Factors Influencing Radon Mitigation Behaviors Among Utah Residents

James D. Johnston, MSPH, PhD, CIH
Siena F. Davis, MPH, CPH, CHES
Gabriel S. Ghanadan
Department of Public Health, Brigham Young University

Andrea M. Jensen, CHES, AE-C
Bryce C. Larsen, MPA, LEHS
Division of Environmental Health, Utah County Health Department

John D. Beard, MPH, PhD
Department of Public Health, Brigham Young University

Abstract **For most individuals, the greatest proportion of radon exposure occurs in the home. Residential radon exposure, however, can be minimized through testing and mitigation. The purpose of our study was to explore mitigation behaviors among individuals who learned their home had high levels of radon (≥4.0 pCi/L or 148 Bq/m^3). We enrolled participants (*N* = 110) from among individuals who visited the Utah County Health Department to purchase a radon test kit. Of those participants with a residential radon level ≥4.0 pCi/L (31%), only 23% performed mitigation within approximately four months after they learned their homes had high radon levels. Traits such as older age, identifying as female, and magnitude of radon level appeared to be associated with performing radon mitigation. Inconvenience and cost appeared to be reasons for not performing radon mitigation. Our findings add to a growing number of studies that document a gap between testing, mitigation, and associated factors. These factors might be best addressed by multifaceted interventions that address policies, risk perception, cost, and other barriers.**

Introduction

Radon (^{222}Rn) is the second leading cause of lung cancer in the U.S. and worldwide (World Health Organization, 2009). For most individuals, the greatest proportion of radon exposure occurs in the home where people spend 60–80% of their time (Cohen Hubal et al., 2000; Klepeis et al., 2001; Spalt et al., 2016). Residential radon exposure can be minimized through testing and mitigation. Appropriately, there is a growing body of research directed at understanding theory-based factors that influence radon testing behaviors of individuals (Davis et al., 2018; Duckworth et al., 2002; Rinker et al., 2014; Weinstein et al., 1990). In homes that are tested and found to have high radon levels, testing must be followed by mitigation to reduce radon levels and ultimately decrease lung cancer rates. To date, however, there is little published data on the proportion of people who mitigate and factors that influence posttesting mitigation behaviors.

The U.S. Environmental Protection Agency's (U.S. EPA) recommended action level for radon is ≥4.0 pCi/L (148 Bq/m^3); for homes with actionable test results, installation of a radon reduction system is recommended as the primary mitigation strategy (U.S. EPA, 2016). The few studies that have assessed radon remediation, however, suggest a relatively low percentage of people actually mitigate after receiving actionable test results. For example, Riesenfeld et al. (2007) found only 43% of Vermont residents mitigated after receiving high test results. A mass media-based radon intervention study in the Washington, DC, area found mitigation percentages ranged from 5.5–40.4% (Doyle et al., 1991). Similarly, a clinic-based intervention study in the Minneapolis, Minnesota, area found <25% of homes with actionable radon levels were mitigated within 1 year of testing (Nissen et al., 2012). Compounding the problem of overall low mitigation percentages, Riesenfeld et al. found approximately 20% of residents who mitigated chose alternative methods to reduce radon rather than installing the recommended radon reduction system. Radon reduction strategies are known to vary in effectiveness, with active ventilation or sub-slab depressurization generally being more effective than sealing cracks or using natural ventilation (Rahman & Tracy, 2009).

