

Original Article

Evaluation of pre take-off heat stress in a modern fighter cockpit: A field study

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ABSTRACT

The time spent by a fighter pilot on ground, prior to take off, could vary due to the start up procedure delays in taxiing. During the summer months, the quantum of heat stress that a pilot encounters in his cockpit prior to being airborne could compromise his operational readiness. Hence, this field study was undertaken to evaluate the cockpit heat stress before take-off to allow realistic assessment of prevailing cockpit stress in a modern fighter aircraft. Wet Bulb Globe Temperature (WBGT) was recorded with a heat stress meter (HSM) during eight randomly chosen operational sorties. The pre take-off period ranged from 23 to 45min in this study. The pre take-off stage was studied in four phases (I-IV), with markers at engine switch on, canopy closure and warm-up prior to take-off. The study revealed that average durations were 15.5min, 9.5min, 2.5min, 1.37min in phase HI, I, II, IV, respectively. The cockpit WBGT ranged from 31.5° to 41.4° C, when the ambient WBGT was between 25.3° and 32.3° C. There was a significant increase ($r=0.826$; $p<0.05$) in cockpit heat in the afternoon hours; and was significantly higher ($r=1.915$; $p<0.05$) prior to canopy closure. In all the sorties there was a significant increase ($r=0.807$; $p<0.05$) in heat stress after canopy closure. It was found that pilots spend up to 65% of total pre take-off period in phase HI. This study found that the heat stress while awaiting off is significant, highlighting that the pre-take-off heat stress in fighter aircraft is largely overlooked, stress can be ignored only at the peril of severely compromising operational readiness. In addition, the study reemphasizes the need for preventive strategies to counter the pre take-off heat stress to reduce the occupant's heat load in a fighter cockpit. The suggested measures include appropriate flight planning, with restrictions during high ambient temperature or limiting low-level sorties to earlier hours of the day; personal and cockpit cooling mechanisms and adequate replenishment of fluids both before and immediately after the sortie.

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Keywords. Heat stress, fighter cockpit, WBGT, pre take-off

A fighter pilot encounters severe heat stress prior to take-off during warm climate in the Indian subcontinent. Several methods of reducing this thermal stress have been propagated but are not actively employed since an Air Conditioning System (ACS) is considered the best bet. It is also a known fact that the ACS does not work efficiently prior to take-off [1-3]. This allows a build up of the cockpit heat load, which if prolonged, could lead to physiological stress with adverse effects or limitations of the performance [4, 5]. The problem is especially severe in high performance fighter aircraft, where design considerations and solar heating due to bubble canopy severely limit the capacity of on-board cooling systems prior to take-off [1, 6, 7].

Initial cockpit temperature can be high in aircraft has been parked in the direct Sun. flight checks, taxiing and prolonged wait for take off at dispersal awaiting landing of other aircraft add to the high cockpit temperatures in environments, especially since

ACS is at its effective at this time [1-3, 7]. Cabin dry temperature as high as 50°C has been recorded both in fighter aircraft and helicopters when ambient temperature was about 25°C [3, 7-11].

Heat load on a pilot [12] is but one of

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several stressors that can be experienced in a fighter cockpit. Operational readiness of a seasoned fighter pilot requires of him optimal flying skills while he continues combating other aviation stresses like noise, vibration, and +G_z stresses. These stressors interact with the heat stress that an aircrew is exposed to prior to take-off; and may compromise performance, more so if adequate precautions to mitigate heat stress are not actively employed. Studies have shown that the decrement in pilot performance due to body heat storage is significant [13]. Hyperthermia-induced dehydration can reduce G tolerance by 0.5 to 1G [14]. The response of the cardiovascular system, which bears the brunt of exposure to heat stress, translates to a sweat loss of about 0.7 kg/hr at 37°C Wet Dry Index [8, 15]. Such physiological responses to the heat stress can adversely affect personal and operational readiness, which in turn may compromise the mission outcome or worst still jeopardize the flight safety [4, 5]. Hence, heat stress in fighter cockpit remains a matter of concern.

