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Effect of Combat Vehicle Operation on Cognitive Workload and Performance

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ABSTRACT

Multifaceted stress factors related to infantry combat vehicle (ICV) operation may be considered as major a source of cognitive workload, which may significantly impact the performance of infantry soldiers. The available literature on the effect of ICV's operational environment on soldier's cognitive workload is scanty or mostly unreported. The present study was designed to observe the effect of ICV operation on the i) cognitive workload ii) cognitive performance and iii) to study the association between cognitive workload and performance. Thirty soldiers [mean(SD)- age: 31.86(2.9) years, weight: 74.40(7.7) kg, and height: 171.33(3.42) cm] volunteered for this study. Their heart rate (HR), heart rate variability (HRV) and respiratory frequency (RF) were recorded at three time points 00th-05th, 25th-30th and 55th-60th minute during the ICV operation. 'A' letter cancellation task (ALCT) was conducted to assess cognitive performance, before and after ICV operation. The internal temperature and relative humidity (RH) of ICV were assessed at same three time-points. Repeated measure ANOVA and Wilcoxon signed ranks test were conducted to observe significant changes in HR, HRV, RF, and cognitive performance. Association between HRV and ALCT was assessed using Pearson's bivariate correlation. Changes were considered significant when p-value was ≤ 0.05. Significant increase in the HR and RF were observed along with significant decrease in both time and frequency domain of HRV after ICV operation. Similarly, ALCT showed a significant increase in the total and net score, and an increased error score in post-ICV operation. A strong positive correlation was observed between the ICV operation run-trial time and the increasing compartmental temperature ($r=0.99$) and RH ($r=0.89$). HRV components showed a negative correlation with ALCT measures. One hour of ICV operation resulted in increased cognitive workload and a significant decrease in the cognitive task performance. Internal temperature and RH of ICV are potential physical stress factors affecting the soldier's workload and performance.

Keywords: Infantry combat vehicle; Heart rate; Heart rate variability; Cognitive workload; Cognitive performance

1. INTRODUCTION

1.1 Multiple Stress Factors of ICV Operation

Infantry combat vehicle (ICV) is a tracked armoured vehicle used in tactical command and control from within the confines of the vehicle for mobile operations. ICV operation accommodates infantry soldiers seated at various positions within the confines of the vehicle therefore, exposing the soldiers to multiple stress factors. Broadly, these factors are identified as vehicular vibration, noise, and thermal stress. The ICV operates over a range of hostile terrain conditions such as desert and jungles, either in training or real time combat situations. The confined internal environment of the ICV is subjected to increasing temperature and relative humidity (RH) along with restricted air circulation. Especially in a desert condition the ambient temperature generally exceeds 50 °C causing an increase in the ICV's compartmental temperature and RH and also the ICV's metal body absorbs and transfers heat to the internal compartment rapidly. Furthermore, poor air circulation further traps the heat within the internal compartment. Moreover, the soldiers' within the ICV dissipate heat generated due to metabolic activities, therefore contributing to the thermal load within the confines of the ICV[1]. In addition, soldiers are required to sit within the constrained space with limited movement and postural fixity, which increases musculoskeletal load[2]. The heavy structure of the ICV maneuver over an undulated terrain causes excessive vibration and noise, which transmits and propagates to the soldiers who are in direct contact with the ICV. Vibration transmitted to human body further impacts neuromuscular transmission[3]. Moreover, under such circumstance, the soldiers are expected to stay combat-ready to take correct decision towards the successful accomplishment of the mission. Thus, the entire scenario may impose significant cognitive workload on the soldiers (Fig. 1).

1.2 Heart Rate Variability as the Predictor of Cognitive Workload

Over the decades the empirical data has established the fact that heart rate variability (HRV) can traditionally be used as one of the important physiological measure to predict cognitive workload[4]. In presence of stress, fear, or an emergency situation sympathetic nervous system (SNS) activation will bring about changes in the domains of HRV and respiratory