Understanding factors that influence radon mitigation behaviors is a necessary first step to developing more effective interventions, as currently there is a paucity of information on this subject. Johnson and Luken (1987) found no significant relationship between high radon levels and participants mitigating their homes. In a later study, however, Doyle et al. (1991) found the magnitude of the reported radon level was positively associated with people taking mitigation steps. Riesenfeld et al. (2007) found that mitigation was associated with higher education, concerns high radon would adversely affect property values, and having a home <10 years old. Weinstein and Sandman (1992) found the home's radon level and the homeowner's global appraisal

TABLE **1**

Demographic and Housing Characteristics of Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Characteristic	#	%
Age (years)		
18–44	7	23
45–54	7	23
55–64	5	17
65–74	5	17
>74	6	20
Gender		
Male	16	59
Female	11	41
Not provided	3	
Race/ethnic background		
Caucasian	29	100
Not provided	1	
Highest grade or degree completed		
Some high school; high school or earned GED certificate; some college	10	33
Bachelor's degree	13	43
Master's degree; some graduate	7	23
Current annual family income		
$15,000–$44,999	6	22
$45,000–$64,999	8	30
$65,000–$84,999	5	19
>$84,999	8	30
Not provided	3	
Relationship status		
Currently married	25	89
Divorced; single, never been married, and not living with a partner	3	11
Not provided	2	
Number of people who live in the home		
1–2	11	39
3–4	9	32
5–9	8	29
Not provided	2	
Mean (*SD*)	3.63 (2.02)	

continued on page 24

of danger were the strongest predictors of the intention to mitigate. Nissen et al. (2012) reported health concerns were the primary reason people listed for mitigation, and cost was the primary reason for no mitigation.

One limitation to understanding radon mitigation percentages in the U.S. is that most of the studies that reported percentages of people who mitigated and their reasons for doing so were primarily conducted in the Eastern and Midwestern states; therefore, these study results might not be generalizable to populations in other U.S. regions. To our knowledge, there are no previous studies that evaluate radon mitigation behaviors in the Intermountain West region, which includes Utah. According to the Utah Department of Environmental Quality (2020), approximately 35% of tested homes in Utah County, Utah, have radon levels ≥4.0 pCi/L. Only 8–18% of Utah residents, however, report having tested for radon (Akerley et al., 2011; Utah Department of Health, 2019). The purpose of this study, therefore, was to explore mitigation behaviors among individuals who learned their home had high levels of radon (≥4.0 pCi/L) after conducting a test using a radon test kit purchased from the Utah County Health Department (UCHD).

Methods

Study Design

Convenience sampling was used to recruit participants (N = 110) at UCHD from May 2014 to January 2016. Participants were individuals living in Utah County who visited the UCHD Division of Environmental Health for the purpose of purchasing a radon test kit. At the time of this study, UCHD sold short-term activated charcoal radon test kits (Air Chek, Inc.) to county residents for $10. From May 2014 to February 2015, participants received $5 off the price of the test kit if they participated in our study. To increase study enrollment and provide additional compensation to participants for completing the radon mitigation survey, compensation was increased to $10 off the price of the test kit for participants who enrolled after February 2015.

Two UCHD employees were trained on study protocols and conducted all recruitment activities, which included asking individuals who visited UCHD to purchase a radon test kit if they would be interested in participating in the study and providing them with a one-page flyer about the study. Those who agreed to participate in the study were asked to complete a consent form and a 52-item survey (Davis et al., 2018; Novilla et al., 2021) while at UCHD. Participants then received a brief educational presentation about radon from a Certified Health

Education Specialist/Environmental Health Educator (i.e., one of the two trained UCHD employees). This presentation reviewed what radon is, how it enters a home, risks of exposure, how a test kit works, how to maintain closed house conditions 12 hr prior and then during the testing time period, where to place the test kit, how long to leave it exposed, how to immediately send the kit back to the lab, and what to do if the test found an elevated radon level. Participants were also provided with educational materials from U.S. EPA and the Utah Department of Environmental Quality (DEQ). Educational information compiled by DEQ included photos of a UCHD employee's mitigation system, average price of having a system installed, and a list of Utah certified radon professionals.

Approximately two weeks after participants purchased their test kits, study personnel checked participants' radon test results online using test kit serial numbers. Participants with radon levels ≥4.0 pCi/L were contacted by phone approximately four months after their test results were posted. At that time, study personnel asked participants to complete a 12-item radon mitigation survey. The institutional review board of Brigham Young University approved this study.

