



Original Article

## Assessment of fatigue in personnel during sustained operations using ‘SOAP’ – Sustained Operational Assessment Profile

MS Butola<sup>1</sup>, YS Dahiya<sup>2</sup>, BK Rao<sup>3</sup>

<sup>1</sup>Specialist in Aerospace Medicine, Director General Medical Services (Air), Air Headquarters, Indian Air Force, New Delhi, India, <sup>2</sup>Specialist in Aerospace Medicine, Dte General of Civil Aviation, New Delhi, India, <sup>3</sup>Medical Specialist, Ex Commandant Armed Forces Medical College, Fortis Hospital, Gurugram, India.



**\*Corresponding author:**

Dr YS Dahiya, MBBS, MD  
(Aerospace Medicine),  
Dte General of Civil Aviation,  
Headquarter, Aurobindo Marg,  
Opposite Safdarjang Airport,  
New Delhi - 110 003, India.

[ysdahiya@gmail.com](mailto:ysdahiya@gmail.com)

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### ABSTRACT

**Introduction:** Sustained operations are the future of any advanced Air Force, which involve round the clock flying operations over a prolonged period. Such operations have the potential of disrupting normal sleep cycle and may cause fatigue among aircrew and ground duty personnel. It is well known that fatigue among crew member is a significant risk to aerospace safety. The present study was hence undertaken to quantify the subjective fatigue and its effects, among the personnel involved in a simulated exercise using Sustained Operations Assessment Profile (SOAP).

**Material and Methods:** SOAP questionnaire, a validated tool, was used for data collection. In the first phase, 1521 personnel involved in the exercise, including aircrew as well as ground duty tradesmen completed the SOAP questionnaires twice during the simulated sustained military operation. The subjective ratings were statistically analyzed using the Wilcoxon matched paired test. The two levels of repeated measures being mean SOAP scores on day 2 and that on day 5. In the second phase, to ascertain differences in the subjective ratings of SOAP among different streams of pilots, data were recorded during another simulated sustained operation after 6 months. A total of 140 aircrew responded to the SOAP questionnaire during 6 days of sustained operations. SOAP score was acquired on day 1 and day 6 of the operations in the second phase.

**Results:** A total of 3042 completed SOAP responses were analyzed. There was a significant increase in ratings of the three cardinal dimensions of SOAP among all personnel. The aircrew rated the subjective effects higher than maintenance or administrative support group. Among the aircrew, the fighter pilots rated significantly higher as compared to transport or helicopter aircrew.

**Conclusion:** The study revealed significant changes in the cardinal dimensions of SOAP among the aircrew who were routinely not involved in shift work (especially fighter pilots). Scientifically designed “shift work” may be an effective strategy to mitigate effects of fatigue during sustained operations, hence, needs to be practiced as a routine by combat Air Force units.

**Keywords:** Sustained operations, Fatigue, Sustained Operations Assessment Profile, Aircrew

### INTRODUCTION

Although fatigue has graduated to be the most deliberated problem in military aviation over the years, it still remains underreported. Largely because, its entity is still not well defined, its signs are not easily noticeable and appreciable, but its effects still remain potentially catastrophic.

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To date, most research data are on transmeridian international operations, where aircrew fly across several time zones. There has been comparatively little research on fatigue in pilots flying during sustained or continuous operations, where the flying starts early in the day and finishes late at night. This can disrupt normal sleep routines and cause fatigue. It is not only the aircrew who are affected by the phenomenon but also the ground duty personnel and the maintenance crew involved in such operations (directly or indirectly) are equally susceptible to fatigue. It is well known that a fatigued crew member is likely to be working at a compromised efficiency and is more likely to commit errors which may result in accident/incident. Sustained operations are the future of any advanced Air Force and fatigue is a significant risk to aerospace safety during such operations. A study was hence undertaken to quantify the subjective fatigue and its effects, among the personnel involved in an exercise, simulating sustained operations for 5 days using Sustained Operations Assessment Profile (SOAP).

## MATERIAL AND METHODS

### Subjects

A total of 1521 aircrew and ground crew at various IAF stations completed the SOAP questionnaires during the first phase of the study. In the second phase, 140 aircrew participated in the study.

