Psychophysiological and fine motor skill differences of elite and non-elite soldiers in an urban combat simulation

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ABSTRACT
Soldiers’ training and experience can influence the outcome of military missions, as well as soldiers physical integrity. The aim of this research was to analyze the psychophysiological and specific fine motor skills response of elite and non-elite soldiers in a combat simulation according to current conflict deployment zones. Rates of perceived exertion, heart rate, blood oxygen saturation, blood lactate, hand and leg strength, cortical arousal, anxiety, autonomic modulation and fine motor skills were analyzed in 20 Elite (EG) and 24 non-elite (NEG) soldiers of the Spanish Army, before and immediately after a close quarter combat in an asymmetrical combat maneuver. As a consequence of the maneuver, elite soldiers presented a higher metabolic, cardiovascular and anxiogenic response than non-elite soldiers, as well as an anticipatory anxiety response showed in the increased sympathetic modulation. Non-elite soldiers improved their fine motor skills after the combat maneuver (−8.34% Vs −11.23% of change in gun reloading time of Elite Group and Non-Elite Group). Finally, experience in international-armed conflicts disposes soldiers toward better self-confidence when facing risk maneuvers (p = .001).

What is the public significance of this article? — The present research analyzes the psycho-physiological response and differences in fine motor skills of two different military units under a combat maneuver (very stressing situation). This research was conducted with the collaboration of two light-brigades of the Spanish Army.

The scientific military literature has not picked up the acute operational psychophysiological reaction of soldiers and its possible extension to training. The principal finding was that Elite soldiers, despite their specific preparation and experience, presented a higher metabolic, cardiovascular and anxiogenic response than non-elite soldiers, as well as an anticipatory anxiety response showed by the increased sympathetic modulation. Experience disposes soldiers toward better self-confidence. Nevertheless, no differences were found in relation with their fine motor skills, improving in both groups after the maneuver. This fact should be taken into account for soldiers training optimization in current theaters of operations.

Introduction
Military operations and tactical training methods are known for their harshness and demands (Drain, Groeller, Burley, & Nindl, 2017; Hendrickson et al., 2010). The standards of fitness and conditioning required for every operational unit may vary, as in general, it will be greater in combat-armed special units (especially infantry, e.g., the elite group analyzed at present study) than in combat support or service support units – e.g., non-elite soldiers group. Military training has been oriented to keep units ready for both peacetime and active deployment periods. Traditionally, it involves not only hard-physical tasks to confront their daily physical demands, but large additional stressing stimuli and situations that may lead to organic strain (e.g., strenuous physical tasks, sleep, hydration and caloric ingest deprivation, extreme and shifting weather conditions, long periods of waiting and inactivity, unknown-facing risks) (Drain et al., 2017; Gomez-Merino, Chennaoui, Burnat, Drogou, & Guezennec, 2003). As consequence, hormonal changes and even immune impairment responses have been described as
result of several weeks of military training (Gomez-Merino et al., 2003; James, Smart, Odom-Maryon, Honn, & Rowan, 2019; Paige, Renshaw, Allen, & Litz, 2019; Zhang et al., 1999). Different studies described as well different organic responses including large body fat loss and only a small loss of lean body mass, decreased testosterone, increased salivary cortisol and increased growth hormone approximately fourfold (reflecting adaptation to negative energy balance) (Bernton, Hoover, Galloway, & Popp, 1995; Moore, Friedl, Kramer, Martinez-Lopez, & Hoyt, 1992; Shippee, Askew, Bernton, Martinez-Lopez, & Kramer, 1994).

In addition, it has been described how the combat scenario or military context, has a strong influence in soldiers performance (Clemente-Suárez, de la Vega, Robles-Pérez, Lautenschlaeger, & Fernández-Lucas, 2016; Li et al., 2003). Thus, it may decrease, specifically in special units (e.g., elite group introduced in present study), since they are deployed in stressful environments, where physical integrity and life is continuously under threat as they face unexpected, unpredictable and uncontrollable situations (Al Jazerra, 2015, 2018; Faiez, 2018; Hughes et al., 2018; Webb, 2016). In this line, acute exposure to a stressor stimuli induce a wide range of behavioral and physiological responses which enhances the probability of survival (Belda, Fuentes, Daviu, Nadal, & Armario, 2015).