Radon Testing Survey

Study personnel used a 52-item paper and pencil survey to measure predictors of radon testing, sources of radon information, attitudes toward potential radon policies in Utah, and demographic and housing characteristics. This survey was completed by participants at UCHD on the day they picked up their radon test kit. Results of the radon testing survey are reported in Davis et al. (2018) and Novilla et al. (2021). For the current study, we used only the information regarding demographic and housing characteristics.

Radon Mitigation Survey

Approximately four months after participants' radon test results were posted, we used a 12-item phone survey to assess initial radon test procedures and results, radon mitigation actions (if any), postmitigation test results (if any), and factors that influenced the decision to mitigate. Some of the survey questions also included follow-up questions.

TABLE **1** *continued from page 23*

Demographic and Housing Characteristics of Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Characteristic	#	%
Number of children who live in the home		
0	14	50
1–2	6	21
3–6	8	29
Not provided	2	
Mean (*SD*))	1.39 (1.77)	
Own or rent home		
Own	29	97
Rent	1	3
Type of residence		
Single family home	30	100
How long lived in the current residence (years)		
0–10	10	34
>10–20	7	24
>20–30	6	21
>30–55	6	21
Not provided	1	
Mean (*SD*)	19.07 (15.39)	
Radon level (pCi/L) [a]		
4.0–4.5	6	20
4.6–5.9	6	20
6.0–7.0	6	20
7.1–9.5	6	20
9.6–19.4	6	20
Mean (*SD*)	7.88 (3.95)	

Note. Participants ($N = 30$) were individuals who completed a survey regarding radon mitigation behaviors after they found out their residence had radon levels greater than or equal to the U.S. Environmental Protection Agency's recommended action level of 4.0 pCi/L.

[a] Category boundaries set at quintiles of the distribution of radon level.

We used four questions to assess radon test procedures and results. Questions included:

1. When you conducted the radon test in your home, what floor did you collect the measurement on?
   a. Follow-up question: If in the basement, was the test conducted in a living area?
      - Follow-up question: Which room?
2. After you completed the radon test, did you find out what the results were?
3. Were the results of your radon test high (above 4.0 pCi/L)?
   a. Follow-up question: What was the level?
4. Did you have the level retested?
   a. Follow-up question: If yes, was the level high again?

We used four questions to assess mitigation actions. Questions included:

1. After testing your home, did you or anyone else do any work to the house to reduce the radon level?
2. What type of work was done to reduce the radon level in your home?
3. Who performed the work to reduce the radon level in your home?

TABLE **2**

Testing and Mitigation Behaviors of Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Variable	#	%
When you conducted the radon test in your home, what floor did you collect the measurement on?		
Basement	26	87
First floor [a]	4	13
If in the basement, was the test conducted in a living area?		
No	4	15
Yes	22	85
In which room was the radon test conducted?		
Bedroom	7	23
Family, great, living, play, or theater room	18	60
Middle or storage room, hallway, or walk-in closet	5	17
After you completed the radon test, did you find out what the results were?		
No	2	7
Yes	28	93
If yes, were the results of your radon test high (above 4.0 pCi/L)?		
Yes	28	100
If yes, did you have the level retested?		
No	19	68
Yes	9	32
If yes, was the level high again?		
No	3	43
Yes	4	57
Not provided	2	

continued on page 26

4. How much money did you spend to reduce the level of radon in your home?

We used two questions to assess radon test results following mitigation. Questions included:

1. Did you have the level retested after you made these changes to your home to reduce radon levels?
2. When your home was retested for radon, was the level high (above 4.0 pCi/L)?
   a. Follow-up question: What was the level?

We used one multiple-choice/short answer question to assess which factors influenced participants to mitigate: What factors influenced you to make changes to your home to reduce radon levels? For individuals who did not mitigate, we asked: What were your reasons for not making changes to your home to reduce radon levels?