Though heat stress in fighter cockpit has been studied amply [1-3,7-10], yet quantification of pre take-off heat stress was deemed necessary to reemphasize the magnitude of the problem. Especially, the pre take-off phase was required to be studied during an operational scenario, at different times of the day, for a realistic assessment. A field study, with prevailing working practices of the ground crew and the aircrew, helped to make accurate evaluation of largely overlooked and ignored pre take-off heat stress borne by the pilot [1, 10]. Precise assessment of the heat stress, to which a pilot is exposed in a modern fighter cockpit, requires an automatic online computation of the ideal heat stress index, Wet Bulb Globe Temperature (WBGT), every minute, from the time the pilot enters the cockpit, before start-up till

landing. Instrumentation with digital Heat Stress Monitor

(HSM) [7] to record in-flight cockpit conditions during a sortie allows recording of heat stress in the cockpit prior to getting airborne. Levels of heat stress prior to take-off are preferably recorded under a wide range of operating conditions in terms of prevailing temperatures and types of sorties flown. The temperature profiles, thus obtained, provide a description of ambient and cockpit thermal stress prior to take-off and also its correlation with duration/ time spent in various phases of the pre take-off stage and the time of the day.

This study on heat stress in a fighter cockpit in pre take-off phase during summer months, aims to highlight a known problem, i.e., heat stress in fighter flying, but on ground prior to being airborne, when an ACS is largely ineffective.

Material and Methods

Assessment of pre take-off heat stress in a modern fighter aircraft, during the day light hours was undertaken in the pre-monsoon summer months of 2006, at an airbase in North India. This period witnesses high humidity and moderately hot ambient conditions. This study was conducted over a period of 2 weeks. There were 8 operational sorties, randomly chosen, for the purpose of data collection. This included 4 sorties during forenoon and another 4 sorties during afternoon hours. Each pre-take off stage was divided into four phases for enabling an evaluative study. This included Phase I: commencing prior to engine start up; Phase II: from engine start-up to canopy-close; Phase III: Canopy-close to engine warm-up; and Phase IV: from engine warm-up till commencing take-off roll. The relevant sortie-related data was obtained as a written feedback from each pilot. This included the time of engine start up, canopy closure, engine warm-up and commencement of take-off roll.

Wet Bulb Globe Temperature (WBGT) [13, 16, 17] is the most accepted integrated measure of heat stress in high heat stress scenario. With the validity and practicality of WBGT being well established in military aviation [18, 19], this index was measured to study the pre take-off heat stress in the cockpit. WBGT was recorded with HSM [7]. Incidentally, the acceptable limit of WBGT is less than 32°C for a pilot in the cockpit of a fighter aircraft [19].

The HSM is a microprocessor controlled, battery-operated device. Its advantages include availability of tripod sensors to record thermal data viz. dry bulb temperature (Tdb), wet bulb temperature (Twb), radiant temperature (Tbg); online computation of WBGT with running time stamp at an interval of 1 minute each [20]; and facility for analysis of stored thermal data against sortie profile as per pilot's written feedback. The HSM recording commenced when the pilot sat in the cockpit to strap up, prior to initiating the startup procedure.

The HSM was placed inside the cockpit after consultation with the pilots participating in the inflight

trials [21]. HSM was firmly fixed in its chosen location, prior to each randomly chosen sortie, with a suitably designed clamp. Prior to the planned sortie for heat stress data collection, the HSM was prepared, calibrated and switched on for data recording as per protocol [7,21]. Immediately after the sortie, stored data from the HSM was downloaded to a compatible personal computer (PC) for analysis later.

Operative Ambient Temperature (OAT/Tdb) was recorded with conventional methods.

Descriptive statistics, including one-tailed test (right tail) for comparison of means of two samples, was applied for this study. The level of significance was < 0.05.

Results

Table 1 and figure 1 show the duration of pre-take-off stage, total and during phases I to IV, where the sorties during forenoon and afternoon have also been compared.

Table 1: Duration of Pre-take-off during forenoon and afternoon

Sortie time	Event/ Sortie no.	Total duration (min)	Phase I (min)	Phase n (min)	Phase III (min)	Phase IV (min)
FN	1	24	10	2	11	1
	2	31	11	2	16	2
	3	31	9	1	20	1
	4	31	10	3	17	1
AN	5	23	6	1	15	1
	6	23	7	2	11	3
	7	23	4	4	14	1
	8	45	19	5	20	1
	Avg	28.87±7.56	9.5±4.5	2.5±1.41	15.5±3.5	1.37±0.69
	Avg FN	29.25±3.5	10.0±0.81	2.0±1.81	16.0±3.742	1.25±0.5
	Avg AN	28.5±11.0	9.0±6.78	3.0±1.82	15.0±3.742	1.5±1.0

