Autonomic and cortical response of soldiers in different combat scenarios

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ABSTRACT

Introduction The study of chronic and acute responses when exposed to extreme, aggressive and stressful environments, such as in combat environments, is becoming increasingly popular as such information leads to better optimisation of soldiers’ physical and psychological performance, as well as mission effectiveness and efficiency. Due to internal complexity, uncertainty and variability of real combat scenarios, a specific approach to all possible types of military combat scenarios is necessary.

Methods Modifications in the autonomic modulation and cortical arousal before and after asymmetrical, symmetrical and close quarter combat simulations were analysed in 31 male professional veteran soldiers (age: 34.5±4.2 years) with between seven and 18 years of experience in their respective units, as well as experience in international missions in current conflict areas such as Lebanon, Afghanistan, Bosnia, Kosovo and Iraq.

Results The three combat situations produced a non-significant decrease in cortical arousal after combat simulations, presenting a trivial effect size in symmetrical and close quarter combat situations and a small effect size in asymmetrical situations. HR increased significantly in the three combat situations, and close quarter combat produced the highest sympathetic modulation of the three situations analysed.

Conclusion Symmetrical, asymmetrical and close quarter combat situations produced an increase in sympathetic modulation, being highest in the close quarter combat situation, where actions are performed at a close distance and in closed spaces.

INTRODUCTION

In actual theatres of operations, soldiers have to deal with a highly stressful and threatening environment, where asymmetrical conflicts predominate, being characterised by continuously evolving urban confrontations and with the presence of civilians. This context induces overstimulation among soldiers as a result of constantly changing characteristics of the environment, with soldiers needing to be always prepared for unexpected attacks or close quarter combat.1 This new scenario combines the characteristics of symmetrical and close quarter combat, both of which have unique characteristics and demands that soldiers have to face,2 which makes the study of internal characteristics and organic responses in each scenario an essential key factor to appropriately prepare soldiers for deployment.3 Studies on military populations have focused on analysing decision-making processes,4,5 the strategic asymmetry of the current battlefields, the coordination systems between different units of an army within the battlefield,6 or the coordination between combat functions and sophisticated weapons system.7 Other authors have focused on soldiers’ organic response in combat, and on body composition,8 muscle power,9,10 maximum strength11 or oxygen consumption parameters12 in combat-related task. Recently, several studies have focused on analysing the psychophysiological response of soldiers in a combat simulation, finding an increase in metabolic, cardiovascular and muscular response,13 as well as an acute cognitive impairment and memory loss directly related to psychophysiological activation.14 This is related to the overstimulation of the brain induced by all possible stimuli that soldiers may identify as a possible life threat, activating the flight-flight phylogenetic defence system and enhancing a large cholinergic and adrenergic response.2 In line with this, chronic exposure to stressful combat situations is one of the factors related to post-traumatic stress disorder (PTSD), an anxiety disorder causing different physiological responses, such as elevated HR, increased BP and depressed HR variability (HRV).15

Key messages

► Fatigue of the central nervous system leads to a delay in the processing of information, incorrect decision-making, and attenuation in working memory and attentional focus.
► In this study, a reduction in cortical arousal values was found, which was greater in asymmetrical combat situations, where the soldier’s brain is highly overstimulated.
► High sympathetic modulation evaluated in combat situations was related to lower operational performance in high-stress situations and to pathologies such as post-traumatic stress disorder; thus, interventions that allow improvement in autonomic modulation before and during deployment could be highly beneficial to military personnel’s health.
► The results obtained from this study improved knowledge on the psychophysiological response of soldiers in different combat scenarios, which is highly important as new combat scenarios are evolving.
► Other tactical athletes who predominantly experience stress in their duty as firefighters, police as well as private security corps could benefit from the results of this study.
The control of cardiovascular autonomic and cortical response in this population has previously been studied by some authors, showing an increased sympathetic response and cortical arousal downregulation, and with this response causing negative effects on cortical functions such as memory or body perception. Understanding how acute combat stress may affect cortical arousal and the autonomic nervous system in different combat scenarios is essential to develop more adaptive and operative training models, a necessity that is supported by the latest research in this field. Thus, the aim of this research was to analyse the autonomic and cortical response of professional soldiers in asymmetrical, symmetrical and close quarter combat situations. The initial hypothesis was that situations that involved close quarter combat would produce higher symptomatic modulation.

