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Factors affecting firefighter occupational cancer risk adjustment

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Abstract

Recent research has shown firefighters are at a higher risk for cancer diagnosis than the general population. Experts have offered six hazard adjustments that may assist in reducing the level of exposure to carcinogens. This study was conducted to better understand what motivates or deters firefighters from engaging in these hazard adjustments. The sample was firefighters who had attended or were otherwise associated with the Alabama Fire College (Alabama, USA). An internet survey was administered to collect the data. The participant recruitment email was opened by 1,539 individuals, and 358 responses were received, giving a response rate of 23%. The findings suggest that firefighters' occupational cancer risk perceptions are high. Also, response efficacy, self-efficacy, and cost of engaging in the behavior were much more reliable predictors of intention and actual hazard adjustment than risk perception, salience, and exposure. The concept of peer perception is used in this Protection Motivation Theory study, which also affects firefighters' completion of hazard adjustment. The findings of this study will assist fire service leaders in adapting education programs, policies, and procedures to better protect firefighters from occupational cancer risk.

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INTRODUCTION

Members of the fire service face many hazards during the course of completing their duties. The fire service operates in a unique environment where it may be perceived that the greater the risk accepted by the firefighter, the less risk there will be to the public[1]. While firefighters face a diverse number of risks when providing emergency services to the public, a newly discovered problem is growing, cancer. Firefighters are regularly exposed to carcinogens during firefighting activities which are suggested to be causing a higher rate of cancer diagnosis[2–4]. In fact, studies have documented the higher cancer diagnosis and morbidity rates in firefighters as compared to the general population[3,5].

This study seeks to examine the ways in which firefighters perceive their occupational cancer risks as well as what affects their intention and the actual completion of adopting cancer hazard adjustment activities. Protection Motivation Theory (PMT) is used to guide the theoretical aspect of this study[6,7]. PMT suggests protection motivations are affected by two factors, threat and coping appraisals.

Risk perception has long been used to measure threat appraisal in many studies[8–11]. Researchers suggest individuals not only examine risks but also that the perceived risk is weighed against the potential benefit of the activity[12–14]. Studies have found that individuals will accept higher levels of risk when they perceive the outcome of the action will be of greater benefit than the risk[15,16]. Some health science and earthquake risk studies also found risk perception has an effect on hazard adjustments and its intentions, but findings are not consistent across events[10,11,17–19]. While hazard salience and hazard exposure are not explicitly mentioned in PMT, studies on natural hazard adjustments have found a positive correlation between hazard salience and hazard adjustments[11,17,20,21].

The coping appraisal includes multiple factors[6,7]. Response efficacy is the individual's perception of how well the hazard adjustment will protect them. Studies found that response efficacy variables strongly correlated with intended and actual hazard adjustments[10,11,17]. Self-efficacy is related to the individual's perception of their ability to complete the hazard adjustment, such as whether it requires special knowledge or skills. Perry & Lindell found that one's responsibility to protect oneself was a significant predictor of hazard adjustments[22]. While the findings in the aforementioned study seem reasonable, they may be challenging to apply in a workplace as unique as the fire service. Previous studies show peers' perceptions might affect one's behavior[23,24]. Therefore, a variable not considered in previous PMT studies is included in this study. That is whether the respondent's peers would frown upon the action. Response cost relates to the cost to the individual of implementing the hazard adjustment, such as effort, costs, or usefulness. Wang et al. found that influenza adjustments variables such as cost, time restraints, and tools required did not negatively correlate with hazard adjustments[18]; however, they did find that being useful for other purposes affects hazard adjustments.

While organizational culture is not directly mentioned in PMT, some variables that are used in the coping appraisal for this study pertain to fire service culture. The fire service is steeped in tradition, many of which can be traced back to its origin. Most occupations struggle to balance risk with the desired amount of production; however, as previously discussed, the increased acceptance of risk by firefighters can be perceived as the desired outcome, greater public safety. While not all fire service traditions are considered negative, some are

being identified as problematic[1]. One problem, in particular, is being dirty after a fire and dirty PPE as a badge of experience and honor. For many years, firefighters with dirty PPE have been viewed as seasoned veterans that are skilled and capable on the fire ground[25]. This view can also affect protection behaviors such as showering and working out after fighting a fire[26,27]. This traditional view, however, is in direct contrast with the suggested hazard adjustment of gross decontamination on the scene as well as washing personnel and personal protective equipment (PPE). Another problem is using PPE and self-contained breathing apparatus (SCBA) properly. Fent et al. noted that firefighters are exposed to carcinogens through inhalation and absorption through the skin[25]. When firefighters do not wear their SCBA through the completion of overhaul activities, they are exposed to higher levels of carcinogens. PPE has also been shown to continue off-gassing carcinogens after a fire which, if not cleaned, will continue to expose firefighters to carcinogens, such as in-vehicle cabs and dormitories[25]. Recent studies of Florida firefighters found that while firefighters had a positive perception of cleaning PPE and its ability to protect them from cancer and other health hazards, many were unlikely to complete the hazard adjustment regularly [23]. The study notes this could be due to concerns about time constraints and functioning in wet PPE.