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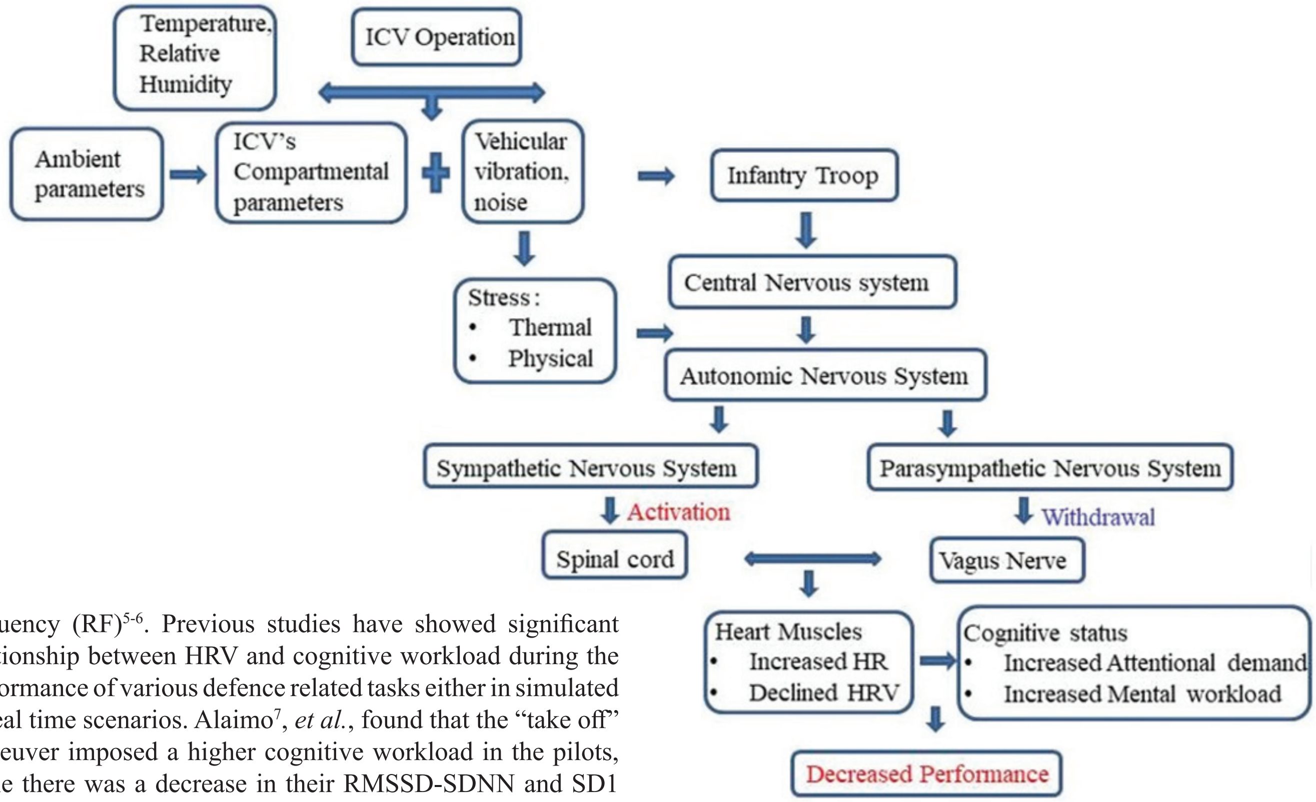

Figure 1. Multiple stress factors i.e. vehicular vibration, noise, and thermal environment during ICV operation resulted in vagal withdrawal followed by an increased SNS activity. Consequently, the HRV decreased indicating that the soldiers were subjected to an increased cognitive workload, which may cause a decline in their performance.

frequency (RF)[5-6]. Previous studies have showed significant relationship between HRV and cognitive workload during the performance of various defence related tasks either in simulated or real time scenarios. Alaimo[7], *et al.*, found that the "take off" maneuver imposed a higher cognitive workload in the pilots, while there was a decrease in their RMSSD-SDNN and SD1 values during the first 120 sec of a simulated flying task when compared to the "approach and landing" task. There are other studies reflecting the benefit of assessing various measures of HRV, both time and frequency domain towards the assessment of pilot's cognitive workload[8-9]. Similarly, HRV can also be used to study the cognitive workload of operators of various land driven combat vehicles considering the multitasking activities they are mostly subjected to, during various combat operations. It has been observed that the military performance inside a stressful and complex environment of a combat vehicle resulted in the increase of HR and RF along with an associated decrease in HRV, which is a clear indicator of increasing cognitive workload[9-10].

1.3 Genesis of Cognitive Workload in Military Environment

Cognitive workload is built up due to the interaction between the operator and the task, where the demand of the task exceeds the expected outcome or performance[11]. The interaction between the stress factors with the physiological and cognitive processing may either enhance or reduce the performance with relevance to a situation by affecting their sensory processing, vigilance, focus of attention on key aspects within the environment, motor speed, and rapid decision-making processes that allows a soldier to accomplish their goal[12-13]. Soldiers, as military personnel, facing traditional challenges of warfare, have a constant requirement to adopt various strategies to make accurate decisions during combat exercise. Thus, it can be postulated that a strategic mission involving ICV operation can always be a significant source of cognitive workload, under which, the balance between the sensory processing and decision-making may get disrupted. The process of decision-making is a complex cognitive phenomenon which requires the functional involvement of various parts of the brain[14]. Since, decision-making includes variety of different cognitive processes, it cannot be assumed as a singular process[15]. Among various cognitive processes of human reasoning and decision-making, "attention, speed of processing, reaction time and accuracy" are of paramount importance[16].

1.4 Letter Cancellation Task as a Measure of Cognitive Performance

Letter cancellation task (LCT) is a simple paper-pencil based method that can be applied under various field situations to assess specific brain functionalities like selective and sustained attention; visuo-spatial scanning; activation and inhibition of responses (involves the visual selectivity and repeated motor response) to evaluate the influence of various physical stress factors[17-20].

1.5 The Present study

In context to military state, various defence organisations have documented the effect of ICV operation on the soldier's health and performance[21-23]. In the majority of these studies data collected was limited to the exposure of the participants at two time points only i.e. before and after the ICV operation. Till

Table 1. Descriptive statistics of the ICV compartmental temperature (°C) and relative humidity (%); and infantry soldiers' HR, RF and HRV indices during the ICV operation. All values are presented in the form of mean (SEM). p ≤ 0.05 is considered significant.

