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Range Firing and its Impact of Physiological Parameters

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ABSTRACT

Any task completion requires the involvement of different parts of the brain and body depending on the complexity of the task on hand. When the task is as complex as the rifle marksmanship, it involves the application of cognitive skills, motor and sensory proficiency at the same time. The cognitive state can be recorded and analysed by using EEG, ECG, and blood pressure modalities. The acquisition of core skill of firing at initial stage will induce stress, anxiety, fear, etc. in the trainees. The recordings using the modalities discussed above were done prior and post firing event in this study. The parameters of the trainees recorded prior to firing indicated the anxious, stressful state of the mind i.e. low cognitive state. The cognitive state got elevated post firing suitably indicated by the physiological parameters. This study is an aid to the armament training institutes to monitor the progress of the trainees and identifying poorly performing trainees so that suitable correction could be done at an early stage.

Keywords: Blood pressure, cognitive state, electroencephalography, heart rate variability

1. INTRODUCTION

The neuron activities of the brain, the PSNS (Parasympathetic nervous system) and SNS (Sympathetic nervous system) activities are responsible for any action of an individual[7-9]. Any act or emotion of an individual is the outcome of either an automated action without his conscious efforts (with automated commands from amygdala of the brain) or a command given by his conscious brain. The core emotions of human are anger, sadness, fear, stress, happiness, love, disgust, shame etc. All these emotional states of the brain are reflected as various physiological parameters in the form of either electrical or magnetic signals. In neuro-science fields, it is proved that these parameters can be recorded and analysed[1,2]. The range firing with any weapon or arm involves application of cognitive skills, motor and sensory proficiency at the same time[4]. The human body indicates different physiological parameters for different states of mind. Therefore, it is expected that different values of physiological parameters will be generated which can be measured for analysis before and after firing.

The aim of this study is to carry out pre and post firing analysis of various physiological parameters, which can indicate the mental or cognitive state of the subjects while handling the weapons. These analyses could be used for improving the proficiency of trainees in the armament training[3,6].

2. STATE-OF-THE-ART TECHNOLOGY

The physiological signals reflect change in the mental state of an individual in the form of either magnetic or electrical signals. The biological signals are detected by many methods such as CT scan, functional Magnetic Resonance (fMRI), Heart rate variability (HRV), Electroencephalography (EEG), blood pressure (BP), etc[5-7,14]. To study the parametric changes which take place pre and post firing, we have focused on EEG, HRV and blood pressure modalities because of their cost effectiveness, easy field employability and applicability for this study.

2.1 Electroencephalography

Mental states are reflected most effectively in the form of EEG signals which are electrical signals of very small amplitude in the range of micro volts. The EEG basically measures the electric signals which are generated by inhibitory and excitatory potentials of postsynaptic. The obtained EEG signals can be divided into various frequency bands for analysis[4,6].

2.2 Heart Rate Variability(HRV)

The Sino-Atrial (SA) receives different inputs generated by the different activities of an individual. The different activities involve all the actions right from waking up till sleep. Due to these various inputs, the instant heart beat is generated. The HRV measures the time duration between these heart beats. All the activities of an individual are contributed by the sympathetic and parasympathetic nervous system. The sympathetic activity symbolises fight or flight response and rest and digest are the parasympathetic activity. Therefore HRV has been used as one of the indices of cognitive state[7-10].

2.3 Blood Pressure

The force of the blood in the arteries wall is termed as Blood pressure. It measures two events, viz. diastolic the pressure when the heart is relaxing i.e. at rest between heart beats, and the systolic i.e. the blood pressure when the heart is

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pumping blood causing heart beats. The cycle of systolic and diastolic blood pressure is affected by different cognitive states of the brain thus can be a useful cognitive indicator[14].

3. MATERIAL AND METHOD

3.1 Subject

The participants in the study were from one of the armament training institutes. A total of 22 subjects participated voluntarily in the study. The armament training does not involve only weapon training directly, instead it involves the physical toughening, general awareness, and the classroom theory of various weapons and of the firing practice with the weapons.

