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Assessment of fatigue among aviation personnel involved in military flying in India employing Multidimensional Fatigue Symptom Inventory – Short Form (MFSI-SF)

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ABSTRACT

Introduction: Fatigue has been recognized as a major safety hazard in modern aviation. There are numerous studies which have addressed various aspects such as the subjective symptoms, objective measures to diagnose fatigue, and its link with operator's performance. This study was a novice attempt to assess the chronic fatigue among the aviation personnel employing "Multidimensional Fatigue Symptom Inventory – Short Form (MFSI-SF)," which is a well validated fatigue questionnaire.

Material and Methods: A total of 93 aircrew and 30 ground crew of either sex from three military air bases were randomly selected for this cross-sectional observational study. The selected participants were requested to respond to 30 items listed in the survey form based on various types of symptoms along with severity that they experienced in the preceding 1 week.

Results: The total fatigue score in case of the studied ground crew was higher than the studied aircrew group and this was statistically significant ($P = 0.00001$). The fighter, transport, and helicopter groups were not different from each other as far as their total fatigue score is concerned. However, ground crew group had significantly higher score in comparison to the score of the fighter, transport, and helicopter groups. In this study, 43.33% of ground crew participants and 11.82% of aircrew participants were observed to have fatigue. On stream-wise analysis, 2.94% of transport aircrew, 14.28% of fighter aircrew, 20.83% of helicopter aircrew, 52.17% Air Traffic Control (ATC) ground crew, and 14.28% of other ground crew who had participated in this study were fatigued.

Conclusion: Fatigue in either form, i.e., acute or chronic, could affect both aircrew and ground crew. The present study had revealed that the proportion of ground crew suffering from chronic fatigue was more than the aircrew. The aircrew who were found to have such type of fatigue were younger in age and experience in comparison to their counterpart ground crew. Among the ground crew, a large percentage of ATC crew had this form of fatigue.

Keywords: Fatigue, Multidimensional fatigue syndrome inventory-short form, Aircrew, Ground crew

INTRODUCTION

Operator's fatigue both in acute and chronic forms has been recognized as a major safety hazard in modern aviation.[1,2] The factors responsible for operator's fatigue include sleep loss, shift work, early wake-ups, workplace noise and vibrations, long working hours, irregular duties, night flying, etc.[1] The existence of these factors in aviation enhances the risk of fatigue among both the aircrew and ground crew. Taneja (2005) had reported that almost one third of the fighter pilots, who had participated in a questionnaire survey felt sleepy/drowsy in the cockpit due to sleep deprivation at some time or the other and that was even more for transport and helicopter pilots.[3] In a recent study (2017), Tripathy had observed prevalence of fatigue among ground crew in IAF.[4] Fatigue can impair information processing and reaction time and can also result in errors that can lead to accidents. About 21% of aviation accidents, 3.6% of fatal highway accidents, and 33% of train accidents have been attributed to human factors, especially the general issue of fatigue.[5]

In military aviation, fatigue surveillance and monitoring have been used to ensure operational safety. Aircrew involved in flying operations are adequately checked. Flight Surgeons (Aviation Medicine Specialists) often carry out the preflight checks for assessing the aeromedical readiness of aircrew before undertaking flying. During these checks, if an aircrew shows symptoms of fatigue, then the flight surgeons declare him/her unfit for flying. However, in the absence of any specific objective fatigue detection tool, diagnosis of fatigue is often based on clinical experience and hence not free from observer's subjective bias. Taneja (2005)[3] had brought out that 42.2% of the fighter aircrew (28 of 83 participants) and 50% transport/helicopter aircrew (35 of 70 participants) had never flown a sortie when fatigued in spite of declared "Fit" in the prefight medical checks. Only few (6%) acknowledged that duty medical officer had ever made them "Unfit" on account of fatigue during such checks. It was also brought out by the participants that there were occasions when the crew would have preferred to have not flown because of fatigue but had to fly because of various reasons. Such limitations are there in the existing fatigue monitoring system followed by various flying establishments. Therefore, there has been a need to assess the fatigue among aviation personnel involved in military flying employing a well-structured and validated questionnaire.