Additionally, a study has shown that peer pressure from senior department members (organizational culture) is a major factor in newer firefighters' decision to implement the suggested hazard adjustments[24]. Other hazard adjustments and protective action decision studies have used the Emergent Norm Theory to explain this phenomenon[28–32]. These studies highlight the importance of education and culture change initiatives in the fire service. These can strongly contribute to an improved operational culture that, in that end, will serve to better protect firefighters from cancer.

Based on the literature, this study intends to use PMT to examine firefighters' intention and actual adoption of firefighting related cancer hazard adjustment actions. This study will introduce a new self-efficacy variable related to fire service culture and peer perception based on the Emergent Norm Theory. In addition, this study would like to examine the association between fire service/individual demographics and hazard adjustment. The followings are the research hypotheses (RHs) and questions (RQs).

RH1: Coping appraisal variables explain more variations in firefighters' cancer hazard adjustment intention than threat appraisal variables.

RH2: Coping appraisal variables explain more variations in firefighters' actual cancer hazard adjustment adoption than threat appraisal variables.

RQ1: Does fire service demographics affect firefighters' cancer hazard adjustment intention?

RQ2: Does previous cancer experience affect firefighters' cancer hazard adjustment intention?

RQ3: Do fire service and personal demographics significantly correlate with firefighters' cancer hazard adjustment intentions and actual hazard adjustments?

RESULTS

Linear regression analyses were used to test RH1 (*Coping appraisal variables are better predictors of hazard adjustment intention than threat appraisal variables*). The results show that RH1 is confirmed (Table 1). Most coping appraisal variables are significant predictors of the hazard adjustment intention with few exceptions; on the other hand, threat appraisal variables only have limited predictability in these models. For example, in Table 1, the model of gross decontamination adjustment intention is significant ($F_{(11,291)} = 8.69$; $p < 0.05$; $Adj\ R^2 = 0.22$);

Table 1. Regression analysis of fire cancer hazard adjustment intentions.

Variables			Gross decon†	Contaminated PPE out of cab†	Washing PPE†	Showering within 1 hr after firefighting†	Workout within 24 hr after firefighting†	Wearing SCBA during overhaul†
Threat appraisal	Hazard salience	How often do you think about occupational cancer?	0.08	0.03	−0.02	0.01	0.01	0.07
	Risk perception	Occupational cancer concern	0.07	**0.14**	0.05	0.10	−0.07	0.11
		Likelihood of cancer diagnoses	**−0.14**	**−0.12**	0.04	−0.02	0.06	−0.05
		Likelihood of cancer being caused by firefighting	0.02	−0.02	−0.06	−0.03	0.08	0.00
	Hazard exposure	Hazard exposure index	0.11	0.10	−0.06	0.01	0.00	0.02
Coping appraisal	Response efficacy	Protect me effectively	**0.27**	**0.30**	**0.31**	**0.31**	**0.31**	**0.32**
	Self-efficacy	Require special knowledge/skills	0.09	0.07	0.09	**0.15**	0.10	**0.23**
		Be frowned upon by peers	**−0.11**	**−0.17**	−0.03	**−0.13**	−0.09	−0.04
	Response costs	Require a lot of effort	**−0.19**	**−0.12**	**−0.15**	**−0.20**	**−0.17**	**−0.24**
		Cost a lot of money	−0.02	0.02	**−0.13**	**−0.11**	−0.01	−0.08
		Also be useful for other purposes	**0.17**	**0.24**	**0.12**	**0.29**	**0.31**	**0.23**
Statistics			$F_{(11,291)} = 8.69$ $P < 0.05$ $Adj\ R^2 = 0.22$	$F_{(11,283)} = 14.08$ $P < 0.05$ $Adj\ R^2 = 0.33$	$F_{(11,291)} = 5.81$ $P < 0.05$ $Adj\ R^2 = 0.15$	$F_{(11,290)} = 14.01$ $P < 0.05$ $Adj\ R^2 = 0.32$	$F_{(11,283)} = 13.60$ $P < 0.05$ $Adj\ R^2 = 0.32$	$F_{(11,290)} = 14.79$ $P < 0.05$ $Adj\ R^2 = 0.34$

† Standardized coefficients are reported. Bold font indicates the coefficient is significant at the 0.05 level.

however, the significant predictors are mainly coping appraisal variables; only one threat appraisal variable is a significant predictor in the model. Table 1 also shows that the coefficients of coping appraisal predictors such as *protect me effectively, require a lot of effort*, and *also be useful for other purposes* are all significant across all six models.

