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Rural Parents' Perceptions of Risks Associated with Their Children's Exposure to Radon

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ABSTRACT ***Objectives:*** To examine the level of awareness of radon issues, correlates of elective testing behaviors, and the accuracy of risk perception for radon exposures among rural residents receiving public health services. ***Design:*** A cross-sectional design was used in which questionnaire data and household analytic data for radon levels were collected from a nonprobabilistic sample of rural households. ***Sample:*** Thirty-one rural households with 71 adults and 60 children participated in the study. Primary household respondents were female (100%), Caucasian (97%), and primarily (94%) between 21 and 40 years of age. ***Measurement:*** Questionnaire data consisted of knowledge and risk perception items about radon and all homes were tested for the presence of radon. ***Results:*** The prevalence of high airborne radon (defined as $\geq$ 4 pCi/l) was 32%. More than a third of the sample underestimated the seriousness of health effects of radon exposure, 39% disagreed that being around less radon would improve the long-term health of their children, and 52% were unsure whether radon could cause health problems. After adjusting for chance, only 21% of the subjects correctly understood their risk status. ***Conclusions:*** This study provides preliminary evidence that low-income rural citizens do not understand their risk of radon exposure or the deleterious consequences of exposure.

Key words: children's health, environmental health, indoor air quality, radon, risk perception, rural health.

Children at Risk

The objective of this article is to explore the level of knowledge and awareness of radon issues among rural residents receiving public health services to better understand the context of rural children's household exposures to radon. Additionally, correlates of elective radon testing behaviors and accuracy of risk perceptions among caretakers (i.e., parents, guardians, grandparents, etc.) of children are explored.

As a vulnerable population, children may experience especially potent exposures to environmental toxins such as heavy metals like lead and mercury, pesticides, and air contaminants such as passive cigarette smoke, molds, and radon. Because children possess different physiologic, behavioral, and biologic capacities than adults, health risks resulting from exposure may be more severe (Dunn, Burns, & Sattler, 2003). Although children share the same routes of exposure with adults, children are at a distinct disadvantage for health consequences from environmental exposures (Schneider & Freeman, 2000). When adjusted for size, children have a greater body surface area, breathe more air, consume more food and fluids, and metabolize toxins differently than adults. In ad-

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dition, developmental behaviors such as placing unclean objects in their mouths, spending large amounts of time on floor surfaces, or being held in close proximity to lit cigarettes place children at additional risk for exposures to environmental toxins.

Awareness of the importance of examining residential characteristics when considering children's exposures to environmental toxins is increasing. Because Americans spend about 90% of their time indoors (Hancock, 2002), the impact of indoor environments on health has recently been examined in regard to outcomes such as asthma, otitis media, respiratory tract infections, allergic syndromes, and low birth weight, as well as potentially fatal outcomes such as ischemic heart disease, sudden infant death syndrome, and various cancers (Zhang & Smith, 2003).

Radon Gas

Radon gas is a colorless, odorless, radioactive gas that occurs from the natural decay of uranium and a number of common minerals throughout the world. Adults and children are exposed to radon in indoor environments where the gas enters buildings through cracks in walls and floors, construction joints, and around pipes, wires, or pumps. Occupational and epidemiological studies have established clear links between chronic exposures to radon and the development of lung cancer. In addition, national policy and regulatory agencies (e.g., Environmental Protection Agency [EPA]; International Agency for Research on Cancer [IARC]) have classified radon as carcinogenic to humans (Frumkin & Samet, 2001). It is important to note that there is no safe level of radon exposure. However, for the purposes of this study, "risk" was defined as equal to or above the EPA's action level of 4 pCi/l. This is the action level for which the EPA, the Centers for Disease Control and Prevention, and the American Lung Association calculate the cost of remediation as being offset by the health benefit (Environmental Protection Agency, 2006).

Household environmental exposures often follow geographic patterns based on the quality of built environments, differing climates, population behaviors, or the nature of geological formations. The EPA has developed a risk index using a composite variable that incorporates factors such as aerial radioactivity and soil permeability. A map of this index shows higher than average risks throughout many Northern tier states, along the Appalachian mountains, and in the Midwest states of Iowa, Indiana, and Ohio (EPA, 2004). However, household radon risks are strongly influenced by microenvironment factors such as foundation type and insulation levels. Potent household exposures to radon occur frequently in Midwestern and Rocky Mountain regions of the United States and repeated exposures for children leading to higher cumulative risk for disease (Little, 1995) suggest the need for intervention.