### SOAP

The SOAP has been used to measure changes in self-report of cognitive, affective, and arousal dimensions of sustained operations. The SOAP questionnaire was developed by the US Air Force Armstrong Research Laboratory to measure fatigue in military and civilian personnel engaged in sustained operations.<sup>[1]</sup> It is a reliable and validated assessment tool to quickly record subjective responses across three broad dimensions of interest, i.e., cognitive, affective, and arousal dimension of personnel involved in such operations. It is a paper and pencil questionnaire, where the subject responds to 90 items (questions) on a 1–5 scale that requires 4–5 min approximately to complete. Ten broad scales of the test include three from cognitive dimensions, namely, poor concentration, boredom, and slowed reactions; three from affective dimensions, namely, anxiety, depression, and irritability; and four from arousal dimensions, namely, fatigue/low energy, poor sleep, work frustration, and physical discomfort. Each of these ten scales further includes nine items that represent related aspects of each dimension. Therefore, the total score for each scale, for example, concentration, could range from 9 (if each item was scored as a “1”) to 45 (if each item was scored as a “5”).

### Experimental protocol

SOAP profile was completed twice during the simulated sustained military operation on two phases. In the first phase, the sustain operation was for 8 days, and in the second phase, it was for 6 days. In the first phase, the SOAP questionnaire was filled up after 48 h of commencement of the exercise and once again at the end of 5 days of sustained operation. In the second phase, to ascertain differences in the subjective ratings of SOAP among different streams of pilots, data were recorded during another simulated sustained operation carried out after 6 months of initial exercise. In this phase, a total of 140 aircrew responded to the SOAP questionnaire during 6 days of sustained operations. SOAP score was acquired on day 1 and day 6 of the operations. The subjects were asked to rate their subjective responses on a scale of 1–5 to obtain subjective measures of concentration, boredom, slowed reactions, anxiety, depression, irritability, fatigue, poor sleep, work frustration, and physical discomfort.

### Statistical analysis

The data were analyzed using non-parametric statistical methods, Wilcoxon matched paired test. The two levels of repeated measures being mean SOAP scores on day 2 and that on day 5. The significance level was kept at  $P < 0.05$ .

## RESULTS

In the first phase, 3042 SOAP responses from 1521 personnel were analyzed. Day 2 responses were taken as “baseline” as it took at least 48 h before the full flying operations commenced for the exercise. The mean score for the three cardinal dimensions of the SOAP on day 2 and day 5 is presented in Table 1 and Figure 1. The mean score for each of the 10 scales (measures of concentration, boredom, slowed reaction, anxiety, depression, irritability, fatigue, poor sleep, work frustration, and physical discomfort) is given in Table 2 and Figure 2. There were statistically significant differences ( $P < 0.05$ ) between the SOAP scores of three cardinal dimensions over 5 days of sustained operations for all personnel.

To determine differences in the subjective ratings more comprehensively, the data of all personnel ( $n = 1521$ ) were combined broadly into four groups, namely, Aircrew, Administrative Support Group, Air Traffic Controller (including Fighter Controllers), and Maintenance Support Group. The probability associated with a Wilcoxon paired *t*-test was obtained for the mean scores of SOAP scales between day 2 and day 5 of the sustained operations. Table 3 presents the statistical differences ( $P$  levels) in the mean SOAP scores of cardinal dimensions of various trades combined in the above-mentioned groups.

**Table 1:** Mean scores for three cardinal dimensions: All personnel (n=1521).

n=1521	Day 2	Day 5	Wilcoxon matched paired test
	Mean±SD	Mean±SD	P value
Cognitive dimension	44.58±18.03	46.36±18.52	0.00004
Affective dimension	44.95±18.27	46.76±18.91	0.00016
Arousal dimension	62.47±27.27	66.18±28.16	0.00000

SD: Standard deviation

**Table 2:** Mean scores for 10 SOAP scales: All personnel (n=1521).

n=1521	Day 2	Day 5
	Mean±SD	Mean±SD
Poor concentration	14.55±6.40	15.36±6.68
Boredom	14.80±6.75	15.35±6.89
Slowed reactions	15.24±6.71	15.65±6.61
Anxiety	16.04±6.76	16.63±6.76
Depression	14.82±6.99	15.27±7.01
Irritability	14.08±6.50	14.86±6.89
Fatigue	15.37±7.41	16.36±7.75
Poor sleep	15.51±7.51	16.45±7.60
Work frustration	15.70±7.38	16.67±7.57
Physical discomfort	15.89±7.71	16.70±7.84

SOAP: Sustained operations assessment profile, SD: Standard deviation

**Table 3:** Differences (P levels) in the mean SOAP scores of cardinal dimensions of various trades combined in groups (using Wilcoxon matched paired test day 2 vs. day 5; significance level P<0.05).

