Effect of Work Shift Rotating on Fatigue Levels of Aircraft Mechanics in Line Maintenance

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1 Introduction

The aviation industry was rapidly growing in recent years. High demand in aircraft usage along with competition push the need of aircraft mechanics to work as shift, especially the maintenance work that done daily at ramp area which are call the line maintenance. High pressure due to schedule induces stress and fatigue to mechanics.

Fatigue is generally referred to as a physiological condition, which causes a decrease in physical and mental performance. A consensus definition of fatigue is difficult. And it is generally accepted that fatigue and fatigue-related impairment are influenced by prior sleep history, work hours, workload, and length of time spent awake (Dorrian et al., 2011; Dawson & McCulloch, 2005). Measuring fatigue is subjective, and the rating scales are the only available tools to assess fatigue (Shahid et al., 2010). The Swedish Occupational Fatigue Inventory (SOFI) was developed to understand the concept of fatigue by measuring the subjective dimensions of work-related fatigue in different occupations (Åhsberg, 1998). SOFI consists of 20 expressions, distributed on the dimensions of lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness (Åhsberg, 2000). Shift workers are at risk of fatigue or sleepiness caused by work-related fatigue, which was a result of insufficient restorative sleep due to circadian disruption (Costa, 1996; Hossain et al., 2003; Shen et al., 2006). Recovery durations are an important factor to reduce fatigue, since on the first day of the rest period, shift workers scored poorer on the sleep quality (Merkus et al., 2015).

"Shift work system" is introduced in aircraft maintenance process to respond to the rapidly growing aviation industry today and to be able to use resources and

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manpower for existing maintenance to be more efficient and cost-effective. It is used in scheduling operations in the aviation industry to change the time characteristics of the aviation personnel resulting in continuity in operations. Different shift systems are used, resulting in different fatigue (Åhsberg et al., 2000; Hakola & Härmä, 2001; Shen et al., 2006). Fatigue is part of human factors that will reduce human performance and increase the chance of accidents while performing maintenance work. It also causes negative effects on aircraft organizations or even aircraft technicians themselves. Thus, this study aims to evaluate the effect of work shift system on fatigue in order to improve shift management to reduce the risk of accidents that may occur from fatigue.

2 Method

2.1 Participants and Data Collection

The participants are aircraft mechanics working on the line maintenance at Don Mueang International Airport. The aircraft mechanics include 164 males and 20 females; the age distribution is 61 (33%) from 20 to 24 years old, 65 (35%) from 25 to 29 years old, 28 (15%) from 30 to 34 years old, and 30 (16%) older than 35 years old. There are three types of shift system examined in this research. Shift systems *P1* and *P2* are slow-rotating shifts, and shift system *P3* is a fast-rotating shift, and all shift systems are listed in Table 1.

2.2 Dependent Variables

Fatigue The paper used the Swedish Occupational Fatigue Inventory (SOFI) to assess fatigue level of the aircraft mechanics. The SOFI was developed by Åhsberg et al. (1997) to contribute to the understanding of the concept of fatigue by measuring the subjective dimensions of work-related fatigue in people from different

Table 1 Shift system

No.	Shift system
P1 (slow-rotating shift)	Two 12-h morning shifts Two 12-h night shifts Four days off
P2 (slow-rotating shift)	Four 12-h night shifts Four days off
P3 (fast-rotating shift)	Two 12-h morning shifts Two days off Two 12-h night shifts Two days off

occupations. The SOFI consists of 20 items belonging to the 5 dimensions: lack of energy (items: worn out, spent, drained, overworked), physical exertion (items: palpitations, sweaty, out of breath, breathing heavily), physical discomfort (items: tense muscles, numbness, stiff joints, aching), lack of motivation (items: lack of concern, passive, indifferent, uninterested), and sleepiness (items: falling asleep, drowsy, yawning, sleepy). The feelings of being tired are graded from 0 (not had such feelings at all) to 6 (had such feelings to a very high degree). Lack of energy is general qualitative fatigue which reflects both the physical (the factors of physical exertion and physical discomfort) and mental (the factors of lack of motivation and sleepiness) (Åhsberg et al., 2000). In this study, the SOFI dimension was translated to local language and was proven by expertise in human factor and high experience mechanics. The pilot test was conducted to verify the reliability with Cronbach's alpha (α), which was measured as 0.861.