Radon Testing

Household testing for radon has become relatively inexpensive and available (i.e., $15.00 per test) and household risk reduction behaviors aimed at minimizing childhood exposure may include low-cost solutions such as not locating bedrooms and playrooms in basements and ventilating low areas of the home, or higher cost solutions such as contracting for full abatement with an average cost of about $1,000 per home (Little, 1995). However, because radon testing is not mandated in the United States, families may or may not elect to adopt risk reduction activities (e.g., testing, abatement, etc.) to minimize or prevent exposures.

Correlates of Radon Testing

Because radon testing behaviors have been positively associated with risk perception of exposure (Weinstein, Lyon, Sandman, & Cuite, 1998), an understanding of the accuracy of community dwellers' risk perceptions and the variables associated with elective testing for radon would enable nurses to appropriately target at-risk populations for education. Studies have examined selected sociodemographic predictors of radon testing behavior and have found that community dwellers generally have superficial knowledge about radon and that testing behavior is negatively associated with being female, belonging to a minority group, having a lower education and family income, and increasing age (Ferng & Lawson, 1996; Halpern & Warner, 1994).

It has recently been noted that previous research on radon exposure, testing, and its correlates is almost nonexistent in the nursing literature (Duckworth, Frank-Stromborg, Oleckno, Duffy, & Burns, 2002). For example, Weinstein, Klotz, and Sandman

(1988) surveyed 657 homeowners in New Jersey who had not tested their homes for radon, and 141 homeowners who had completed testing. The authors concluded that people who did not test held "optimistic biases" wherein they underestimated the risks associated with exposure to radon. In another study (Weinstein, Sandman, & Roberts, 1990), researchers mailed questionnaires, informational brochures, and radon test kit order forms to 271 households in New Jersey and examined the numbers of orders for test kits according to varying presentations of the magnitude of the threat of radon (presented in the informational brochures). Although test orders were found to be unrelated to the degree of threat presented in the brochures, self-reported risk likelihood, risk seriousness, and concern were strongly correlated with intentions to test as well as test orders.

Two further studies support the idea that perception of radon as a health risk is related to intentions to conduct radon testing or mitigation (Duckworth et al., 2002; Weinstein et al., 1998), but no studies reviewed examined radon risk perception and testing specifically among vulnerable rural populations receiving public health nursing services. Specific focus on rural populations is warranted because knowledge gained will inform health policy and clinical practice interventions to address disparate health outcomes. Rural families suffer from limitations in human capital and environmental resources for which education and access to health care are empirical indicators, respectively (Leight, 2003). Specific focus on families receiving public health nursing services is warranted because interviews with rural leaders revealed that in addition to economical and common sense solutions to environmental health problems, they wanted nurse researchers to use "insider" leadership to implement an environmental health agenda (Larsson, Butterfield, Christopher, & Hill, 2006). Public health nurses are "insiders" in their rural communities; trusted voices from whom information that may not be considered "agenda neutral" can be delivered in a culturally sensitive manner.

Methods

Design

The Environmental Risk Reduction through Nursing Intervention and Education study (ERRNIE) is a 5-year project designed to (1) determine the prevalence of multiple environmental exposures among rural children, (2) engage the community and experts in environmental health in determining priority environmental exposures and palatability of risk reduction educational materials and strategies, (3) deliver and evaluate environmental risk reduction education to rural families by public health nurses through a randomized-controlled trial, and (4) evaluate the capacity and needs of public health nurses to integrate environmental health into their practices. The ERRNIE project capitalizes on the existing public health infrastructure, which is already working with at-risk populations through programs such as Women, Infants, and Children, immunization clinics, and the HeadStart program among others. Cross-sectional data presented here were gathered in preliminary stages of the development of the ERRNIE project to understand the prevalence and context of radon exposures among the population of interest.

