

Psycho-physiological response of soldiers in urban combat

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Título: Respuesta Psico-fisiológica de soldados en combate urbano.

Resumen: Los actuales conflictos armados son asimétricos y se caracterizan por desarrollarse en zonas urbanas. Estos nuevos requerimientos del combate han sido poco estudiados por la literatura actual. El objetivo de este estudio fue analizar los cambios en la activación cortical, lactato sanguíneo, fuerza muscular, modulación autonómica y percepción subjetiva de esfuerzo en una simulación de combate urbano. Se analizaron 20 soldados antes y después de la simulación de combate.

Los resultados muestran como en este tipo de combates se produce una alta estimulación del sistema nervioso simpático, que produce un aumento de la fuerza muscular, la frecuencia cardíaca y la concentración sanguínea de lactato de los combatientes. A pesar de ello, la percepción subjetiva de esfuerzo de los combatientes no es acorde a la respuesta fisiológica que presentaron, siendo esta percepción subjetiva de esfuerzo inferior a la respuesta fisiológica evaluada. Además el procesamiento de la información y la activación cortical disminuyen después de realizar las tres simulaciones de combate.

Estos resultados ponen de manifiesto la respuesta psico-fisiológica de los combatientes durante el combate, ayudando así a su mejor comprensión y posibilitando una mejora de los actuales métodos de entrenamiento de los combatientes.

Palabras clave: Combate; activación cortical; estrés; fuerza; sistema nervioso simpático; frecuencia cardíaca.

Abstract: Current armed conflicts are asymmetrical and are developed in urban areas. These new requirements have not been studied for current literature. The aim of this study was to analyse changes in cortical arousal, blood lactate, muscle strength, autonomic modulation and rate of perceived exertion in a simulated urban combat. We analyzed 20 soldiers before and after an urban combat simulation.

The results showed how urban combat produced high sympathetic nervous system activation, increasing the muscle strength, heart rate and blood lactate concentration of the soldiers. Despite this effort, rate of perceived exertion were not consistent with the physiological response that soldiers presented, the rate of perceived exertion was lower than the physiological response evaluated. Furthermore, the information processing and cortical arousal decreased after the urban combat simulation.

These results have showed the psycho-physiological response of soldiers in combat, helping to better understanding and enabling an improvement of current training methods of soldiers.

Key words: Combat; cortical arousal; stress; strength; sympathetic nervous system; heart rate.

Introduction

In current theaters of operations asymmetrical conflicts predominate, characterized by combat in urban areas in constant evolution and with presence of civilians. These asymmetrical conflicts are in constant change and the soldier must be prepared for unexpected attacks or close quarter combat.

It is known as different psychological states directly influence the physiological response of the human organism. Urban combat is a situation in which the soldier is exposed to a lot of stimuli which may arise as a threat against him, and this situation may be highly stressful for the soldier. The realization of missions in current conflict zones, cause different diseases in soldiers, due to psychological stress of those missions (Marx, Brailey, Proctor, McDonald, Graefe, Amoroso, Heern and Vasterling, 2009; Turker, Sinclair, Mohr, Adler, Thomas and Salvi, 2009). Despite this, there are no empirical studies that show what combat situations cause the high episodes of stress in the soldiers.

The study of cognitive and organic response during combats, whether simulated or real, has been limited and only focused on research organic parameters (like heart rate variability, maximal oxygen uptake or muscular strength) be-

fore and after carrying out different missions (Lester, Knapik, Catrambone, Antczak, Sharp, Burrell and Darakh, 2010; Nindl, Leone, Tharion, Johnson, Castellani, Patton and Montain, 2002; Ricciardi, Deuster and Talbot, 2007; Rintamäki, Oksa, Rissanen, Mäkinen, Kyröläinen, Keskinen, Kauranen and Peitso, 2005). In this line of research, Lester et al (2010) analyzed the body composition and physical fitness of 73 infantry soldiers after 13-month mission in Iraq and. After complete the mission, both the strength of the upper and lower limbs increased (7% and 8% respectively), as well as muscle strength (9%), and aerobic performance decreased 13% and fat mass increased 9%. Has also been shown as the percentage of fat is a valuable indicator of performance, when analyzing an incremental test performed with the combat equipment (Ricciardi et al, 2007). Rintamäki et al (2005) observed how after 12 days of military maneuver in winter period, there is no cumulative fatigue in soldiers. Also has no negative effects on maximal strength and maximal oxygen uptake and produce a decrease in heart rate of the soldiers, because to the training performed in these maneuvers. Therefore the response of soldier's organism during combat is not really known at present.