METHODS

Participants

Thirty-one male subjects from the Spanish Army (age: 34.5±4.2 years, height: 176.4±8.4 cm, weight: 74.6±8.7 kg, 63.3±8.0 kg muscle mass, 7.6±3.2 kg fat mass) were analysed. Soldiers had between seven and 18 years of experience in their respective units, as well as experience in international missions in current conflict areas such as Lebanon, Afghanistan, Bosnia, Kosovo and Iraq. While in combat, soldiers were fully equipped with official uniform, boots, and all combat equipment such as bullet-proof vest, helmet, firearm, assault rifle, knife, shackles or bridles, and a combat backpack weighing 12 kg and containing antifragment, vest, helmet, firearm, assault rifle, knife, shackles or bridles, and other basic equipment. The total weight of the team of each soldier was 23.6 kg.

Measures and instruments

Prior to starting the research, the experimental procedures were explained to all soldiers. The following variables were evaluated before and immediately after each of the three combat situations (asymmetrical, symmetrical and close quarter combat):

- Cortical arousal, measured by the critical flicker fusion threshold (CFFT) according to previous research.
- Cardiovascular response by HR and HRV, monitored with a Suunto band (Suunto, Vantaa, Finland), with a sampling frequency of 1000 Hz. Using this band, the R-R intervals (time interval between the R waves on ECG) can be analysed to evaluate HRV and the number of beats per minute to evaluate HR. Before the first combat simulation, while the soldiers were on their waiting base, 20 minutes of their time were taken to examine their HR and HRV baseline levels. During the three combat situations, the HR and HRV parameters of each soldier were analysed as in previous research. Subsequently, the following parameters of HRV time domain were analysed using the Kubios HRV software program (University of Kuopio, Kuopio, Finland): HR; mean NN, mean of all R-R intervals; SDSD (ms), SD of the difference between consecutive R-R intervals; RMSSD (ms), square root of the mean of the squared differences of all successive R-R intervals; and SDANN (ms), SD of the average of R-R intervals corresponding to every five minutes.

Design and procedures

Considering actual combat scenarios that other authors have described, the research procedures were divided into three different situations, carried out on non-consecutive days with at least three days of rest in between. In the first scenario, soldiers had to face an asymmetrical combat situation in an urban area. The second one is a traditional symmetrical combat situation. The third scenario is a close quarter combat in a melee situation. The following tasks were designed by military officers in charge of preparing the soldiers for combat, replicating real warfare/combat scenarios and situations.

Asymmetrical combat in an urban area

Simulation was set in a populated urban area (market), where the tactical team received orders to perform a direct action to arrest an insurgent. In order to find him, soldiers had to identify three buildings where the insurgent may be hiding, according to the information given to them. To identify the buildings and to capture the insurgent, soldiers were divided into five units with four soldiers each. All units were located in a waiting base outside the urban area. An officer picked the soldiers up at the waiting base and took them to the urban area to start the operation.

In the first building, there was a warehouse where soldiers found two native individuals who collaborate with the ally’s forces but do not understand their language. The second building was a typical Middle East house with three rooms, where there were two subjects (none of them understands the language of the unit). The first subject collaborates but carries a hidden weapon, while the second subject shouts hysterically frightened by the presence of the unit. The third building has a three-room house in demolished condition. An insurgent is found inside and opens fire at the unit and launches himself against them, an incidence that the unit had to solve by firing and neutralising him using close quarter combat techniques. Further exploring the building, soldiers found the wanted insurgent and his wife, both without any weapon or showing any possible threat to the unit. Finally, the soldiers had to evacuate and protect the insurgent from an attack carried out by a civilian mass (hostile to the insurgent) that recognises him and attempts to attack him.

Symmetrical or traditional combat

In this simulation, soldiers were divided into five units with four soldiers and must take a defensive position. Concealment smoke was used as a barrier for a duration of five minutes, facilitating their movement until they arrive at their defensive positions, with no restrictions on the use of weapons as dictated by circumstances.