Note: FN: Forenoon (sortie 1 -4), AN: Afternoon (sortie 5-

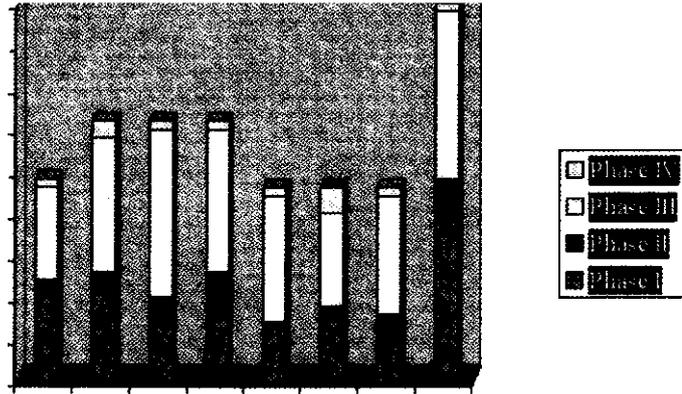


Fig 1: Duration of Pre take-off (Phases I-IV) in Sorties

Table 2: Ambient v/s cockpit heat stress during sorties

Ambient WBGT (Ambient Tdb)	Cockpit WBGT avg (Tdb avg) °C & PTO duration	PhI WBGT avg (Tdb avg) °C in	Ph II WBGT avg (Tdb avg) °C	PhIII WBGT avg (Tdb avg) °C	PhIV WBGT avg (Tdb avg) °C	sortie
28.29 °C (32 °C)	37.4 ±1.04 (44.31±1.80) (24 mins)	37.21±1.49 (42.91±1.55)	37.55±0.21 (45.35±1.21)	37.53±0.63 (45.28±1.39)	37.2 (45.5)	1
25.3 °C (27 °C)	30.05 ± 1.00 (32.91±1.44) (31 mins)	29.24±0.96 (31.72±1.45)	31.15±0.07 (35.35±1.21)	30.42±0.65 (33.44±0.81)	30.5±1.41 (33.75±2.48)	2
26.2 °C (28 °C)	30.21 ±1.67 (33.76±2.38) (31 mins)	28.91±0.43 (30.64±0.55)	29.4 (31.2)	31.02±1.45 (35.32±1.12)	26.6 (33)	3
28.62 °C (30.4 °C)	33.54 ±2.24 (40.09±3.92) (31 mins)	31.32±1.18 (35.64±0.76)	31.3±0.17 (36.47±0.25)	35.1±1.55 (43.15±1.71)	36.1 (43.5)	4
29.26 °C (32.6 °C)	35.7±1.19 (42.35±2.44) (23 mins)	34.37±0.58 (39.78±0.25)	34.9 (39.5)	36.39±0.87 (43.65±2.02)	34.9 (41.2)	5
30.66 °C (33.4 °C)	39.12±1.61 (45.80±2.29) (23 mins)	39.91±0.66 (46.34±0.81)	41.05±0.49 (48)	38.89±1.25 (45.98±1.69)	36.83±2.25 (42.4±4.27)	6
28.06 °C (29 °C)	34.63±1.96 (39.33±3.38)	31.8±0.36 (34.87±0.25)	32.95±0.89 (37.6±1.87)	36.06±0.68 (41.57±1.58)	32.7 32.5	7
30°C (33 °C)	35.9 ±1.04 (42.31±3.87) (45 mins)	35.63±2.62 (39.56±1.88)	32.16±0.15 (37.82±0.53)	37.14±1.29 (46.11±1.80)	34.8 (41)	8

Note: FN: Forenoon (sortie 1-4),AN: After noon (sortie 5-8)

During the 8 operational sorties in a modern fighter aircraft, the duration of pre-take off stage was found to range from 23 to 45 minutes (average 28.85 ± 7.56 min). Phase III and Phase I were found to contribute a maximum of 65.2% and 42.2%, respectively, to the time spent in a pre take-off stage of the sortie. Pre-take-off stage was found to occupy 29.9% to 51.7% of the total sortie duration (range 70 to 87 min) in this study.