Researchers employed various tools to identify and level the severity of fatigue. Multidimensional fatigue syndrome inventory-short form (MFSI-SF) is one such tool. This inventory is a self-reported instrument with a multidimensional scale that aims to capture the global, somatic, affective, cognitive, and behavioral symptoms of fatigue.[6] It has been used to assess the fatigue associated with various clinical conditions of chronic nature.[7,8] However, adequate data on the application of MFSI-SF to assess chronic fatigue among aviation personnel were not available in the scientific literature. This study was conducted with the aim to assess chronic fatigue among the aviation personnel involved in military flying in India employing MFSI-SF. The aim was also to determine the differences in the level of fatigue among the personnel from different streams/trades of military flying.

MATERIAL AND METHODS

Subjects

A total of 93 military aircrew from different streams (fighter, transport, and helicopter) and 30 ground crew from different branches and trades including Air Traffic Control (ATC) crew of either sex from three military air bases were selected randomly for this cross-sectional observational study.

Materials

The multidimensional fatigue symptom inventory-SF (MFSI-SF), which consisted of 30 statements was used for the study. This questionnaire is shorter version of the original MFSI which was devised by Stein *et al*. in 1998 and was designed primarily to assess the multidimensional nature of fatigue.[8] Reliabilities for the five empirically derived scales in the original validation study were 0.96 for the general scale, 0.85 for the physical scale, 0.93 for the emotional scale, 0.90 for the mental scale, and 0.88 for the vigor scale.[6]

Methodology

This questionnaire survey was carried out in a phase wise manner in three different military air bases involving both aircrew and ground crew. The participants were requested to respond to 30 items listed in the survey form, based on various types of symptoms they experienced in the preceding one week. They also indicated the extent of the severity of various symptoms using a 5-point Likert scale (0 = not at all; and 4 = extremely). Ratings were summed to obtain scores for five subscales (general or subjective fatigue, physical fatigue, emotional fatigue, mental fatigue, and vigor). The total MSFI-SF score was obtained by adding the general, physical, emotional, and mental subscale scores and subtracting vigor subscale score. Total MFSI-SF score ranged from −24 to 96 with 24 as cutoff score. Higher scores indicated higher levels of fatigue.

Analysis

Statistical analysis was carried out using Microsoft Excel and Statistica (version 12). The data were expressed as mean ± standard deviation. The data with normal distribution were analyzed by *t*-test or ANOVA. The data, which were not normally distributed, were analyzed by non-parametric statistical tests (Chi-square, Mann–Whitney U-test, Chi-square for goodness for Fit).

RESULTS

Demographic data

A total of 123 personnel from three military air bases had participated in this cross-sectional survey. The details of demographic data along with the level of experience and length of service of the participants are depicted in Table 1.

Mann–Whitney U-test and Chi-square tests showed a statistically significant difference in age, length of service, and marital status (married/single ratio) but no significant difference in sex (male/female ratio) between aircrew group and ground crew group [Table 1]. Average age and length of service were lesser among aircrew group in comparison to the ground crew group.

MFSI-SF results

Two-way ANOVA [Tables 2 and 3] showed that compared to aircrew group, ground crew group had significantly higher total fatigue score (P = 0.00001) and in all its subscales except vigor.

For general (P = 0.00005), physical (P = 0.00001), emotional (P = 0.00001), and mental (P = 0.00001), these differences were statistically significant. However, the difference in the vigor dimension was not statistically significant (P = 0.229).

Stream effects

In the aircrew group, there were 35 fighter, 34 transport, and 24 helicopter aircrew participants. The fatigue scores of these streams were compared with that of ground crew group by employing one-way ANOVA [Table 4].