Before run trial			During run trial				
Temperature (°C)		34.24 (1.84)		Time (min)	00^{th} –05^{th}	25^{th} -30^{th}	55^{th} -60^{th}
Ambient Parameters	RH (%)	62.2 (10.66)	ICV compartmental Parameters	Temperature (°C)	35(0.85)	37.02(0.59)	39.70 (0.53)
				RH (%)	70 (3.43)	80.75(4.73)	89.5 (4.08)
				Mean HR (beats/min)	81.08 (1.19)	93.50 (1.82)	102.37 (1.80)
				Mean RF (breaths/min)	16.26 (0.17)	24.64 (0.18)	24.58 (0.14)
				Mean RR (ms)	749.94(10.56)	646.78 (11.91)	596.77 (10.61)
			Time domain	SDNN (ms)	55.34 (4.09)	25.80 (2.04)	46.52 (4.74)
				RMSSD (ms)	29.70 (3.28)	12.65 (1.48)	15.83 (2.31)
				LF (ms^2)	823.6 (99.4)	214.4 (28.9)	483.7 (145.6)
			Frequency domain	HF (ms^2)	348.4 (72.7)	64.6 (20.6)	99.2 (33.1)
				LF/HF	4.8 (0.6)	7.7 (0.9)	1.7 (1.0)

date, there is a dearth of literature on evaluating the effect of ICV operation on cognitive workload and cognitive performance. On the other hand, available data shows a majority of the results interpreted on the basis of subjective evaluation is mostly under simulated conditions. Thus, there is a need to explore the objective data on the effect of real-time ICV operation on cognitive workload and cognitive performance in order to establish a practical estimation on the combat vehicular stress.

In view of the above, the present study was undertaken to explore and assess the effect of ICV operation on the changes observed in the i) cardiorespiratory responses i.e. respiratory frequency (RF), heart rate (HR) and heart rate variability (HRV), which in turn can predict cognitive workload; ii) changes in cognitive performance at the domain of executive functioning; and iii) study the association between cognitive workload and performance by correlating different measures of HRV with task performance.

2. MATERIALS AND METHODS

2.1 Study Participants

Thirty (30) healthy male Indian infantry soldiers with a minimum of 5 years of experience and the knowledge of operating an ICV under different conditions served as participants. They were asked to abstain from smoking, alcohol and caffeine intake for 24 h before the commencement of the study. The demographic details of the participants are as follows in the form of mean (SD); range- age: 31 (2.9); 26-33 years, weight: 74.40(7.7); 66.20 –80. 25 kg, and height: 171.33(3.42); 163.25 cm – 180.27 cm. The participants were asked to restrain from performing any strenuous activity over the period of 24 h before their participation in the study. However, they were allowed to carry on with their basic activities that would not significantly modulate their physiological responses.

2.2 Ethics Statement

The study protocol was approved by the Institutional Ethics Committee for the use of humans as experimental subjects. The experiment also conforms to the principles outlined by the declaration of Helsinki protocol, 1985. Before the commencement of the experiment, the participants signed an informed consent form and were permitted to withdraw from the study at any given point of time.

2.3 Equipment

2.3.1 Infantry Combat Vehicle

An existing ICV was used for the present study. All the experiments were conducted in the afternoon time period from 13:00 to 14:00, on a rough terrain characterised by dry soil with occasional undulations. The speed of the ICV was maintained at 35 km/h – 40 km/h. During its operation, the hatch of the ICV was closed.

2.3.2 Ambient Parameters

The ambient temperature and RH was recorded at five different locations of the ICV run-track within the radius of 5 km using a digital hygrometer (HTC, India). The average ambient temperature (°C) and RH (%) were calculated (Table 1).

2.3.3 Infantry Combat Vehicle Compartmental Parameters

The compartmental temperature (°C) and RH (%) (Table 1) inside the ICV were recorded using a digital hygrometer at three time points (i) 0^{th} - 05^{th} min, (ii) 25^{th} - 30^{th} min and (iii) 55^{th} - 60^{th} min of the trial.

2.3.4 Recording of Heart Rate, Respiratory Frequency and Heart Rate Variability

The sensors (BH-3) of the physiological status monitoring system (Zephyr bio-harness, M/s Medtronic, USA), were accurately placed at the soldiers' chest region via bio-harness for continuous monitoring of their vital parameters. Followed by this a recording software "OmniSense live™" was run during the trial to ensure proper data acquisition from the sensors. Subsequently, the data was downloaded for further analysis using OmniSense Analysis™ software. For HR and RF analysis, a Microsoft excel file containing the HR and RF changes per sec, for one-hour trial was exported and processed. For analysis of HRV, raw .CSV* file was exported from OmniSense Analysis software to Kubios (version 2.0, 2008, Finland) software. The RR interval files of each subject were pre-processed using auto-artefacts correction feature in the Kubios software. The RR values with a minimum length of 5 min were considered at three time points i.e. (i) initial 5 min of the ICV operation from 0^{th} -05^{th} min, (ii) during ICV operation from 25^{th} - 30^{th} min and (iii) just before the termination of the ICV operation from 55^{th} - 60^{th} min, were taken for analysis.

