



Psychophysiological and Specific Fine Motor Skill Modifications in a Checkpoint Action

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Abstract

In last years, the insurgency attacks on task forces bases and checkpoints have been common. The study of psychophysiological response of soldiers in these asymmetrical and non-controlled situations remains a challenge. The present research aimed to analyze the psychophysiological response and the variations in specific fine motor skill after a checkpoint simulation which included surveillance, unexpected attacks, and melee combat. Psychophysiological parameters –heart rate, blood glucose, pressure, oxygen saturation, and lactate, legs' strength, skin temperature, cortical activation, anxiety-, as well as fine motor skills were analyzed in a sample of 24 professional Spanish Army soldiers (35.67 ± 6.62 years, 177.21 ± 7.37 cm, 82.29 ± 11.02 kg, 26.17 ± 2.82 BMI, 15.25 ± 7.44 years of experience in their unit) before and after a checkpoint simulation. The checkpoint surveillance operation produced a significant increase ($p < 0.05$) in rated perceived exertion, heart rate, blood lactate concentration, legs' strength and somatic anxiety, and a significant decrease in blood oxygen saturation and skin temperature values. We concluded that results were consistent with an activation of sympathetic nervous system, triggering a fight-flight response, a chain of intense psychophysiological reactions and a misinterpretation of perceived exertion. Results may help predicting soldiers' physical and operative behavior in real situations.

Keywords Psychophysiology · Lactate · Stress · Anxiety · Military

Introduction

Investigation in military field has been focused mainly on organic modifications after a timed-period missions, like the increase in upper and lower strength, muscle power and lean mass, consequence of a 13 months mission in Iraq [1], or the decrease in the basal heart rate of the soldiers after a 12-days winter military boot camp [2]. Due to the stress that involve combat operations, the Post Traumatic Stress Disorder (PTSD) emerged as one of the main psychosomatic disorder

with a prevalence of up to 30% [3–5]. In addition, the stress induced by combat operations and its extension in time, could affect warfighters' health when becoming chronic [6]. Focused on the soldiers' acute organic response and the analysis of the influence of combat stress, recent studies showed how in different combat situations, the sympathetic nervous system is highly activated triggering an increase in cardiovascular response, muscle strength, blood lactate, creatine-kinase, urea, disturbing cognitive processes as cortical arousal, subjective perception of effort, or memory functions [7–11]. This maintenance of a high sympathetic nervous system activation represents a cardiovascular risk factor as well as other psychosomatic pathologies [12, 13].

Current armed-conflict areas are unpredictable, with a high degree of uncertainty, and characterized by asymmetrical confrontation and unexpected attacks that differ from the conventional warfare [14, 15]. These new environments cause a state of anxiety in soldiers due to the standing alertness and overstimuli. In last years, the insurgency attacks on task forces bases and checkpoints have been common, being also press reported [16–19]. In this frameworks, soldiers need to be prepared for unexpected attacks, close quarter, and melee combat,

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on the premise that they have to respond respecting the rules of engagement [20]. The preparation to this new context and traditionally military training has involved strenuous physical tasks as well as a variety of additional stressing situations sharpened to lead to organic strain (e.g. sleep, hydration and caloric ingest deprivation, extreme and shifting weather conditions, long periods of waiting and inactivity) [21, 22]. Recently and based on the specific conditions of current theaters of operations, several studies are showing the effectiveness of specific technical training in close quarter and melee combat circumstances [23–25]. In particular, checkpoints are erected and enforced within contiguous areas under military or paramilitary control. They are highly specific situations, hardly trainable and ever analyzed and studied thus far.

However, it is necessary to apply all these knowledge under closed-to-real situations in order to better understanding and improving soldiers' response. It has been suggested that executive functions are the first cognitive functions that suffer when people are stressed [26, 27]. Furthermore, marksmanship and performance is affected by physiological overexertion [28–30]. Thereby, the present research aimed to analyze the psychophysiological modifications of soldiers after a military checkpoint operation. We hypothesized that the checkpoint area would increase the psychophysiological response negatively affecting specific fine motor skills. This information has a direct application for training systems conducted before the deployment in actual theatres of operations in order to improve soldiers' performance and their survival.

Material and method

Experimental approach to the problem

To accomplish the study objective, psychophysiological response and fine motor skills of an operative light infantry unit were analyzed before and after a checkpoint maneuver.

Participants

A sample of 24 professional Spanish Army soldiers was recruited by convenience (35.67 ± 6.62 years, 177.21 ± 7.37 cm, 82.29 ± 11.02 kg, 26.17 ± 2.82 BMI, 15.25 ± 7.44 years of experience in their unit). Most of them with experience in international missions in current armed-conflicts. The soldiers were equipped with the standard equipment (± 12 kg) and a simulated rifle. All the procedures performed in the present investigation complied with the principles of the Declaration of Helsinki, all the participants signed an informed consent, and the procedures were approved by the Headquarters of the Units.