3.2 Method

Before recording, the subjects have finished the class room studies of different weapons and couple of firing sessions with the weapons but the trainees have not reached a stage where they could be termed as experts. The time of recording was chosen such that the subjects were going to be assessed for their accuracy in the firing of the weapon for the first time. And of course, the fatigue of range firing and the mental strain of the evaluation were causing stress and anxiety amongst the subjects.

One set of recording of EEG, HRV and blood pressure was carried out on subjects just before the start of firing event and the other set of recording immediately after they have finished their firing. On each occasion, the duration of the recording was for five minutes.

3.3 Recording Procedure

For recording the EEG data and HRV data BIOPAC MP150 Systems were used[13]. The MP 150 system simultaneously supports the recording of EEG with a cap (21Electrode) connected to 10 modules and the five electrode recording of HRV data with three modules. The data recording was done simultaneously for 5 minutes. The MP150 system has both the hardware and software for data recording. The blood pressure was recorded with a digital sphygmomanometer of citizen micro human tech (Model No. CH-432B).

3.4 EEG Recording

The cap used for EEG covers the entire brain. The frontal part is covered by electrodes FP1, FP2 ,F3, F4, F7, F8, and FZ, central part by electrodes C3,C4, and CZ , parietal area by electrodes P3, P4, and PZ, occipital area by electrodes O1 and OZ, temporal part by electrodes T3, T4, T5, and T6 and two earlobe electrodes A1 and A2[5,6,13]. The raw EEG data was amplified with a gain of 10000 using built in feature of BIOPAC MP 150 system. To derive the desired frequency band of delta (up to 4 Hz), theta (4 Hz to 7 Hz), alpha (8 Hz to 12 Hz), beta (12 Hz to 30 Hz) and gamma (30 Hz to 100 Hz), the amplified EEG signal was band pass filtered in the range 0.1 Hz to 100 Hz .The acquired data was collated and the mean of amplitudes of all the parameters of the subjects was calculated.

3.5 HRV Recording

Five electrodes (One electrode each for left arm, left leg, right arm, right leg, and chest) connected with 03 modules of MP 150 system along with EEG modules were used for recording HRV data. Frequency domain analysis, time domain analysis and geometric analysis were done for the recorded data.QRS detector (a modified pan tompkins detector) was used for extracting RR intervals.The frequency information was extracted by re-sampling. A welch periodogram was used to determine the power spectral density. The PSD of very low frequency, low frequency, high frequency components have been calculated along with vagal, sympathetic and sympathetic vagal balance parameters[10,13].

Time domain analysis was carried out using cubic spline interpolation. The derived time domain parameters are mean RR interval (in seconds), mean heart rate (in second), RMSSD (square root of the mean of the sum of the squares of differences between adjacent NN interval in millisecond.), NN50 (The number of pairs of successive NNs that differ by more than 50 ms in units of count.) and pNN50 (percentage of difference between adjacent NN intervals that are greater than 50 ms.). Along with time domain analysis, RR triangular index and TINN (triangular interpolation of NN interval histogram in millisecond) of geometric parameters were also determined[9].

3.6 Blood Pressure

For blood pressure, we have taken three readings which were averaged for the study.

4. RESULTS

The marksmanship of arms i.e. rifle weapon is a very skilful activity which requires the application of cognitive and motor skills simultaneously. The firing activity will cause fear, anxious moments, and stress of acquiring good precision in the firing i.e. low cognitive state. The low cognitive state as we presume prior to firing is expected to be reflected in the physiological parameters. These parameters might change after finishing the firing session. The control of the changes in the physiological parameters prior to firing could help in improving the accuracy during firing[4].