2.3.5 'A' letter Cancellation Task

A modified version of the letter cancellation task (LCT) protocol developed by Talland[24], was used to measure the sustained and selective visuospatial attention, and cognitive workload. The soldiers were provided with an LCT sheet having 21 arrays of letters (target letter-A and non-target letters). They were instructed to strikeout as many target letter 'A' as possible from the set of randomly interspersed alphabets in the specified time of 5 min. A sample of 'A' letter cancellation (ALCT) sheet along with a processed ALCT sheet is presented in Fig. 2.

Each letter of the ALCT was scored as 1. The total number of letters stricken out (letter 'A' and wrong letters) was calculated to obtain the total score. The wrong letters stricken out were counted as error score. The net score was calculated by subtracting the error score from the total score. The total score, net score, and error score were further processed for statistical analysis.

2.4 Procedure

The study was carried out for the duration for one hour during an afternoon period. Before the commencement of the ICV operation (pre- ALCT), ALCT was conducted. Participants were given three trial sessions in order to get habituated before they performed the final ALCT. Followed by this, the soldiers were instructed to take their respective position inside the ICV along with their necessary safety gears as per the standard norms of the ICV operation. Subsequently, the ICV was operated on an already determined run-track. On completion of one hour ICV operation trial, participants were required to immediately take another ALCT (post- ALCT) to assess their cognitive performance.

2.5 Statistical Analysis

Statistical analysis was carried out using SPSS statistical software, version 21.0 (IBM, uSA). Changes were considered significant when p value was less than 0.05 ($p \leq 0.05$).

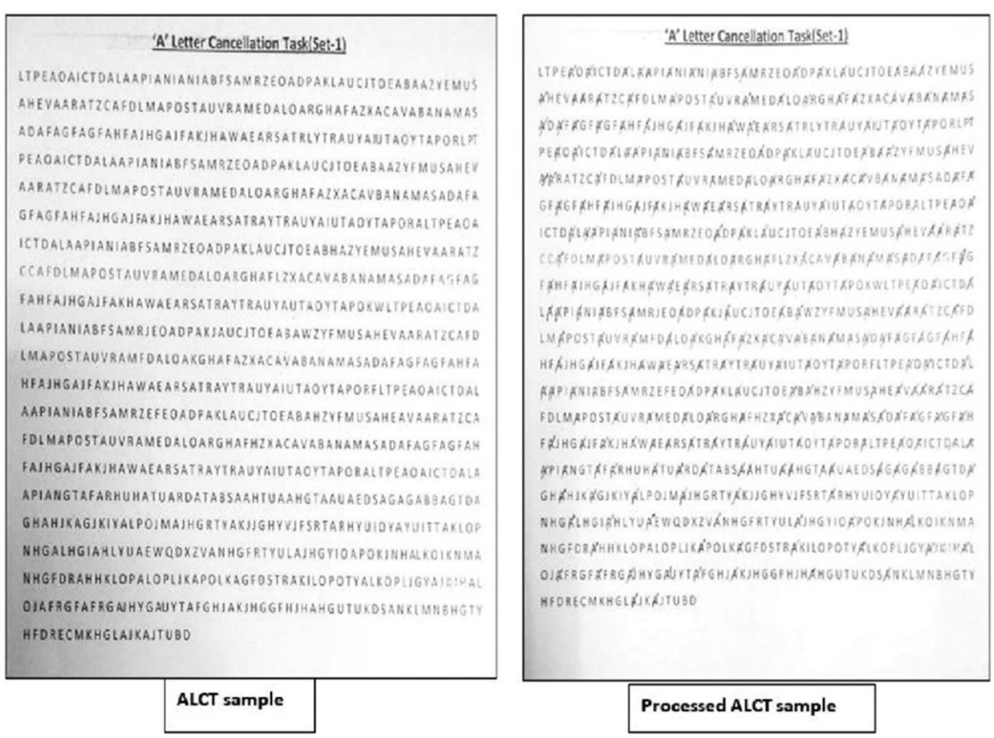

Figure 2. 'A' letter cancellation task (ALCT) sample, No of rows: 21, No of letters per line: 53 & 56 (Alternate), Total 'A' letters: 296, Time: Lower limit: At maximum speed, as early as possible; Upper limit - Not exceeding 5 minutes.

2.5.1 Respiratory Frequency, Heart Rate and Heart Rate Variability

The RF, HR, and HRV parameters of both time and frequency domain (FFT spectrum) were analysed using one- way repeated measure ANOVA to confirm the significant changes between the different time points (0^{th} - 05^{th}, 25^{th} - 30^{th} and 55^{th} - 60^{th} minute) of the ICV operation.

2.5.2 'A' Letter Cancellation Task

The Shapiro-Wilk test of normality showed that the 'A' letter cancellation task data was not normally distributed. Hence, nonparametric Wilcoxon signed ranks test was performed to analyse pre-post changes in the data within the same group.