Linear regression analyses were used to test RH2 (*Coping appraisal variables are better predictors of actual hazard adjustment adoption than threat appraisal variables*). Table 2 shows that this hypothesis is also confirmed. While the regression models for actual adjustments identified fewer significant predictors than the hazard adjustment intention models did, coping appraisal variables were much more significant predictors of actual hazard adjustments (see Table 2). For example, there was only one significant threat appraisal variable in the model for *washing PPE* (*likelihood of cancer diagnosis being caused by firefighting*), and it was a weak predictor. On the other hand, the coping appraisal variable *protect me effectively* produced significant results in all six models. In examing other models, the regression model for *wearing SCBA during overhaul* produced significant results in five of the six coping appraisal variables, and none of the threat appraisal variables was significant.

T-test and Analysis of Variance (ANOVA) were used to test RQ1 (*Does fire service demographics affect firefighters' adjustment intention?*) & RQ2 (*Does previous cancer experience affect firefighters' adjustment intention?*). Five fire service demographic variables were used to test their effects on the hazard adjustment intention index.

(1) *Type of department:* there was a significant difference in the mean scores for career firefighters' (M = 3.66, SD = 0.71) and volunteer firefighters' (M = 3.45, SD = 0.72) intentions to complete hazard adjustments ($t_{(312)} = 2.05, p < 0.05$).

(2) *Years in the service:* years of fire service experience did not have a significant effect on hazard adjustment intentions for the five conditions ($F_{(4,309)} = 2.07$, *ns*).

(3) *Firefighter Rank:* rank did not have a significant effect on hazard adjustment intentions for the six conditions ($F_{(5,307)} = 0.57$, *ns*).

(4) *Number of total responses:* the number of department calls for service had a significant effect on hazard adjustment intentions ($F_{(4,308)} = 3.27$, $p < 0.05$). Table 3 shows that the departments that responded to between 2,500 to 4,999 calls annually had the highest intention to complete hazard adjustments.

(5) *Number of fire responses:* the number of department fire calls did not have a significant effect on hazard adjustment intentions ($F_{(4,307)} = 1.35$, *ns*).

Several t-tests and ANOVA tests were conducted to determine if personal demographic variables affect hazard adjustment intentions. The results show only previous cancer experience has a significant effect on hazard adjustment intentions ($F_{(2,311)} = 3.25$, $p < 0.05$). Table 4 shows that people are more likely to adopt hazard adjustments if their coworkers are diagnosed with cancer.

Correlation Analyses were used to test RQ3 (*Do fire service and personal demographics significantly correlate with hazard*

Table 3. Number of total responses and hazard adjustment intention.

Number of responses	Mean	SD	N
0–499	3.56	0.72	49
500–1,499	3.59	0.66	41
1,500–2,499	3.47	0.73	47
2,500–4,999	3.89	0.59	69
≥ 5,000	3.57	0.76	107
Total	3.63	0.71	313

$F_{(4,308)} = 3.27, p < 0.05$

Table 2. Regression analysis of fire cancer actual hazard adjustment.