2.3 Independent Variables

Shift system The duration of work shifts that is designed to cover the day is usually either 8 h or 12 h; however, the aircraft line maintenance mostly uses 12 h shift work. Three types of shift system were examined in this study: two shift systems (*P1* and *P2*) are classified as slow-rotating shift and the other (*P3*) is fast-rotating shift.

Sleep durations Sleep is a mechanism to recover from work-related fatigue. The study of Dorrian (2011) suggests that sleep duration less than 5 h or more than 16 h of wakefulness can significantly increase the likelihood of fatigue. This study collected sleep duration by dividing into three groups: less than 5 h, 5 h–8 h, and more than 8 h.

Work experience Work experience represents the duration that participants experience in shift work. Higher work experience means higher duration in shift system.

2.4 Statistical Analysis

Descriptive statistics were used to obtain a simple measure of each dimension, a mean of five SOFI fatigue ratings. Analysis of variance (ANOVA) and two-way analysis of variance and analysis of covariance (ANCOVA) were performed on the data collected to test the differences between groups (shift system and work experience).

3 Results and Discussion

3.1 Participant Demographics

Difference in participant demographic and work-related background variables between the shift pattern groups is shown in Table 2. Most of the participants were male due to the nature of job. Shift systems *P1* (49 participants) and *P2* (52 participants), which are slow-rotating shifts, are equal to 55% of samples, and shift system *P3* (83 participants) is 45% of samples.

3.2 Difference Between Shift Systems

Results show that shift systems *P1* and *P2*, which are slow-rotating shifts, have the higher rating in lack of energy dimension than shift system *P3*, which is a fast-rotating shift. But, in the lack of motivation and sleepiness dimensions, the rating from shift systems *P1* and *P2* (slow-rotating shift) is less than shift system *P3* (fast rotating), as shown in Table 3. Analysis of variance (ANOVA) is used to test the differences, and the results show that the difference between shift systems *P1* (swing shift: 2 day shifts and two night shifts) and *P2* (permanent shift: four night shifts) was not significant. This result is consistent with the finding from Merkus et al. (2015) that the swing shift had no effect on fatigue.

But the fatigue was affected by the shift rotating system, as found in the study of Hakola, T., and Härmä, M. (2001). Fast-rotating shift had less fatigue in terms of lack of energy ($P3 < P2$). However, some contradictions had been found, and the

Table 2 Demographic characteristics within each shift pattern

		Shift system							
		P1 (slow rotating)		*P2* (slow rotating)		*P3* (fast rotating)		Total	
Total		49	(27%)	52	(28%)	83	(45%)	184	(100%)
Gender	M	38	(21%)	46	(25%)	80	(43%)	164	(89%)
	F	11	(6%)	6	(3%)	3	(2%)	20	(11%)
Age (years old)	20–24	15	(8%)	11	(6%)	35	(19%)	61	(33%)
	25–29	20	(11%)	21	(11%)	24	(13%)	65	(35%)
	30–34	3	(2%)	8	(4%)	17	(9%)	28	(15%)
	>35	11	(6%)	12	(7%)	7	(4%)	30	(16%)
Work experience (years)	<2	13	(7%)	11	(6%)	28	(15%)	52	(28%)
	2–4	12	(7%)	8	(4%)	29	(16%)	49	(27%)
	>4	24	(13%)	33	(18%)	26	(14%)	83	(45%)
Sleep duration	<5 h	6	(3%)	15	(8%)	5	(3%)	26	(14%)
	5–8 h	37	(20%)	35	(19%)	53	(29%)	125	(68%)
	>8 h	6	(3%)	2	(1%)	25	(14%)	33	(18%)