Recent investigation has described the acute psychophysiological response of soldiers during combat, relating how stress directly affect the hypothalamic-pituitary-adrenal (HPA) axis, sympathetic nervous system response, memory, immunologic, neuroendocrine, cardiovascular and digestive systems (Clemente-Suárez & Robles-Pérez, 2013; Clemente-Suárez & Robles-Pérez, 2012; Clemente-Suárez, Robles-Pérez, & Fernández-Lucas, 2016, 2017; Delgado-Moreno, Robles-Pérez, & Clemente-Suárez, 2017; Delgado-Moreno et al., 2017; Sánchez-Molina, Robles-Pérez, & Clemente-Suárez, 2017; Suárez & Pérez, 2012).

Specific training, workloads and real combat experience can strongly influence performance, decision-making and the psychophysiological response in combat (Clemente-Suárez, de la Vega, et al., 2016; Tornero-Aguilera & Clemente-Suárez, 2018; Tornero-Aguilera, Robles-Pérez, & Clemente-Suárez, 2017). In current theater of operations, many different units are deployed, and often required to face threats under compromising conditions, including darkness, unfamiliar territories and languages, unexpected noise or erratic bystanders. To the best of our knowledge, the most effective training to achieve the higher operative performance in these new combat scenarios, is still unknown. Thus, the present research aimed to analyze the psychophysiological and specific fine motor skills response of elite and non-elite soldiers in combat.

Previous military investigation that confront novice and elite-experienced units (Clemente-Suárez, de la Vega, et al., 2016; Clemente-Suárez, Robles-Pérez, et al., 2016), lead us to hypothesize that elite soldiers – with more specific operative training and experience – would successfully complete the maneuver with a lower psychophysiological response than non-elite, and fine motor skills would not be negatively affected by combat stress. This information has a direct application for training systems conducted before the deployment in actual theaters 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 two operative light infantry units were analyzed before and after an urban asymmetrical combat simulation.

**Participants**

Twenty (19 males and 1 female) elite soldiers (EG) (28.95 ± 6.38 years, 178.47 ± 6.19 cm, 80.26 ± 12.90 kg, 25.14 ± 3.10 BMI, 8.95 ± 6.43 years of experience in their unit) and 24 non-elite male soldiers (NEG) (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) of the Spanish Army, with experience in international missions in current armed conflicts were analyzed. 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 a voluntary-informed consent, and the procedures were approved by the Headquarters of the Units.

**Procedure**

The combat simulation consists in an asymmetrical urban action. The objective of the mission was to rescue a prisoner, an isolated allied soldier who had to be evacuated from the conflict zone to a safe area. Simulation was conducted in accordance with real suburbs conditions in actual urban-conflict areas. During the operation, soldiers were organized into intervention groups of four soldiers, who had to clean-and-ensure several buildings, dealing with diverse conflicts: unarmed and armed civilians, disguised terrorist, potential armed/disarmed enemy (Kalashnikov rifles, concealed weapons, etc.), including also, possible thre-
and even distant snipers (Figure 1). Soldiers had to respond in every moment according to International Law and rules of confrontation in diverse situations.

Before and immediately after the combat simulation, the following measurements were made according to previous studies (Clemente-Suárez, de la Vega, et al., 2016; Clemente-Suárez & Robles-Pérez, 2015; Clemente-Suárez et al., 2017; Clemente-Suárez, Robles-Pérez, et al., 2016; Sánchez-Molina et al., 2017):

1. Heart rate (HR) and heart rate variability (HRV) with a Polar V800 HR monitor with RR measurement function (POLAR, Finland) following procedures of previous studies (Clemente-Suárez, Fernandes, et al., 2015). The Kubios HRV software (University of Kuopio, Kuopio, Finland) was used to analyze the following HRV parameters of time and frequency domains: Square root of the mean value of all sum of squared differences of all R-Rs following intervals (RMSSD); Low Frequency band (LF); High Frequency band (HF).

2. Blood Oxygen Saturation (BOS) by pulse oximeter (PO 30 Beurer Medical).

3. Blood lactate by taking a sample of 5 μl of capillary blood from a finger of the subjects and analyzed with the Lactate Pro lactate system (Akagui, Tokyo, Japan).

4. Fine motor-specific skills, by means of the time of ammunition of a pistol magazine (PMTR): 10 bullets 9 mm parabelum in a Beretta gun charger.

5. Cortical arousal and fatigue of the Central Nervous System using the Lafayette Instrument Flicker Fusion Control Unit (Model 12021) by the procedure of previous research (Sánchez-Molina et al., 2017).