Variables			Gross decon†	Contaminated PPE out of cab†	Washing PPE†	Showering within 1hr after firefighting†	Workout within 24 hr after firefighting†	Wearing SCBA during overhaul†
Threat appraisal	Hazard salience	How often do you think about occupational cancer?	−0.05	−0.01	−0.04	−0.01	0.00	−0.10
	Risk perception	Occupational cancer concern	−0.02	−0.08	−0.01	0.01	0.09	−0.06
		Likelihood of cancer diagnoses	0.04	0.10	−0.06	0.00	−0.09	0.04
		Likelihood of cancer being caused by firefighting	0.00	0.08	**0.13**	0.04	−0.07	0.07
	Hazard exposure	Hazard exposure index	−0.02	0.05	0.09	0.06	0.03	0.01
Coping appraisal	Response efficacy	Protect me effectively	**−0.13**	**−0.17**	**−0.30**	**−0.30**	**−0.29**	**−0.17**
	Self-efficacy	Require special knowledge/skills	−0.12	**−0.15**	0.05	−0.14	**−0.17**	**−0.27**
		Be frowned upon by peers	0.09	**0.12**	0.09	−0.01	0.02	0.06
	Response costs	Require a lot of effort	0.14	0.11	0.09	**0.19**	0.11	**0.29**
		Cost a lot of money	0.06	0.11	0.11	0.03	0.07	**0.15**
		Also be useful for other purposes	**−0.17**	**−0.13**	0.06	−0.08	−0.06	**−0.18**
Statistics			$F_{(11,291)} = 3.09$ $P < 0.05$ $Adj\ R^2 = 0.07$	$F_{(11,285)} = 3.91$ $P < 0.05$ $Adj\ R^2 = 0.10$	$F_{(11,291)} = 5.10$ $P < 0.05$ $Adj\ R^2 = 0.13$	$F_{(11,290)} = 4.27$ $P < 0.05$ $Adj\ R^2 = 0.11$	$F_{(11,283)} = 13.60$ $P < 0.05$ $Adj\ R^2 = 0.32$	$F_{(11,290)} = 8.54$ $P < 0.05$ $Adj\ R^2 = 0.22$

† Standardized coefficients are reported. Bold font indicates the coefficient is significant at the 0.05 level.

Table 4. Previous cancer experience and hazard adjustment intention.

Previous cancer experience	Mean	SD	N
Myself	3.55	0.83	25
Coworker	3.70	0.70	200
None	3.47	0.68	89
Total	3.62	0.71	214

$F_{(2,311)} = 3.25, p < 0.05$

adjustment intentions and actual hazard adjustments?). Results indicate fire service and personal demographic variables both produced some significant correlations with the hazard adjustment intentions and actual hazard adjustments and the six hazard adjustments. Being a career fighter was negatively correlated with placing contaminate PPE out of the passenger cab ($r = -0.15$, $p < 0.05$) but positively correlated with gross decon ($r = 0.15$, $p < 0.05$), washing PPE ($r = 0.13$, $p < 0.05$), showering within 1 hr ($r = 0.12$, $p < 0.05$), and workout within 24 hr ($r = 0.17$, $p < 0.05$). Years in the fire service correlated negatively with workout within 24 hr ($r = -0.18$, $p < 0.05$). Rank correlated negatively with showering within 1 hr ($r = -0.13$, $p < 0.05$) and working out within 24 hr ($r = -0.24$, $p < 0.05$) and positively with contaminated PPE out of the passenger cab. Calls for service by the department correlated positively with washing PPE ($r = 0.13$, $p < 0.05$), showering within 1 hr ($r = 0.12$, $p < 0.05$), and workout within 24 hr ($r = 0.14$, $p < 0.05$) and negatively with contaminated gear out of the compartment ($r = -0.16$, $p < 0.05$). Number of fire related calls correlated positively with workout within 24 hr ($r = 0.15$, $p < 0.05$) and negatively with contaminate PPE out of the passenger cab ($r = -0.13$, $p < 0.05$) and wearing SCBA through overhaul ($r = -0.17$, $p < 0.05$). Age correlated positively with PPE out of cab ($r = 0.18$, $p < 0.05$) and negatively with workout within 24 hr ($r = -0.18$, $p < 0.05$). Number of children correlated negatively with workout within 24 hr ($r = -0.14$, $p < 0.05$). Lastly, household income correlated positively with washing PPE ($r = 0.18$, $p < 0.05$).

Actual completion of adjustments produced a lower amount of significant correlation results. Being a career firefighter negatively correlate with contaminate PPE out of cab ($r = -0.11$, $p < 0.05$), but positive correlations with washing PPE ($r = 0.14$, $p < 0.05$) and workout within 24 hr ($r = 0.15$, $p < 0.05$). Years in the fire service produced a negative correlation to work out within 24 hr ($r = -0.14$, $p < 0.05$). Rank produced a negative correlation to work out within 24 hr ($r = -0.15$, $p < 0.05$). Calls for service produced a positive correlation to work out within 24 hr ($r = 0.21$, $p < 0.05$) and showering within 1 hr ($r = 0.12$, $p < 0.05$). Number of fire related calls produced a positive correlation for work out within 24 hr ($r = 0.17$, $p < 0.05$) and a negative correlation for wearing SCBA through overhaul ($r = -0.14$, $p < 0.05$). Age produced a negative correlation for work out within 24 hr ($r = -0.15$, $p < 0.05$). Number of children produced a negative correlation for work out within 24 hr ($r = -0.13$, $p < 0.05$). Lastly, household income correlated positively to washing PPE ($r = 0.20$, $p < 0.05$).