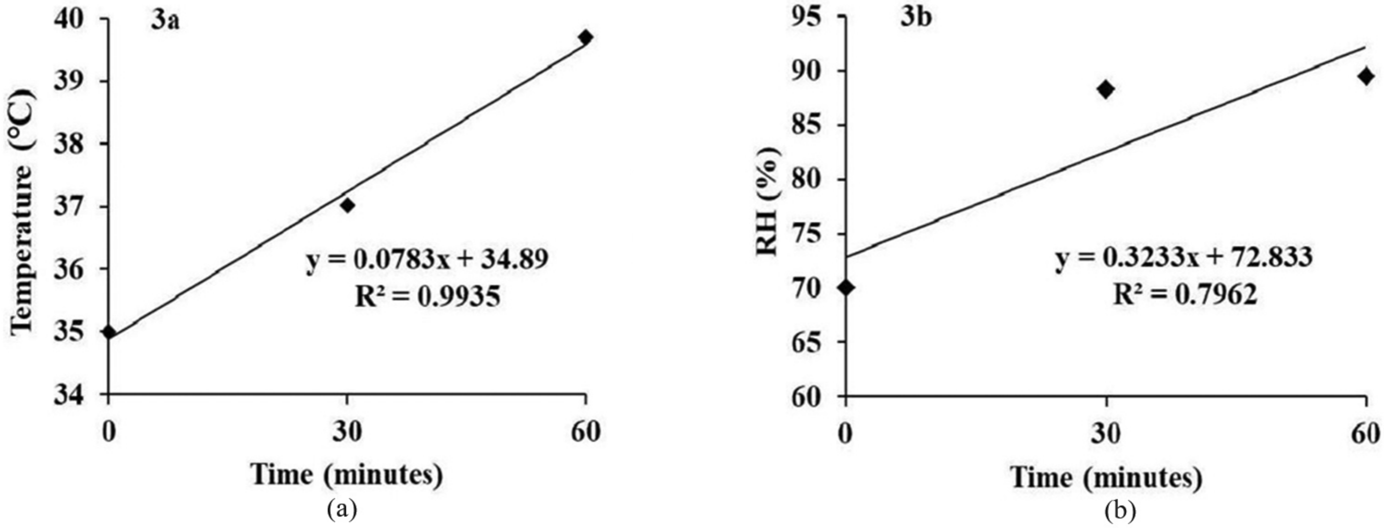

Figure 3. (a) Effect of ICV operation time (minutes) on the corresponding increasing compartmental temperature (°C) and (b) Effect of ICV operation time (minutes) on the compartmental relative humidity (RH) (%).

