Modifying Effects of Perceived Adaptation to Shift Work on Health, Wellbeing, and Alertness on the Job among Nuclear Power Plant Operators

Masaya TAKAHASHI1, Takeshi TANIGAWA2*, Naoko TACHIBANA3, Keiko MUTOU4, Yoshiko KAGE4, Lawrence SMITH5 and Hiroyasu ISO2

1 National Institute of Industrial Health, 6–21–1 Nagao, Tama-ku, Kawasaki 214-8585, Japan
2 Department of Public Health Medicine, Doctoral Program in Social and Environmental Medicine, Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1–1–1 Tennoudai, Tsukuba 305-8575, Japan
3 Osaka Medical Center for Health Science and Promotion, 1–3–2 Nakamichi, Higashinari-ku, Osaka 537-0025, Japan
4 Human Factors Group, R&D Center, Tokyo Electric Power Company, 4–1 Egasaki-cho, Tsurumi-ku, Yokohama 230-8510, Japan
5 Shiftwork Research and Resources, School of Psychology, University of Leeds, Leeds, LS2 9JT, UK

Abstract: This study examined the relationship between perceived adaptation to shift work and shift-related problems. A total of 608 male operators at nuclear power plants completed a set of validated questionnaires including a modified version of the Standard Shiftwork Index, which covered adaptation to shift work, fit to job content, chronotypes, chronic fatigue, sleep, naps, shift work locus of control (SHLOC), psychological health, social/family life, daytime sleepiness, workload, alertness on the job, and lifestyle factors. Participants were divided into two groups according to their perceived level of adaptation to shift work. The good adaptation group showed better outcomes than the poor adaptation group in terms of fit to job content, chronic fatigue, daytime sleep before night shifts, social and family disruption, SHLOC, psychological health, and alertness during night shifts (ps<0.001). Operators who reported good adaptation also took a more frequent, longer nap and more cigarettes during night shifts (ps<0.05). The cross-sectional study design cannot determine a causal relationship between perceived adaptation and shift work problems, yet the present results suggest that the effects of working shifts may be modified by perceptions of shift work adaptation.

Key words: Shift work, Adaptation, Health, Wellbeing, Alertness

Introduction

Both industrialized and industrializing societies are increasingly requiring shift work. Working shifts has tremendous impact upon the body, workplace, and society1,2. Problems experienced by shift workers result principally from misalignment of circadian phase with shift work schedules, as well as extended time awake3–5. Some people seem to tolerate shift work quite well, whereas others find this more difficult. Prior research has thus focused upon inter-individual differences in circadian adaptation (e.g., age, gender, morning-evening type, personality, and body temperature) and explored techniques to promote circadian adaptation, such as bright light, exercise, and pharmacological aids3,6–8.

Among indicators for circadian adaptation to shift work, core body temperature is the gold standard3,9. Precise
assessment of circadian phase via core body temperature measurement, however, is almost impossible in field studies, because of various masking effects of exogenous factors (i.e., light, sleep-wake cycle, activity, posture, and food intake)9). One alternative would be the use of questionnaires. Even with this method, we sometimes encounter difficulty in selecting minimum but satisfactory scales. In addition, lengthy questionnaires might result in a low response rate and increased missing data due to reduced motivation of participants. A possible, and parsimonious, solution would be to ask participants to express their perception of the extent to which they feel adapted to shift work. This notion is supported by a number of previous findings to indicate the utility of a single question on perceived health status, stress symptoms, or shift work tolerance10–16). Moreover, self-evaluation of shift work adaptation has been reported to represent the degree of circadian adaptation, as measured by mood, oral temperature, and urinary levels of potassium, sodium, and 17-OH17).

The present study examined the relationship between perceived adaptation to shift work and health, wellbeing, and alertness on the job in a sample of nuclear power plant operators. On the basis of research results with single-item methods, we hypothesized that higher levels of perceived adaptation to shift work would be related to fewer shiftwork-related problems.