	Aircrew	ASG	ATC and FC	MSG
	n=190	n=256	n=276	n=799
Cognitive dimension	0.00	0.46	0.56	0.11
Affective dimension	0.00	0.22	0.67	0.27
Arousal dimension	0.00	0.06	0.08	0.004

ASG: Admin Support Group, ATC: Air Traffic Controller, FC: Fighter Controllers, MSG: Maintenance Support Group, SOAP: Sustained operations assessment profile

The responses from 190 aircrew were analyzed separately for the SOAP scale ratings. The aircrew included pilots (from three streams, namely, fighter, transport, and helicopter), flight gunners, and flight engineers. The mean scores and SD for the 10 SOAP scales are presented in Table 4 and Figure 3.

Table 5 presents the statistical differences (P levels) in the mean SOAP scores for the 10 scales of various trades (other than aircrew) combined in the above-mentioned groups.

The statistical differences between the mean scores of various SAOP scales obtained in the second phase, on day 1 and day

**Table 4:** Mean scores for 10 SOAP scales: All aircrew (n=190).

n=190	Day 2	Day 5	Wilcoxon matched paired test
	Mean±SD	Mean±SD	P value
Poor concentration	14.03±5.55	17.76±6.97	3.75524E-11
Boredom	14.47±6.45	18.27±8.30	6.11987E-09
Slowed reactions	13.27±5.40	17.00±7.32	3.33229E-10
Anxiety	13.52±4.57	16.86±6.86	1.91907E-09
Depression	13.66±6.60	17.22±7.71	6.38368E-09
Irritability	14.01±6.29	17.37±7.88	4.76136E-08
Fatigue	14.63±6.69	18.38±8.08	1.94707E-09
Poor sleep	15.41±7.20	18.65±8.53	1.6257E-06
Work frustration	15.25±7.86	18.80±8.93	2.143E-06
Physical discomfort	14.53±6.58	17.95±7.99	1.41408E-07

SOAP: Sustained operations assessment profile, SD: Standard deviation

**Table 5:** Differences (P levels) in the mean SOAP scores for 10 scales of various trades (other than aircrew) combined in groups (using Wilcoxon matched paired test day 2 vs. day 5; significance level P<0.05).

	ASG	ATC and FC	MSG
	n=256	n=276	n=799
Poor concentration	0.424	0.511	0.020
Boredom	0.017	0.821	0.596
Slowed reactions	0.2559	0.983	0.602
Anxiety	0.508	0.521	0.102
Depression	0.692	0.958	0.540
Irritability	0.029	0.609	0.044
Fatigue	0.0001	0.249	0.172
Poor sleep	0.005	0.163	0.046
Work frustration	0.034	0.164	0.008
Physical discomfort	0.149	0.322	0.073

ASG: Admin support group, ATC: Air traffic controller, FC: Fighter controllers, MSG: Maintenance support group, SOAP: Sustained operations assessment profile

6 of the sustained operation among the different streams of the aircrew are shown in Table 6.

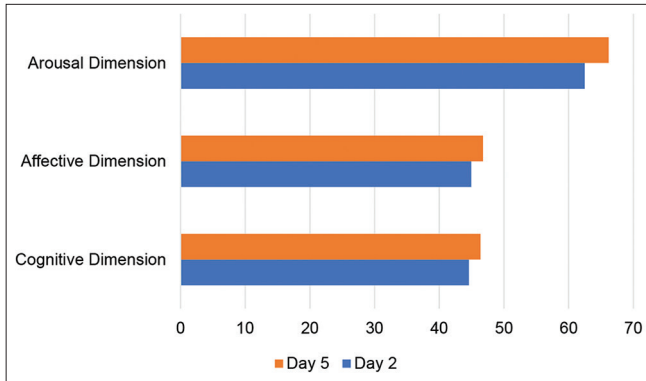


Figure 1: Mean scores for three cardinal dimensions: All personnel (n = 1521).

## DISCUSSION

### Effect of sustained operation

The statistically significant differences in the subjective SOAP ratings of day 2 and day 5 of the simulated sustained operations signify cumulative effects on cognition, affect, and arousal of the personnel involved in these operations.<sup>[1]</sup> The confounding effects of other stressors on the subjective ratings have been ruled out in the study. The prime adverse environmental factor in India is heat stress. Heat stress during sustained operations may have similar effects on the dimensions of SOAP ratings.<sup>[1-4]</sup> Since the experimentation was carried out in the month of November, which is a thermally comfortable weather period in India, heat