DISCUSSION

Both regression models show strong support for PMT. Similar to previous studies, coping appraisal variables better explain the variations in adjustment intentions and actual adjustments compared to threat appraisal variables[33]. Similar to other firefighter cancer risk perception studies[23], our sample has a considered high level of cancer risk perceptions; however, they proved to be poor predictors of adjustment intentions. Risk perception is an even poorer predictor of actual adjustments. These findings are consistent with some earthquake adjustment studies[11,17]. Hazard salience was also measured high in this study; however, it was not a significant predictor in the models. These findings contradict those found in Russell et al.[21]. In addition, although our study participants are engaged in activities with high levels of cancer hazard exposure, the findings suggested that the hazard exposure index was not a significant predictor in any of the regression models, which differs from previous research[21,22,34–36]. As mentioned in Jackson's study[34], this result might be due to the ambiguity of how researchers measure hazard exposure in different studies.

In this study, response efficacy was the only variable significantly predicting both adjustment intentions and actual adjustment models. Self-efficacy variables also produced several significant results in the regression models confirming Floyd et al. claims that response efficacy and self-efficacy appear to be the most important aspects to concentrate on in order to change behavior which also coincides with previous research[10,11,17,18,37,38]. The most intriguing consideration specific to this study is the use of the new self-efficacy variable that was related to fire service organizational culture (be frowned upon by my peers), which proved to be a significant predictor in at least some of the models and confirms previous findings that peer pressure can have an effect on taking suggested hazard adjustments[24,39]. This finding could prove a valuable addition to coping appraisal evaluation for the fire service and any organization with strong peer cultures. Lastly, the response cost variable with the most significant result is *require a lot of effort*. This variable was a significant predictor in all adjustment intention models and half of the actual adjustment models, confirming previous research[11,17,38]. Also *useful for other purposes* produced significant results in all of the intention models as well as the actual adjustment models, which also coincides with previous research[11,17,18].

The analyses for RQ1 and RQ3 produced three significant results. The first and possibly most important is that career firefighters had a greater intention to complete the suggested cancer hazard adjustments than did volunteer firefighters. This could be due to the tradition that career firefighters have typically kept their PPE in the cab with them or possibly due to the fact that many volunteers may keep PPE in the trunk or storage spaces of their personal vehicles. The importance of this is the need for more training in the volunteer fire service on the implementation of the hazard adjustments and their effectiveness. In addition, survey respondents that reported their organization responded to between 2,500–4,999 calls annually had the highest intention to complete the hazard adjustment. One possible explanation for this is that these individuals have enough regular exposure to hazardous activities, yet they have enough time at the station not to make responses for education and training on the suggested hazard adjustments. Lastly, previous cancer experience produced significant results for hazard adjustment intention, which supports previous research[9,11,17,21,35,36]. Although fire service leaders are not able to directly control this variable, this finding could support the concept that efforts similar to that of the Boston Fire Department, making education efforts personal by sharing real life cases of cancer victims in the fire service, could be an effective educational tool.

The correlations of fire service and personal demographics with adjustment intentions and actual adjustments produced several expected results; however, there were two that warrant discussion. The first, previously mentioned, was that volunteer firefighters were more likely to place contaminated PPE outside of the cab. This finding was the only significant negative correlation for the type of department in both intention and actual adjustment correlations. This could be due to the fact that career firefighters have nowhere on the apparatus to store the PPE or that volunteer firefighters could be storing their PPE in personal vehicle cargo areas. Either way, future research should consider storage solutions for career and volunteer firefighters to combat the exposure to contaminated PPE in the cab. This study also found age, rank, and years in the fire service had negative correlations with working out within 24 hr of firefighting activities. This could be due to age, physical ability, lack of education, or belief in the hazard adjustment.