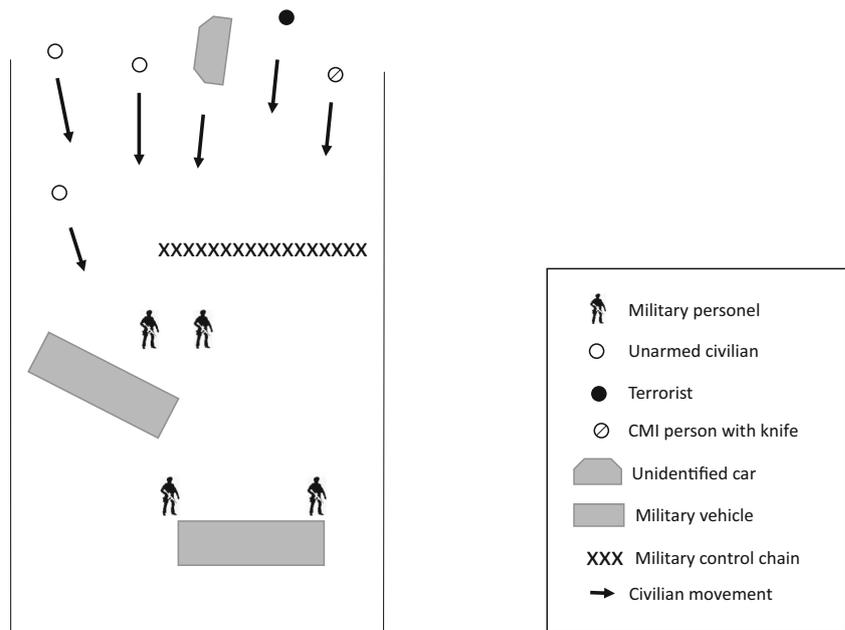
Procedure

A cross-sectional pre-post design was used in order to minimize individual differences in psychophysiological responses as previous similar studies in this population [9, 10, 15, 20]. The independent variable was the checkpoint maneuver with two evaluation moments: before and after. The simulation was conducted in accordance with real checkpoint actions occurred in actual conflict areas. It consisted in a military checkpoint in the suburbs of a conflict area. Soldiers in units of 4, had to control and surveillance a local insurgence suburb area in a control point. Settled in the checkpoint, soldiers had to deal with diverse actors which could represent: normal civilian, disguised terrorist, potential armed/disarmed enemy (Kalashnikov rifles, concealed knives, etc.), cars with possible threatens as improvised explosive devices (IED), weapons and even distant snipers (Fig. 1). Actors were passing by along or wandering the control area over more than 1 h It all contributed to a hostile and stressful environment.

One hour before and immediately after the simulation, the following measurements were made according to previous studies [7, 14, 31–33]:

1. Rated Perceived Exertion (RPE), 6–20 scale [34].
2. Heart rate (HR) with a Polar S800i HR monitor (Kempele, Finland)
3. Blood Oxygen Saturation (BOS) by pulse oximeter (PO 30 Beurer Medical).
4. Blood Glucose level by the portable glucometer One Touch Basic, LifeScan Inc. (Madrid)
5. Blood lactate by taking a sample of 5 μ l of capillary blood from a finger of the subjects and analyzed with the Lactate Pro lactate system (Akagui, Tokyo, Japan)
6. Skin temperature by a digital infrared thermometer (Temp Touch; Xilas Medical, San Antonio, TX).
7. Legs strength manifestation. The horizontal jump with feet together is used to assess the strength of the leg muscles. Participants must jump forward as far as possible over the starting line and fall without touching the ground with their hands. The distance is measured in cm from the starting line and the back heel mark. Two attempts were made with the best result noted down.
8. Blood pressure by a portable OMRON HEM-7321-E system (Omron Electronics Iberia, Madrid, Spain).
9. Cortical arousal and fatigue of the Central Nervous System using the Lafayette Instrument Flicker Fusion Control Unit (Model 12,021) by the procedure of previous research [33].
10. Anxiety response by the CSAI-2R [35], that consists in 17 items that assess Cognitive Anxiety (CA), Somatic Anxiety (SA) and Self-Confidence (SC), with 5, 7 and 5 items respectively. The response scale evaluated the intensity of each symptom on a scale of 1 (not at all) to 4 (very much).