6. Leg strength manifestation by the means of a vertical jump test. We used the Ergojump System (Bosco System, Ergotest Technology) which recorded flight time (s) and jump height (m) to evaluate three vertical types of jump: 2 Squat Jump (SJ), 2 Contramovement Jump (CMJ) and 2 Abalakov jump (ABK) as previous research (Clemente-Suárez, 2014). The best intent of each type of jump was chosen.

7. Isometric hand strength (IHS) by a grip dynamometer (Takei Kiki Koyo, Japan).

8. Rated Perceived Exertion (RPE), 6–20 scale (Borg, 1970).

9. Anxiety response by the CSAI-2R (Cox, Martens, & Russell, 2003), 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). Finally, the state anxiety was analyzed by the STAI questionnaire Spanish validated version (Guillén-Riquelme & Buela-Casal, 2011), which evaluates a transient emotional state, characterized by subjective feelings, consciously perceived, attention and apprehension and hyperactivity of the autonomic nervous system.

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. Normality 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 including groups segmentation (EG and NEG), since several of the study variables did not meet the parametric assumptions. Subsequently, to analyze the differences in pre and post averages (extended to all variables) Mann–Whitney test and T-Test were performed. Effect size was calculated with Cohen D test. The level of significance for all the comparisons was set at $p < .05$.

**Results**

RPE, HR and blood lactate of both groups presented a significant increase. However, CMJ presented a significant decrease (Table 1). There were no significant differences in fine motor skills.

In EG unit, RMSSD and HF decreased at the end of the maneuver (Table 2). By contrast, SJ, LF and somatic anxiety increased. After the combat simulation, HR, BOS and lactate were significantly lower in NEG. On the other hand, CFFT were significantly higher in this unit.

**Discussion**

The aim of the present investigation was to analyze the psychophysiological response and specific fine motor skills of elite and non-elite soldiers in combat. The initial hypothesis was not confirmed since elite group did not present the lowest psychophysiological response, and specific fine motor skills improved in both groups after the combat maneuver.

The low basal RMSDD showed a large anticipatory anxiety response in EG. This fact could be related with a higher emotional load of these soldiers, since this group is specialist in this combat requirements and tactics, and they were self-pressed to obtain a good execution since they felt observed and evaluated (Hart, Leary, & Rejeski, 1989). This response could be also explained according to the heart rate variability (HRV) analysis, since it has been observed, that low basal heart rate variability is linked with overtraining, muscular injuries and possible health disorders (Morgan, Aikins, Steffian, Coric, & Southwick, 2007; Roldas, Pedrel Carballido, Capdevila, & Villegas Garcia, 2008), which is in line with the hard-training and under-pressure condition of the EG. HF values, related to parasympathetic nervous system activity, were significantly lower in EG than in NEG before and after the maneuver. By contrast, LF was higher in EG than in NEG in the basal sample, and both groups also increased this parameter in the combat maneuver. This increase in the sympathetic response could explain the higher cardiovascular response of EG than NEG in the combat simulation, consequent with previous studies in symmetrical, asymmetrical and urban simulated combat (Clemente-Suárez & Robles-Perez, 2013; Clemente-Suárez, Robles-Pérez, et al., 2016; Delgado-Moreno et al., 2017; Sánchez-Molina et al., 2017), and greater than in extreme sport events, such as ultra-endurance race events (Clemente-Suárez, 2014; Podstawski, Boraczyński, Nowosielska-Swadżba, & Zwolińska, 2014).

Contradictory results in basal values were found when analyzing HRV and anxiety tests, since EG presented lower somatic anxiety (SA) values and greater sympathetic activation. Similar results have been found in recent studies (Sánchez-Molina, Robles-Pérez, & Clemente-Suárez, 2018), revealing that high sympathetic modulation in stressful contexts may negatively affect memory and perceptive processes (Delgado-Moreno et al., 2017). Nevertheless, self-confidence (SC) of EG was higher than in NEG, probably due to higher operative training and experience. Furthermore, after combat simulation, significant increases in both groups regarding HR were found, presenting EG significantly greater cardiovascular response than NEG. This issue can become specially sensitive in military maneuvers, since several authors have correlated high cardiovascular response with degradation in accuracy and shooting marksmanship (Frykman, Merullo, Banderet, Gregorczyk, & Hasselquist, 2012; Tenan, LaFiandra, & Ortega, 2016). This HR increase was in line with the significant blood lactate increase, levels largely over the anaerobic threshold (Sjödin & Jacobs, 1981). The stress and emotion of reviving stressful real situations and the perception of major assessment could be hidden beneath this high lactate increase of EG.