Methods

Participants

A total of 608 male shift workers at nuclear power plants participated in the study. This sample was drawn from all of male shift workers at the plants (n=613). The response rate was 99.2%. Female shift workers were not included in the current study because of a very small sample size (n=3). The mean age of the participants was 32.9 ± SD 9.4 yr (range 18–54). The mean length of shift work experience was 11.2 ± 7.3 yr (range 0.5–32.0); and the mean length of their experience on the current shift system was 7.4 ± 5.6 yr (range 0.1–32.0). Fifty-seven percent were married. Participants worked under a rapidly rotating shift schedule (Fig. 1), which comprised a cycle of day shift 1 (8:30–15:00)–day shift 2 (8:30–21:00)–afternoon shift (15:00–21:00)–night shift 1 (21:00–8:30)–night shift 2 (21:00–8:30)–day off 1–day off 2–day off 3. Working for three to four cycles was followed by 14 consecutive days of day/training shifts (8:30–17:00).

The study protocol was reviewed and approved by the power plant’s Committee of Safety and Health that represented the labor union, workers, the employer, and occupational health staff and by the Research and Development Center of the company.

Questionnaires

Participants completed a set of self-report questionnaires regarding a number of aspects of shift work. The questionnaires, based principally on the Standard Shiftwork Index (SSI)18), covered items referring to i) biographical information, ii) moderator variables (chronotypes, shift work locus of control [SHLOC], and exercise), iii) major difficulties caused by working shifts (adaptation to shift work, fit to job content, social life, fatigue, daytime sleepiness, shift system advantages, psychological wellbeing), and iv) problems associated with each shift (sleep disturbance, alertness on the job, workload, and night-shift specific items). Sleep-activity patterns in a shift cycle were also measured on a log, but the data will be reported elsewhere.

Adaptation to shift work was assessed by the question “How well do you feel adapted to the current rotating three-
shift schedule?”. Participants rated their level of perceived adaptation on a scale ranging from 0% to 100% in units of 10%. Higher scores indicated better levels of perceived adaptation. Fit to job content was measured by the question “How well do you fit the current job content?” using the same response scale as for perceived adaptation. Morningness-Eveningness was rated both for the time period before starting working shifts and for the current time period on a five point scale, with higher scores showing more evening types. Information on exercise was collected as times per week according to its intensity. Frequency of regular leisure time physical activity long enough to work up a sweat was also measured (1=never/rarely, 2=sometimes, 3=often).

The scales selected from the SSI included social and family disruption (4 items), psychological wellbeing (the General Health Questionnaire-12), shift system advantages (1 item), retrospective alertness rating (at 2-h intervals during each shift: 1=Very alert, 3=Alert, 5=Neither alert nor sleepy, 7=Sleepy (but not fighting sleep), 9=Very sleepy (fighting sleep))19), sleep disturbance (5 items), and workload (4 items). Chronic fatigue was measured using 22 items modified from the Checklist Individual Strength questionnaire20). In addition, we measured daytime sleepiness by the Epworth Sleepiness Scale (ESS, 8 items)21) and SHLOC by the corresponding scale (16 items)22). The scales mentioned above were translated into Japanese by the research team, and were back-translated by an independent translator living in the US for over ten years. The back-translated scales were verified by a native English speaker (LS) in the team. Listed are the Cronbach’s alpha coefficients for the translated scales, with the exception of the retrospective alertness rating: social and family disruption (0.71), chronic fatigue (0.91), psychological wellbeing (0.80), ESS (0.68), SHLOC (0.88), sleep disturbance (averaged over shifts=0.69), and workload (averaged over shifts=0.67).

Night-shift specific items were measured with respect to a) amount of time spent outside in the morning and in the afternoon before the shifts on a four point scale (1=almost always inside, 2=mostly inside, 3=mostly outside, 4=almost always outside), b) coping to promote daytime sleep before the shifts (free description), c) napping during the shifts (its frequency, duration, desired time to start napping), d) the number of caffeinated drinks and cigarettes before and during shifts, frequency of alcohol use after the shifts, and e) frequency of meal intake before shifts.

**Procedure**

Eligible participants received detailed explanations of the current study from the researchers and were asked to take part in it. The questionnaires were distributed to them by supervisory staff of the plants and returned to the staff in sealed envelopes within one month, and then forwarded to the research team.

**Statistical analyses**

Participants were divided into good and poor adaptation groups by a median split of the perceived adaptation scores (=70%). Because the good adaptation group was significantly younger than the poor adaptation group (31.5 ± 9.3 vs. 34.8 ± 9.2 yr, F(1,604)=18.73, p<0.001), differences between the two groups were examined by analysis of covariance (ANCOVA) with age as a covariate. Additionally, differences in alertness on the job between groups as a function of time on shift were tested by a repeated-measures ANCOVA with age as a covariate. Degrees of freedom (dfs) for this ANCOVA were corrected according to the Greenhouse-Geisser procedure, but original dfs are reported in the text. The Tukey-Kramer method was used for post-hoc comparisons.