One-way ANOVA [Table 4] showed that the P-value corresponding to the F-statistic is lower than 0.05, suggesting that the one or more streams were significantly different. Multiple comparison tests were carried out using Tukey-Kramer HSD test [Table 5]. This *post hoc* test had identified the pairs of streams, which were significantly different from each other. The fighter, transport, and helicopter groups were not different from each other as far as their total fatigue score in concerned. However, each of them had significantly lower score in comparison to that of ground crew group [Figure 1].

Fatigue analysis

Considering the cutoff value of 24 for total fatigue score in MFSI (SF),[6] 11 (of 93) aircrew and 13 (of 30) ground crew were grouped into "Crew with fatigue" and the rest 99 (82 aircrew and 17 ground crew) were grouped into "Crew without fatigue."

The Chi-square statistic was 14.336 with P = 0.0001 (Significant at P < 0.05). The Chi-square statistic with yates correction was 12.4002 with P = 0.0004 (significant at P < 0.05). The results were suggestive that ground crew group had significantly higher proportion of fatigued crew than the aircrew group (43.33% vs. 11.82%) [Figure 2].

It was also observed that there were 5 (of 35) fighter aircrew, 1 (of 34) transport aircrew, 5 (of 24) helicopter aircrew, 12

Table 1: Demographic data of the participants (n=123).

Demographic data	Aircrew (n=93)	Ground crew (n=30)	Statistical analysis
Age in years			
Range	20–40	21–54	Z score
Average	28.5	34.5	(−2.81)
SD	4.6	9.10	P-value (0.004)
Flying experience in hours			
Range	23–3100	NA	NA
Average	773.8	NA	
SD	632.5	NA	
Service experience in years			
Range	1–19	1–35	Z score
Average	6.9	13.3	(−3.23)
SD	4.8	9.6	P-value (0.001)
Sex			
Male	87 (93.5%)	26 (80%)	χ^2score
Female	6 (6.45%)	4 (13.3%)	(1.43)
			P-value (0.234)
Marital status			
Married	63 (67.7%)	27 (90%)	χ^2score
Single/bachelor	30 (32.2%)	3 (10%)	(5.72)
			P-value (0.01)
Branch/trade			
Fighter pilot	35 (37.6%)	ATC crew 23 (76.6%)	NA
Transport pilot	34 (36.5%)	Other ground crew 7 (23.3%)	
Helicopter pilot	24 (25.8%)		

Table 2: Results of two-way ANOVA on comparison of five dimensions of MFSI (SF) and the total fatigue score in aircrew (*n*=93) and ground crew (*n*=30).

Source of variations	Sum of squares	df	Mean square	F	*P*-value	F crit
Between rows	29,675.11	122	243.238	4.051	1.39E-30	1.247
Within columns	13,065.93	5	2613.185	43.52822	2.11E-38	2.228
Error	36,620.91	610	60.034			
Total	79,361.94	737				

Table 3: Results of *post hoc* analysis using Tukeyparison the total fatigue score.

Variables	Aircrew	Ground crew	*P*-value
General symptoms	4.22±3.79	8.06±5.62	0.00005
Physical symptoms	3.30±4.24	8.8±5.52	0.00001
Emotional symptoms	3.84±4.98	9.26±5.98	0.00001
Mental symptoms	3.77±4.19	8.06±5.03	0.00001
Vigor	16.17±3.76	15.16±4.42	0.2296
Total fatigue score	−1.20±16.9	19.1±22.84	0.00001

(of 23) ATC ground crew, and 1 (of 7) other ground crew, who were fatigued. The Chi-square statistic was 22.335 with $P = 0.0001$ (Significant at $P < 0.05$) suggesting that the proportions (2.94% of transport aircrew, 14.28% of fighter aircrew, 20.83% of helicopter aircrew, 52.17% ATC ground crew, and 14.28% of other ground crew) of crew having fatigue were of statistical significance and may not had occurred by chance.