Nevertheless, all units completed their mission successfully and in similar time, showing how EG, despite the greater blood lactate levels, did not present an acute decrease in performance, which could compromise the accomplishment of the mission. However, more studies based on longer-in-time maneuvers are suggested to analyze the effect of physiological fatigue and lactate production in stressing situations.

The presence of high levels of lactate, which could compromise the contractile capacity of the muscle, presenting attenuations in muscular performance, were compensated by the large sympathetic activation presented by soldiers measured by the HRV parameters. Thus, after combat, significant increases in hand and leg strength were presented, fact previously reported in asymmetrical combat (Clemente-Suárez & Robles-Perez, 2013; Delgado-Moreno et al., 2017; Suárez & Pérez, 2012). Despite this large autonomic modulation, fine motor skills were not negatively affected, but improved after combat simulation in NEG,
Table 1. Physiological and fine motor skills results.

| Variable     | Elite Group       | Non-Elite Group    | % Change | t     | P     | Cohen’s D |
|--------------|-------------------|--------------------|----------|-------|-------|-----------|
| PRE          | POST              | % Change           | t        | P     | Cohen’s D |
| PMRT (s)     | 35.71 ± 7.21      | 32.75 ± 6.94       | −8.34    | −1.68 | .092  | −0.41     |
| RPE          | 6 ± 0.1           | 12.87 ± 2.17       | 114.58   | −4.32 | .000  | 68.75     |
| HR (ppm)     | 73.50 ± 10.59     | 97.37 ± 15.75      | 32.48    | −7.58 | .000  | 2.25      |
| BOS (%)      | 97.04 ± 0.99      | 96.41 ± 0.77       | −0.64    | −1.94 | .052  | −0.63     |
| Lactate (mM) | 1.96 ± 0.64       | 9.17 ± 6.13        | 367.20   | −4.28 | .000  | 11.10     |
| IHS          | 56.27 ± 10.29     | 57.70 ± 9.04       | 2.54     | −1.76 | .090  | 0.14      |
| SJ (s)       | 0.34 ± 0.08       | 0.39 ± 0.04        | 11.74    | −3.79 | .000  | 0.51      |
| CMJ (s)      | 0.40 ± 0.13       | 0.43 ± 0.06        | 9.36     | −0.86 | .389  | 0.28      |
| ABK (s)      | 33.14 ± 15.13     | 19.52 ± 8.43       | −41.10   | −2.72 | .006  | 0.06      |

Between parenthesis p values lower than 0.05. Pistol Magazine Reload Time (PMRT); Rating of perceived exertion (RPE); Blood Oxygen Saturation (BOS); Isometric hand strength (IHS); Squat Jump (SJ); Contramovement Jump (CMJ); Abalakov jump (ABK)

Table 2. Cortical, psychological and heart rate variability results.

| Variable     | Elite Group       | Non-Elite Group    | % Change | t     | P     | Cohen’s D |
|--------------|-------------------|--------------------|----------|-------|-------|-----------|
| PRE          | POST              | % Change           | t        | P     | Cohen’s D |
| CFFT (Hz)    | 35.28 ± 3.21      | 35.50 ± 3.41       | 0.35     | −0.51 | .614  | 0.00      |
| CA           | 9.54 ± 3.91       | 10.25 ± 4.22       | 7.42     | −1.83 | .066  | 0.18      |
| SA           | 9.95 ± 2.52       | 12.58 ± 2.81       | 26.36    | −3.51 | .000  | 1.04      |
| SC           | 17.41 ± 2.60      | 17.16 ± 2.56       | −1.44    | −0.58 | .556  | −0.10     |
| State Anxiety| 5.62 ± 5.28       | 9.50 ± 5.87        | 68.89    | −2.71 | .012  | 0.73      |
| RMSSD (ms)   | 23.16 ± 8.20      | 9.12 ± 6.50        | −60.60   | −4.16 | .000  | −1.71     |
| LF (nu)      | 70.08 ± 9.22      | 83.98 ± 5.85       | 6.19     | −2.92 | .004  | 0.53      |
| HF (nu)      | 20.82 ± 9.22      | 15.94 ± 5.80       | −23.46   | −2.95 | .003  | 0.53      |