Statistical Analyses

We used SAS version 9.4 to conduct all analyses. We calculated frequencies and percentages for all demographic and housing characteristics as well as radon testing and mitigation behaviors. We also calculated means and standard deviations for the few demographic and housing characteristics collected as continuous variables. We used simple exact unconditional logistic regression models to estimate unadjusted exact odds ratios and exact 95% confidence intervals for associations between demographic and housing characteristics and whether participants mitigated their residence for radon after learning their residence had radon levels above the U.S. EPA's recommended action level. We considered multiple versions (e.g., continuous if appropriate, two categories, three categories, etc.) of the demographic and housing characteristics and used the versions that had the lowest values of the Akaike information criterion (Akaike, 1974; Howe et al., 2011). Given our small sample size, we considered any demographic or housing characteristic that had an *OR* ≥2.00 or ≤0.50 to be associated with mitigating. We used Spearman's correlation coefficients to estimate associations between demographic and housing characteristics and individual reasons participants did not mitigate.

Results

More than 50% of participants were older than 54 years, identified as male, had completed at least a bachelor's degree, had a current annual family income of at least $45,000, were currently married, and owned their home (Table 1). All participants were Caucasian; the means for the number of people who live in the home, number of children who live in the home, how long they have lived in their current residence, and radon level were 3.63 people, 1.39 children, 19.07 years, and 7.88 pCi/L, respectively.

For the radon tests, 87% were conducted in a basement and 85% of these were conducted in a living area (Table 2). For all radon tests, 60% were conducted in a family, great, living, play, or theater room. Moreover, 93% of participants found out their radon test results and 100% of these had high radon levels. Of these participants, 32% retested their residence of whom 57% received a high result again. Only 23% of participants mitigated their residence (i.e., performed or had performed any work to the house to reduce the radon level). Of participants who mitigated, 57% installed a system for ventilation or to draw out the radon, 80% employed a professional contractor, and 80% spent more than $1,000. Of those who mitigated their residence, 80% retested their residence after mitigation and of these, 50% received high results again (i.e., mitigation did not lower the radon level below the U.S. EPA's recommended action level; results not shown).

Among participants who mitigated their residence, 75% selected "concern for your own health" and 75% selected "concern for your children's health" as factors that influenced them to make changes to their home to reduce

radon levels (Table 2). In contrast, among participants who did not mitigate their residence, reasons for not mitigating selected by at least 25% of participants included "inconvenience," "the cost is too great," and "radon levels in my home were not high enough to really concern me" (Table 3).

Demographic and housing characteristics that had *OR*s ≥2.00 for associations with mitigating residence included age >64 years versus 18–64 years, identifying as female versus male, renting versus owning a home, and a radon level ≥6.0 versus 4.0–6.0 pCi/L (Table 4). There were only two statistically significant Spearman's correlation coefficients for associations between demographic and housing characteristics and individual reasons participants did not mitigate: 1) radon level and "making changes to my home would not reduce radon levels enough to make a difference" (r = .45, p = .03) and 2) radon level and "other (please specify)" (i.e., all of the "other" responses together; r = .45, p = .03).

TABLE **2** *continued from page 25*

Testing and Mitigation Behaviors of Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Variable	#	%
After testing your home, did you or anyone else do any work to the house to reduce the radon level?		
No	23	77
Yes	7	23
If yes, what type of work was done to reduce the radon level in your home (select all that apply)?		
A system was installed for ventilation or to draw out the radon	4	57
Doors or windows were opened	2	29
Other: Put a pipe in the floor	1	14
If yes, who performed the work to reduce the radon level in your home (select all that apply)?		
A professional contractor	4	80
A member of the home or friend	1	20
Not provided	2	
If yes, how much money did you spend to reduce the radon level in your home?		
≤$100	0	0
$101–$500	1	20
$501–$1,000	0	0
$1,001–$2,000	3	60
>$2,000	1	20
Not provided	2	
If yes, what factors influenced you to make changes to your home to reduce radon levels (select all that apply)?		
Concern for your own health	3	75
Concern for your children's health	3	75
Concern about property value	1	25
Other: Saw a television program about it and I got a flyer in my mail saying that the mayor had tested his house	1	25
Not provided	3	

Note. Participants (N = 30) were individuals who completed a survey regarding radon mitigation behaviors after they found out their residence had radon levels greater than or equal to the U.S. Environmental Protection Agency's recommended action level of 4.0 pCi/L.