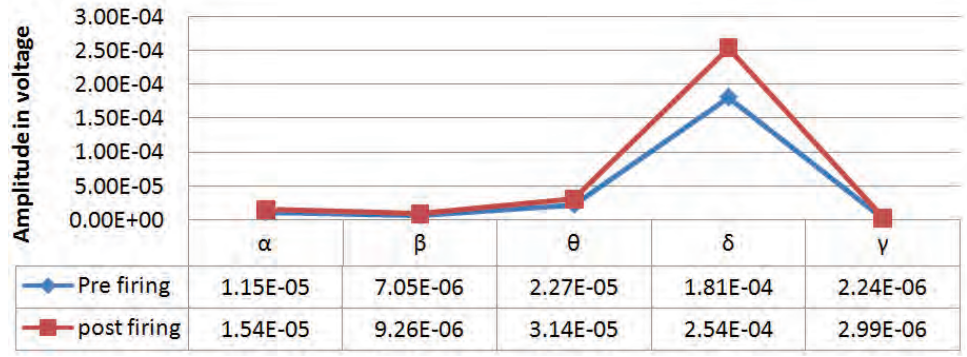
4.1 EEG Analysis

In our study, unlike prevailing in most of the studies where certain parts of the brain are only studied, we have studied the entire brain area i.e. frontal (channel 1, channel 2, channel 6), central (channel 3), occipital (channel 5), parietal (channel 4) and temporal (channel 7 and channel 8) areas of the brain.

The trend of the mean amplitudes of the parameters (alpha, beta, theta, delta and gamma) for channels from 1 to 10 of EEG has been shown in the figures from 1 to 5 for both prior and post firing event. As evident in the Fig. 1, the amplitudes of all the parameters of channel 1of EEG which covers the left frontal part of the skull were low before the firing and which got elevated post firing .The right frontal part of the brain is covered by the electrodes of the chanel 2.The amplitudes of all the EEG parameters viz. alpha, beta, theta, delta and gamma of channel 2 were higher prior to firing and got lowered post firing. These two trends of parameters indicate the lack of skills of the subjects in rifle marksmanship[4,6,11,12].

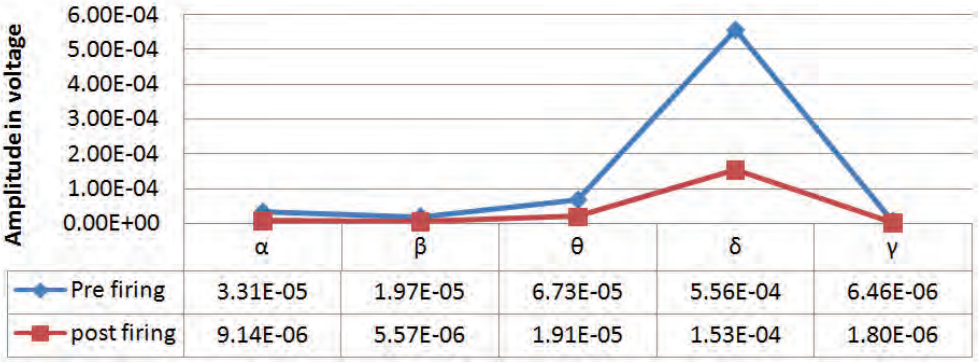
Fig. 2 indicates trends of amplitudes of EEG parameters of channel 3 and 4. Amplitudes of EEG parameters of central

Channel 1



	α	β	θ	δ	γ
Pre firing	1.15E-05	7.05E-06	2.27E-05	1.81E-04	2.24E-06
post firing	1.54E-05	9.26E-06	3.14E-05	2.54E-04	2.99E-06