Each soldier had to pass the following obstacles:

- Sprint of 100 m.
- Triple stair bar obstacle (final height of 1.80 m).
- Obstacles over watercourse (an inclined bridge broke with a light of one metre and balance bars of four metres).
- Descent on a moat using a ramp and a climb of four metres.
- Step on low barbed wire of eight metres.

After passing these obstacles, the unit had to clean a trench under the following conditions:

- A local subject that collaborates with the unit but with a hidden weapon.
- A local subject armed with a rifle that does not understand the language of the unit but seems to collaborate.
- A local subject who is sitting crying but has an assault rifle on his knees.
- A local subject trying to assault the unit with a knife at a distance of five metres.
- A local subject that attacks the unit with a knife.
The unit then had to reduce an insurgent who was inside the trench praying, without opposing any resistance. Thus, appropriate use of force was necessary.

Close quarter combat
In this situation, soldiers were organised into 10 teams with two soldiers each and were advised that a unit of insurgents were gaining access to the military facility. At the moment they were informed, the soldiers did not dispose of any weapons; therefore, in case of an incident, the soldiers would have to use an appropriate force with their bare hands. Before the simulation, the unit was subjected to a physical and psychological activation, composed of three series of 10 explosive jumps and 20 push-ups while subjected to a stressful situation, being shouted at and demoralised by the instructors. Immediately after, an insurgent equipped with the ‘Black Man personal protective equipment’ (equipment designed to prevent the subject from being damaged, being totally protected against shocks or pressures) would enter the simulation and attempt to attack the soldiers. This simulation was conducted in low-light conditions, and soldiers had to arrest the opponent without using firearms or any other weapon.

Data analysis
Data were analysed using the SPSS V.22.0 statistical package. First, normality of the sample was determined using the Kolmogorov-Smirnov test. Given that all variables fulfilled the hypothesis of normality, an analysis of variance was carried out using Bonferroni post-hoc test. The effect size was evaluated using the Cohen’s d test. For all comparisons, a significance index of p<0.05 was accepted.

| Table 2 | HRV parameters in the three scenarios evaluated |
|---------|--------------------------------------------------|
|         | Basal | Asymmetrical combat | ES Asymmetrical combat vs basal | Symmetrical combat | ES Symmetrical combat vs basal | Close quarter combat | ES Close quarter combat vs basal |
| HR (bpm) | 64.2±15.9 | 140.0±9.6 | 126.2±11.0 (0.019)* | - | 131.9±10.7 (0.011)* | - | 
| Mean NN (ms) | 872.8±150.4 | 450.9±93.7 | 491.9±74.8 (0.022)* | 7.90 | 5.64 | 407.9±62.8 (0.037)* | 6.33 |
| SDSD (ms) | 122.9±83.9 | 121.2±92.5 | 134.4±72.6 | 0.02 | 0.16 | 89.0±45.7 (0.042)* | 0.74 |
| RMSSD (ms) | 234.0±166.1 | 208.3±130.3 | 214.6±124.6 | 0.20 | 0.16 | 166.1±85.3 (0.036)* | 0.80 |
| SDANN (ms) | 435.3±73.3 | 151.2±117.0 (0.021)* | 2.43 | 227.7±45.3 (0.029)* | 4.58 | - | - |

RESULTS
CFFT non-significantly decreased after three combat situations, presenting a trivial effect size in symmetrical and close quarter combat situations and a small effect size in asymmetrical situations (Table 1).

The HR values increased significantly in the three combat situations with a large effect size. The mean NN values decreased significantly with a large effect size in the three combat scenarios analysed with respect to the basal sample, as well as SDANN (Table 2).

DISCUSSION
The aim of this research was to analyse the autonomic and cortical modification responses of professional soldiers in asymmetrical, symmetrical and close quarter combat situations. The initial hypothesis was confirmed since the results have shown higher sympathetic modulation in close quarter combat situation.

Of the three scenarios evaluated, the asymmetrical scenario presented the highest cardiovascular response, although movements in this context are characterised by lower speed compared with symmetrical and close quarter combat scenarios. This may be due to the fact that in urban areas a greater number of stimuli must be controlled in a relatively short period of time, which can cause this overstimulation and episodes of anxiety, resulting in increased HR. In the HRV analysis, the decrease in the different parameters of time domain corresponded to an increase in sympathetic activity. The increase in sympathetic activity is related to the activation of the flight-fight system, which prepares an individual to deal with any possible threat.

