Preliminary Study on the Relation between the Coping Patterns and Mental Health of Radiation Control Personnel and Nondestructive Inspectors Engaged in the Periodic Inspections of Nuclear Power Plants

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Abstract: Preliminary Study on the Relation between the Coping Patterns and Mental Health of Radiation Control Personnel and Nondestructive Inspectors Engaged in the Periodic Inspections of Nuclear Power Plants: Chika NAGAOKA, et al. Department of Management, Otemon Gakuin University—

Objective: In order to safely manage nuclear power plants, their workforce should be mentally healthy. This study clarifies the coping strategies of radiation control personnel and nondestructive inspectors engaged in the periodic inspection of nuclear power plants, the effect of the coping strategies on their mental health, as well as any effect based on whether or not they had worked after the nuclear disaster caused by the Great East Japan Earthquake and tsunami in March 2011.

Methods: A questionnaire survey was administered to 133 technicians attending a certification course, and among them, our subjects of analysis were 104 people with work experience in radiation control and/or nondestructive inspection.

Results: The results indicated that even among workers of the same company who were assigned to similar duties in the periodic inspections of nuclear power plants, the group that had worked at a nuclear plant after the disaster had a tendency to use coping strategies, such as giving up and avoidance-like thinking, which was dissimilar to the group that had not worked at a nuclear plant after the disaster. Further, the former group had higher levels of distress than those who tended to use other coping strategies. In addition, the results suggested that the plan-drafting strategy adopted by the group that had not worked after the disaster did not result in stress reduction.

Discussion: Based on these results, we propose a stress management program specifically for radiation workers. (J Occup Health 2014; 56: 169–177)

Key words: Coping behavior, Fukushima nuclear accident, Mental health, Nuclear power plants, Workers

Since the disaster at the Fukushima Daiichi nuclear power plant in March 2011, awareness concerning formulation of measures to safely manage nuclear power plants has been consistently growing. In this study, we clarify the stress coping patterns of subcontract workers engaged in the periodic inspections of nuclear power plants (hereinafter referred to as periodic inspection) and their effects on the workers’ mental health. We also propose effective stress management guidelines for workers who may be involved in radiation work in the future.

The organization responsible for periodic inspections has a pyramid structure. The head is the person responsible for the power company. Next is the chief and deputy chief of periodic inspection operations from the primary contracting company who supervise several groups, such as the safety management group, quality control group and radiation control group, which play the role of operations control (staff function), and the instrumentation group equipment group, testing group, and plumbing group, which do the actual inspection work (line function; responsibilities may vary according to the plant or job). Each group is headed by a group leader from the primary contracting company, who is the person in charge of operations, and another person-in-charge from the primary contracting company. The workers from subcontracting companies are positioned in the next level below.
The workers under the person in charge of operations from the primary contracting company are those who are actually engaged in periodic inspection; hence, they take on an enormous amount of work and risk.

The survey subjects of this study were the radiation control personnel and the nondestructive inspectors deployed by the subcontractors to fulfill the requirements of the power company or the primary contracting company mainly during periodic inspection. All of them have highly specialized knowledge about radiation. The nondestructive inspectors conduct inspections using radiation or ultrasound to detect flaws in structures. The radiation control personnel perform important tasks of radiation protection by measuring the amount of radiation within a controlled area, providing guidance to workers and supervising them. They have radiation-related work experience in nuclear power plants across Japan or in nuclear-power-related organizations. To obtain high-quality work free of human errors from workers, it is indispensable to maintain their mental health in good condition\(^5\). Therefore, to carry out high-quality periodic inspections, radiation control personnel and the nondestructive inspectors should be mentally healthy. For this purpose, the stress management of these workers is considered an important factor for the safe management of nuclear power plants. However, little study has been done so far about the stress management of radiation workers.