CONCLUSIONS

This study is an attempt to understand what motivates firefighters to take the suggested hazard adjustments that have been set forth by experts. Unfortunately, even though firefighters are well informed about their increased cancer risk, this study and previous studies find that firefighters do not always take the suggested hazard adjustment[39]. One major finding of this study is the importance of response and self-efficacy. Fire service organizations should begin to focus exposure reducing training efforts on the effectiveness of the hazard adjustment and on finding effective ways individuals can carry them out. One way this could be accomplished is by fire service leaders partnering with the research community and identifying the most effective hazard adjustments. The risk perception results of this study confirm, along with a previous study, that firefighters are aware of their cancer risk[23]. However, care must be taken not to create a culture of fatalism which can be caused by an oversaturation of awareness and a lack of hazard adjustments. In other words, if firefighters perceive they are going to get cancer no matter when there will be a tendency to not complete the hazard adjustments.

The fire service, as a whole, must collaborate with researchers to discover, through field research, the most effective means of reducing exposure to carcinogens and the most efficient means of completing these activities. Once these have been identified, the data needs to be presented to firefighters in a way that will increase response and self-efficacy. To date, educational programs have offered little in the way of explanation when compared to other protective measures such as hazardous materials decontamination procedures. The time has come for educational programs to become a much more formal effort, possibly even certification level programs similar to technical rescue or hazardous materials response.

Another major finding in this study is the importance of peer perception and pressure. As mentioned earlier, the fire service is ripe with traditions, but these traditions and the traditional view of what makes a good firefighter can stand in the way of safety. This highlights the importance for fire service administrators and officers to create a cultural norm of safety. These hazard adjustments should be something that takes place in every incident that has the potential for exposure and should be mandated by incident commanders and company officers. In conclusion, fire service leaders should use the results of this and other studies to continue evolving firefighter safety and health initiatives to further protect the future of the fire service.

There are some limitations to this study. The sample was firefighters that had previously attended or are in some way affiliated with the AFC. As with any self-reporting study, one limitation is accurate reporting. Although everyone that responded was informed that the study was for firefighters only, one cannot know for sure if that were the case. Another limitation of this study was the narrowness of the sample. A large majority of the sample was male career firefighters with 21 or more years of experience in the fire service. Future studies may benefit from attempting to oversample to achieve a more diversified sample.

MATERIALS AND METHODS

Sampling

This study was conducted in cooperation with the Alabama Fire College (AFC). The sample was career and volunteer firefighters that affiliated with AFC or have attended AFC courses. The internet survey was developed using *Survey Monkey* (www.momentive.ai). The survey was modeled considering previous surveys[10,11] and distributed using the method used by Dillman et al.[40]. The data was collected from 11/28/2017 to 12/26/2017. The participant recruitment email was opened by 1,539 individuals, and 358 responses were received, giving a response rate of 23%.

Coding

The survey instrument consisted of 27 items. The survey instrument can be shared upon request. Six items were asked to measure fire fighters' cancer risk hazard adjustment actions: (1) gross decontamination after a fire, (2) placing contaminated PPE in compartments other than the passenger cab, (3) washing PPE after a fire, (4) showering within 1 hr of firefighting activities, (5) working out within 24 hr of firefighting activities, and (6) wearing self-contained breathing apparatus until the completion of overhaul activities These items were suggested by firefighting reports and previous studies[5,6,24].

Respondents were asked to rate their threat appraisal in nine items. Three risk perception related questions were asked using 5-point Likert scales to measure them. Hazard salience was measured by having respondents report the frequency of thinking about occupational cancer risk. In addition, respondents were asked to rate different job aspects for their potential to expose them to cancer causing carcinogens. A hazard exposure index was created by using the hazard exposure variables (*Cronbach's* $\alpha = 0.76$). Six survey questions were used to measure coping appraisals. These questions asked respondents to rate their views on the hazard adjustment actions in this survey. In order to measure response efficacy, respondents were asked how effectively they felt the adjustment actions would protect them. Next, to measure self-efficacy, respondents were asked to consider whether they felt the adjustment actions would require specialized knowledge or skills to complete. In a second self-efficacy measurement, respondents were asked to consider if any of the adjustment actions would be frowned upon by their peers. In order to measure response cost, respondents were asked if they felt the adjustment actions would require a lot of effort to complete, if they felt the adjustment actions

would cost a lot of money and if they thought the adjustment actions would be useful for purposes other than preventing occupational cancer.

The survey also measures individuals' intention to complete each of the six protective actions; respondents were asked if each of the actions would be something they are likely to do. A hazard adjustment intention index for all adjustment actions was created by using the variables (*Cronbach's* $\alpha = 70$). In order to measure the actual protective actions, individuals were asked if they take any of the six protective actions after firefighting activities.