Sample

Thirty-one rural households containing 71 adults and 60 children were referred from a city/county health department in rural Montana and consented to participate in the ERRNIE project. Eligibility criteria required that each family have at least one child under 6 years of age, live within the county where the research was taking place (Economic Research Service rural–urban continuum code 5; Economic Research Service United States Department of Agriculture, 2003), utilize either a private or community well as their primary source of water, and read/speak English. Each family was asked to designate a primary household respondent who would complete questionnaires gathering data on household characteristics and the children. Of the designated household respondents, all were female, most (94%) were between 21 and 40 years of age, and the majority were Caucasian (97%). Consistent with a population receiving public health services, 58% of the sample either had no source of health insurance or were receiving Medicaid and 68% of families had a total income of less than $35,000 (Table 1).

Procedure

Following referral from the city/county health department, potential participants received a telephone call from ERRNIE project staff to introduce the project, explain the purpose and requirements of the project, ensure that eligibility criteria were met, and set a date for a single home visit by ERRNIE project staff. Each potential participant consented to share personal

TABLE 1. *Sociodemographic Description of Household Respondents*

	Participants (n = 31)	Sample (%)
Age (years)		
21–30	20	64.5
31–40	9	29.0
41–50	0	0
50+	2	6.5
Ethnicity		
Caucasian	30	96.8
Hispanic or Latino	0	0
Black/African American	0	0
American Indian or Alaskan Native	1	3.2
Other	0	0
Marital status		
Married	21	67.7
Divorced/separated	2	6.5
Widowed	0	0
Never married	3	9.7
Living with partner	5	16.1
Education (no. of years of school completed)		
12 or less	12	38.7
13–15	11	35.5
16–18	8	25.8
19 or greater	0	0
Income		
< $10,000	5	16.1
$10,000–19,999	4	12.9
$20,000–24,999	3	9.7
$25,000–34,999	9	29.0
$35,000–45,999	6	19.4
$46,000–54,999	0	0
$55,000 or greater	4	12.9
Health insurance		
None	12	38.7
Medicaid	6	19.4
Private health insurance	10	32.3
"Other"	3	9.7

contact information with the ERRNIE team during a previous visit with the city/county health department. All potential participants elected to participate in the study. Consent forms and questionnaires were mailed out a week in advance so that the participants would have time to review the materials and complete them before the home visit. During the home visit, questionnaires, consents, and samples for the household exposures of interest were collected. Project personnel placed a 48-hr, charcoal, radon screening test (DR. HOMEAIR, Alpha Energy Laboratories, Carrollton, TX) in the lowest occupied level of the home. Test placement and instructions were reviewed with the primary household respondent. Tests were mailed to the laboratory in the supplied, postage-paid package by the household respondent. Results from each test were faxed to ERRNIE project staff from the laboratory. Any household with a radon level at or above 4 pCi/l (EPA established action level) was retested using a long-term radon test. Those households with elevated levels following the second test were referred to environmental health specialists at the county health department for follow-up. Each family was provided the EPA's publication "Consumer's Guide to Radon Reduction" (Environmental Protection Agency Office of Air and Radiation, 2003) as well as other informational material at the conclusion of the home visit.

Instrument

A total of 8 risk perception and interpretation items were analyzed to address our research questions. A single item asked the household respondent to rank their response on a 7-point scale (strongly disagree to strongly agree) to the statement "Our children are at risk for being exposed to radon." To examine general knowledge of radon issues, 3 items asked the household respondent to rank their responses on the same scale to statements including "We can sense (taste, smell, see) radon," "Health effects due to radon are likely to be serious," and "Being around less radon would improve the long-term health of my children." Similarly, the following 3 items used a 7-point scale and addressed awareness of radon issues by asking "How unsure or sure do you feel about . . .": "whether radon in your home could cause health problems," "how to find out if your home is safe or unsafe," and "whether you should take steps to reduce radon in your home." Lastly, a single item asked "Have you ever had your home tested for radon" (yes/no).