In this study, we focus on the stress coping strategies and mental health of radiation control personnel and nondestructive inspectors. Coping is a personal effort done independently to handle a stress response or a stimulus causing a stress reaction\(^5\). Several coping strategies, such as planning and avoidance-like thinking and the use of a combination of multiple coping strategies rather than one particular coping strategy, are known to occur\(^4\). In addition, individuals can freely vary the coping pattern they use depending on the quality and strength of the stressor, the situation in which they are subjected to the stressor and so on\(^9\).

In order to understand the effects of coping on mental health, it is more important to consider the combination of multiple coping strategies (the coping pattern) rather than considering one particular strategy\(^9\). In previous research\(^9\), survey subjects were grouped based on the similarities in their coping patterns using the cluster analysis technique, and their mental health statuses were compared.

On the basis of the above, we first clarified if there was a difference in the coping patterns of survey subjects who had worked at nuclear power plants (including plants other than the Fukushima Daiichi nuclear power plant) after the March 2011 nuclear disaster. Since the nuclear disaster was a big shock, there might be a heavy mental load on the workers of not only the Fukushima Daiichi nuclear power plant where the accident happened but also on those of other nuclear plants. Therefore, we expected a difference in the coping strategies used by these workers after the March 2011 disaster.

To investigate this, we first classified the survey subjects (i.e., the workers of a certain subcontracting company who have experience in radiation-related work) into clusters based on coping pattern. Subsequently, we looked for the differences in the percentage of people in each coping cluster between the group that had not engaged in radiation-related work and the group that had engaged in radiation-related work after the accident. By evaluating the workers belonging to the same subcontracting company, we were able to make a direct comparison more easily by reducing the factors that needed to be considered.

Further, it is known that there is a situational-specific effect for coping, i.e., the effect of coping varies depending on the situation of the individual. For example, in emotion focused coping, i.e., trying to stop thinking about a problem and driving away one’s own negative emotions in situations where controlling the problem is possible, the likelihood of direct reduction of stress is generally low\(^2\); but in situations where control is not possible, this method of coping is associated with lower levels of distress\(^5,8\). Based on these notions, it is possible that the relation between coping and mental health would be different between persons who had engaged in radiation-related work and those who had not engaged in radiation-related work after the nuclear disaster, even among those who belonged to the same company. The reason for this might be the different mental situations that both groups have encountered. In this study, we examined distress using the General Health Questionnaire (GHQ)-12\(^9\), which is used to measure mental health.

Based on the results of this study, we proposed guidelines for implementing an effective stress management program for radiation workers who will be directly involved in the safety management of nuclear power plants.

**Method**

**Survey subjects**

The survey subjects were the 133 technicians (all males) who attended a certification course on radiation safety management (a 2-day program conducted within the period of December 2010 to January 2012, and was conducted 8 times in total). They either had work experience in periodic inspections or had plans to pursue work mainly in periodic inspection.
of nuclear power plants. Among the respondents, the data of 104 people who had prior experience in periodic inspections and whose answers were not deficient were considered for analysis. Their periodic inspection tasks were mainly nondestructive testing and radiation control.

Procedure
We conducted an anonymous questionnaire survey. The questionnaire set, which included an informed consent sheet, was distributed to 79 survey participants during their training period. After answering the questionnaire, the survey participants enclosed it in the provided envelope and submitted it to the person conducting the survey. It was conveyed that neither their cooperation with this survey nor the contents of their responses would affect their training evaluation. Since the remaining 54 people finished their training before the start of this survey, the questionnaire set was distributed to them through a person-in-charge at their workplace. After answering the questionnaire, the survey participants sealed it in provided envelope and sent it to the investigator by mail. We conducted the survey from the beginning of July 2011 until March 2012, corresponding to the period of 4 to 12 months after the nuclear disaster. The participants gave prior informed consent in compliance with ethical policies.