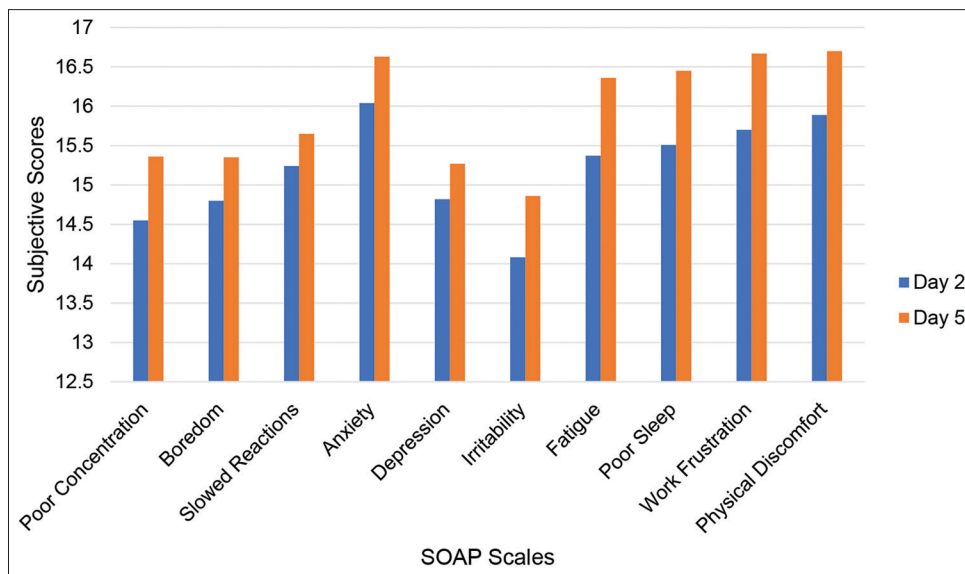


Figure 2: Mean scores for 10 sustained operations assessment profile scales: All personnel (n = 1521).

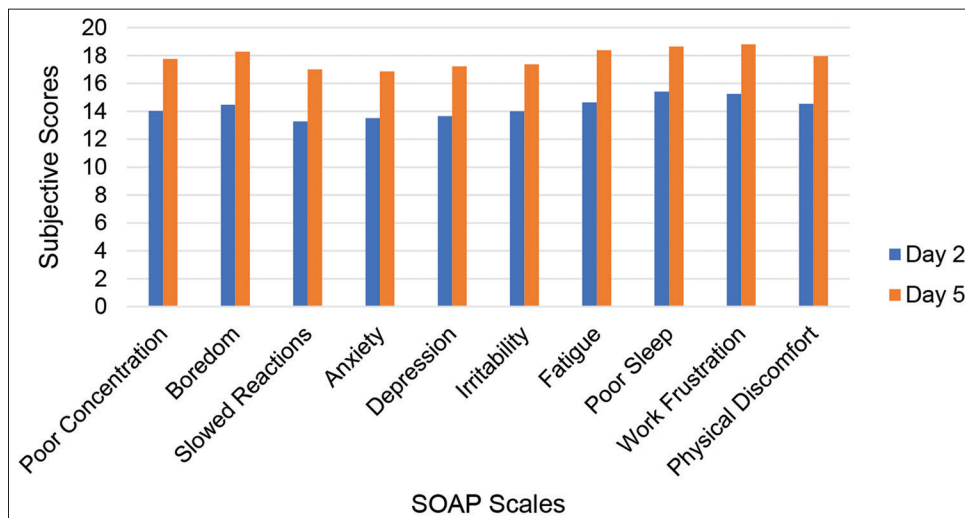


Figure 3: Mean scores for 10 scales: All aircrew (n = 190).

**Table 6:** Differences (*P* levels) in the mean scores of aircrew (using Wilcoxon matched paired test day 1 vs. day 6; significance level  $P < 0.05$ ).

	All pilots ( <i>n</i> =140)	Fighter ( <i>n</i> =109)	Transport ( <i>n</i> =08)	Helicopter ( <i>n</i> =32)
Poor concentration	0.001072122	0.000132608	0.4652	0.8864
Boredom	0.000004	0.000001	0.1422	0.4564
Slowed reactions	0.0000005	0.0000003	0.9165	0.5869
Anxiety	0.000571313	0.00004	0.5929	0.6021
Depression	0.0000001	0.0000004	0.0678	0.4471
Irritability	0.00000005	0.0000002	0.3454	0.5011
Fatigue	0.0000001	0.0000001	0.2851	0.6682
Poor sleep	0.000012	0.000005	0.9165	0.4352
Work frustration	0.000008	0.0000003	0.3452	0.0503
Physical discomfort	0.00000003	0.0000007	0.4184	0.2296

stress due to weather can be confidently discounted for confounding the findings of the study.