Fig. 1 Map of action during checkpoint simulation



11. State anxiety was analyzed by the State-Trait Anxiety Questionnaire (STAI) Spanish validated version [36] which evaluates a transient emotional state, characterized by subjective feelings, consciously perceived, attention and apprehension and hyperactivity of the autonomic nervous system.
12. Fine motor specific skills, by means of the time of ammunition of a pistol's magazine (PMTR): 10 bullets 9 mm parabelum in a Beretta gun charger.

Statistical analysis

Statistical analysis was performed with the SPSS 21.0 statistical program. The descriptive statistics used to report the results were the Mean ± standard deviation (using traditional statistical techniques). Normality and homoscedasticity of the sample was determined with the Shapiro-Wilk test. Then, to analyze differences between pre and post samples T-Test and a Wilcoxon mean comparison analysis of related measures was performed, since several of the study variables did not meet the parametric assumptions. Effect size (ES) was calculated with Cohen's D test ($ES = (Post\text{-}test\ mean - Pre\text{-}test\ mean) / Pre\text{-}test\ SD$). The level of significance for all the comparisons was set at $P < 0.05$.

Results

The results of RPE, HR, blood lactate concentration, legs' strength and somatic anxiety presented a significant increase

after the simulation. Blood oxygen saturation and skin temperature values presented a significant decrease after the task (Table 1).

Discussion

The present research aimed to analyze the psychophysiological modifications of soldiers after a military checkpoint operation. The initial hypothesis was sustained since the simulation of a checkpoint area increased the psychophysiological warfighters' response affecting negatively to specific fine motor skills.

We found how soldiers reached blood lactate concentration above the anaerobic threshold [37] –the physiological moment in which lactate accumulates in blood and ultimately may produce inability and failure in the activity-. This significant increase in lactate, seemed to be caused by the unexpected uncertainties, and prepare the organism for close range attacks as close quarter, and melee combat (involving control and striking techniques). This anaerobic metabolism activation contribute to supply the required energy for these activities, being this response similar than in previous studies in simulated combat [7, 9, 15, 20]. The great tension and consequent neurophysiological activation and muscle mobilization along the maneuver, didn't allow the fall or clearance of lactate levels during the exercise. Fear is the underlying emotion of the fight, flight, freeze system which is part of the body's defensive motivational system [38]. Previous research [7, 15, 20, 39, 40] has assumed the correlation between the activation of the sympathetic nervous system and the limbic *fight-flight*

Table 1 Psychophysiological and fine motor skills results

Variable	Unit	PRE	POST	% Change	t/Z	P	Effect size Cohen's
RPE	–	6.00 ± 0.00	10.75 ± 1.11	79.17	−4.392	.000	–
HR	bpm	77.42 ± 12.73	93.92 ± 16.63	21.31	−6.650	.000	−1.30
O ₂ sat	%	97.13 ± 0.61	96.04 ± 1.00	−1.12	4.660	.000	1.79
Glucose	mmol/l	6.08 ± 0.76	6.16 ± 0.99	1.44	.000	1.00	−0.11
Lactate	mmol/l	2.20 ± 0.43	4.58 ± 2.91	107.95	−4.258	.000	−5.53
Body T ^a	°C	38.45 ± 0.52	36.51 ± 1.16	−5.05	7.953	.000	3.73
HJ	cm	150.63 ± 11.53	164.79 ± 9.01	9.41	−8.517	.000	−1.23
BP Syst		142.42 ± 15.37	141.22 ± 17.29	−0.84	.289	.775	0.08
BP Diast		89.58 ± 8.92	90.09 ± 9.87	0.56	−.418	.676	−0.06
CFFT	Hz	36.22 ± 0.33	35.60 ± 0.33	−1.77	−1.512	.131	0.18
CA		7.50 ± 5.23	8.30 ± 5.60	10.6	−1.788	.074	−0.15
SA		3.30 ± 2.73	6.04 ± 4.55	83.5	−2.863	.000	−1.00
SC		17.25 ± 2.33	17.54 ± 2.57	1.7	−.861	.389	−0.09
State anxiety		7.48 ± 6.84	9.70 ± 6.90	29.67	−1.615	.120	−0.32
PMRT	time (s)	35.72 ± 7.21	37.45 ± 9.13	4.86	−1.402	.174	−0.24

Between parenthesis *p* values lower than 0.05. Rating of perceived exertion (RPE); Blood Oxygen Saturation (O₂ sat); Horizontal Jump (HJ); Blood pressure systolic/diastolic (BP sys/dias); Critical Flicker Fusion Threshold (CFFT); Cognitive Anxiety (CA); Somatic Anxiety (SA); Self-Confidence (SC); Pistol Magazine Reload Time (PMRT)

defense system in similar military maneuvers. This mechanism prepares the body to deal with any arising threat.