DISCUSSION

Fatigue is defined as "an experience of tiredness, dislike of present activity, and unwillingness to continue"[9] or as a "disinclination to continue to performing the task at hand and a progressive withdrawal of attention" from environmental demands. In a study (1994), Brown ID had reported that the incidence of fatigue in general population is 14–22%.[10] It is important to identify fatigue among the operators early so that an incident or accident can be prevented. Fatigue assessment can be done objectively as well as subjectively. Objective fatigue measures focus on physiological processes or performance such as reaction time or number of errors.[11] Subjective ways to assess fatigue include diary studies, interviews, and questionnaires.[12-14] However, convincing empirical study exploring the multidimensional aspect of chronic fatigue is still lacking in aviation industry.[15] Etiologically, fatigue is multifactorial and its manifestations are multidimensional. As per Petrie and Dawson (1997), the symptoms of fatigue can be grouped into five categories, i.e., cognitive dysfunction (i.e., forgetfulness, loss of concentration, missing things, feeling mentally slow, easily distracted, careless, difficultly in planning, being confused,

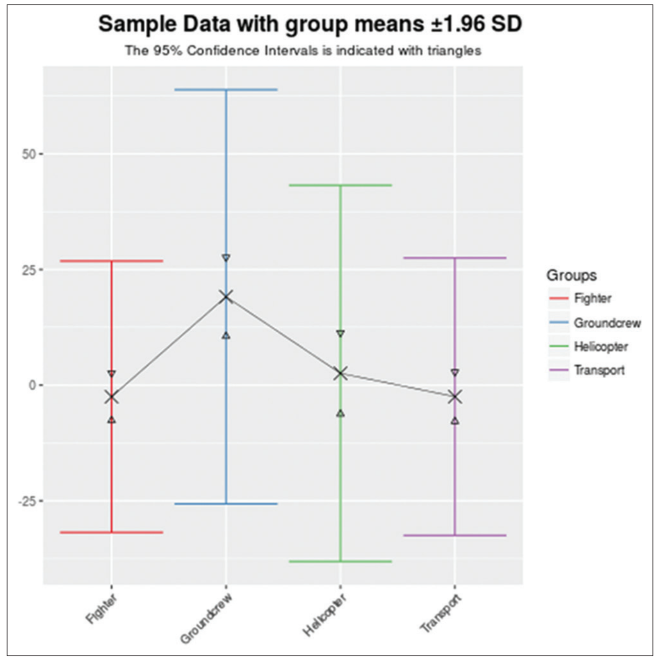

Figure 1: Comparison of means of total fatigue score among the ground crew and aircrew from different streams.

uncoordinated, and clumsy), sleepiness, emotional disturbance (i.e., feel nervous, irritable, to withdraw, and to become quiet), boredom, and physical effects such as sore eyes, sore muscles, and feeling low energy.[2] With this regard, MFSI gives an excellent platform to carryout objective analysis of chronic fatigue.

MFSI is an 83-item self-report questionnaire. It is designed to assess the principal manifestations of chronic fatigue. The MFSI consists rationally as well as empirically derived subscales. The empirically derived subscales, which were developed using factor analysis, are considered to assess general, physical, emotional, and mental manifestations of fatigue as well as vigor, which estimates the patient's energy level.[7] In this study, MFSI-SF has been used. It is a derivative of the original MFSI. It consists of 30-items questionnaire that yield scores only for the empirically derived subscales. Preliminary research suggests that it has acceptable psychometric properties and may be used as a substitute for the MFSI when time constraints and scale length are of concern.[6]