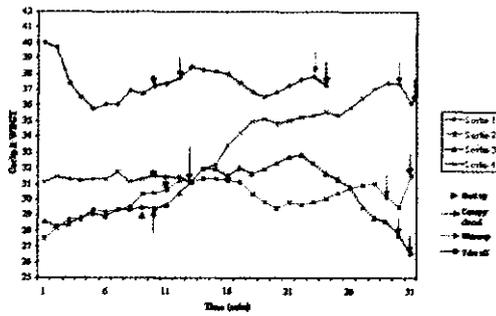


Fig 2: Pre take-off cockpit heat stress (WBGT) : Forenoon

Cockpit heat stress (cockpit WBGT) was expectantly more than the ambient heat stress (WBGTamb). While cockpit WBGT ranged from 31.5°C to 41.4°C, ambient WBGT was between 25.3°C and 32.3°C. This was true for cockpit WBGTmax and cockpit WBGTavg also when assessing the heat stress for the entire pre take-off duration and during phases I to IV.

WBGTavg in the cockpit prior to take-off was more than 32°C in 6 out of 8 sorties. WBGTmax in the cockpit was found to range from 31.5°C (Tdb 35.5°C) to 41.4°C (Tdb 48°C), in this study. Cockpit WBGT was found to increase as time progresses during the pre take-off period (Table 2).

Amount of heat soak in a parked aircraft confers greater heat stress with increasing durations of time, when ambient conditions were comparable since cockpit Tdb and Tbg increases with time. On exposure to increasing pre-take-off duration,

The ambient and cockpit heat stress during pre take-off stage, including .during Phase I to IV, is given in table 2, figure 2 and 3.

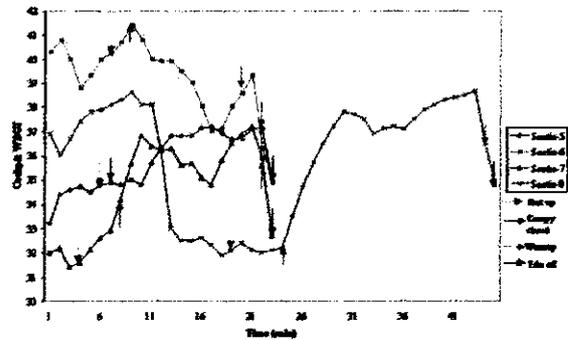


Fig 3: Pre take-off cockpit heat stress (WBGT) : Afternoon

WBGT continues increasing with time, as was found on comparison of mean cockpit WBGT of the pre take-off stage and during phases I to IV during forenoon and afternoon sorties (Table 3 and Figure 4).

Comparison of mean cockpit WBGT of the pre take-off stage before and after canopy closure during forenoon and afternoon sorties is given at table 4 and figure 5.

The findings in this in-flight field study suggested that there is a significant increase in cockpit heat stress prior to canopy-closure (Phase I+II) in the afternoon sorties when compared to forenoon (r=.915; p<0.05). It was also found that there was a significant increase in cockpit heat stress after canopy-closure in all the sorties (r=0.807; p<0.05) and the pre take-off cockpit heat stress is more in the afternoon hours (r=0.826; p<0.05) when compared to forenoon, the increase being significant,

Table 3: Comparison of mean cockpit WBGT between forenoon and afternoon

Phases Sortie time	III	IV	Total Sortie
FN AN r	31.67±3.48		
value	35.82±3.04		
S/NS	2.391(p<0.0		
	1) NS		
	32.42±3.23		
	34.13±3.35		
	33.08±3.0		
	37.02±1.43		
	2.447(p<0.0		
	1) NS		
	32.2±4.39		
	35.42±2.77		
	35.52±3.27		
	36.27±2.49		
	0.826(p<0.0		
	5) S		

Note: FN: Forenoon (sortie 1-4), AN: Afternoon (sortie 5-8), S: Significant, NS: Not significant