[a] These should be rooms above ground level.

Discussion

Our findings add to a small number of prior studies that found a gap between testing and mitigation among people who receive test results at or above the U.S. EPA's recommended action level of 4.0 pCi/L. In our study of participants with radon levels ≥4.0 pCi/L, only 23% had mitigated by the time of the follow-up phone survey approximately four months later. This finding most closely matches Nissen et al. (2012), who found fewer than 25% of participants in Minnesota mitigated after receiving high test results. The percentage of people who mitigated in our study was lower than that reported by Riesenfeld et al. (2007), who found 43% of Vermont residents mitigated after receiving high test results; our study results, however, were within the range (5.5–40.4%) reported by Doyle et al. (1991) for a mass media-based radon intervention study in the Washington, DC, area. These findings suggest intervention measures should not be limited to efforts to increase radon testing alone but must focus also on increasing the proportion of individuals who follow through with mitigation.

Although Riesenfeld et al. (2007) found mitigation was associated with higher education and concerns high radon levels would adversely affect property values, we did not find strong evidence that education was associated with mitigation and only 25% of our respondents selected "concern about property value" when asked about factors that influenced mitigation. Like Nissen et al. (2012), we found health concerns for themselves and their children were a primary reason for mitigation. We also found older individuals and female participants were more likely to mitigate.

In addition, our findings are similar to those of prior studies that found the magnitude of the radon level in the home was associated with mitigation. In our study, individuals who had radon levels >6.0 pCi/L were more likely to mitigate than individuals with lower radon levels. Doyle et al. (1991)

TABLE **3**

Reasons for Not Making Changes to the Home to Reduce Radon Levels Among Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Reason [a]	#	%
I am not concerned about radon affecting my health	1	4
Radon levels in my home were not high enough to really concern me	6	26
The benefits of reducing radon levels were not clear to me	2	9
The cost is too great	7	30
Inconvenience	8	35
Making changes to my home would not reduce radon levels enough to make a difference	4	17
The radon level in my home was not measured in a living area	1	4
Other (please specify)	16	70
Currently comparing prices of mitigating on my own versus hiring a professional	1	4
Waiting for radon test results	4	17
Haven't had time	3	13
Need to retest	3	13
I would have done something if my retest results from other areas in my house were also high, but in more open areas the test results were lower. My storage room has little air flow, so the results there were high.	1	4
Looking for the right company right now. Not enough information on radon companies. Had neighbors who spent a lot of money on radon-reducing systems, but radon levels weren't reduced enough to be worth it.	1	4
Might be other health problems to worry about at our age	2	9
Mitigation is scheduled for a couple weeks from now, but the company doing it was scheduled out	1	4

Note. Participants ($N = 30$) were individuals who completed a survey regarding radon mitigation behaviors after they found out their residence had radon levels greater than or equal to the U.S. Environmental Protection Agency's recommended action level of 4.0 pCi/L. Participants ($n = 23$, 77%) indicated that they did not do any work to the house to reduce the radon level (Table 2).

[a] Participants were asked to select all reasons that applied.

found the proportion of people who mitigated radon in their homes increased from approximately 12% for homes with radon levels between 4.0–20.0 pCi/L to >40% for homes with radon levels >20 pCi/L. Similarly, Weinstein and Sandman (1992) found that 75–80% of individuals who had homes with radon levels >20.0 pCi/L mitigated. Together, these findings suggest one's perception of risk might play an important role in the decision to mitigate. Indeed, 26% of participants in our study who did not mitigate selected "radon levels in my home were not high enough to really concern me" as a reason why. Interestingly, Weinstein and Sandman found that perceived threat was a stronger predictor of mitigation than the actual radon level. Future studies of the relationship between perceived versus actual risk and individuals' decisions to mitigate are needed to guide future interventions.