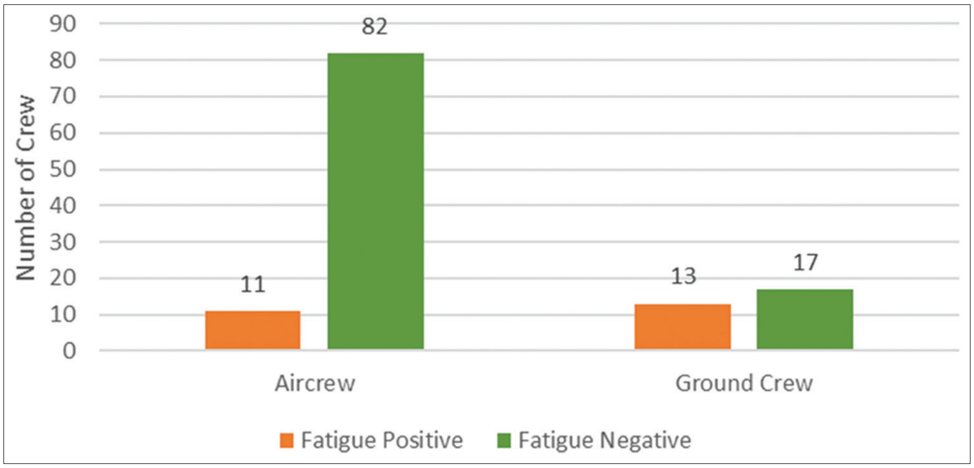

Figure 2: Number of aircrew and ground crew with total fatigue score >24 in MSFI (SF).

Table 4: Results of one-way ANOVA on comparison of total fatigue score of MFSI (SF) in fighter pilot (n=35), transport pilot (n=34), helicopter pilot (n=24), and ground crew (n=30).

Source of variations	Sum of squares	df	Mean square	F	*P*-value
Between groups	9805.29	3	3268.43	9.306	***0.000***
Within groups	41793.9	119	351.209		Permutation *P* (*n*=999
Total	51599.2	122	3E-05		
Components of variance (only for random effects):					
Var (group): 95.498		Var (error): 351.209		ICC: 0.213782	Omega 2: 0.1685

Levene's test for homogeneity of variance, from means *P* (same): 0.002
Levene's test, from medians *P* (same): 0.009
Welch F test in the case of unequal variances: F=7.151, df=60.65, *P*=0.0003

Table 5: Results of *post hoc* analysis using Tukey's pair-wise comparison.

	Fighter	Transport	Helicopter	Ground crew
Fighter		0.9995	0.7393	***0.0001***
Transport	0.33		0.7444	***0.0001***
Helicopter	1.44	1.427		***0.008***
Ground crew	6.556	6.507	4.563	

Tukey's Q below the diagonal, *P* (same) above the diagonal. Significant comparisons are bold and italic. The observed effect size f is large (0.48). That indicates that the magnitude of the difference between the averages is large

A total of 123 personnel from three air bases had participated in this cross-sectional survey. Average age and length of service were significantly higher among ground crew group (34.5, 13.3 years) in comparison to the aircrew group (28.5, 6.9 years). One-way and two-way ANOVA showed that compared to aircrew group, ground crew group had significantly higher total fatigue score (19.1 vs. −1.20) and most of its subscale scores: General (8.06 vs. 4.22), physical (8.8 vs. 3.30), emotional (9.26 vs. 3.84), and mental (8.06 vs. 3.77). However, the difference in the vigor sub-scale was not statistically significant (15.16 vs. 16.17).

Of 93 in the aircrew group, there were 35 fighter, 34 transport, and 24 helicopter aircrew. When the total fatigue scores of these streams were compared with that of ground crew group, the result of one-way ANOVA had indicated that the one or more streams were significantly different. Tukey-Kramer HSD tests had confirmed that fighter, transport, and helicopter groups were not different from each other. However, each of them had significantly lower score in comparison to that of ground crew group.

Considering the cutoff value of 24 for total fatigue score in MFSI (SF),[6] there were 11 (of 93) aircrew and 13 (of 30) ground crew were positive for fatigue and the rest 99 (82 aircrew and 17 ground crew) were negative for fatigue. This difference was also statistically significant [Figure 2]. It was also observed in the study that there was significant difference both in age (29.1 vs. 31.1 years) and service experience (length of service) (7.9 vs. 10.2 years) among aircrew (fatigue) and ground crew (fatigue) groups.

