cigarette smokers. *Addict Behav* 2008; **33**: 1619–24.
 - Ward KD, Eissenberg T, Gray JN *et al.* Characteristics of U.S. waterpipe users: a preliminary report. *Nicotine Tob Res* 2007; **9**: 1339–46.
 - Primack BA, Fertman CI, Rice KR *et al.* Waterpipe and cigarette smoking among college athletes in the United States. *J Adolescent Health* 2010; **46**: 45–51.
 - Janz NK, Becker MH. The Health Belief Model: A decade later. *Health Educ Behav* 1984; **11**: 1–47.
 - Pierce JP, Choi WS, Gilpin EA *et al.* Validation of susceptibility as a predictor of which adolescents take up smoking in the United States. *Health Psychol* 1996; **15**: 355–61.
 - Pierce JP, Gilpin EA, Emery SL *et al.* Has the California tobacco control program reduced smoking? *J Am Med Assoc* 1998; **280**: 893–9.
 - Cronbach LJ. Coefficient alpha and the internal structure of tests. *Psychometrika* 1951; **16**: 297–334.
 - Braun RE, Glassman T, Wohlwend J *et al.* Hookah use among college students from a Midwest University. *J Community Health* 2012; **37**: 294–8.
 - Weinstein ND. Unrealistic optimism about susceptibility to health problems. *J Behav Med* 1982; **5**: 441–60.
 - Ayanian JZ, Cleary PD. Perceived risks of heart disease and cancer among cigarette smokers. *J Am Med Assoc* 1999; **281**: 1019–21.
 - Cummings KM, Hyland A, Giovino GA *et al.* Are smokers adequately informed about the health risks of smoking and medicinal nicotine? *Nicotine Tob Res* 2004; **6**: S333–40.
 - Ajzen I, Fishbein M. *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall, 1980.
 - Dalton MA, Sargent JD, Beach ML *et al.* Positive and negative outcome expectations of smoking: implications for prevention. *Prev Med* 1999; **29**: 460–5.
 - Dunlop SM. Talking "truth": predictors and consequences of conversations about a youth antismoking campaign for smokers and nonsmokers. *J Health Commun* 2011; **16**: 708–25.
 - Richardson AK, Green M, Ziao H *et al.* Evidence for truth(R): the young adult response to a youth-focused anti-smoking media campaign. *Am J Prev Med* 2010; **39**: 500–6.
 - The BACCHUS Network. *Reducing Hookah Use: A Public Health Challenge for the 21st Century*. Available at: <http://www.tobaccofreeu.org/pdf/HookahWhitePaper.pdf>. Accessed: 3 September 2012.
 - Levy DT, Friend KB. The effects of clean indoor air laws: What do we know and what do we need to know? *Health Educ Res* 2003; **18**: 592–609.
 - Keeter S, Miller C, Kohut A *et al.* Consequences of reducing nonresponse in a national telephone survey. *Public Opin Quart* 2000; **64**: 125–48.
 - Sheehan KB. Email survey response rates: A review. *J Comput-Mediat Comm* 2001; **6**. Available from: <http://jcmc.indiana.edu/vol6/issue2/sheehan.html>. Accessed: 5 September 2012.
 - Pealer LN, Weiler RM, Pigg RM *et al.* The feasibility of a web-based surveillance system to collect health risk behavior data from college students. *Health Educ Behav* 2001; **28**: 547–59.
 - Porter SR, Whitcomb ME. Non-response in student surveys: The role of demographics, engagement, and personality. *Res High Educ* 2005; **46**: 127–52.
-