This research aims to analyze changes in variables of cortical arousal, blood lactate, muscle strength, autonomic modulation and rate of perceived exertion in an urban combat simulation.

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Method

Research design

A descriptive study was performed; pre-post changes were analyzed in selected physiological and psychological variables in twenty soldiers, those realized an urban combat simulation divided in 5 units of 4 soldiers each one. The sampling type selected was intentional because the difficulty to obtain the participant for the study.

Participants

We analyzed 20 soldiers of Spanish Army and Spanish Forces and Security Corps (19 male and 1 female; 34.5±4.2 years; 176.4±8.4 cm; 74.6±8.7kg; 63.3±8.0 kg muscular mass; 7.6±3.2 kg fat mass). Soldier served in the Army, Air Force, Navy, Civil Guard and National Police. All subjects had 14.5±4.4 years of professional experience in their units, most of them had experience in international missions in current conflicts: Lebanon, Afghanistan, Bosnia, Kosovo and Iraq.

Soldiers were equipped with standard uniform and boots, tactical fighting load carrier of the Army, simulated pistols, simulated rifle, simulated knives, shackles or flanges and a backpack with 12 kg to simulate the equivalent weight of the task force for this type of operation. The total weight carried was 23.6 kg.

Prior to participation, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent in accordance with the Declaration of Helsinki.

Instrumentation and study variables

Before and after the urban combat simulation we measured the next parameter.

1. Rating of perceived exertion (RPE), 6 – 20 scale (Borg, 1970).
2. Isometric lumbar and legs strength with TKK. 5402 (Takei Scientific Instruments CO. LTD) dynamometer. Soldiers did 2 repetitions of maximal contraction, in which they did raise the bar of the dynamometer in a standing position with 135° knee flexion. From 2 repetitions we only analyzed the best sample (Ishikawa et al, 2011).
3. Lower body muscular power was estimated by means of vertical jump test. We used the Ergojump System (Bosco System, Ergotest Technology) which recorded flight time (s) and jump height (cm) to evaluate three vertical types of jump. 2 Squat Jump (SJ), 2 Contramovement Jump (CMJ) and 2 Abalakov jump (ABK). We chose the best intent of each type of jumps. We choose to use vertical jumps as they provide further insight into the force capabilities of leg extensor muscles and present a high degree of reliability (Moir et al, 2004).

4. Blood lactate concentration. We took 32 µl blood samples in one finger of the soldier. To analyze lactate concentration used by Dr. Lange. Miniphotometer plus LP 20. v 1.4.
5. Cortical Activation was measures trough the Critical Flicker Fusion Threshold (CFFT). Soldiers were seated in front of a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12021), which was constructed to control extraneous factors that might distort CFFT values. Two light-emitting diodes (58 cd/m²) were presented simultaneously in the viewing chamber, one for the left eye and one for the right eye. The stimuli were separated by 2.75 cm (center to center) with a stimulus-to-eye distance of 15 cm and a viewing angle of 1.9°. The inside of the viewing chamber is painted flat black to minimize reflection. The flicker frequency increment (2 Hz/sec) changed in two ways: either it increased from 10 to 100 Hz until the participant perceived fusion, or it decreased from 60 to 0 Hz until flicker was detected. After a fovea binocular fixation, participants were required to respond by pressing a button upon identifying the visual flicker (descending frequency) and the fusion (ascending frequency) thresholds. Prior to the experiment they performed as many practice trials as needed to become familiarization with the exigencies of the CFF test. Then, three ascending and three descending trials were performed alternatively (Davranche and Pichon, 2005). Subjects carried out the test three times with an interval of 5 seconds. With this data was obtained the CFF Threshold (CFFT), which is the average of the values obtained in the ascending test and descending test.

Before urban combat simulation body composition was assessed with a segmental multifrequency bioimpedance analyser (InBody 720, Biospace Co. Ltd., Seoul, South Korea), also, all of soldier wore a Suunto heart rate monitor with RR measurement function. We analyzed 20 minutes of heart rate variability (HRV) while soldier were waiting in a waiting area. We use this measurement like baseline of HRV and heart rate (HR) parameters. Then we analyzed RR and HR during urban combat simulation. We used Kubios HRV software (University of Kuopio. Kuopio, Finland) to analyze HRV. Parameters analyzed were Average RR (ms) average of time between RR intervals and SDNN (ms) standard deviation of the time between RR consecutive intervals.