In further analysis, it was also observed that there were 5 (of 35) fighter aircrew, 1 (of 34) transport aircrew, 5 (of 24) helicopter aircrew, 12 (of 23) ATC ground crew, and 1 (of 7) other ground crew, who were positive for fatigue. Considering that 11.82% of aircrew and 43.33% of ground crew were fatigue positive in this study, a goodness of fit Chi-square test was conducted to confirm that the stream-wise proportions (2.94% of transport aircrew, 14.28% of fighter aircrew, 20.83% of helicopter aircrew, 52.17% ATC ground crew, and 14.28% of other ground crew) were not as per the proportions expected [Figure 3]. However, a similar study with larger sample size would be required to confirm whether such proportion will hold good for the aviation personnel involved in military flying.

In a similar study (unpublished), Uday and Mohapatra (2019) had carried out a fatigue assessment survey among naval aircrew employing the MFSI (SF) and brought out a similar result, where ground crew had higher fatigue score than that of aircrew (17.38 vs. 3.06).[16] In a study in IAF (2018), Tripathy had confirmed the high occurrence of fatigue among the maintenance personnel and brought out that the fatigue among these personnel could be manifested in many ways, namely, getting up with a lousy feeling (42%), laziness (75%), sleepiness (56 %), loss of concentration (63%), body aches (36%), irritated feelings (28%), early loss of temper (17%), and do not feel like talking to others (9%).[4] Similar manifestations of fatigue have also been documented in other study.[17] A study to assess fatigue among naval aircrew had also used a questionnaire based on a similar type of symptoms.[18] MSFI (SF) employed in the current study was a multidimensional fatigue inventory and it had incorporated the questions meant to identify such symptoms.

Tripathy (2018) had identified a number of fatigue contributing factors, which were high work load, shift duty, inadequate sleep, mental stress, secondary duties, extended working hours, and inadequate time to relax.[4] Incomplete recovery has been identified as a common source of fatigue among the shift workers.[19-21] This could be a contributing factor for high occurrence of fatigue among the ground crew in the current study. Demand to maintain high serviceability rate, minimizing aircraft on ground number, and constant pressure from the superiors are often the additional factors toward occurrence of fatigue among ground crew.

A number of fatigue mitigating strategies are presently in practice in military flying in India.[22] Many such fatigue prevention strategies are aircrew oriented with little focus toward ground crew.[23,24] The reason for a lesser proportion of aircrew exhibiting fatigue in this study could be due to the existing fatigue mitigating program, which is fairly followed by all the aircrew. In these air bases, no such program was instituted for the ground crew personnel. It is therefore recommended that similar fatigue prevention program may be formulated and put into practice for the ground crew personnel.

In this study, it was observed that the mean age and the length of service among the aircrew (fatigue) group were 29.13 and 7.9 years respectively suggesting that the young aircrew were at higher risk for fatigue. Open source information/news in media had brought out that aircrew are spending late nights using their mobile phones and tablets to log into Facebook, Twitter, WhatsApp, and other social medias.[25] Lack of sleep and disruption of work-rest schedule due to operational reasons could be other reasons for the aircrew getting fatigued.

Interestingly, the majority of the ground crew personnel with fatigue were from the trade ATC (12 of 13). In a survey carried out to assess fatigue among IAF crew (2003), Taneja had brought out that the fatigue was a common occurrence among ATC crew also.[26] This study has observed similar findings.