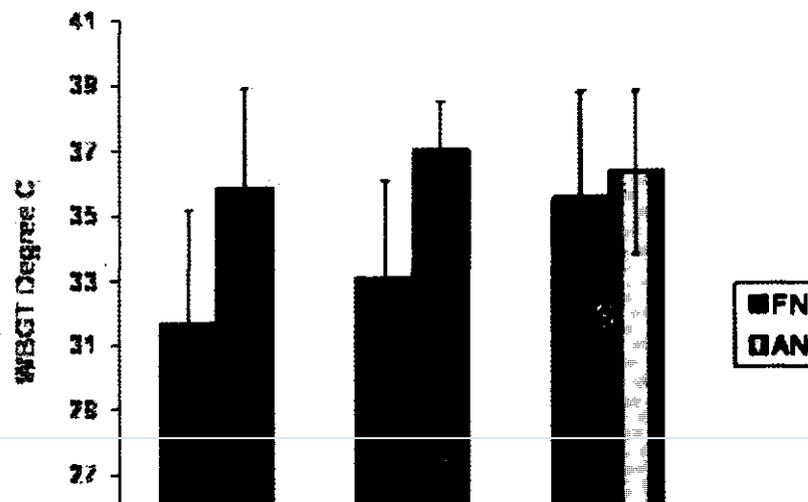
Table 4: Comparison of mean cockpit WBGT (PTO) -before and after canopy closure (I+II; II1+IV) during forenoon and afternoon hours

Phases Sortie time	I+II (n=4)	FN+AN sorties (PhI+II) (n=8)	m+iv (n=4)	FN+AN sorties (Phfl+IV) (n=8)	rvalue (FN+AN sorties)
FN AN r		33.6±3.74	33.02±3.0	34.9±3.14	0.807(p<0.0
value S/NS			9	31.8±3.41	35.82±3.04
			36.92±1.5	1.915(p<0.05) S	5) S
			6	5.216	

FN (between I+II and III+IV), r: 0.915 (p<0.05); S AN

(between I+II and III+IV), r: 0.885 (p<0.05); S

Note: FN: Forenoon (sortie 1-4), AN: After noon (sortie 5-8), S: Significant, NS: Not significant



with respect to the time of flight.

Discussion

This field study was undertaken to record the actual cockpit conditions prevailing before take-off, during eight randomly chosen operational sorties, thus allowing a realistic assessment of heat stress on a fighter pilot prior to being airborne. This inflight field study revealed that the cockpit WBGTavg prior to take-off was more than 32°C, in six out of eight sorties. The pre take-off stage ranged from 23 to 45 min (average 28.85 ±7.56 min), accounting for 29.9% to 51.7% of entire sortie duration (70-87min). The maximum WBGT was in the range of 31.5°C (Tdb 35.5°C) and 41,4°C (Tdb 48°C) during the pre-take off stage. This reemphasizes the fact that the fighter pilot is exposed to long periods of unacceptable levels of heat stress prior to being airborne, as was reported in earlier reports as well [1, 7, 10]. Ideal test conditions envisage that WBGTavg should be less than 32 °C in a sortie, with aircraft flying at 0.6 Mach at 200m while evaluating an ACS of a modern fighter aircraft [21].

minimum amount of time the pilot spends in the fighter cockpit prior to canopy-closure is 7 min and the maximum. 24 min (average 12.0 ± 5.34 min), whereas, after canopy-closure prior to take-off, the fighter pilot spends between 12 to 21 min (average 16.87 ±3.22 min). The events that follow canopy-closure, mainly getting permission from ATC prior to taxiing, may at times entail waiting.

The heat stress in Phase III was much more than in Phase I (Table 2) in each of the eight sorties. The average time spent in respective phases, I to IV, in the forenoon and afternoon sorties was comparable (Table 1). The pre take-off heat stress (WBGTavg) in the afternoon sorties was significantly more than that in the forenoon (1=0.826, p<0.05,Table3).

The stage of pre take-off that precedes canopy-closure (Phases IH-II) witnesses greater cockpit heat stress during the afternoon sorties when compared to forenoon. There was a significant difference in cockpit heat stress in the forenoon and afternoon sorties, prior to canopy-closure (r=1.915, p<0.05, Table 4). The stage of pre take-off that follows canopy-closure (Phases III+IV) was found to confer greater cockpit