The independent variable of this research was the urban combat simulation; the dependent variables were the RPE, SJ, CMJ, ABK, blood lactate concentration, CFFT, isometric lumbar and legs strength, average RR and SDNN parameters.

Procedure, urban combat simulation

Urban combat simulation pretended that soldiers will face situations of combat in urban areas to assess their re-

sponse to intervention with different incidences, using a proportionate use of force (according to the rules of engagement) that can range from to talk, a fire action, shackled operating procedures and implementation of control techniques, striking and knock down.

Simulation was set in direct action to arrest a terrorist. In this context, a team of soldiers performed an advance in a busy urban area (zoco). The team had security support of other forces and had the mission to recognize and to find a terrorist from a list of the six most wanted terrorists in the area. Before the simulation, soldiers had to study and memorized the list of most wanted terrorists. To find the

terrorist soldiers had to recognize three buildings, where they were given information that could be the wanted terrorist (Figure 1).

For the recognition of buildings and capture the terrorist, soldiers were divided in 5 teams of 4 soldiers each one. Each of the teams was placed in a waiting area outside the simulated zoco. Before starting the simulation, an officer picked the team up from the waiting area and led them to the zoco. Then, the officer gave the order to find and capture a terrorist with a proportionate use of force. In that moment the team must recognize three buildings to find the terrorist.

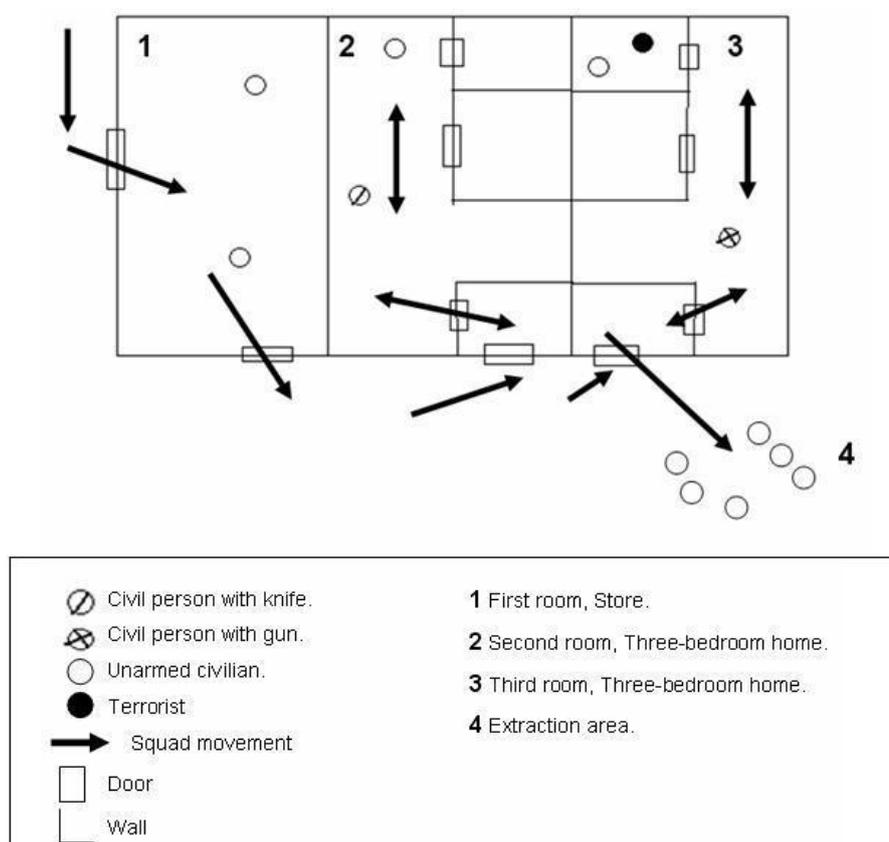


Figure 1. Map of movement during urban combat simulation.

The first building simulates a store in which the team found two civilians who cooperate with the team, but they did not understand the language of the team.

The second building simulates a three-room house in which there were two civilians (none of them understood the language of the team). One civilian cooperated, but carried a hidden knife in his clothes and the second screamed hysterically frighten by the presence of the team, but he did not represent a threat.