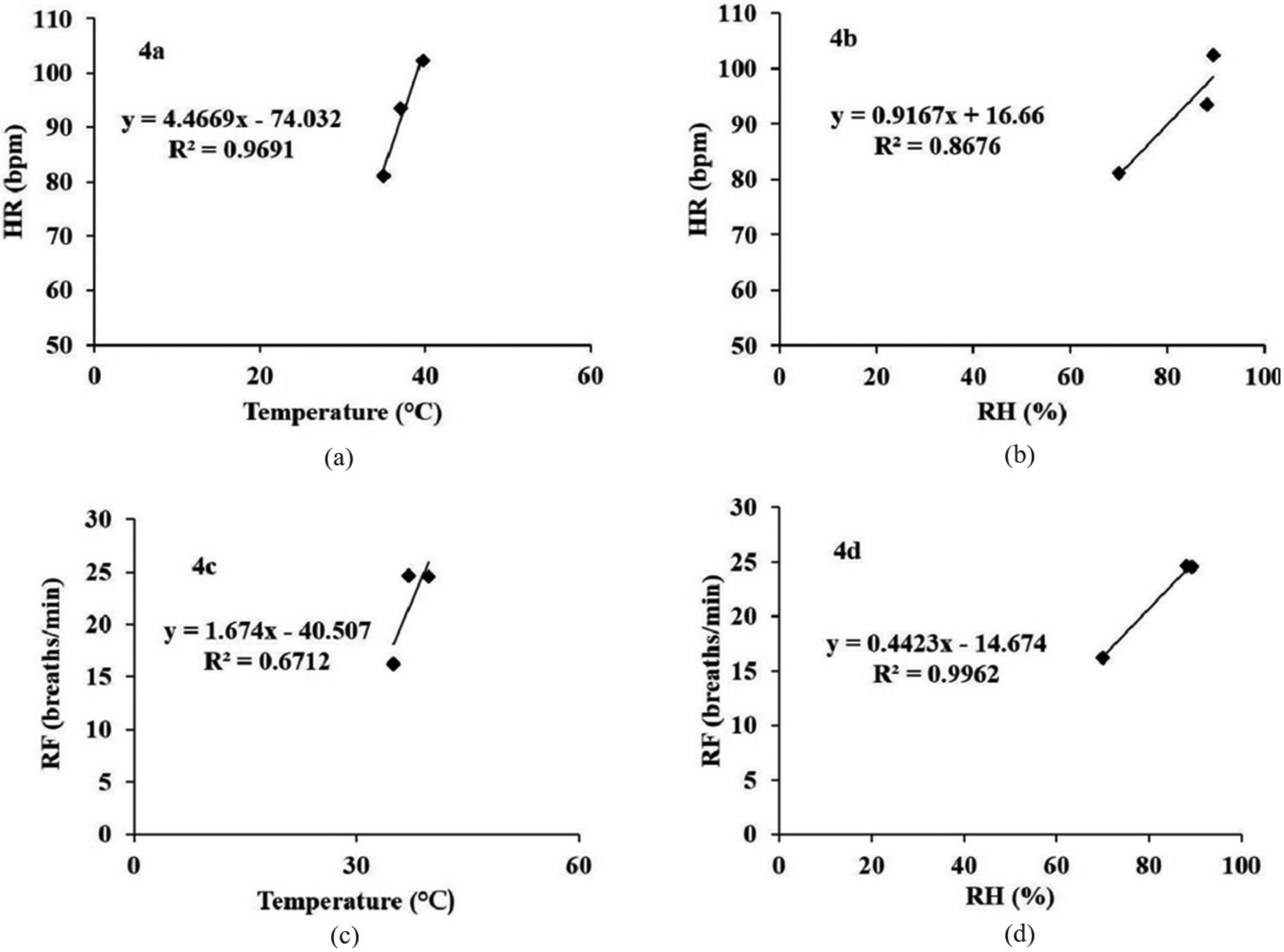

Figure 4. (a) Effect of compartmental temperature (°C) on Heart rate (HR, bpm: beats per min), (b) Effect of compartmental RH (%) on Heart rate (HR, bpm: beats per min), (c) Effect of compartmental temperature (°C) on respiratory Frequency (RF: breaths per min), and (d) Effect of compartmental relative humidity (RH, %) on respiratory Frequency (RF: breaths per min).

2.5.3 Correlation between ALCT and HRV Parameters

A bivariate Pearson's product moment correlation coefficient (r) was conducted to study the association between the individual ALCT and HRV parameters of the soldiers.

3. RESULTS

3.1 Temperature and Relative Humidity

The average ambient temperature and RH were observed to be 34.24 °C and 62.2 per cent respectively. The compartmental temperature and RH recorded at 0^{th} - 05^{th}, 25^{th} - 30^{th} and 55^{th} - 60^{th} min. of the ICV operation gradually increased showing a strong positive correlation of r=0.99, R^2=0.99 and r=0.89, R^2 =0.79 respectively with time. [Table 1; Fig. 3(a) and 3(b)].

3.2 Heart Rate and Respiratory Frequency

The HR was found to increase gradually with the ICV operation time. The increase in HR strongly correlated with the increasing compartmental temperature (°C) (r=0.98) and RH (%) (r=0.93). Further, the positive slope obtained in the regression analysis demonstrated a proportionate increase in HR along with the compartmental temperature (°C) (R^2 =0.97) and RH (%) (R^2 =0.87) (Fig. 4 (a) and 4 (b). RF response to the ICV operation also showed a positive correlation with compartmental temperature (°C) (r=0.81, R^2=0.67) and RH (%) (r=0.99, R^2=0.99) (Fig. 4 (c) and 4 (d).

The results of one-way repeated measure ANOVA showed a statistically significant increase in both HR [$F_{(2,58)}$= 3455.15, p= 0.000] and RF [$F_{(1.65,48.07)\ )}$= 67.41, p=0.000] during the ICV operation. The Post-hoc bonferroni pairwise comparison for HR revealed significant increase (p= 0.000) in all individual pairs of time interval, however for RF significant increase (p=0.000) was observed at 0^{th} - 05^{th} and 25^{th} - 30^{th} min. time interval only (Table 2).

3.3 Heart Rate Variability

The results of one way repeated measure ANOVA revealed an overall significant change in HRV (time and frequency domain – FFT parameters) across all the three time points (Table 2). The time domain factors i.e. mean RR, SDNN, and RMSSD showed a significant change of ($F_{(2,58)}$= 194.44, p= 0.000),($F_{(2,58)}$ = 36.32, p= 0.000), and ($F_{(2,58)}$= 42.03, p= 0.000) respectively. However, for SDNN and RMSSD, pairwise comparison showed a significant decrease from 0^{th} to 30^{th} minute (p=0.000) of the ICV operation (Table 2). In contrast, from 30^{th} to 60^{th} minute of the ICV operation, SDNN showed a significant increase (p=0.000), while RMSSD showed a non-significant increase (p=0.131).

In case of frequency domain, the FFT spectrum analysis components of ALCT performed post-ICV operation mostly showed a negative correlation. The strength of the correlation ranged from low to moderate. The results are represented in Table 4.

3.4 'A' Letter Cancellation Task

ALCT conducted post-ICV operation results showed 7.35 per cent, 7.17 per cent and 29.23 per cent increase in the total score, net score, and error score respectively compared to pre-operation condition (Table 3). Table 3 representing the Wilcoxon Signed Rank test comparing pre and post ALCT values showed a significant increase in both total score (p=0.005) and net score (p=0.005), post-ICV operation. Also, error score showed a non-significant increase (p=0.62) for post-ICV operation.