In line with this, the close quarter combat simulation showed higher sympathetic activation, showing how short-distance combat situations performed in close contexts produce greater sympathetic activation than in combats carried out in open places, where threats are easier to predict and control. In addition, the high sympathetic modulation evaluated in combat situations was related to lower operational performance in high-stress situations in soldiers and to pathologies such as PTSD, since the veteran soldiers with this pathology showed higher sympathetic modulation than subjects without this...
pathology. Intervention programmes that allow soldiers to improve autonomic modulation before and during deployment could be beneficial, preventing them from developing these disorders.

The response of soldiers in these extreme stress situations is going to be highly influenced by the previously learnt action and procedures which have been recorded in their neuromuscular motor memory, these being autonomically activated and processed by superior cortical systems. This is especially important in situations where soldiers have to face friend-foe discrimination, armed-disarmed subjects or soldiers-non-soldiers. The rise in sympathetic modulation increases pupillary contraction, facilitating focus on a single element that the soldiers. The rise in sympathetic modulation increases pupillary contraction, facilitating focus on a single element that the soldier considers a dangerous situation, which would explain the loss of peripheral vision characteristic of the so-called ‘tunnel effect’.

The information control process in these scenarios is basic to soldiers’ survival and operations, and taking into account the effect of sympathetic hyperactivity on cortical status, the analysis of autonomic and cortical response allows for a better comprehension of these systems in stressful context. The decrease in the CFFT values below the baseline levels recorded in the three combat situations has previously been determined to be related to a state of fatigue of the central nervous system and a decrease in the processing of information. Previous research has found that stressful situations reduce attention and memory. The decrease in cortical arousal could be due to the inclination of the combatant to perform operating procedures that have been overlearnt or where they are well trained for and that require less cognitive effort, and thus maximise their performance at a minimum cost of cognitive resources. However, how fatigue of the central nervous system is due to overstimulation that the soldier suffers during combat has been shown. Within these three combat situations, the greatest decrease in CFFT occurred in the asymmetrical combat situation, where there is a great number of uncertainties (such as windows, holes, changes in light, civilians, children or any other threats) that the brain could interpret as possible elements from which a hostile response or threat can arise, and therefore the integrity of the subject can be endangered. This situation could cause a state of anxiety in which the brain is over-stimulated, causing symptoms of fatigue of the central nervous system. Other stressful military contexts such as air combat jet manoeuvres, air mobile protection teams in an air accident manoeuvre, control of checkpoints, assault manoeuvres with chemical, biological, radiological and nuclear personal protective equipment, and other melee actions different from those evaluated in the present research also elicited a large cortical demand, but asymmetrical combat remains the most demanding one.

Limitations and future lines of research

The small number of subjects analysed is one of the main limitations of the present work, and with a greater number of participants more reliable results could be expected, especially with regard to CFFT. However, the impossibility of recruiting soldiers with operational experience limited this investigation. Another limitation was the use of indirect cortical measurement instruments, such as the flicker fusion system. Logistical and economic difficulties limited the use of more modern systems, but the fact that evaluations were conducted in manoeuvre fields and simulated war zones made the use of other instruments nearly impossible.

Practical applications

The results of the study highlight the psychophysiological response of soldiers in different combat scenarios, which is highly important as new combat scenarios are evolving. To our knowledge no previous combat evaluations comparing all types of military combat scenarios have been assessed. Yet the application of this information would lead to better optimisation of training of soldiers, either physical and psychological. Other tactical athletes who predominantly experience stress in their duty as firefighters, police as well as private security corps could benefit from the results of this study.

CONCLUSION

Symmetrical, asymmetrical and close quarter combat situations produced an increase in sympathetic modulation, being higher in close quarter combat situations, where actions are performed at a close distance and in closed spaces.

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Contributors

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Competing interests

None declared.

Patient consent for publication

Not required.

Ethics approval

All soldiers gave their voluntary written informed consent in accordance with the Declaration of Helsinki. The procedures conducted in the present research were designed and approved by the headquarter of the unit and approved by the University Ethics Committee (ro: CIPI/18/093).

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Data availability statement

All data relevant to the study are included in the article or uploaded as supplementary information.

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