Question contents
1) Basic attributes
The subjects were asked about their gender, age, marital status, final academic background, number of jobs (this is an indicator of whether the subjects would continue working at the current company or not), years of employment in each job and recent duties. They were asked about the month and year of their most recent work.
2) Coping strategy
Seven items were developed to measure coping strategies using the Tri-axial Coping Scale (TAC-24) as a reference. The TAC-24 includes subscales such as plan drafting, getting information, catharsis, positive interpretation, giving up, distractive recreation and avoidance-like thinking (i.e., "trying not to have unpleasant thoughts"). The seven items that had high factor loadings for the seven-factor (subscale) were used in this study. Another subscale, one concerning evading one’s responsibilities, which is included in the TAC-24 and is unstable as a factor, was not used in the present study. The survey participants also answered questions regarding their possible thoughts and actions towards a mentally difficult situation related to their work at a nuclear power plant, and strategies for alleviating the mental stress after the situation. A 5-point Likert-type scale was used for the 7 items, with responses ranging from 1 (never) to 5 (often).
3) Mental health
The answers of the subjects were obtained using the GHQ-12, a scale for measuring mental health. The GHQ-12 is a shortened version of the GHQ with a minimum number of items, and its validity as a stress indicator has been confirmed by several studies. In the GHQ, the participant is asked to assess changes in mood, feelings and behaviors in a recent four-week period. The participant evaluates their occurrence on a 4-point response scale consisting of the following response options: “less than usual”, “no more than usual”, “rather more than usual” and “much more than usual”. The score was calculated in conformance with the original Goldberg GHQ method. Higher scores for the GHQ-12 indicate deteriorated mental health. The cut-off point of 2/3 or 3/4 points is considered appropriate, and a score of 3 or 4 points or higher is an indicator for mental health disorders.
4) Effects of nuclear disaster
The subjects were asked to write freely about the effects of the accident that occurred at the Fukushima Daiichi nuclear power plant in March 2011.

Analysis
We performed a nonhierarchical cluster analysis by the k-means method using the value obtained by standardizing the scores of the 7 items for the coping scale and the Euclidean distance. We created 2 to 5 clusters and grouped the subjects accordingly. We determined the number of clusters by considering the similarities between the cases and the possibility of interpreting the cluster pattern.

The differences among the clusters were examined using Fisher’s exact test and the Kruskal-Wallis test. The differences between the group that had worked after the accident and the group that had not worked after the accident were examined using Fisher’s exact test and the Mann-Whitney U test.

Results
Demographic characteristics of the study sample
1) Overall attributes
Approximately 42% of the subjects were 50 years old (Table 1). In addition, about 85% had been working in the current company since they began working. The number of years of employment in each job varied from less than 1 year to about 35 years. Workers with only nondestructive testing experience and those who were mainly engaged in radiation control but had prior experience in nondestructive testing were included. About 49% of the people scored 3 points or more on the GHQ, and 36.5% of them
scored 4 points or more. The free descriptions of the survey subjects showed their strong feelings of anger and shock when watching news about the nuclear disaster at the Fukushima Daiichi nuclear power plant and anxiety about their jobs (Table 2).

After considering the possibilities of interpreting the cluster patterns and the similarities between cases, 4 clusters were identified (Fig. 1).

The first cluster (CL1) had low scores for all the coping strategies, i.e., none of the coping strategies were performed adequately (24 persons, 23.1% of the total).

### Table 1. Demographic characteristics of the sample

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<th></th>
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### Table 2. Frequently provided comments of the survey subjects

Comments of the survey subjects

(a) I felt a great shock knowing that the reference value for the radiation dose that had been maintained strictly in our day-to-day work was raised significantly by the government after the accident.

(b) I was dejected due to the half-baked designs and provisions of the power companies, which were in contrast with the high-quality work I performed daily in my field.

(c) I felt enraged due to the excessively bad response and information provided by the power companies and the government to the local residents after the accident, which were in contrast with the high-quality work I performed daily in my field.