Respondents were also asked to answer questions about fire service demographics such as the type of department (Career vs. Volunteer), years of service, current rank, the number of calls for service annually their department responds to, and the number of fire-related responses their department responds to including structure, dumpster, vehicle, and wildland annually. Lastly, respondents report their personal demographics such as age, marital status, number of children, the highest education level, household income, and cancer experience.

Analytical method

Univariate analyses were used to test the research hypotheses and questions. As mentioned in the previous section, most measures are ordinal data; they are treated as continuous data in the analyses. Since a 5-Likert scale is used and the sample size is considered large, possible bias is insufficient to alter the substantive interpretations[41]. RH1 and RH2 are trying to identify the variables that significantly explain the variations in the dependent variable: firefighters' cancer hazard adjustment intentions and actual adjustments; therefore, linear regression analyses were used for these two hypotheses. RQ2 and RQ3 aim to determine the significance of mean differences in cancer hazard adjustment intentions based on the study participant's demographic data. Depending on the categories of each demographic variable, a t-test was used when a demographic variable only has two groups; an Analysis of Variance (ANOVA) was used when a demographic variable has three or more groups. Finally, RQ3 is to identify the significant correlations among the variables. Pearson's *r* was used to identify the significant correlations at the 0.05 level. IBM SPSS ver. 25 were used to conduct the regression, ANOVA, and correlation analyses (www.ibm.com/analytics/spss-statistics-software?mhsrc=ibmsearch_a&mhq=SPSS).

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Conflict of interest

The authors declare that they have no conflict of interest.

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REFERENCES

1. De Lisi SM. 2005. Organizational culture in the fire service. *Fire Engineering* 158:119
2. Daniels RD, Kubale TL, Yiin JH, Dahm MM, Hales TR, et al. 2014. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009). *Occupational and environmental medicine* 71:388–97
3. LeMasters GK, Genaidy AM, Succop P, Deddens J, Sobeih T, et al. 2006. Cancer risk among firefighters: A review and meta-analysis of 32 studies. *Journal of Occupational and Environmental Medicine* 48:1189–202
4. Pukkala E, Martinsen JI, Weiderpass E, Kjaerheim K, Lynge E, et al. 2014. Cancer incidence among firefighters: 45 years of follow-up in five Nordic countries. *Occupational and Environmental Medicine* 71(6):398–404
5. Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA. 2006. Cancer incidence in Florida professional firefighters, 1981 to 1999. *Journal of Occupational and Environmental Medicine* 48:883–88
6. Maddux JE, Rogers RW. 1983. Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology* 19:469–79
7. Rogers RW. 1975. A protection motivation theory of fear appeals and attitude change1. *The Journal of Psychology* 91:93–114
8. Huang SK, Lindell MK, Prater CS. 2016. Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies *Environment and Behavior* 48:991–1029
9. Lindell MK, Perry RW. 2012. The protective action decision model: theoretical modifications and additional evidence. *Risk analysis* 32:616–32
10. Lindell MK, Whitney DJ. 2000. Correlates of household seismic hazard adjustment adoption. *Risk Analysis* 20:13–25
11. Wu H, Greer A, Murphy H, Chang R. 2017. Preparing for the new normal: Students and earthquake hazard adjustments in Oklahoma. *International Journal of Disaster Risk Reduction* 25:312–23
12. Norman P, Boer H, Seydel ER. 2005. Protection motivation theory. In *Predicting Health Behaviour*, eds. Conner M, Norman P. 2nd Edition: xiv,385. London, UK: Open University Press. pp. 81–126
13. Sjoberg L. 1999. Consequences of perceived risk: Demand for mitigation. *Journal of Risk Research* 2:129–49
14. Slovic P. 1992. Perceptions of risk: Reflections on the psychometric paradigm. In *Social Theories of Risk*, eds. Krimsky S, Golding D. Westport, CT: Sheldon Krimsky and Dominic Golding. pp. 117–52
15. Fischhoff B, Slovic P, Lichtenstein S, Read S, Combs B, et al. 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits *Policy Sciences* 9:127–52
16. Starr C. 1969. Social Benefit versus Technological Risk: What is our society willing to pay for safety? *Science* 165:1232–38
17. Greer A, Wu H, Murphy H. 2020. Household adjustment to seismicity in Oklahoma. *Earthquake Spectra* 36:2019–32
18. Wang F, Wei J, Huang SK, Lindell MK, Ge Y, et al. 2018. Public reactions to the 2013 Chinese H7N9 Influenza outbreak: perceptions of risk, stakeholders, and protective actions. *Journal of Risk Research* 21:809–33
19. Wang PW, Ahorsu DK, Lin CY, Chen IH, Yen CF, et al. 2021. Motivation to have COVID-19 vaccination explained using an extended protection motivation theory among university students in china: The role of information sources. *Vaccines* 9:380
20. O'Brien P, Mileti D. 1992. Citizen participation in emergency response following the Loma Prieta earthquake. *International Journal of Mass Emergencies and Disasters* 10:71–89
21. Russell LA, Goltz JD, Bourque LB. 1995. Preparedness and hazard mitigation actions before and after two earthquakes. *Environment and Behavior* 27:744–70
22. Perry RW, Lindell MK. 2008. Volcanic risk perception and adjustment in a multi-hazard environment. *Journal of Volcanology and Geothermal Research* 172:170–78