A forward stepwise regression model was also used to elucidate the factors associated with perceived adaptation to shift work as a dependent variable. Each measure described above was entered as an independent variable into this model if it was significantly correlated with perceived adaptation to shift work. When a correlation coefficient between two independent variables was 0.8 or larger, one variable that was correlated with the perceived adaptation to shift work higher than the other was selected to be entered. These criteria left twenty seven-measures as possible independent variables: age, perceived fit to job content, chronotype (past and current), social/family disruption, chronic fatigue, ESS, shift system advantages, SHLOC, GHQ-12, sleep disturbance (sleep periods on day shift 1, between afternoon shift and night shift 1, before night shift 1, between night shifts 1 and 2, after night shift 2, and on day off 1), workload (on day shift 1, day shift 2, afternoon shift, and night shift 1), amounts of time spent outside in the afternoon before night shift 1, nap duration usually taken during night shift 1, the number of cigarettes (before and during night shifts), frequency of alcohol use after night shifts, and weekly frequency of exercise (at moderate and mild levels).

These statistical analyses were performed using StatView for Windows version 5.0J (SAS Institute Inc, Cary, NC) and SPSS for Windows release 10.0J (SPSS Inc, Chicago, IL).

**Results**

The results of the ANCOVA comparing the good and poor adaptation groups for shift work problems are summarized
in Table 1, together with effect size (partial $\eta^2$). This table includes measures with significant differences between the groups. Overall, the good adaptation group reported significantly fewer problems resulting from shift work than did the poor adaptation group. In particular, good adaptation was characterized by greater fit to job content, higher SHLOC, better psychological wellbeing, as well as lower levels of chronic fatigue and social and family disruption. Significant between-group differences were also observed for sleep disturbance and workload on each shift. During night shifts, the workers perceiving good adaptation to shift work reported taking more frequent, longer naps, and smoking more cigarettes than those perceiving poor adaptation. The percentage of smokers among the good adaptation group was also significantly higher by 12% (p=0.021 in a multiple logistic model controlling for age).
Repeated-measures ANCOVAs for alertness on night shifts showed significant main effects of group (night shift 1: \(F(1,598)=26.24, p<0.001, \eta^2=0.042\); night shift 2: \(F(1,600)=26.54, p<0.001, \eta^2=0.042\)) and time on shift (night shift 1: \(F(5,2990)=76.83, p<0.001, \eta^2=0.114\); night shift 2: \(F(5,3000)=48.11, p<0.001, \eta^2=0.074\)). But an interaction of group by time on shift was not significant. Post-hoc comparisons indicated consistently greater alertness over the entire period of both night shifts among the good adaptation group than among the poor adaptation group (\(p<0.05\), Fig. 2). A main effect of group was significant for day shift 1 (\(F(1,600)=4.97, p=0.026, \eta^2=0.008\)) and afternoon shift (\(F(1,600)=5.14, p=0.024, \eta^2=0.008\)). A significant main effect of time on shift was also observed for day shift 1 (\(F(3,1800)=85.37, p<0.001, \eta^2=0.125\)) and afternoon shift (\(F(2,1200)=12.43, p<0.001, \eta^2=0.020\)). But no significant interaction between group and time on shift was found for day shift 1 or afternoon shift. The post-hoc tests showed increased alertness of the good adaptation group in the middle of those shifts, though the magnitude was small (Fig. 2). Only a main effect of time on shift was significant for day shift 2 and day/training shift (\(p<0.001\)).

A stepwise regression analysis showed seven predictive factors for the perceived adaptation to shift work (Table 2). An increase in perceived adaptation was associated with increase in perceived fit to job content, younger age, evenness, less problems in social and family life, more undisturbed sleep in the daytime before the first night shift,
increased amount of time spent outside in the afternoon before the first night shift, and greater internal SHLOC. These factors explained 61% of the variance.

Discussion

This study aimed at examining the relationship of perceived adaptation to shift work with workers’ self-reported health, wellbeing, and alertness on shift. Perceived adaptation distinguished shift workers reporting fewer problems in health and wellbeing from those reporting more problems. Likewise, the good adaptation group showed greater alertness on night shifts than did the poor adaptation group. The results also suggested that perception of shift work adaptation was associated with perceived fit to job content, age, chronotype, social and family life, daytime sleep before the first night shift, amount of time spent outside before the first night shift, and SHLOC.