(d) I had a feeling of anxiety that although I had been doing a high-quality work in maintaining safety, the people around me might have a bad notion about my work in the future, owing to the critical attitude towards nuclear power plants that has grown recently in Japan.

(e) Since the prospects of nuclear power plants becoming operational again are remote, I had a feeling of insecurity that it might become difficult for me to find a job (since this was a period where the operation of nuclear power plants was irregular, it was difficult to predict the timing and quantity of work offered to subcontractors by the primary contracting company).

(f) After the accident, I did not tell my relatives that I had worked/was working at the Fukushima Daiichi nuclear power plant to keep them from being worried.
The second cluster (CL2) had high scores for plan drafting, getting information and catharsis and low scores for giving up and avoidance-like thinking (32 persons, 30.8% of the total). A characteristic of this cluster is relatively good use of approach-oriented coping strategies for active engagement in stressful conditions.

The third cluster (CL3) had low scores for plan drafting and high scores for giving up (24 persons, 23.1% of the total).

The fourth cluster (CL4) had markedly high scores for avoidance-like thinking and giving up. The scores for positive interpretation and getting information were relatively higher than those for the other clusters. Unlike the other clusters, all the coping strategies were performed from time to time in this cluster (24 persons, 23.1% of the total).

Across the 4 clusters, there were no significant differences in age, educational qualification, or marital status (Fisher’s exact test). Additionally, there were no differences in the GHQ scores based on cluster (Kruskal-Wallis test).

2) The groups that had and had not worked at a nuclear plant after the accident

Among the analysis subjects, 47 people (45.2%) were involved in periodic inspections after the 2011 disaster at the Fukushima Daiichi nuclear power plant (hereinafter referred to as the post-accident work group), and 57 people (54.8%) were not involved in periodic inspection after the 2011 accident (hereinafter referred to as the post-accident non-work group). The
latter group included people who were not involved in radiation work during the period from the occurrence of the accident until the survey because no requests for them to work came from the contracting company. This group also included people with work experience before the accident but who will possibly not work in the future due to age.

There was no difference in age between the post-accident work and non-work groups (Fisher’s exact test). However, the percentage of people in their 20s was greater in the work group (19.1%) than in the non-work group (8.8%), and the percentage of people 50 years old or older was greater in the non-work group (45.6%) than in the work group (38.3%). Further, the groups did not differ in terms of marital status or educational qualification (Fisher’s exact test).

Among the post-accident non-work group, the percentage of people whose GHQ scores were greater than 3 was 43.9%, and the percentage of people who scored 4 points or higher was 38.6%. On the other hand, among the post-accident work group, the percentage of people whose GHQ scores were 3 or more was 55.3%, and the percentage of people who scored 4 or higher was 34.0%. Although the post-accident work group had more people with particularly high GHQ scores than the post-accident non-work group (Fig. 2), no significant differences in mental health were observed between the post-accident non-work group and work group (Mann-Whitney U Test).

**Differences in coping strategies between the post-accident non-work group and the work group**

For both the post-accident work group and non-work group, the number of people falling under each cluster was calculated (Fig. 3). The ratio of the number of people in each cluster differed between the two groups (Fisher’s exact test, \( \chi^2=8.24, \text{df}=3, p<0.05 \)). CL1 had a tendency to be different from both CL3 and CL4 in terms of the ratio of the number of people (Holm’s method, \( p<0.05, .10 \), respectively); hence, the ratio of the number of people under CL1 was higher for the post-accident non-work group than for the work group. On the other hand, the ratios of the numbers of people under CL3 and CL4 were higher for the post-accident work group than for the non-work group.