Channel 2



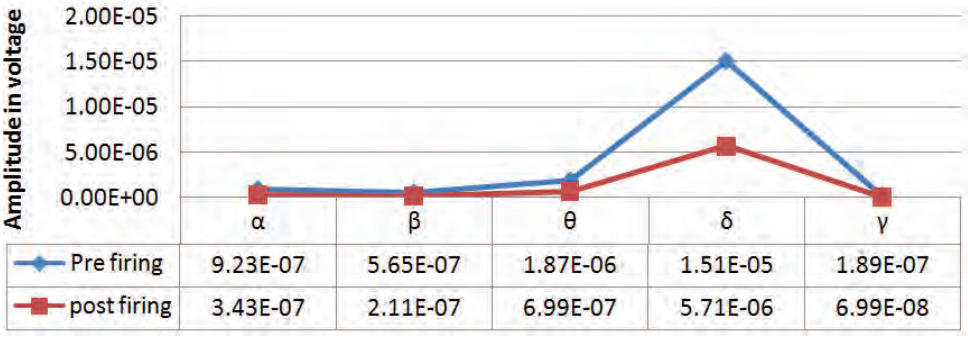
	α	β	θ	δ	γ
Pre firing	3.31E-05	1.97E-05	6.73E-05	5.56E-04	6.46E-06
post firing	9.14E-06	5.57E-06	1.91E-05	1.53E-04	1.80E-06

Figure 1. Trends of amplitudes of alpha, beta, theta, delta and gamma parameters of EEG recorded prior and post firing i.r.o. channel 1 and channel 2.

location (channel 3) have decreased post firing. It indicates the release of stress on the subjects post firing. The channel 4 covers the parietal region of the brain and amplitudes of all the parameters of EEG have increased post firing. The increased amplitudes in the parietal region are related with lack of skills and decision making[4,6,11,12].

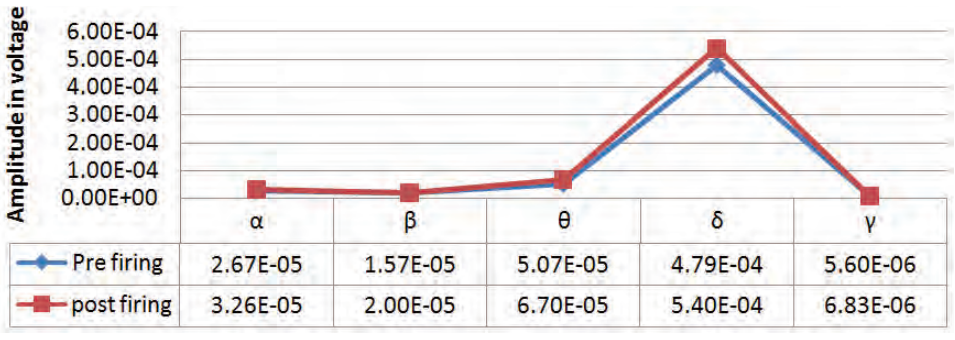
The trends of parameters of channel 5 and 6 are displayed in the Fig. 3. In both the cases the amplitudes of the EEG

Channel 3



	α	β	θ	δ	γ
Pre firing	9.23E-07	5.65E-07	1.87E-06	1.51E-05	1.89E-07
post firing	3.43E-07	2.11E-07	6.99E-07	5.71E-06	6.99E-08

Channel 4



	α	β	θ	δ	γ
Pre firing	2.67E-05	1.57E-05	5.07E-05	4.79E-04	5.60E-06
post firing	3.26E-05	2.00E-05	6.70E-05	5.40E-04	6.83E-06

Figure 2. Trends of amplitudes of alpha, beta, theta, delta and gamma parameters of EEG recorded prior and post firing i.r.o. channel 3 and channel 4.

parameters have decreased post firing. The decrease in the parametric values of EEG in the occipital region is associated with reduction of anxiety, tension, etc which had occurred after the firing[4,12].

Figure 4. shows the trends of parameters i.r.o. channel 7 and 8. In both the cases, the amplitudes of EEG parameters (alpha, beta, theta, delta and gamma) have shown decreasing trend from prior to post firing. It definitely indicates the release of stress on the subjects in post firing recording.