Doyle et al. (1991) suggest some of the factors that can interfere with people completing radon mitigation are it is time consuming, technical and complex, and requires coordination with other professionals. Our findings partially support this assessment, as 35% of those who did not mitigate responded it was inconvenient and another 13% responded they had not mitigated due to time constraints. We found 30% of people responded they did not mitigate due to cost, which was also reported by Nissen et al. (2012) as a barrier to mitigation.

Considering radon mitigation is a relatively complex task, we suggest that multifaceted interventions similar to those used by the Iowa AIR Coalition are needed (Bain et al., 2016). Specific intervention measures used in Iowa included increasing radon awareness and testing, sharing stories from lung cancer survivors at community events and legislative sessions, advocating for radon testing and radon-resistant new construction, and providing financial assistance or low-interest loans to help individuals or families cover the costs associated with mitigation. This intervention in Iowa led to a 108% increase in the number of homes mitigated across the state from 2009–2014. For renters, we suggest policies are needed that require property owners to test for radon and to mitigate if levels are ≥4.0 pCi/L.

Our study was limited by its relatively small sample size. Although we enrolled 110 participants, only a small percentage (31%) had homes with radon levels ≥4.0 pCi/L, and of these, only 23% mitigated their homes. Thus, even though some of the odds ratios from our study were large, they were not statistically significant. The small sample size also meant we could not adjust for potential confounders or estimate

TABLE **4**

Associations Between Demographic and Housing Characteristics and Mitigating Residences for Radon Among Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Characteristic	Mitigated		Did Not Mitigate		Exact *OR*[a]	Exact 95% CI[a]
	#	%	#	%		
Age (years)						
18–64	3	43	16	70	1.00	Reference
>64	4	57	7	30	2.93	[0.38, 25.74]
Gender						
Male	2	33	14	67	1.00	Reference
Female	4	67	7	33	3.78	[0.42, 51.67]
Not provided	1		2			
Highest grade or degree completed						
Some high school; high school or earned GED certificate; some college; bachelor's degree	5	71	18	78	1.00	Reference
Master's degree; some graduate school	2	29	5	22	1.42	[0.11, 12.77]
Current annual family income						
$15,000–$54,999	3	50	9	43	1.00	Reference
>$54,999	3	50	12	57	0.76	[0.08, 7.07]
Not provided	1		2			
Relationship status						
Currently married	5	83	20	91	1.00	Reference
Divorced; single, never been married, and not living with a partner	1	17	2	9	1.94	[0.03, 45.02]
Not provided	1		1			
Number of people who live in the home						
1–2	3	50	8	36	1.00	Reference
3–4	3	50	6	27	1.31	[0.13, 13.74]
5–9	0	0	8	36	0.31[b]	[0.00, 2.23]
Not provided	1		1			

continued ▸

unconditional logistic regression models for mitigating that simultaneously included multiple demographic or housing characteristics as independent variables. We also note that our sample of participants was taken from a relatively homogenous population. The majority of participants were Caucasian, identified as male, had at least a bachelor's degree, and owned their home. Thus, our results might not generalize to more diverse locations. We also used an approximately four month follow-up period for this study. It is possible the percentage of individuals who mitigated would have been higher had the follow-up period been longer.

Conclusion

Our findings add to a growing number of studies that have documented the gap between testing and mitigation. In this study, only 23% of individuals with radon levels ≥4.0 pCi/L mitigated their homes. Considering that this study consisted largely of college-educated homeowners who self-selected to purchase a radon test kit from UCHD, the low percentage of individuals who followed through with mitigation is concerning. Factors that could explain whether individuals mitigate include age, gender, magnitude of radon level, inconvenience, time, and cost. These factors likely would be best addressed by multifaceted interventions that address policies, risk perception, cost, and other barriers.

Acknowledgements: We thank the participants of the study and the Utah County Health Department staff and administration for their support.