**Coping strategies and mental health of the post-accident non-work group and work group**

The distributions of GHQ scores for each cluster for the post-accident non-work and work groups are shown in Fig. 4. In the post-accident non-work group, there was no difference in GHQ scores according to cluster (Kruskal-Wallis test, Fig. 4 (a)). On the other hand, when considering the post-accident work group, a trend toward differences in the distribution of GHQ scores according to cluster was observed (Kruskal-Wallis test, \( p=0.067 \), Fig. 4 (b)). Among the people in CL4, the percentage of people with a GHQ score of 3 points or more was high; on the contrary, none of
the subjects in CL1 had a GHQ score of 3 points or more. CL1 was significantly different from CL4 in terms of GHQ scores (Holm’s method, p<0.01). CL4 included persons having particularly high GHQ scores.

Further, the GHQ scores only tended to be different between the post-accident non-work and work groups in CL1, and significant differences were not observed in other clusters (Mann-Whitney test).

Discussion
The results indicated that, although the subjects were workers from the same company who had similar duties in periodic inspection of nuclear power plants, from the perspective of coping, the group that had worked at a nuclear plant after the accident was different from the group that had not worked. From the results, it is clear that, depending on whether a person had engaged in radiation work after the accident, the coping pattern used by the individuals, as well as the effect of coping on mental health, varied.

Differences in coping pattern depended on whether a person had worked at a nuclear plant after the nuclear disaster

Participants from the post-accident work group, compared with the post-accident non-work group, tended to belong to CL3 or CL4 (Fig. 3).

In CL4, it was interesting to note that although avoidance-like thinking was quite often used, getting information was also being used relatively often. From the free descriptions of the survey subjects (Table 2, (a−c)), we surmise that, even if they had received information, the people in CL4 could not have avoided being in the mental state of “trying not to think about unpleasant things”.

Further, in CL4, there were relatively higher scores even for positive interpretation, i.e., trying to think that things were not all bad. According to the previous studies, positive interpretation is most commonly used for coping with extreme stressors such as traumatic events or major losses. The free descriptions written by the survey subjects (Table 2, (d−f)), showed that the stress they experienced after the accident was extreme.

Based on these findings, it is inferred that the significant shock and anxiety experienced by the survey subjects likely caused changes in their individual coping strategies. The results indicated that it was more difficult for the post-accident work group to fall under CL1, where none of the coping strategies were used, compared with the post-accident non-work group (Fig. 3). Therefore, even people in CL1 who did not use any coping strategies before the accident could not help but implement some form of coping if they had worked after the accident.

Coping pattern and mental health
The results showed that in the post-accident work group, the mental health of individuals tended to vary according to the coping pattern, but in the post-accident non-work group, there were no variations in mental health according to the coping pattern used (Fig. 4). This shows that the effect of coping varied depending on whether the individual had engaged in radiation-related work after the accident.

CL4 in the post-accident work group, in which avoidance-like thinking scores were significantly higher, had a greater proportion of people with higher GHQ scores than the other clusters (Fig. 4 (b)). A positive relation between avoidance-like thinking and severity of distress has been repeatedly reported in previous studies, such as that of Endler and Parker. Further, Mattlin et al. suggested that avoidance-like thinking, when not combined with problem-focus coping, increases distress. Since the plan drafting scores of CL4 were lower than the significantly higher avoidance-like thinking scores (Fig. 1), the results of this study are thought to be consistent with the previous studies.

However, in the post-accident non-work group, variations in mental health due to coping pattern were not observed. For example, in CL4 of the post-accident non-work group, a trend toward a greater proportion of people with higher GHQ scores than the other clusters was not observed (Fig. 4 (a)). This is not consistent with findings of many previous studies, such as that of Endler and Parker. On the other hand, Baum et al. studied the relation between coping strategies and mental distress 17 months after the Three Mile Island (TMI) nuclear disaster using the residents of TMI and people living near an undamaged nuclear plant more than 100 miles from TMI as the survey subjects. The results showed that, unlike the people living near the undamaged nuclear plant more than 100 miles from TMI, the residents of TMI actively tried to forget, and this was associated with reduced distress. The “trying to forget” coping strategy reported by Baum et al. and “avoidance-like thinking” coping strategy reported in this study are similar. Therefore, it is inferred that the results regarding the post-accident non-work group in this study are consistent with the above results of Baum et al.