The trends of parameters of channel 9 and 10 of EEG are displayed in Fig. 5.The amplitudes of the parameters have

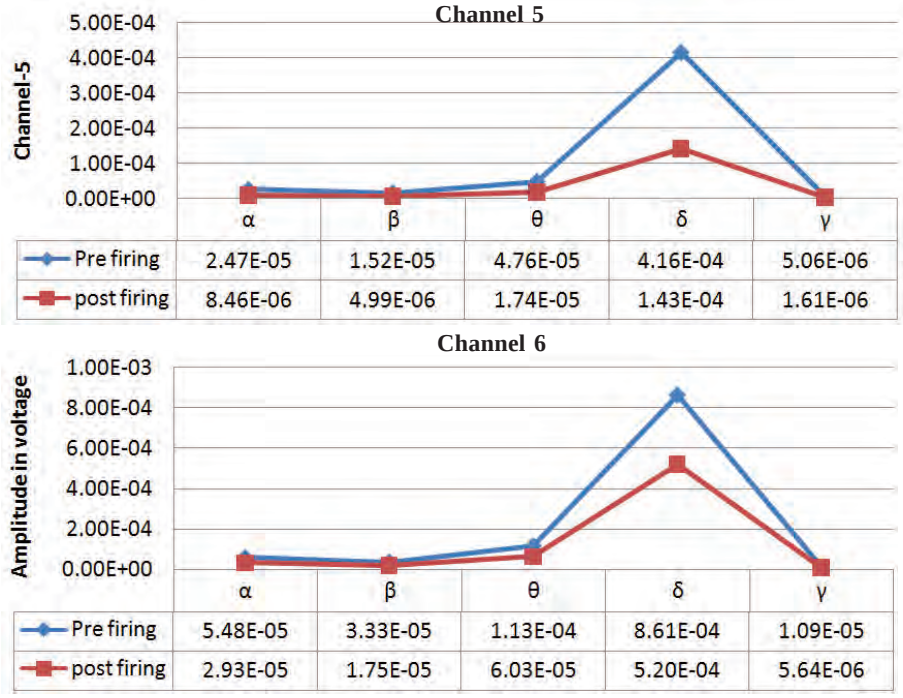


Figure 3. Trends of amplitudes of alpha, beta, theta, delta and gamma parameters of EEG recorded prior and post firing i.r.o. channel 5 and channel 6.