3.5 Correlation between Heart Rate Variability and different Measures of 'A' Letter Cancellation Task

The bivariate pearson's correlation coefficient analysis between the HRV parameters and the interfering with the selective and sustained attention, speed of processing, and error.

Table 2. One way repeated measure ANOVA and pairwise comparison of Heart Rate Variability (HRV) (time and frequency domain) measures with different time points of the ICV operation.

					Pairwise comparison		
		df value	F value	P value	0^{th} – 05^{th} min Vs 25^{th} – 30^{th} min	0^{th} – 05^{th} min Vs 55^{th} – 60^{th} min	25^{th} – 30^{th} min Vs 55^{th} – 60^{th} min
Time domain	HR	(2,58)	3455.149	0.000	0.000	0.000	0.000
	RF	(1.75,50.622)	67.415	0.000	0.000	0.000	1.000
	Mean RR	(2,58)	194.438	0.000	0.000	0.000	0.000
	SDNN	(2,58)	36.320	0.000	0.000	0.490	0.000
	RMSSD	(2,58)	42.033	0.000	0.000	0.000	0.131
Frequency domain	LF	(1.738,50.405)	13.650	0.000	0.000	0.025	0.175
	HF	(1.285,37.257)	15.416	0.000	0.001	0.001	0.700
	LF/HF	(1.715,49.73)	9.819	0.001	0.002	0.000	1.000

Table 3. Comparative mean (SEM) and percentage change in total, net and error scores of the infantry troop before and after the ICV operation. (significant at p≤ 0.01)**

	Pre	Post	% change	significance
Total scores	1022.60 (23.16)	1097.80 (14.85)	7.35**	0.005
Net Score	1013.93 (22.90)	1086.60 (15.07)	7.17**	0.005
Error score	8.67 (1.21)	11.20 (2.11)	29.23	0.62

Table 4. Pearson's correlation between post ALCt (total score, net score and error score) and HrV indices at 0th - 05th, 25th - 30th and 55th - 60th minute of the ICV operation. All values presented in the form of Pearson's coefficient (significance). (* significant p ≤ 0.05).

	Minutes	Total score	Net score	Error score
SDNN	00^{th} -05^{th}	-0.045(0.812)	-0.068 (0.722)	0.165 (0.383)
	25^{th} – 30^{th}	-0.146 (0.443)	-0.193 (0.308)	0.351 (0.057)
	55^{th} – 60^{th}	-0.090 (0.635)	-0.110 (0.562)	0.152 (0.424)
RMSSD	00^{th} -05^{th}	-0.215 (0.255)	-0.249 (0.184)	0.280 (0.149)
	25^{th} – 30^{th}	-0.208 (0.270)	-0.257 (0.171)	0.385* (0.043*)
	55^{th} – 60^{th}	-0.252 (0.179)	-0.289 (0.122)	0.259 (0.183)
LF	00^{th} -05^{th}	-0.211 (0.263)	-0.237 (0.208)	0.191 (0.329)
	25^{th} – 30^{th}	-0.258 (0.169)	-0.290 (0.120)	0.246 (0.207)
	55^{th} – 60^{th}	-0.352 (0.057)	-0.380* (0.038)	0.227 (0.246)
HF	00^{th} -05^{th}	-0.199 (0.292)	0.102 (0.593)	0.298 (0.124)
	25^{th} – 30^{th}	-0.188 (0.320)	0.176 (0.353)	0.123 (0.534)
	55^{th} – 60^{th}	-0.279 (0.135)	0.153 (0.421)	0.234 (0.231)

4. DISCUSSION

The present study was aimed to investigate the effect of the ICV operation on the changes in HRV and cognitive performance of the soldiers. Changes in HR, RF and various results (Table 2) of LF (ms^2) ($F_{(1.79,50.41)}$= 13.65, p= 0.000) and domains of HRV reflected the cognitive workload imposed HF (ms^2) ($F_{(1.28,37.28)}$= 15.47, p= 0.000) showed a significant change across all the time points. The pairwise comparison between the time points showed a significant workload the task performance was found to be affected by decrease (p= 0.000) from 0^{th} to 30^{th} min. in both LF (ms^2) and HF (ms^2) however, from 0^{th} to 60^{th} min. significant decrease (p=0.001) was observed only in HF (ms^2). The LF/HF ratio, decreased significantly ($F_{(1.76, 49.73)}$ = 9.82, p= 0.001) across the all the time points. Pairwise comparison of the same showed a significant decrease from 0^{th} to 30^{th} minute (p=0.002) and 0^{th} to 60^{th} minute (p=0.000) of the ICV operation with a non-significant (p > 0.05) increase from 30^{th} to 60^{th} min.

4.1 Heart Rate, Respiratory Frequency, and Heart Rate Variability

The changes in HR and RF showed an overall significant increase during the ICV operation, moreover, the pairwise comparison revealed an increase in the HR between all the three time points whereas, for RF a significant change was observed only at an initial 30 min of the trial. Thus, signifying that, the infantry soldiers were under cardiorespiratory stress (Table 2). These results reiterate similar observations obtained from the previous study[1], which showed a strong positive correlation between the ICV operation run-trial time and temperature (r=0.99) and RH (r=0.89). Besides thermal stress, the previous study[1] has also demonstrated that vibration exposure above the Eu(PA)VD standard additionally contribute to ICV operational stress, which could further exaggerate the cognitive workload.