Corresponding Author: James D. Johnston, Associate Professor, Department of Public Health, Brigham Young University, 2045 Life Sciences Building, Provo, UT 84602.
Email: james_johnston@byu.edu.

TABLE **4** *continued*

Associations Between Demographic and Housing Characteristics and Mitigating Residences for Radon Among Radon Mitigation Survey Participants, Utah County, Utah, May 2014–January 2016

Characteristic	Mitigated		Did Not Mitigate		Exact *OR*[a]	Exact 95% CI[a]
	#	%	#	%		
Number of children who live in the home						
0	4	67	10	45	1.00	Reference
1–2	2	33	4	18	1.24	[0.08, 13.83]
3–6	0	0	8	36	0.27[b]	[0.00, 1.81]
Not provided	1		1			
Own or rent home						
Own	7	100	22	96	1.00	Reference
Rent	0	0	1	4	3.29[b]	[0.00, 62.43]
How long lived in the current residence (10 years)					1.06	[0.58, 1.89]
Not provided	1		0			
Radon level (pCi/L)						
4.0–6.0	1	14	11	48	1.00	Reference
6.1–9.0	3	43	7	30	4.39	[0.29, 269.48]
9.1–19.4	3	43	5	22	5.95	[0.37, 377.14]

Note. Participants ($N = 30$) were individuals who completed a survey regarding radon mitigation behaviors after they found out their residence had radon levels greater than or equal to the U.S. Environmental Protection Agency's recommended action level of 4.0 pCi/L. Of these, 23 participants (77%) indicated that they did not do any work to the house to reduce the radon level and 7 participants (23%) indicated that they did do work to the house to reduce the radon level (Table 2). CI = confidence interval.

[a] Estimated via simple exact unconditional logistic regression models.

[b] Median unbiased estimate.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/TAC.1974.1100705

Akerley, W., Keyser, C., Edwards, S., Wilson, R., Van Duren, T., Akerley, D., Tranter, S., & Sharry, S. (2011). Awareness of radon-associated health risks in Utah. *Utah's Health: An Annual Review*, *16*, 58–60. https://collections.lib.utah.edu/ark:/87278/s6mh0mpp

Bain, A.A., Abbott, A.L., & Miller, L.L. (2016). Successes and challenges in implementation of radon control activities in Iowa, 2010–2015. *Preventing Chronic Disease*, *13*, Article 150596. http://dx.doi.org/10.5888/pcd13.150596

Cohen Hubal, E.A., Sheldon, L.S., Burke, J.M., McCurdy, T.R., Berry, M.R., Rigas, M.L., Zartarian, V.G., & Freeman, N.C. (2000). Children's exposure assessment: A review of factors influencing children's exposure, and the data available to characterize and assess that exposure. *Environmental Health Perspectives*, *108*(6), 475–486. https://doi.org/10.1289/ehp.108-1638158

Davis, S.F., Johnston, J.D., Magnusson, B.M., Novilla, M.L.B., Torgersen, B.K., Schnell, A.J., & Crandall, A. (2018). Predictors of radon testing among Utah residents using a theory-based approach. *Journal of Environmental Health, 80*(6), 20–27.

Doyle, J.K., McClelland, G.H., Schulze, W.D., Elliott, S.R., & Russell, G.W. (1991). Protective responses to household risk: A case study of radon mitigation. *Risk Analysis, 11*(1), 121–134.