In this field study, it was found that the 40 i

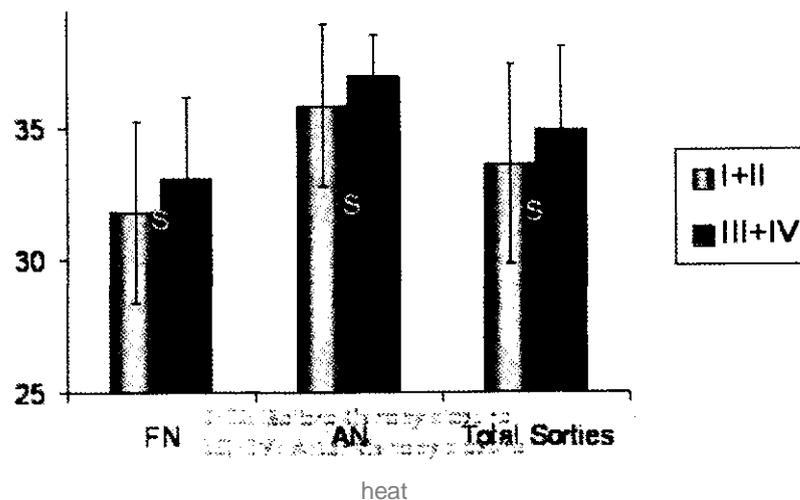


Fig 5: Comparison of Mean Cockpit WBGT (PTO): Before (I+II) & After (in+TV) Canopy closure (FN/AN)

stress in the afternoon sorties when compared to forenoon. However, the difference was not significant (Table 4).

On comparing the cockpit heat stress before and after canopy-closure, it was found that there was greater cockpit heat stress after the closure of canopy and the difference was significant both in forenoon ($r=0.915$, $p<0.05$) and afternoon sorties ($r=0.885$, $p<0.05$) i.e., it was found to be true for all sorties ($r=0.807$, $p<0.05$) irrespective of the time of sortie (Table 4).

A higher OAT need not provide greater ambient heat stress (WBGT) if the decrease in humidity causes greater evaporative cooling, therefore lesser stress on the individual. It is not always that a higher OAT will render ambient WBGT to be higher when two environmental conditions are being compared [10] for example, when OAT 30.4°C, RH 70% was compared to OAT 32°C, RH 52%, it was found that WBGT was higher in the former though T_{bg} in the former was 36.2 °C as compared to T_{bg} 40.5 °C in the latter.

A higher ambient heat stress would usually indicate greater cockpit heat stress (pre-take-off). However, with the aircraft parked in the open with prolonged exposure to the Sun, there is greater heat soak in the cockpit [1, 7, 10, 15]. This leads to unusually high T_{bg} readings, thereby the cockpit WBGT, which were found even on the days when ambient WBGT was relatively comfortable. Thus solar radiation plays a significant role, as was evident from results recorded during pre take-off heat soak at different times of the day [22]. The

radiant temperature in the cockpit contributes to the heat stress measured as a weighted mean. Measures to reduce radiant heat to reduce heat stress in closed cockpit are essential for conserving pilot's efficiency [22,23].

Aircraft structure in flight is heated directly and by friction between its surface and the air. This aerodynamic heating increases during high-speed low level flying [24-26]. However, in pre take-off phase, the aircraft skin radiates heat to the pilot and warms the cockpit air. Heat load from the avionics adds to the total heat load. A transparent canopy admits solar radiation but retains re-radiation from the cockpit structures. This green house effect further raises the cockpit heat load [26]. Sweating would increase cockpit humidity, which, with time increases heat stress to the aviator. With profuse sweating, the wet overlying clothing allows transfer of sweat by 'wicking'. Although sweat removed from the skin in this way and evaporated from the clothing removes less heat from the body than sweat evaporated at the skin surface. In the close confines of the cockpit, with conditions stimulating profuse sweating it is desirable to promote it i.e, dehumidify the air around. But, ACS is quite ineffective during pre take-off stage [26]; besides flying clothing interferes with evaporative and non-evaporative pathways of heat exchange with the environment. After closure of the canopy and events thereafter, especially while taxiing or waiting to take-off, can produce particularly high cockpit temperatures [26-28], The cabin conditioning system at this time will be at its least effective with the engines at near idle r.p.m. Hence, conditions in the microclimate between the skin and inner layer of clothing are required to be adjusted so that thermal stresses imposed by the cabin environment can be mitigated.

Flying efficiency of aircrew cannot be at its highest unless they are protected from thermal stress [26]. Task performance is impaired when heat stress reaches certain levels. In military flying it is possible to derive conditions that would be appropriate to crew comfort after due considerations of those basic principles that govern heat exchange. Thus, it is imperative that thermal comfort of the aircrew should be the primary aim in the design of climatic conditions within aircraft cabin, but should it prove impossible to meet the

defined requirements prior to take-off, then recourse must be made to on ground solutions to minimize heat strain [26]. If a low level sortie is planned, where cockpit heat stress is more than other sortie profiles (step-up or endurance), it is pertinent to focus on the requirements of reducing pre take-off duration and adopting pre-cooling methods. Pre-cooling is a must, especially in afternoon hours so that the fighter pilot is spared excessive heat strain prior to being airborne. This includes covering the canopy, wetting the canopy cover and using mobile air conditioning units [26]. It is also advisable to restrict low level sorties to the early hours of the day with minimum time in pre take-off stage. These simple methods could be easily adopted to reduce the pre take-off heat load on the operator.