In a recent report of Italian organization on reduction of stress among ATC personnel, it was found that the tolerance

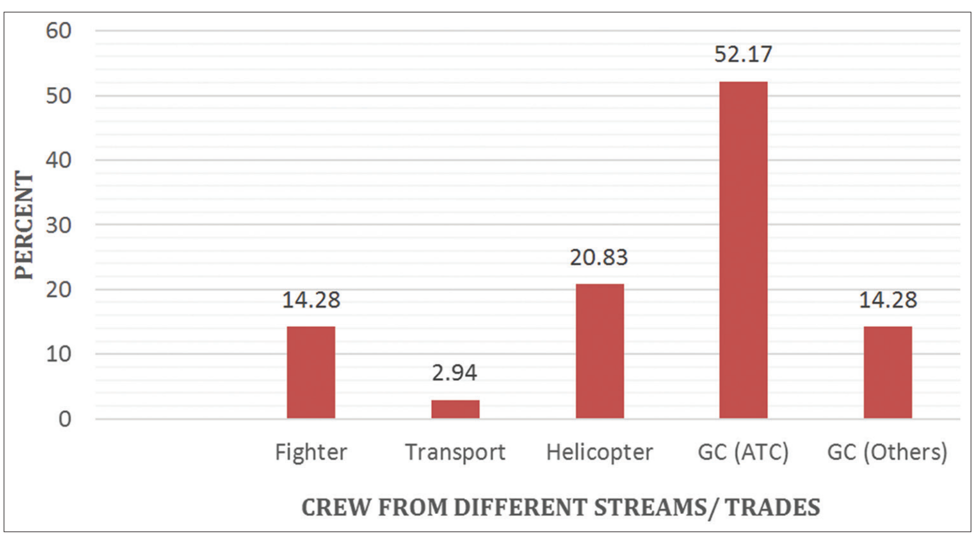

Figure 3: Percentage of fatigued crew from different streams/trades.

of shift and night work could be improved by several interventions. Costa recommended for adopting a rapidly rotating shift system, keeping the shift rotation as regular as possible, which will allow better organization of personnel, family, and their social life.[27] The same may be adopted by the ground crew doing shift duties in air bases.

When schedule related fatigue cannot be avoided, it at least can be mitigated through schedule-optimization strategies recommended by Caldwell *et al*.[28] Employability of fatigue avoidance scheduling tool was investigated for its suitability among naval aircrew.[18] The same tool can be used as a fatigue prevention strategy in air bases.

Limitation of the study

The sample size is small for comparison of total fatigue score of subgroups such as fighter, transport, helicopter, and ATC. Severity of fatigue as per the total fatigue score was not correlated with the symptoms presented by the crew. The level of occupational workload of the crew in the past 1 week was not considered while undertaking the MFSI-SF testing, where the responses to the questionnaire were based on their experience of past 1 week. Another limitation is about application of MFSI-SF, which is not yet validated for its employability to detect acute fatigue. Second, this is a questionnaire, whose results are based on subjective responses from the individual undertaking the test.

CONCLUSION

Fatigue, whether acute or chronic is a big "No" in aviation. Therefore, it is a mandatory requirement for the organization to place adequate preventive strategies to identify the crew who is operating with this risk and also provide them necessary opportunities to mitigate fatigue. Although there are practical difficulties in placing objective tools in flying bases, a simple, relatively short yet validated questionnaire could be handy toward the goal of identifying fatigue-prone crew. This study was an attempt to employ SF of MFSI and it had brought out the following scientific facts:

1. Fatigue especially chronic fatigue could affect both aircrew and ground crew as well
2. The proportion of ground crew suffering from chronic fatigue was more in comparison to the aircrew
3. The aircrew who were found to have chronic fatigue were younger in age and experience in comparison to their counterpart ground crew
4. Among the ground crew, a large percentage of ATC Crew had such form of fatigue.

However, a study with larger sample size would be required to substantiate our findings and explore the possible factors contributing to fatigue among aircrew and ground crew. Never-the-less, better awareness, optimal sleep-wake cycle, avoiding over-indulgence to social media, involvement of section commanders to provide effective work-rest schedules, early recognition of stressed out and fatigued crew, and seeking of medical help if deemed necessary are the areas which could be explored as an immediate short term measure to mitigate fatigue.

Declaration of patient consent

Participant's consent not required as participant's identity is not disclosed or compromised in this study.

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Conflicts of interest

There are no conflicts of interest.

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