The simulated sustained operations continued for 8 days, which included the continuous operational deployment of various complements of the fleet. The detailed information of the operations, being restricted, has not been described in the results. However, it is worth mentioning that all personnel were detailed for their qualification specific duties. During sustained operations, the tradesmen and aircrew commenced "shift work" whenever operationally feasible. However, it cannot be denied that due to operational necessities, some of the tradesmen would have been detailed to work beyond their normal tour of duty.

During the sustained operations, to ensure maximum availability of "flying fit" aircrew, only non-pharmacological measures for fatigue and alertness management such as good sleep hygiene and adequate sleep/rest before the mission and scientific rostering of aircrew for flying<sup>[2]</sup> were employed. "Adequate rest" was ensured for the aircrew as per the extant flying orders, including "flight duty time limitation" (FDTL). In addition, the well-known "strategic cockpit napping" (in transport aircraft and dual cockpit fighter aircraft) and activity breaks<sup>[5-7]</sup> were prescribed and practiced by the aircrew. The flying missions during the sustained operations period were short-haul missions; therefore, fatigue, tiredness, or boredom inherent to long-haul or ultra-long-haul flying sorties were not present.<sup>[7,8]</sup> None of the units resorted to pharmacological fatigue management, i.e., use of Go and No-Go pills (modafinil and zolpidem, respectively).

In the study, mean response scores of all the personnel ( $n = 1521$ ) over 5 days of sustained operations indicated accumulated, statistically significant, increase in all dimensions of SOAP, namely, cognition, affect, and arousal.<sup>[1]</sup>

### Beneficial effect of shift work

On fine-grained analysis of SOAP scores, over 5 days of sustained operations among the personnel of different trades/

branches, it was revealed that the personnel from trades such as Air Traffic Controllers and Aircraft Maintenance Crew, the SOAP rating scores were not significantly increased. This statistically backed finding can be explained by the routine working philosophy of these branches of IAF, wherein the personnel of these trades are routinely involved in "shift work." Hence, the sustained operations and continuous manning did not result in statistically significant changes in any of the dimensions of SOAP. On the contrary, the Administrative Support Group, Flying Branch, and Air Defense revealed a statistically significant increase in SOAP ratings. Once again, the answer lies in the working philosophy of these branches in IAF. These branches do not routinely follow a "shift work" culture; hence, sustained operations have resulted in statistically significant adverse effects on cognition, affect, and arousal of the personnel.<sup>[2]</sup> There is enough literature available to support that circadian disruption (that happens when individuals initially break into "shift" work) is a major cause of aircrew fatigue.<sup>[9-11]</sup>

Although, personnel from trades such as Air Traffic Controllers and Aircraft Maintenance Crew who did not reveal statistically significant differences in the cardinal dimensions of SOAP scores, there were significant changes in certain SOAP scales, namely, poor concentration, irritability, work frustration, fatigue, and poor sleep, which are reasonable due to the perceived or actual work pressure during such operations and long working hours.

### Fine-grained analysis of pilots' ratings

All aircrew (all pilots, flight engineers, flight gunners, etc.) showed significantly higher subjective response after 5 days of sustained operations in all the 10 SOAP scales. To further understand this observation, aircrew from various streams (namely, fighter, transport, and helicopter) responded to the SOAP questionnaire during subsequent simulated sustained operations exercise organized after 6 months of the original study. In this study, 140 aircrew from all the three streams responded to the 90 sustained operations profile questions

over 6 days of sustained operations. The analysis revealed that the pilots from transport and helicopter stream did not show statistically significant differences in any of the SOAP scales, whereas fighter pilots experienced a statistically significant increase in their SOAP scores. The possible explanation of this observation finds basis in the basic differences in the operational tasking of various streams of aircraft. The transport and helicopter aircrew are routinely involved in long working hours with multiple takeoffs and landings; therefore, these aircrew may be better adapted to long working hours and sustained operations as compared to fighter aircrew.

## CONCLUSION

The study revealed significant changes in various dimensions of SOAP during simulated sustained operations among the personnel who are routinely not involved in shift work (including fighter pilots). Shift work is an important alertness management tool to mitigate effects of fatigue, hence, needs to be practiced as a routine by combat Air Force units. The limited opportunities for "rest" during sustained military operations need to be gainfully utilized to reduce the pre-load of fatigue. The implications of other non-pharmacological techniques for fatigue management also need to be understood and rehearsed frequently.

## Declaration of patient consent

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

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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