The overall significant decrease in HRV i.e. both in the time domain (mean RR, SDNN, and RMSSD) and frequency domain (LF and HF) and its associated increase in the RF indicated the activation and prevalence of SNS activity over PSNS activity. The LF/HF ratio indicating the overall autonomic tone significantly increased in the initial 30 minutes of the ICV operation. Furthermore, the increase in HRV time frame from 25^{th} - 30^{th} to 55^{th} - 60^{th} min. in comparison with initial 30 min. i.e. 00^{th} – 25^{th} min., signifies a decrease in SNS and a concurrent increase in the vagal activity. This reversal of autonomic tone towards PSNS activity may implicate possible progression of short-term cardiorespiratory adjustment of the soldiers to the ICV operational stress, which ensued as per the demand of the present study protocol. However, prolonged ICV operation in real-time combat situation doesn't eliminate the potential risk of increased cognitive workload which could compromise the successful execution of the combat task as the effect of potential stressors like thermal stress, vehicular vibration, noise, etc continues to build up relative to the duration of the ICV operation. Hence ICV operation results in broad autonomic adjustments at the domains of RF, HR, and HRV confirming the imposed cognitive workload on infantry soldiers[25-26].

4.2 Changes in Cognitive Performance

ICV operational stress resulted in significant cognitive workload, which further influenced performance of theALCT. Results showed a significant increase in total score and net score; and a non-significant increase in the error rate with a percentage increase of 7.35 per cent, 7.17 per cent, and 29.18 per cent respectively when compared to pre-run trial. Although the ALCT showed an enhanced performance in total score and net score immediately after the ICV operation indicating a positive influence of stress on the speed of processing the task. It can be inferred that the modulation in the activities in ANS resulted in altered arousal level causing an increase in the cognitive performance up to a certain threshold. However; over-arousal to stress can lead to negative influence on the task performance which was observed in the error score, which increased by 29.18 per cent

thus reflecting the inaccuracy (selective attention) in the task performance. These observations are in corroboration with the finding of the previous studies[27-28]. Letter cancellation task involves parameters like sustained attention, selective attention, concentration, visual scanning, and activation and inhibition of rapid responses[17] revealing the functional involvement of different areas of the brain[29]. Total number of cancellations represents the measure of motor skill and speed of processing a task, net score represents a measure of sustained attention and selective attention, and the error in cancellation indicates a lack of focused attention, which is cognitive distraction and inaccuracy in a task. As a whole, the different domains of these task performances represents executive functioning of the brain, which involves exclusive participation of fronto-parietal cortex.

4.3 Correlation between Cognitive Workload and Task Performance

ALCT parameters showing a negative correlation with different HRV components reveal an association demonstrating an inverse relationship between cognitive workload and cognitive performance. Neurovisceral Integration Model explains the association between the cardiac vagal tone and cognitive functioning, the cognitive system in specific. It suggests that brain areas that are anterior, insular, and orbitofrontal cortices; amygdala; periaqueductal grey matter; ventral striatum; and autonomic motor nuclei of the brainstem are also involved in cardiac autonomic activity through vagus nerve[30]. An increase in SNS activities followed by the exposure to stressful condition resulted in the increased speed of processing as the result of increased arousal levels. However, continued reduction in the vagal tone and increase in SNS activity limits the cognitive ability to respond flexibly to stress, therefore lacking the potential to generate appropriate responses and inhibit inappropriate responses[31]. Studies including military reports[14,21,23,26,32-36] have often highlighted the complexity of increased cognitive workload often leading to a decline in the soldier's performance due to their exposure to various environmental and mechanical stressors.

5. CONCLUSION

The present study, stated that a short duration of ICV operation increased cognitive workload of the infantry soldiers and therefore, affected their performance. Consequently, it can be postulated that the process of decision-making may get affected towards successful accomplishment of the combat mission. Observations of the present study suggest that increased temperature and RH in ICV plays a vital role in increasing RF, HR, HRV, and cognitive workload in addition to operational task of the soldiers. Results derived from this methodological approach, when extrapolated to real time combat scenario, characterised by prolonged duration and unpredictable threats may exaggerate the cognitive workload many folds therefore, severely compromising the decision-making processes. The findings of this present study can be utilised as an ergonomic input to minimise thermal stress and load, which may reduce cognitive workload of the soldiers during the ICV operation.

These points should be considered during the initial stage of designing the next generation combat vehicle so as to maintain combat readiness of soldiers.

6. LIMITATIONS

The present study was limited to a relatively short duration run-trial involving a smaller sample size. Furthermore, an in-depth analysis of vehicular vibration, radiant heat, and air flow was lacking. Further studies will be undertaken to address the effect of multifaceted stress factors on cognitive workload and performance, more critically by involving larger sample size and longer duration operations.

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