Table 3 Demographic characteristics within each shift pattern

SOFI fatigue dimension	*P1* (slow); $n = 49$ Mean (SD)		*P2* (slow); $n = 52$ Mean (SD)		*P3* (fast); $n = 83$ Mean (SD)		Total; $n = 184$ Mean (SD)		*F; df = 2*	*p*
Lack of energy	3.7	(0.9)	4.1	(1.1)	3.5	(1.6)	3.7	(1.4)	3.809	0.024* *(P2 > P3)*
Physical exertion	2.2	(1.2)	2.6	(1.4)	2.7	(1.8)	2.6	(1.6)	1.494	0.227
Physical discomfort	2.3	(1.3)	2.6	(1.4)	2.6	(1.8)	2.5	(1.6)	1.007	0.367
Lack of motivation	1.7	(1.5)	2.1	(1.3)	2.7	(1.9)	2.2	(1.7)	5.982	0.003* *(P1 < P3)*
Sleepiness	2.7	(1.5)	3.2	(1.5)	3.7	(1.7)	3.3	(1.6)	6.290	0.002* *(P1 < P3)*

Remark: $*p < 0.05$

result in this study shows that the slow-rotating shift is more suitable to reduce the mental fatigue, and age of population and shift pattern may be the reason of difference.

3.3 *Effect of Work Shift Rotating and Work Experience*

Some studies have shown that gender also had an effect on fatigue (Åhsberg, 2000); however, there is a small amount of female sampling in shift system *P3*, and to exclude the effect of gender and prevent bias result, only male respondents were considered. The fatigue rating of shift systems *P1* and *P2* had been merged as the slow-rotating shift and was compared to the fast-rotating shift. Two-way analysis of variance and analysis of covariance (ANCOVA) was used to study the different five fatigue dimensions of two independent variables (work experience and shift rotating), while sleep duration was used as covariate.

The results are shown in Table 4. It demonstrates that there is no difference in lack of energy dimension, but both physical fatigue (physical exertion and physical discomfort dimensions) and mental fatigue (lack of motivation and sleepiness dimensions) ratings of the slow-rotating shift are significantly less than the fast-rotating shift. Since the fast-rotating shift has less recovery duration, this may be the main factor (Merkus et al., 2015) that causes higher fatigue.

Lack of energy and physical fatigue (physical exertion and physical discomfort) are also dependent on the work experience. As shown in Fig. 1, work experience between 2 and 4 years has experience in highest level of lack of energy and physical fatigue (physical exertion and physical discomfort). A correlation exists between work experience and the fatigue rating; however, whether this correlation is causal cannot be concluded.

Table 4 Significant test of SOFI fatigue dimensions of work experience and shift rotating

SOFI fatigue dimension		Work experience	Shift rotating	Work experience × shift rotating
Lack of energy	*F*	5.018	1.094	3.343
	p	0.008*	0.297	0.038*
Physical exertion	*F*	4.451	7.862	1.313
	p	0.013*	0.006*	0.272
Physical discomfort	*F*	5.136	6.119	1.506
	p	0.007*	0.014*	0.225
Lack of motivation	*F*	1.400	20.381	2.104
	p	0.250	0.000*	0.125
Sleepiness	*F*	1.236	10.723	1.476
	p	0.293	0.001*	0.232