Reliable differences in both shift work problems and alertness on night shifts were found between workers with good perceived adaptation and those with poor adaptation. Our participants have semiannual health check-ups that include medical history, physical examination, chest radiographs, electrocardiogram, blood pressure, biochemical tests, and urinary analysis, according to the Labor Safety and Health Regulations in Japan. They may be regarded as otherwise healthy individuals. Nevertheless, it is highlighted that a significant difference by perceived level of shift work adaptation was observed for most of the scales adopted. These findings may support our hypothesis presented, implying that perceived adaptation could be potentially useful as an overall assessment of the health, wellbeing, and alertness of shift workers. This possibility obviously should be tested in a follow-up study. Methodologically, this single-item measure seems to serve as a parsimonious approach to indexing shift workers’ responses, though further efforts should be made to validate such a method using objective indicators of the physiologic function and alertness.

In the present study, significantly increased alertness during night shifts was found for the workers with good perceived adaptation, as compared to the workers with poor perceived adaptation. Presumably, multiple factors including main sleep, naps, and physical/mental health status may be attributed to differences in night shift alertness. But the good adaptation group reported smoking more cigarettes during the night shifts than did the poor one. If the good adaptation group relies on the alerting effects of nicotine, alternative ways to maintain alertness should be advised (e.g., advice on caffeine use, and physical activity) in order to reduce resort to risky behaviors that may harm health in the longer term.

The present data suggest that perception of fit to job content may be the most important factor relevant to perceived adaptation to shift work, given its predominance in the standardized regression coefficient. This finding is of prime importance, since previous studies have extensively addressed the characteristics of shift workers and the features of shift schedules such as shift length, the number of night shifts, direction of shift rotation, and timing of shift changeover. Since the early 1990s, however, it has been emphasized that job content and work schedules should be simultaneously optimized. Adjusting operational demand and reducing other job stressors through ergonomic principles may facilitate shift work adaptation.

Consistent with existing evidence, participants who were younger and classified as more evening types showed better perception of adaptation to shift work. The results also support the view that increased satisfaction with social and family life is a key issue for shift workers. A significant association between increased quality of daytime sleep before the first night shift and superior adaptation agrees with previous findings on the efficacy of such a prophylactic nap to counteract night-shift problems. Although the standardized regression coefficients were quite small, perceived adaptation was also found to be positively associated with the amounts of time spent outside in the afternoon before the first night shift and internal SHLOC. There are few data to account for the former association, and a detailed analysis of the sleep-activity log would provide some information. However, SHLOC internality has been shown to be related to fewer shift work problems.

We acknowledge several limitations. The cross-sectional nature of the current study cannot provide an answer to the causality between perceived adaptation and shift-related problems, but it would be expected that shift workers might benefit by modifying such factors that were associated with perceived adaptation. Toward this end, occupational health and safety staff within an organization should assist shift workers to learn appropriate ways of modifying their knowledge and behavior for promoting shift adaptation. Presuming that educational materials in plain language might be necessary, and as a practical consequence of the present results, we have developed and issued a brochure of guidance to help improve shift working life that has been distributed to all the participants. Our preliminary analyses showed that at a period of 3 to 4 months after receipt of the brochure, about 50% of the operators reported reading through it, and trying to improve their life of working shifts according to...
suggestions and recommendations in the brochure. Besides, about 25% reported that the brochure would be useful in reducing shift work problems.

Another limitation is that the measures used in this study were self-reported, although data were collected with the validated scales to evaluate a wide range of problems due to shift work. In addition, the results obtained might be difficult to interpret if elderly participants would have continued working shifts because of higher levels of health than that of the operators who were unable to do so (“the healthy worker effect”). Although the study subjects worked a variety of different jobs at the plants, they do represent a single occupational group. Further research is required to examine whether or not the current findings could be generalized to different groups of workers.

In conclusion, the present study shows that better perceived adaptation to shift work may be associated with fewer problems encountered while working shifts. This finding implies the potential of using perceived adaptation as a possible proxy for the health, wellbeing, and on-the-job alertness of shift workers. It seems likely that a question regarding shift work adaptation is advantageous in terms of research methodology on account of its parsimonious value, but this possibility needs to be explored. The factors connected with perceived adaptation might also be used to devise intervention strategies for improving shift work situations.

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