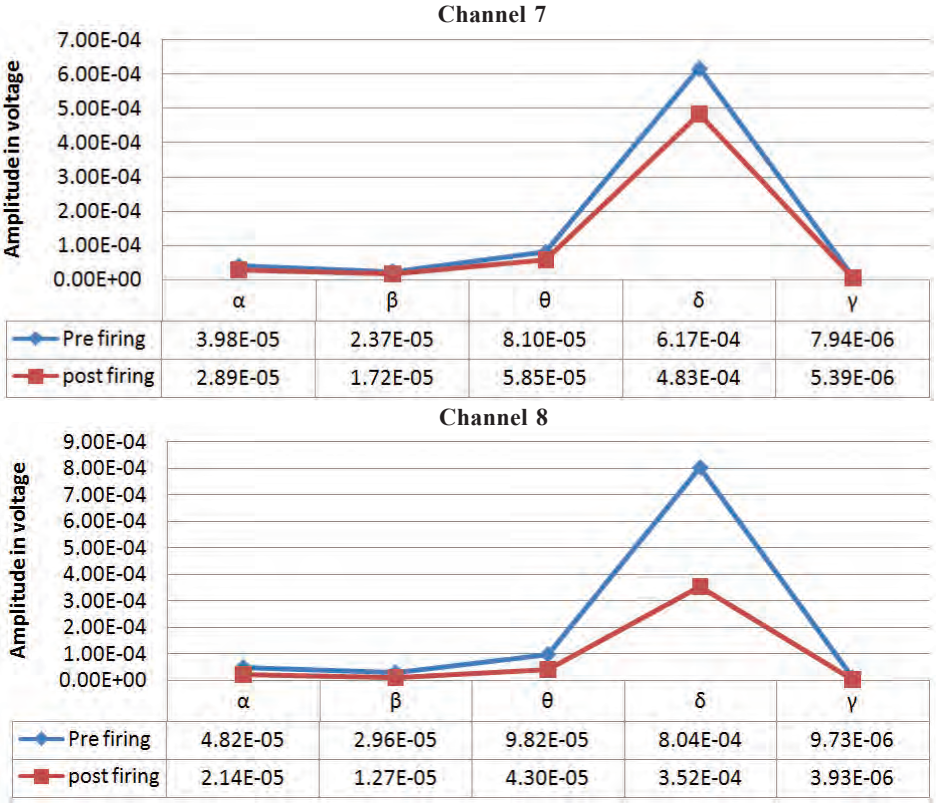


Figure 4. Trends of amplitudes of alpha, beta, theta, delta and gamma parameters of EEG recorded prior and post firing i.r.o. channel 7 and channel 8.

negligibly changed of channel 9 and 10 indicating its little role in the cognitive-motor engagement.

4.2 HRV and Blood Pressure Analysis

For frequency domain analysis, the recorded raw HRV signal was decomposed in the following frequency bands: Very low frequency (VLF) range below 0.04 Hz, low frequency (LF) range 0.04 Hz – 0.15 Hz, high frequency (HF) range 0.15 Hz - 0.4 Hz and very high frequency (VHF) range above 0.4 Hz. Along with this the sympathetic, vagal and sympathetic vagal balance were also calculated[8-10,13]. The power spectral density of all the parameters in ms^2 was calculated. The results of the frequency domain analysis are shown in the Fig. 6.

The VLF PSD has not changed significantly from pre to post firing. As such the VLF PSD for a recording of 5 min is less significant[9]. The LF, HF and VHF PSD parameters

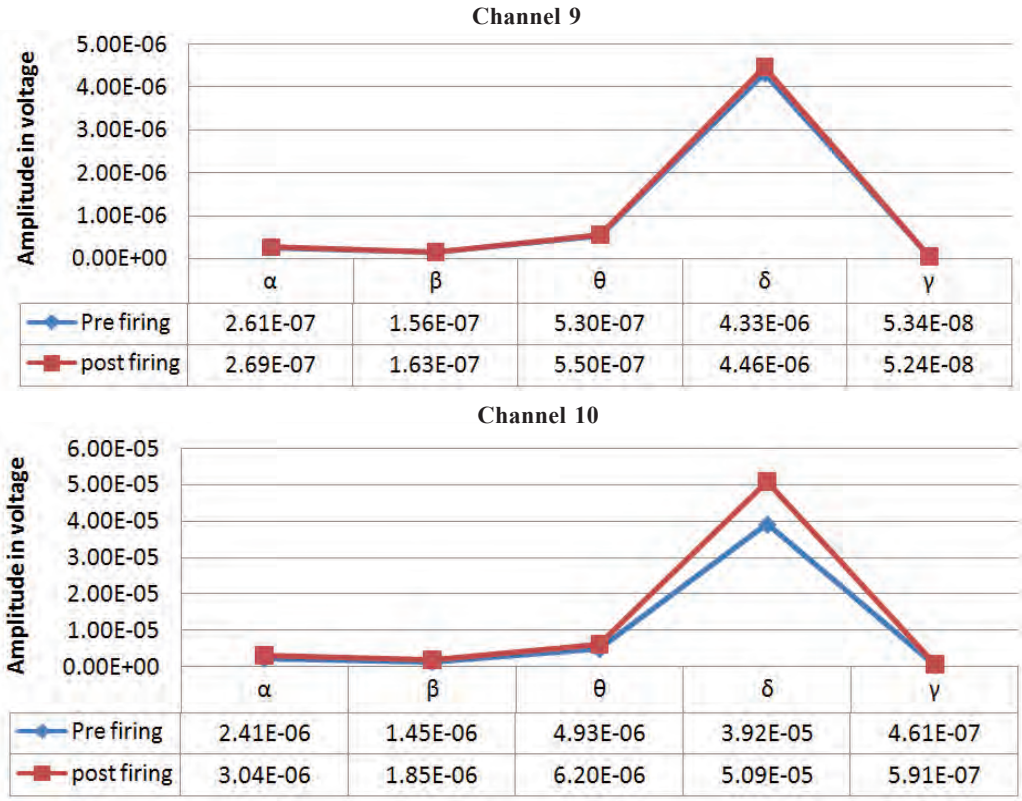


Figure 5. Trends of amplitudes of alpha, beta, theta, delta and gamma parameters of EEG recorded prior and post firing i.r.o. channel 9 and channel 10.