Between parenthesis p values lower than 0.05. Critical Flicker Fusion Threshold (CFFT); Cognitive Anxiety (CA); Somatic Anxiety (SA); Self-Confidence (SC); Square root of the mean of the sum of the squares of the differences between adjacent normal R-R intervals (RMSSD); Low frequency (LF); High frequency (HF)

*p < .05. Between parenthesis p values lower than 0.05.
probably due to previous practices under stressful conditions. The fact that EG did not present significant differences pre and post combat simulation may be explained due to a clear ceiling effect in performance, in which the PMRT is very good in both moments, being poor influenced by the activating context of the combat, implying an optimal coping in similar contexts (Clemente-Suárez, de la Vega, et al., 2016).

After the maneuver, NEG showed an increased cortical arousal and EG a small effect size increased tendency, which according with previous studies (Niepel et al., 2013) matches with the improvement in fine motor skills (PMRT) and leg strength. By contrary, other studies obtained an impairment in cortical arousal and a decrease in several strength parameters (Clemente-Suárez, Delgado-Moreno, González-Gómez, & Robles-Pérez, 2015; Clemente-Suárez & Robles-Pérez, 2012; Clemente-Suárez, Robles-Pérez, & Montañez-Toledo, 2015); thus, it may be explained due to the inherent characteristics of the present simulation, since soldiers are constantly overstimulated by threatening stimuli that may compromise their physical integrity. Significant increases after combat simulation in NEG’s cortical response, is translated as an increased state of awareness and avoidance behavior, which has already been shown in similar military maneuvers (Clemente-Suárez, Robles-Pérez, et al., 2016; Sánchez-Molina et al., 2017, 2018) and police corps against distressing situations (Renden et al., 2014). Improvements in the specific fine motor skills and muscular strength, suggests that soldiers conducted the combat simulation within an optimal arousal and alertness levels (Vickers & Williams, 2007). The enhance of cortical inference seems to be associated with the activation of muscle fibers resulting in the increased lactate levels. In addition, the intensifying of biological processes’ speed linked to the increment in lactate provoked the increasing of body temperature (González-Alonso et al., 1999).

Self-regulation and self-control of stress and emotions is inherent to traditional military training (Drain et al., 2017; Gomez-Merino et al., 2003; Hendrickson et al., 2010). Despite the larger specific training and operative experience of EG, elite soldiers did not show an efficient psychophysiological response to current theaters of operations compared to non-elite soldiers. These parameters may be related to the tunnel effect and the decision and reaction time in close quarter combat as previous studies suggested (Clemente-Suárez & Robles-Perez, 2013). This result allows us to think about the importance of psychological training and the ability to manage stress in elite special corps. Likewise, experience in military missions, seem to dispose soldiers toward better self-confidence feelings.

Limitations of the study and future research lines
The principal limitations of the present research were the small sample size analyzed, the lack of a direct cortical arousal measurement instrument, and the lack of control of stress hormones such as cortisol or alpha amylase. These limitations were subject to financial and technological constraints that precluded a larger study. Future research might seek to address these issues.

We proposed the approach of a prolonged maneuver in order to analyze the effect of the accumulative fatigue as well as the large lactate concentration on the psychophysiological response and performance of soldiers.

Practical application
Data obtained in the present study improve actual knowledge about the soldier’s psychophysiological response in current armed conflicts, and how training and experience can affect their performance. Blood lactate levels reached, indicate the importance of lactic tolerance and lactate clearance workouts. Current training tendencies suggest high-intensity interval training (HIIT) as an effective method to reach this aim in military population (Clemente-Suárez & Robles-Perez, 2013). Cortical arousal and HRV alterations highlighted the influence of stress and anxiety on physiological response during critical situations as a combat. Results come to reinforce the importance of psychological training factors in the ability of dealing with distressing situations. Beyond HR, assessment of autonomic nervous system throughout HRV is key to monitor individual adaptation to training and know more about essential acute and chronic physiological processes.

Conclusion
Elite soldiers presented a higher metabolic, cardiovascular and anxiogenic response than non-elite soldiers in a close quarter combat maneuver. Both groups presented an anticipatory anxiety response showed in the increased sympathetic modulation, improving non-elite soldiers their fine motor skills. Finally, experience disposes soldiers toward better self-confidence.

Disclosure statement
No potential conflict of interest was reported by the authors.
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