Further, the current results revealed that CL2 of the post-accident non-work group, which often used plan drafting strategies, did not vary from the other clusters with respect to the proportion of people with high GHQ scores (Fig. 4 (a)). A number of previous studies, such as that of Penley et al. have repeatedly reported a relation between plan drafting strategies and stress reduction. The present study did not agree with those reports. However, TMI studies have shown...
that the plan drafting of TMI residents was associated with higher levels of distress. This result can be regarded as consistent with the results of Baum et al.\(^2\)

It can likewise be stated that the psychological condition of the post-accident non-work group was similar to that of the TMI residents. Although the post-accident non-work group was involved in nuclear power for their occupation, they were in a position where they were unable to work on the problem directly to control it. The perception of the controllability of a problem is considered the key to evaluating the effect of problem-focused coping\(^3\). However, it can be said that the post-accident work group was aware of its roles and responsibilities in controlling the problem. This supports the perception that the survey subjects showed a strong sense of duty and a sense of validity towards their nuclear power plant-related work.

Persons with a GHQ of 3 points or higher were not observed in CL1 in the post-accident work group, which did not implement any of the coping strategies adequately (Fig. 4(b)). Since there were only 5 relevant people, further investigations are needed before drawing conclusions about the factors of stress reduction. However, it was shown that 3 (2 in their 50 s and 1 in his 30 s) out of the 5 people concerned had 15 to 30 years of hands-on experience in nondestructive inspections, and of these, 2 had about 10 years of experience in coordinating nondestructive inspectors. According to another study by the authors (under preparation for publication) using the same subjects, job ability and efficacy improve with the number of years of work experience. Therefore, it is implied that a worker improves his ability to work and his efficacy as he accumulates experience and is able to stay mentally healthy during major incidents such as an accident like that at the Fukushima Daiichi power plant.

Of the remaining 2 persons in CL1 in the post-accident work group, one person was engaged in nuclear power plant work for only a very short period (just a few days per year), and the other was involved in a nuclear power-related organization that differs in nature from the power plants of a typical power company. Thus, the psychological influence of working after the nuclear disaster was not particularly evident in these subjects due to the differences in workplace attributes or shortness of the working period.

Future tasks

Although this is a preliminary study, we arrived at relevant suggestions for planning stress management programs for the workers of subcontracting companies who plan to work at nuclear power plants in the future.

Since the mental health of an individual who naturally uses avoidance-like thinking often declines when he does nuclear-power-plant-related work, it is desirable to perform appropriate interventions in advance. Further, it would be effective to also teach people who may work in nuclear power plants in the future to use multiple coping strategies rather than avoidance-like thinking alone. On the other hand, for individuals who have not worked since the accident and who are in a situation where they do not feel they have control over the problem, it would be effective to ensure that they understand that getting information about the current situation alone is inadequate. Poor mental health of individuals leads to human errors\(^4\) that can cause serious accidents. For this reason, consideration of the mental health of workers of nuclear power plants is extremely essential in the future.

Further, this study suggests the need for a long-term plan to train young workers. The results of this study indicated a situation in which people with many years of experience were tough and remained unperturbed even during negative events such as the accident. In order to safely manage nuclear power plants, which will continue to be around for several decades, highly skilled people will be needed several decades from now.

We identified a number of limitations of our study. Since this survey was carried out after the nuclear disaster, we were unable to examine the variation in coping strategies before and after the accident. Moreover, the number of samples was insufficient, and we were unable to demonstrate a causal relationship. It is expected that useful knowledge can be obtained by conducting more surveys, by expanding the number of survey subjects or types of work and by performing a longitudinal study, through which thorough safety management of nuclear plants can be achieved. Although the topic of this study addresses issues regarding stress management of radiation workers in nuclear power plants and has been barely studied in the past, its importance in the safety management of nuclear power plants is extremely high.

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