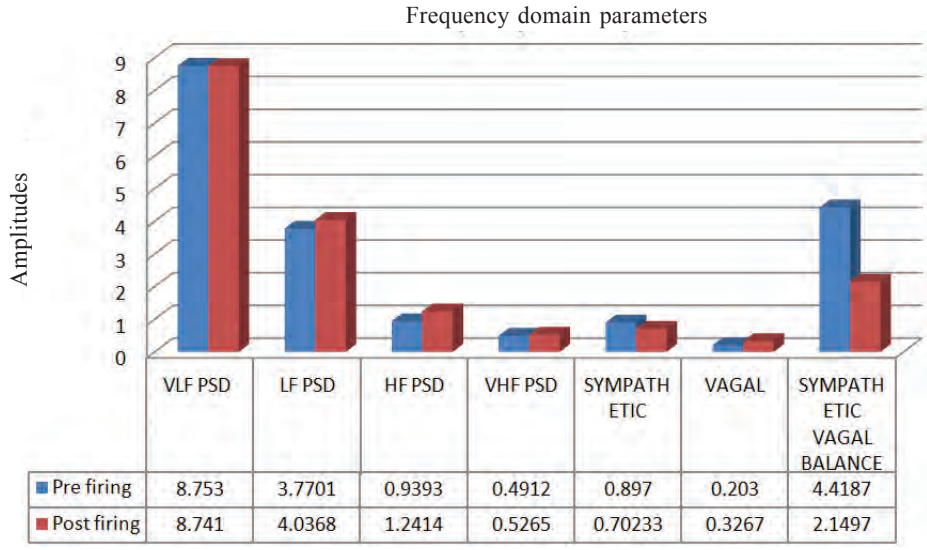


Figure 6. The trend of frequency domain parameters viz. VLF, LF, HF and VHF PSD in ms^2 and sympathetic, vagal parameter and the ratio of sympathetic and vagal balance i.r.o. pre and post range firing events.

have increased post firing[12]. The increase in these parameters indicates that there was tremendous stress, nervousness and tension prior to firing which was relieved post firing. The HF component is particularly directly related with vagal activity. The sympathetic parameter is an indication of fight or flight response i.e. fretfulness, anxious states of mind. That is why it was higher prior to firing and reduced after the firing. On the contrary, the vagal parameters signify the rest and digest process. It means that the lower levels of these parameters prior to firing positively indicated the fearful states of mind, which got relaxed post firing indicated by the increase in the vagal parameter. Correspondingly, the ratio of sympathetic and vagal parameters was higher before firing and it reduced after the firing. This ratio is more often used as an indication of the state of the mind[9].

4.3 Trend Analysis (Time Domain Analysis and Geometric Analysis)

The trend of the time domain, geometric and blood pressure parameters are shown simultaneously in Fig. 7. The mean RR interval and the mean heart rate (HR) parameters have not shown any significant change during the event of firing. The RMSSD, pNN50 and TINN parameters have shown decreasing trend whereas NN50 has shown increasing trend. Apart from this, the RR triangular index has not changed significantly. All these parametric changes indicate that all the subjects were psychologically under stress prior to range firing and the stress got relived subsequent to the firing[12]. As shown in the figure, the systolic and diastolic blood pressures were initially high prior to firing. This got reversed following the completion of firing task again indicating reduction in the stress level[14].

5. CONCLUSION

The rifle marksmanship involves various steps i.e. the classroom teaching, weapon handling, practicing the firing in the field. It is a very skilful activity involving the application of cognitive and visio-motor skills simultaneously. The firing task will cause tense, anxious and stressful moment in the subjects since they are in the process of acquisition of the expertise. The subjects will have reduced speed and accuracy as well.