The third building simulated a three-room house. In the first room was the guard of the terrorist who shot the team. The team had to shoot and neutralize with close quarter combat techniques the threat. In the final room, the team

found the terrorist who was with his wife. The team had to recognize, arrest and transfer the terrorist, while the woman was scolding the team and attempting to prevent the arrest peacefully.

Finally, the team had to evacuate and protect the terrorist, defending him from civil mass attack (hostile to the terrorist) that recognized the terrorist and tried to attack him.

Statistical analysis

Data obtained in this study were analyzed with SPSS 17.0 statistical program. Shapiro-Wilk normality test was used to test homogeneity of each variable. Then, to analyze differ-

ences between pre and post samples a dependent-T test was performed for parametric data, CFFT, Isometric Strength, Heart Rate, Average RR, SDNN, SJ and CMJ. Wilcoxon test was performed on non parametric data, ABK and Average RR. The level of significance for all the comparisons was set at $p < .05$.

Results

Values are reported as mean \pm SD. Time to realize the urban combat simulation was 11.3 ± 2.0 minutes. The speed average to realize the combat simulation was 1.6 ± 0.2 km/h. Values of isometric strength increased significantly after the urban combat simulation. The values of RPE were 12.7 ± 2.2 . The blood lactate concentration also increased significantly from 2.82 ± 1.04 mmol/l to 5.08 ± 2.32 mmol/l at the end of combat simulation. Results of the three high jumps showed a significantly increase (Table 1).

Table 1. Result obtained in the urban combat simulation.

	Unit	PRE	POST	% Change / (p)	Effect Size Cohen's D
CFFT	Hz	37.82 \pm 3.30	36.59 \pm 3.57	-3.25	-.37
Isometric Strength	N	126.82 \pm 34.29	146.53 \pm 24.73	9.5*	.57
Heart Rate	bpm	64.23 \pm 15.90	140.05 \pm 9.61	118.1* (.000)	4.77
Average RR	ms	872.76 \pm 150.39	450.76 \pm 93.65	-48.4* (.034)	-2.81
SDNN	ms	224.90 \pm 124.81	189.07 \pm 98.37	-15.9	-.29
Blood Lactate	mmol/l	2.82 \pm 1.04	5.08 \pm 2.32	80.0* (.001)	2.28
SJ	m	0.30 \pm 0.04	0.33 \pm 0.05	11.2* (.000)	.75
CMJ	m	0.30 \pm 0.05	0.33 \pm 0.05	8.4* (.001)	.60
ABK	m	0.36 \pm 0.04	0.38 \pm 0.05	4.8* (.010)	.50

* $p < .05$. Critical Flicker Fusion Threshold (CFFT), Squat Jump (SJ), Countermovement Jump (CMJ), Abalakov Jump (ABK).

Discussion

The aim of this research was to study changes in variables of cortical arousal, blood lactate, muscle strength, autonomic modulation and rate of perceived exertion in a simulated urban combat.

Analysis of results shows how CFFT of soldiers decrease. This decrease is related with fatigue of central nervous system and a decrease in processing information (Li, Jiao, Chen and Wang, 2004). These results show the high psychological load in an urban combat situation, where soldiers have to control high numbers of uncertainties (such windows, doors, holes, light changes ...). Soldiers could interpret these uncertainties as possible elements from could appear a hostile response and could compromise their integrity, being for them a threat. This situation could cause on soldiers a state of anxiety (Martens, Vealey and Burton, 1990), in which the brain is over stimulated with all of these stimuli and becoming a very stressful situation for them. This situation could produce symptoms of fatigue of central nervous system, as shown results obtained in CFFT. This high state of attention and activation in this stressful situation in urban areas causes in the organism of soldiers a constant state of alert to respond quickly to any stimulus that appears. This high state of activation and muscle tension is reflected in blood lactate values, which increased significantly above values of anaerobic threshold (5.08 ± 2.32 mmol/l) (Sjödín and Jacobs, 1981). Increase in blood lactate concentration occurred despite the movements of soldiers in this simulation were mostly at low speed, walking and in static position (speed average was 1.6 ± 0.2 km/h). Therefore,

it should be noted the increase in energy metabolism of soldiers reaching over the anaerobic threshold. In another context the same activities (walking or static position) would not produce concentration of lactate over the anaerobic threshold. This situation shows a high influence of the psychological state (stress) in the physiological response of soldiers. The physiological response of soldiers in urban combat is totally disproportionate to the real physical activity being carried out by them.