It was found that during Phase I, some pilots took only 4 min to start-up after entering the cockpit, and others took 19min. Similarly, during phase III, some pilots took 11 min from canopy-closure to warm-up while others took up to 20 min. Since the minimum pre take-off duration in this study was 23 min and the maximum, 45 min, it was not surprising to find that the major contribution to delay in takeoff was due to time spent in Phase 111, followed closely by Phase I. But this is where intervention is possible to reduce the duration of exposure to the pre take-off heat stress. Care must be taken, while planning day sorties in the summer months, to minimize the time spent in the cockpit prior to take off as far as it is operationally feasible. Since it is possible to complete all checks prior to start-up in 4 minutes, one should try to; similarly, since it is possible to warm-up for a take-off after canopy closure within 11 minutes that should be aimed at. Since Phase II and IV together take 2 to 6 minutes, the time spent by a fighter pilot in the cockpit of a modern fighter aircraft can, thus theoretically, be brought down to the range of 17 to 21 min if a conscious and deliberate attempt is made to do so.

When sorties are planned in afternoon hours, it is important that the least amount of time is spent in pre take-off (Phase I-IV), after canopy-closure (Phase III and IV) and in the checks that precede start-up (Phase f). This is especially important because of the significant statistical difference, revealed in this study, in cockpit heat stress between forenoon and afternoon sorties in entire pre takeoff stage of sorties, more so after canopy-closure (Phase 111 and IV) and Phase I of the pre take-off stage.

Cockpit heat stress is more than ambient because several aircraft factors contribute to increase the thermal stress inside the cockpit [24-26]. In the Indian tropical climate, the implications of these additional factors are much more serious than what they are in countries with moderate and cold climates [7,8, 10,28]. It is important to mention at this point that the efficiency of the ACS is compromised in hot weather conditions in older Russian fighter aircraft [1-3], where efficient cooling is known to start after the aircraft climbs above 2 Km, with ram air-cooling being an essential requirement of such a system. Operational guidelines exist for cancellation of sorties, whenever the OAT (Tdb) is higher than 40°C, it is more applicable to the low level sorties rather than other sortie profiles (mid-level/ step-up and endurance). This study draws attention to the pre take-off duration which extends from 23 to 45min (Fig 1), where 75% of the sorties were found have unacceptable heat stress during the pre take-off stage, despite of comfortable ambient conditions (27.0/33.4°C OAT/Tdb). If this study was undertaken at ambient temperature nearing the maximum permissible limit (< 40°C) [29], the recorded heat stress during pre take-off would have been startlingly alarming. Thus performance decrement that accompanies prolonged exposure to heat must not be ignored in military flying [24,30].

This study emphasized that the heat stress encountered during pre take-off largely goes unnoticed, unregistered, unaccounted for and ignored. We would like to draw the attention of the medical and operational fraternity to the obvious heat stress on the occupant of a fighter cockpit, so that necessary precautions can be suggested at the squadron level [26]. It is reiterated that phase HI ranges from 11 to 20 min and maximum amount of time is spent in this phase. This is the phase where the pilot is inside a closed cockpit, taxiing to the take-off point and awaiting permission for take-off. Statistical evidence draws focus to the heat load on a pilot after canopy closure, especially during afternoon hours. A concerted coordination between ATC and the pilot will help in minimizing the duration of this phase and hence the pre take-off heat stress which if ignored could be incapacitating [30], especially in fighter flying.

Conclusion

Aviation Medicine specialists and operation planners must adopt strategies to reduce the pre take-off heat stress that could adversely compromise the occupant's heat load. The measures could include restriction of flight during severely high WBGT or limiting low-level sorties to earlier hours of the day, personal and cockpit cooling mechanisms, adequate replenishment of fluids preflight and in-flight, and an emphasis on personal fitness and acclimatization of the aircrew. The measures are required to counter the pre-take-off heat stress that is largely overlooked and ignored at the peril of severely compromising flying fitness of the aircrew and their operational readiness.

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