Results

All data were entered into the Statistical Package for Social Sciences version 12.0. Because of our small sample size, variables measured on a 1–7 scale were reduced to two ordinal categories so that agreement scales (knowledge questions) reflected either any disagreement or any agreement. Similarly, scaled variables for awareness questions were treated in like manner so that dichotomous variables were produced indicating any degree of either unsure or sure. Neutral responses were aggregated with the "disagree" or "un-

TABLE 2. *Risk Agreement Between Rural Residents' Perceived Risk of Exposure to Radon and Household Monitoring Results (n = 31)*

	Residents' risk perception				
Radon results (pCi/l)	No risk (% sample)	Any risk (% sample)	Raw % agreement	κ (kappa)	p
< 4	15 (48)	6 (19)	.65	.21	.244
≥ 4	5 (16)	5 (16)			

sure" group as neutrality for knowledge and awareness suggests uncertainty. Spearman's rank-order correlations were calculated to examine associations between ordinal variables, and κ statistics were calculated to examine risk agreement. Table 2 represents a 2×2 comparison of household respondents' risk perception for their children's radon exposure within the home and actual household radon test results. Ten households had radon values above the EPA action level of 4 pCi/l and were divided equally between respondents who perceived any risk or no risk of exposure. For these 10 households, the average radon level was 10.0 pCi/l ($SD = 5.85$) and values ranged from 4.10 to 24.10.

Twenty out of the 31 household respondents (65%) were accurate in their assessments of risk; 15 respondents (48%) with radon levels under 4 pCi/l indicated that they were not at risk and 5 respondents (16%) with radon levels at or above 4 pCi/l indicated that they perceived some risk. Household respondents who were inaccurate in their assessments included 5 (16%) who did not perceive risk and had radon levels exceeding 4 pCi/l, and 6 (19%) who perceived some risk even though their radon levels were less than 4 pCi/l. Raw agreement between risk perception and actual risk appears moderate at 65%. However, when adjusting for chance agreement through the use of the κ statistic, agreement falls to 21% (*ns*).

Rural residents had some basic knowledge about radon. In terms of the nature of the exposure, all respondents understood that they would be unable to taste, smell, or see radon (see Table 3). However, over a third of the sample disagreed to some extent that health effects from radon exposure are likely to be serious (36%) or that being around less radon would improve the long-term health of their children (39%).

The overall awareness of radon issues among this sample appears to be low. Approximately 52% of the sample stated that they were unsure to some extent whether radon could cause health problems and just over half of the sample knew how to find out whether their homes were safe from radon (55%) (see Table 4). This sample appeared least aware of whether or not they should take steps to reduce radon in their homes, with 65% indicating that they were either neutral or unsure.

Despite the small sample of rural households, statistically significant associations were found for a number of variables and testing behavior (see Table 5). Expectedly, significant positive associations were found for both household income ($r = .373$, $p < .05$) and home ownership ($r = .474$, $p < .01$) and ever having tested for radon. Likewise, a moderate positive association was found between testing for radon and one's confidence in his or her ability to find out whether his or her home is safe or unsafe. Education level and knowledge variables associated with radon were not reliably associated with home testing, although the correlations were in the direction expected. For example, if a person responded that health effects due to radon are likely to be serious (indicating some knowledge), they would be slightly more likely to have tested their homes ($r = .118$, *ns*). We were unable to explore associations between gender and testing behavior because all household respondents were female.

Discussion

These data provide evidence that rural residents in our sample have a basic knowledge about radon, although many underestimate the seriousness or long-

TABLE 3. *Knowledge of Radon Among Rural Residents (n = 31)*

Based on your opinion, how strongly do you disagree or agree with each of the following statements?	Disagree (%)	Agree (%)
We can sense (taste, smell, see) radon	31 (100)	0 (0)
Health effects due to radon are likely to be serious	11 (35.5)	20 (64.5)
Being around less radon would improve the long-term health of my children	12 (38.7)	19 (61.3)

TABLE 4. *Awareness of Radon Among Rural Residents (n = 31)*

How unsure or sure do you feel about . . .	Neutral or unsure (%)	Slightly to very sure (%)
whether radon in your home could cause health problems?	16 (51.6)	15 (48.4)
how to find out whether your home is safe or unsafe?	14 (45.2)	17 (54.8)
whether you should take steps to reduce radon in your home?	20 (64.5)	11 (35.5)

term health effects for children exposed to radon. Likewise, over half of our sample stated that they did not know how to find out whether their homes were safe or whether or not they should take steps to reduce radon in their homes. These data are consistent with previous research, which suggests that up to 30% of the population in some states have no knowledge of radon and 20% to 30% do not perceive harmful effects from long-term exposure (Ford, Eheman, Siegel, & Garbe, 1996).