Blood lactate is one of the most common parameters to delimitate physical activity intensity and it tends to correlate with RPE [41]. We found a misinterpretation of the effort and physiological workload during the operation, since RPE values were lower than the postulated by previous literature at the lactate range evaluated in the present research. This fact has been related to the increased sympathetic activation and the information processing deterioration [11, 15]. This response was also analysed in previous asymmetrical combat simulations [8–10] and underground operations [15], but in sustained manoeuvre (various days) this misinterpretation was not found [42].

Previous researchers have described the correlation between blood lactate accumulation and the loss in velocity as an indicator of neuromuscular fatigue [43]. Even more in accordance with our investigation, the decrease in vertical jump performance was evidenced as early as lactate values were similar to those reached by soldiers at present study [44]. Probably consequently to the neurophysiological activation processes, explosive legs' strength values were significantly higher at the end of the maneuver. The action of restraining down threats and bouts, and the necessity of full alertness, contributed to the activation of the SNS, which is responsible for the *fight-flight* response of the organism [8]. Contrary to what could be expected and showed in sportive population, the muscle activation produces an increase in the muscular strength of the subjects. Another consequence, is the significant decrease in O₂ saturation at the end of the maneuver. This

lead us to think that regular values can drop to risky ones during strenuous and stressing activities as close quarter combat in checkpoint situations, values also found in combat pilots in hypoxia training [45]. Nonetheless, more specific investigation is needed to ascertain this statement. As it is widely known, skin temperature has a wide range of variation, which depends on deep (core) body temperature (and do not represent ambient temperature) [46]. A reflection of, and feedback from internal heat-exchange response was the significant soldiers' temperature decrease. The main thermoregulatory role of thermal cutaneous signals is to provide auxiliary feedback to the thermoregulation system, reducing the system's response time and making body temperature stable [46].

Anxiety scores were higher after the maneuver, being significant this increase in somatic anxiety spectrum. This is the physiological manifestation of anxiety referred to affective and psychophysiological elements of the anxious experience derived from the autonomous action [47, 48]. In the framework of this maneuver is important to emphasize the uncontrollability of variables: context and time. Concerning context, this situation is the opposite of what this brigades are used to confront. In this case, they are awaiting, monitoring and expectant to any threat and unexpected uncertainties; by contrast, they are used to face the enemy directly. Regarding the time, the simulation took up above an hour, being totally out of their control the workload arrangement. Lack of control above the situation, the uncertainties, the amount of them, and the length of the simulation are beneath the increased anxiety scores after the simulation.

Despite not significant, a decrease tendency in cortical activation was found. This tendency has been also described in previous studies with military population [9, 15, 20, 40, 49]. It is associated with CNS fatigue and impairment in executive and cognitive processing that can lead to slower and inaccurate responses [50, 51]. These consequences are crucial when facing critical situations that require special alertness, and decisive immediate decision-making and reactions. In this respect, recent military and special corps investigation has shown an improvement tendency in fine motor skills (PMRT) after simulated maneuvers, as a sample of avoidance and emergency behavior [9, 33, 52]. In contrast, in present study, mean of the pistol reload time, worsened. It suggest the impairment in executive processes already described, or a rapid relaxation of soldiers as a consequence of the fatigue. Further investigation with different prolonged in time tasks is suggested to clarify this point.

In general, results were consistent with an activation of sympathetic nervous system, triggering a *fight-flight* response and a chain of intense psychophysiological reactions: significant increases in HR, blood lactate concentration, legs' strength and anxiety. The realism, unpredictability of the context, time and threatens, and lack of control over the situation may play a key role in activating the sympathetic nervous system. Results and data obtained may help predicting soldiers' physical and operative behavior in real situations.

Limitations of the study and future research lines

The principal limitations of the present research were the small sample size analyzed (a larger sample would empower statistical analysis), and the no control of stress hormones –as cortisol and alpha amylase–. These limitations were subject to financial and technological constraints that precluded a larger study. Future research might seek to address these issues.

Practical application

Data obtained in the present study allow us a better knowledge about the physiological response of soldiers in current simulated theaters of combat. In addition, its analysis and data crossover with psychological variables, emphasizes its clear connection with aspects as stress, anxiety and/or fear. This information, may be used to improve and refine current military trainings, allowing the entrance of new and more specific methodologies reinforcing the importance of psychological training factors.

Conclusion

A simulated checkpoint situation produced an increase in the psychophysiological response, significant increasing HR, blood lactate concentration, leg strength and anxiety and decreasing fine motor skills.

Compliance with ethical standards

Conflict of interest None.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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