Remark: *$p < 0.05$

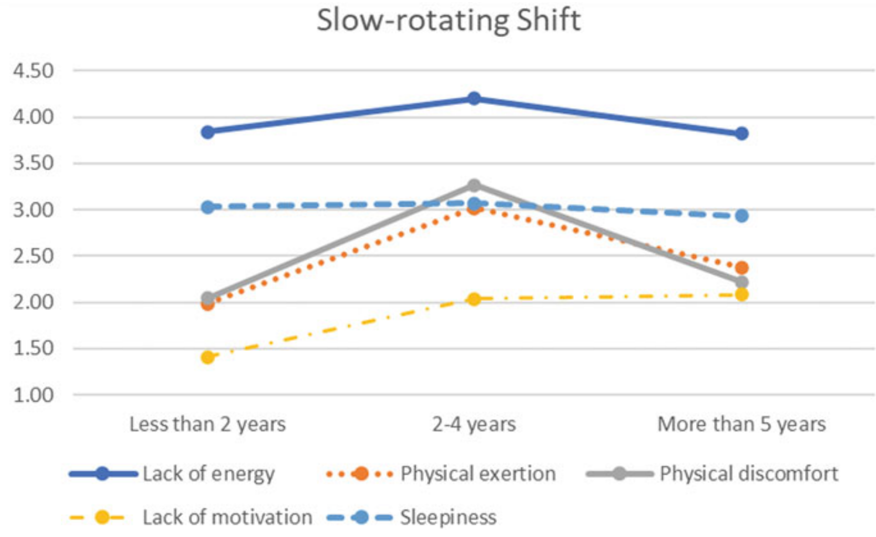

Fig. 1 SOFI fatigue dimensions of work experience for slow-rotating shift

Considering the interaction between work experience and shift rotating, the high work experience with fast-rotating shift and the fatigue rating in lack of energy tended to increase significantly. This reflects that high exposure to fast-rotating shift can cause high level of fatigue rating in lack of energy (Fig. 2).

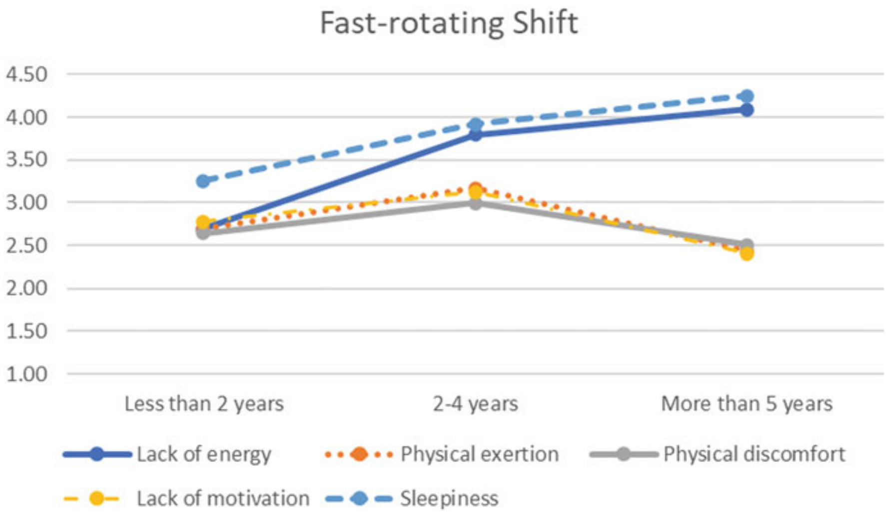

Fig. 2 SOFI fatigue dimensions of work experience for fast-rotating shift

3.4 Limitation

There are some limitations to the current study that must be noted. First, this study focused on subjective fatigue, and no objective performance indicators were analyzed for this study. Such measures may be of benefit, particularly access to performance record, incidents, accidents, or near-misses. These data would have been of benefit had they been available. Second, case study was selected from two companies, although these two companies were quite similar in terms of location and operations, but there may be some latent factors that cannot be controlled in this study. Generalization should be done with caution.

Finally, the Swedish Occupational Fatigue Inventory (SOFI) was chosen for this study as it has been validated (Åhsberg et al., 2000) and widely used (Shen et al., 2006) and was considered to be the optimal choice at the time the studies were conducted. Other tools that are available could be used to compare and confirm the results of the study.

4 Conclusion

In conclusion, the fast-rotating shift had more negative impact on physical fatigue and mental fatigue than slow-rotating shift. Overall fatigue in slow-rotating shift was higher than fast-rotating shift due to the extended shift work, but the difference was not statistically significant. Extended shift work might have a negative effect on overall fatigue and physical fatigue; especially, extended fast-rotating fatigue might increase significantly than overall fatigue.

Finally, this research contributes to the understanding of the effect of shift rotating on subjective fatigue. Therefore, in shift system design, the recovery durations might be one of the main factors to reduce risk of work-related fatigue.

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