The results of the EEG, HRV and blood pressure have indicated that there was tremendous stress on the subjects prior to firing. The parametric changes after the firing have revealed the release of the stress on the subjects. Also the increase of amplitudes in the left frontal area and reduction in the right frontal area is an indication of lack of the skills in the subjects. The lack of proficiency in the subjects is also suggested by the increase of amplitude of EEG signals in the parietal area of the brain.

The parametric changes in the sympathetic and vagal (parasympathetic) parameters have also underlined the tension on the subjects prior to firing which got reduced post firing.

This study should help the armament training institutes to monitor the progressive changes of the trainees i.e. their transition from novices to experts. And if some individual is underperforming in the peer group then a suitable intervention can be done.

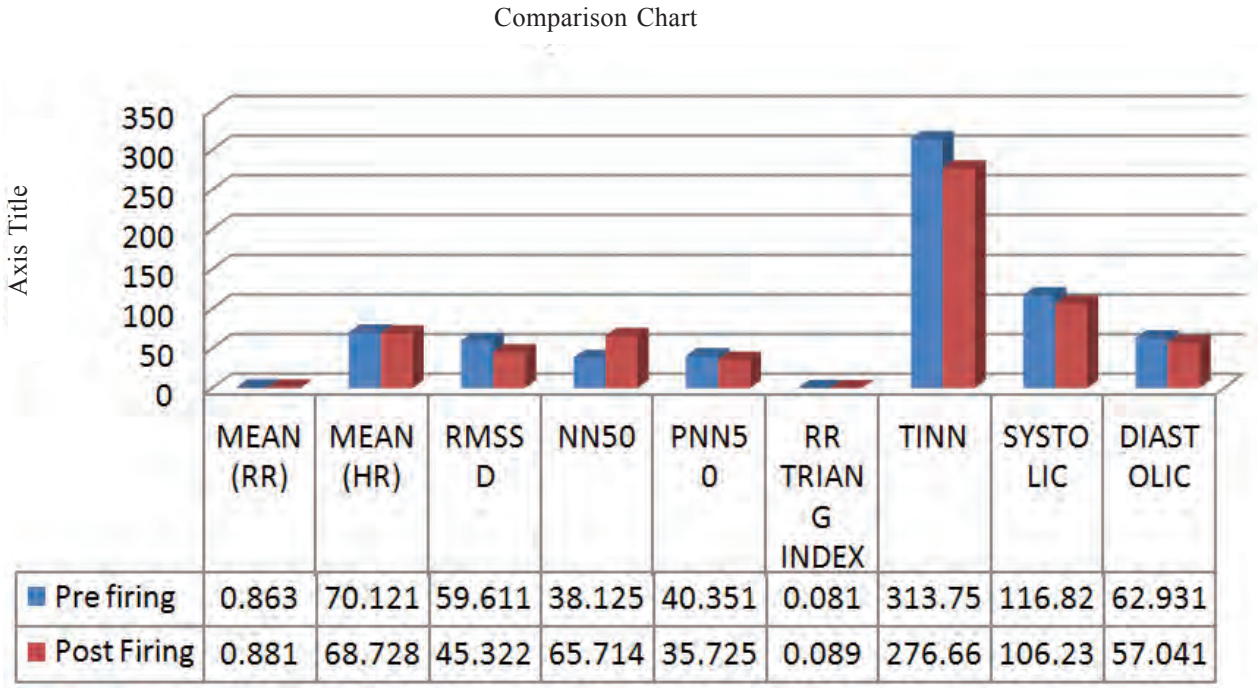


Figure 7. The time domain parameters viz. mean RR interval in sec, mean HR in seconds, RMSSD in ms, NN50 in units of count and pNN50 in % are shown in the figure. The geometric parameters viz. RR triangular index and TINN in ms are also displayed along with systolic and diastolic blood pressure inn mm of Hg.

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