Associations between radon testing, demographic variables, and knowledge and awareness of radon issues also confirm previous findings. Greater household income, home ownership, and knowledge of how to find out whether one's home is safe from radon are significantly associated with testing behavior. Although the significant positive association between home ownership and household income ($r = .424, p < .05$) makes the interpretation of these variables difficult with respect to each variable's individual impact on testing for radon, other studies have reported that greater household income is associated with radon testing (Ford et al., 1996; Halpern & Warner, 1994). The association between knowledge of how to find out whether the home is safe from radon and testing makes sense in terms of households that have tested in the past and the knowledge gained from that process. Because the relationship is assessed using a correlation of cross-sectional data, no conclusions are possible regarding the temporal nature between this variable and testing. However, as others have found that a knowledge of radon and radon testing is associated with future testing, it is possible that increasing knowledge about how to find out whether the home is safe from radon may predict future testing (Halpern & Warner, 1994; Kennedy, Probart, & Dorman, 1991; Weinstein et al., 1988).

Because risk perception has been shown to be a critical variable with respect to radon testing behavior (Sandman & Weinstein, 1993; Weinstein et al., 1990), an examination of the accuracy of risk perception for radon exposure among rural households is warranted. Our data suggest that after adjusting for chance, the level of agreement between actual risk and perceived risk of radon exposure is quite low (21%). Disagreements appear to be equally split between those who perceive risk of exposure when radon levels are below 4 pCi/l (19%) (i.e., false positive) and those who do not perceive risk when levels are over the EPA established action threshold (16%) (i.e., false negative). The latter situation causes the most concern because elec-

TABLE 5. *Correlations Among Radon Testing, Demographic Variables, and Awareness and Knowledge of Radon Issues*

	1	2	3	4	5	6	7	8	9	10
1. Ever had home tested for radon	—									
2. Education level	.190	—								
3. Income	.373*	.523**	—							
4. Home ownership	.474**	.419*	.424*	—						
5. We can sense (taste, smell, see) radon	−.218	−.421*	−.327	−.212	—					
6. Health effects due to radon are likely to be serious	.118	.294	−.089	.075	−.239	—				
7. Being around less radon would improve the long-term health of my children	.146	.173	−.206	.134	−.209	.709**	—			
8. Whether radon in your home could cause health problems?	.182	.284	.194	.162	−.375*	.585**	.670**	—		
9. How to find out whether your home is safe or unsafe?	.399*	.214	.225	.208	−.507**	.354	.322	.455*	—	
10. Whether you should take steps to reduce radon in your home?	.120	.157	.224	.172	−.128	.201	.405*	.245	.362*	—

Note:
*Significant at .05.
**Significant at .01 (two-tailed).

tive testing behavior is less likely when personal risk perception is low (Weinstein et al., 1998).

This study has a number of limitations. First, the sample suffers from self-selection bias as participants were referred by the local health department and agreed to participate. The sample was strengthened by restrictive eligibility criteria (Norwood, 2000) but may not represent all rural, low-income families using public health services. Second, the relatively small sample size does not allow for either more complex statistical modeling or broad generalization. Third, questionnaire and radon testing data are cross-sectional, making inference related to causation problematic. Finally, we may have underestimated both the prevalence of radon exposures within the sample and the nature of the disagreements between actual and perceived risk of radon exposure by designating the EPA action level of 4 pCi/l as the "risk for exposure" threshold. Other comparisons using alternative thresholds are possible. Further, radon levels are known to fluctuate and the radon screening tests that we used only capture radon levels over a 48-hr period.

The findings from this study have a number of important implications for public health nursing practice. The vulnerability of rural populations in terms of isolation from health providers and information is clear with respect to issues surrounding radon exposure. Our findings conclude that rural citizens receiving public health services have educational needs about both the health consequences and risk of radon exposure. However, successful interventions surrounding radon exposures pose a new set of challenges to nurses who generally feel unprepared to manage environmental threats to health (Van Dongen, 2002). Nurses need to explore new skills such as the ability to access environmental health data from local, state, and national sources, as well as learn how to integrate environmental health into their busy practices. With this in mind, the ERRNIE project is currently testing an intervention delivered by public health nurses aimed at supporting positive behaviors to reduce radon exposures for rural underserved populations. Experiences from this intervention will suggest how nurses can be successful at intervening with at-risk populations to prevent health consequences from radon.

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