Despite the high blood lactate concentration and the decrease in CFFT, the value of RPE was 12.7 ± 2.2 . This value does not correspond with none of the two parameters discussed before (lactate and CFFT). These results suggest that soldiers are not really aware of the psychological or physiological load during urban combat, showing RPE values commensurate with the external load carried by them during the action (static situations and movements at low speed).

Analyzing data obtained in lumbar and legs isometric strength and high jumps results, we can see how all values increased significantly after the urban combat simulation. This increase in strength values of soldiers may be due to the psychological status of the soldiers. This can be explained by the defence mechanisms of the human organism, such as the fight-flight response in which the sympathetic nervous system is activated and prepares organism to any hazard (Sandín, 2003). In the urban combat, organism of soldiers interprets how this situation is a source of stimuli that could be considered dangerous or could endanger the physical integrity of them. Therefore, in this situation fight-flight response is activated. In this case the sympathetic system produced an increase in muscle activation, which produces an increase in muscle strength of soldiers. Comparing

strength values obtained in the urban combat simulation with other studies, we can see higher increase after perform a urban combat simulation than after complete a 13 months mission (Ricciardi et al, 2007) or a 12 days manoeuvres (Rintamäki et al, 2005), although adaptations occur in these two studies were due to training and the tasks performed by soldiers. Instead, increase in strength parameter in present research may be to the fight-flight response.

In urban combat, movements are carried out mainly with low speed, but the HR average present high values (140.05 ± 9.61 bpm). This may be the soldiers must control a large number of stimuli in a relatively short period of time, such as doors, windows, holes, light changes... This situations increases psychological stress and this over-stimulation can cause episodes of anxiety in the soldiers (Martens, 1990). This could account for the highest values of HR during urban combat.

HRV values showed a high activation of the sympathetic nervous system (SNS), because of the decrease in the variables of Average RR and SDNN (De la Cruz et al, 2008). This high SNS stimulation is due to activation of the defense system of fight-flight, which prepares the organism to deal with any threats that appear. This sympathetic activation causes decreased in blood flow to parts of the body not directly involved in the response action, such as the organs involved in digestion or in the process of urination or defecation. It is known as a high percentage of the fighters who participated in battles during World War II said they had urinated or defecated during combat. Later, this was attributed to the activation of the SNS, due to implementation of the fight-flight mechanism activated by the stressful conditions of combat (Grossman and Siddle, 2000). The values of HRV obtained in this research confirmed this theory with empirical data, shown the high activation of the SNS even in a combat simulation, and can expect a greater response in a real combat situation.

The sympathetic activation that reflects the data obtained, would be related to high blood lactate values and increases in strength values after the urban combat simulation. This fact shows as in a combat situation the fight-flight mechanism is activated, and shows an increase in sympathetic activity. The sympathetic activation causes increased in heart rate, muscle strength and energy metabolism of the organism (as shown by the high concentration of blood lactate). On the other hand we have seen how the information processing and cortical arousal decreased, as shown CFFT data. These facts suggest during urban combat, due to the high stress, the responses of

soldiers to the different situations they are facing, are processes in the limbic system, activating the fight-flight mechanism because the information processing of cerebral cortex decrease.

Study limitations

The principal study limitations were we analyzed one female soldier with the rest of the male soldiers. We included this female soldier because she was part of the unit that we analyzed. We also analyzed only 20 subjects, it will be best if we had been analyzed more than 30 subjects, but the unit that we analyzed only had 20 subjects.

Practical application and future research lines.

The results had shown the response of soldiers during an urban combat simulation, which occurs in currents armed conflicts in the world. These data allow us to better understand the psycho-physiological response of the soldiers in combat situations to which they face, facilitating their understanding and opening the way to improve current training processes.

Data from CFFT demonstrate that need to improve systems for stress management training, with specific training for better performance in the current urban combat situations. In addition, lead us to think about the importance of psychological training and the ability to manage stress. These parameters may be related to the tunnel effect and the decision and reaction time in a close quarter combat, factors that would be interesting to analyze in future research.

Conclusion

After an urban combat simulation soldiers suffer an alteration of their psycho-physiological basal state. Urban combat produces high sympathetic nervous system stimulation, as shown heart rate variability data. The sympathetic nervous system stimulation produces an increase in muscle strength, heart rate and blood lactate concentration. Despite this, rate of perceived exertion of soldiers are not consistent with the physiological response that they had, showing a rate of perceived exertion below the physiological response. Furthermore, the information processing and cortical arousal decrease after the urban combat simulation.

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