Duckworth, L.T., Frank-Stromborg, M., Oleckno, W.A., Duffy, P., & Burns, K. (2002). Relationship of perception of radon as a health risk and willingness to engage in radon testing and mitigation. *Oncology Nursing Forum*, *29*(7), 1099–1107. https://doi.org/10.1188/02.ONF.1099-1107

Howe, C.J., Cole, S.R., Westreich, D.J., Greenland, S., Napravnik, S., & Eron, J.J., Jr. (2011). Splines for trend analysis and continuous confounder control. *Epidemiology*, *22*(6), 874–875. https://doi.org/10.1097/EDE.0b013e31823029dd

Johnson, F.R., & Luken, R.A. (1987). Radon risk information and voluntary protection: Evidence from a natural experiment. *Risk Analysis*, 7(1), 97–107. https://doi.org/10.1111/j.1539-6924.1987.tb00973.x

continued on page 30

References *continued from page 29*

Klepeis, N.E., Nelson, W.C., Ott, W.R., Robinson, J.P., Tsang, A.M., Switzer, P., Behar, J.V., Hern, S.C., & Engelmann, W.H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Science & Environmental Epidemiology*, *11*(3), 231–252. https://doi.org/10.1038/sj.jea.7500165

Nissen, M.J., Leach, J.W., Nissen, J.A., Swenson, K.K., & Kehn, H. (2012). Radon testing and mitigation: An intervention in a primary care setting. *Journal of Cancer Education*, *27*(3), 566–572. https://doi.org/10.1007/s13187-012-0346-z

Novilla, M.L.B., Johnston, J.D., Beard, J.D., Pettit, L.L., Davis, S.F., & Johnson, C.E. (2021). Radon awareness and policy perspectives on testing and mitigation. *Atmosphere*, *12*(8), Article 1016. https://doi.org/10.3390/atmos12081016

Rahman, N.M., & Tracy, B.L. (2009). Radon control systems in existing and new construction: A review. *Radiation Protection Dosimetry, 135*(4), 243–255. https://doi.org/10.1093/rpd/ncp112

Riesenfeld, E.P., Marcy, T.W., Reinier, K., Mongeon, J.A., Trumbo, C.W., Wemple, B.E., & Kaminsky, D.A. (2007). Radon awareness and mitigation in Vermont: A public health survey. *Health Physics*, *92*(5), 425–431. https://doi.org/10.1097/01.HP.0000254862.50407.4a

Rinker, G.H., Hahn, E.J., & Rayens, M.K. (2014). Residential radon testing intentions, perceived radon severity, and tobacco use. *Journal of Environmental Health, 76*(6), 42–47.

Spalt, E.W., Curl, C.L., Allen, R.W., Cohen, M., Adar, S.D., Stukovsky, K.H., Avol, E., Castro-Diehl, C., Nunn, C., Mancera-Cuevas, K., & Kaufman, J.D. (2016). Time–location patterns of a diverse population of older adults: The Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). *Journal of Exposure Science & Environmental Epidemiology*, *26*(4), 349–355. https://doi.org/10.1038/jes.2015.29

U.S. Environmental Protection Agency. (2016). *A citizen's guide to radon: The guide to protecting yourself and your family from radon* (EPA 402/K-12/002). https://www.epa.gov/sites/production/files/2016-12/documents/2016_a_citizens_guide_to_radon.pdf

Utah Department of Environmental Quality, Division of Radiation Control. (2020). *Short term radon test results by county and ZIP code as of June 2019*. https://documents.deq.utah.gov/waste-management-and-radiation-control/planning-technical-support/radon/DRC-2017-002146.pdf

Utah Department of Health. (2019). *Public Health Indicator Based Information System (IBIS): Complete health indicator report of radon*. https://ibis.health.utah.gov/ibisph-view/indicator/complete_profile/Radon.html

Weinstein, N.D., & Sandman, P.M. (1992). Predicting homeowners' mitigation responses to radon test data. *Journal of Social Issues*, *48*(4), 63–83. https://doi.org/10.1111/j.1540-4560.1992.tb01945.x

Weinstein, N.D., Sandman, P.M., & Roberts, N.E. (1990). Determinants of self-protective behavior: Home radon testing. *Journal of Applied Social Psychology*, *20*(10), 783–801. https://doi.org/10.1111/j.1559-1816.1990.tb00379.x

World Health Organization. (2009). *WHO handbook on indoor radon: A public health perspective*. https://apps.who.int/iris/bitstream/handle/10665/44149/9789241547673_eng.pdf