23. Harrison TR, Yang F, Anderson D, Morgan SE, Wendorf Muhamad J, et al. 2017. Resilience, culture change, and cancer risk reduction in a fire rescue organization: Clean gear as the new badge of honor. *Journal of Contingencies and Crisis Management* 25:171–81
24. Maglio MA, Scott C, Davis AL, Allen J, Taylor JA. 2016. Situational pressures that influence firefighters' decision making about personal protective equipment: A qualitative analysis. *American Journal of Health Behavior* 40:555–67
25. Fent KW, Evans DE, Booher D, Pleil JD, Stiegel MA, et al. 2015. Volatile organic compounds off-gassing from firefighters' personal protective equipment ensembles after use. *Journal of Occupational and Environmental Hygiene* 12:404–14
26. Firefighter Cancer Support Network. 2013. Taking Action Against Cancer in the Fire Service. *Report*. Firefighter Cancer Support Network, Online. https://firefightercancersupport.org/wp-content/uploads/2017/11/taking-action-against-cancer-in-the-fire-service-pdf.pdf
27. National Fallen Firefighters Foundation. 2015. Occupational Cancer in the Fire Service. Report. National Fallen Firefighters Foundation, Emmitsburg, Maryland. www.tkolb.net/FireReports/2015/Report_of_the_Fire_Service_Occupational_Cancer_Alliance_Meeting_January_2015.pdf
28. Aguirre BE, Wenger D, Vigo G. 1998. A test of the emergent norm theory of collective behavior. *Sociological Forum* 13:301–20
29. Lindell MK, Perry RW. 2000. Household adjustment to earthquake hazard: A Review of Research. *Environment and Behavior* 32:461–501
30. Turner J. 1991. *Social Influence*. Bristol, PA: Open University Press
31. Turner R. 1964. Collective Behavior. In *Handbook of Modern Sociology*, ed. Faris REL. Chicago, IL: Rand McNally. pp. 382–425
32. Turner R, Killian L. 1986. *Collective Behavior*. Englewood Cliffs, NJ: Prentice-Hall
33. Floyd DL, Prentice-Dunn S, Rogers RW. 2000. A meta-analysis of research on protection motivation theory. *Journal of Applied Social Psychology* 30:407–29
34. Jackson EL. 1981. Response to earthquake hazard: The west coast of North America. *Environment and Behavior* 13:387–416
35. Lindell MK, Hwang SN. 2008. Households' perceived personal risk and responses in a multihazard environment. *Risk Analysis* 28:539–56
36. Lindell MK, Prater CS. 2000. Household adoption of seismic hazard adjustments: A comparison of residents in two states. *International Journal of Mass Emergencies and Disasters* 18:317–38
37. Hyman A, Arlikatti S, Huang SK, Lindell MK, Mumpower J, et al. 2022. How do perceptions of risk communicator attributes affect emergency response? An examination of a water contamination emergency in Boston, USA *Water Resources Research* 58:e2021WR030669
38. Lindell MK, Mumpower JL, Huang SH, Wu H, Samuelson CD, et al. 2017. Perceptions of protective actions for a water contamination emergency. *Journal of Risk Research* 20:887–908
39. Harrison TR, Muhamad JW, Yang F, Morgan SE, Talavera E, et al. 2018. Firefighter attitudes, norms, beliefs, barriers, and behaviors toward post-fire decontamination processes in an era of increased cancer risk. *Journal of Occupational and Environmental Hygiene* 15:279–84
40. Dillman DA, Smyth JD, Christian LM. *Internet, Phone, Mail and Mixed-Mode Survey: The Tailored Design Survey*. New Jersey: John Wiley & Sons. 528 pp.
41. Johnson DR, Creech JC. 1983. Ordinal measures in multiple indicator models: A simulation study of categorization error. *American Sociological Review* 48:398–407