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Modification in Psychophysiological Stress Parameters of Soldiers after an Integral Operative Training Prior to a Real Mission

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Abstract: (1) Background. Military personnel could be defined as “Tactical Athletes”. However, experimental evidence about the effects of new HIIT trainings in comparison with traditional training schedules is lacking. The aim of this study was to experimentally analyze the modifications on psychophysiological and performance response of soldiers after completing experimental integral operative training. (2) Methods. A total of 43 male subjects of a special unit force of the Spanish armed forces were randomly selected and assigned into the experimental and control groups assessed after training and after deploying in a real operation area. The experimental group underwent an integral operative pre-mission 6-week training (IOT), and the control group, the 6-week traditional training. (3) Results. HIIT-based integral operative training significantly improved combat performance (melee combat score) and the psychophysiological stress response, as measured by heart rate variability indexes. (4) Conclusion. This study provides experimental evidence supporting a new integral operative effective for improved autonomic regulation, reduced perceived stress, melee and close-quarter combat techniques, in addition to aerobic and anaerobic performance and lower body strength in comparison with the traditional training.

Keywords: heart rate variability; stress; tactical athletes; soldiers; physical activity



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1. Introduction

Military training is a challenging phenomenon, given the innate needs and demands of soldiers’ duties and the changing combat scenarios, which are highly demanding, unpredictable and asymmetrical [1]. Extensive knowledge of technical–tactical military skills, high physical and psychological performance, self-confidence, combat preparedness and readiness among other attributes, have defined soldiers as “Tactical Athletes” [2].

In combat, survival itself may be compromised, triggering the phylogenetic flight–fight response mediated by the autonomic nervous system, producing increased sympathetic modulation [3]. This response elicits a large organic activation, producing, for example, a blood lactate concentration that exceed the anaerobic threshold, reaching values as high as elite 400 m athlete; in line with this, muscular and cardiovascular response also increase, and cortical arousal changes accordingly depending on the context [4]. The stressful nature of combat also affects higher cortical processes, showing, in previous studies, how the exposition to intense acute combat stress impairs several psychological processes including perception, memory, cognitive function and even perceived exertion [5].

When this exposure to stress becomes chronic, authors reported higher risk of hypertension, anxiety and depressive symptoms, as well as posttraumatic stress disorder (PTSD), [6–8]. The maintenance of a continuous alert state, maintaining a large sympathetic modulation during the deployments could produce a disruption of the autonomic modulation, leading to a significant basal dysregulation of the vagal tone, which is associated with previous psychological disorders [9]. Then, the preparation of warfighters that allow them to a better autonomic modulation and a correct and adaptative autonomic response is presented as a necessity for actual theatres of operations.

In this line, recent research in athletes and military populations supports the adoption of innovative training models based on low volume and high intensity, demonstrating higher physical benefits than traditional programs, often used among tactical athletes [9]. High-intensity interval training (HIIT) allows a higher external validity with real combat scenarios (symmetrical, asymmetrical, or close quarter combat situations) and better physical outcomes. Furthermore, the use of reverse periodization allow lower volume and higher intensity, meaning lower rate of injury and more specific training [10–12], a more resilient psychophysiological profile [13] and greater adaptations for both tactical [14] and non-tactical athletes [15]. However, to our knowledge there are no studies that combine these elements, a reverse periodization training program, based on a HIIT that integrates military elements, thus an integral operative training (IOT). The comparison with traditional training (TT) approaches would serve to clarify what is the best approach to prepare tactical athletes before being deployed in combat.

Then, the aim of this study is to analyze the modifications on psychological, physiological, and performance variables of soldiers after completing an experimental integral operative training or a traditional training prior to deployment in an international mission. Our initial hypothesis was that the integral operative training would decrease sympathetic modulation and increase physical and melee performance.

2. Materials and Methods

2.1. Participants

The sample was composed of 43 male subjects belonging to a special unit force of the Spanish armed forces, and included the 100% of operatives of the Spanish armed forces sent to the theater of operations in a current conflict. Soldiers had 12.3 ± 8.8 years of experience in the Armed Forces and 8.8 ± 10.1 month of experience in international missions in current conflict areas. The inclusion criteria were interim soldiers belonging to the special unit who were not enrolled in any mission or activity different from the physical training program imposed during the whole training process. Exclusion criteria were less than 4 years of professional experience in the unit, the presence of any medical condition or injury at the moment or during the training process, or the intake of any dietary supplement, stimulants, or other ergogenic aids. This research complied with the tenets of the Declaration of Helsinki. Informed consent was obtained from each participant and the procedures were approved by the Headquarters of the Unit and the ethics committee of the European University of Madrid, Spain (CIPI/18/093).

2.2. Design

To complete the research, aiming and looking for a real application of the results, this intervention was carried out in the preparation for a real mission in current conflict areas. A double-blind design was conducted. Soldiers were randomly selected and assigned into the experimental ($n = 23$, 34.7 ± 8.6 years, 178.1 ± 7.9 cm, 86.4 ± 10.6 kg, 27.1 ± 1.2 BMI) or control groups ($n = 20$, 31.7 ± 7.5 years, 175.2 ± 9.1 cm, 80.7 ± 16.3 kg, 26.1 ± 1.8 BMI). Experimental group performed an integral operative 6-week training (IOT) had been previously proposed [16], and the control group, 6-week training as usual performing they traditional training program (TT). Both groups were evaluated before and after the 6-weeks of training.

Traditional training program (TT): This training lasted 5 sessions per week of 1 h long performing continuous aerobic training and 2 sessions of 2 h per week of theoretical and practical techniques for the operative area in where mission will be conducted.

2.3. Measures

The following variables were analyzed before and after completing the 6 weeks of training:

2.3.1. Psychological Measures

The State-Trait Anxiety Inventory (STAI). This self-report questionnaire was designed to measure the presence of anxiety symptoms through two subscales: state anxiety scale (S-Anxiety), focused on assessing the state of anxiety at the same time of application, and the trait anxiety scale (T-Anxiety), referred to the stable tendency to report negative emotions such as anxiety, worries and fears. It is composed of 40 items, of which 20 belong to each subscale, that are answered in a four-point Likert scale [17]. Higher scores indicate greater anxiety levels. Cronbach's alpha = 0.821.

2.3.2. Physiological Measures

Heart rate variability (HRV). It was measured by the analysis of the R-R interval of the heartbeat and used as an autonomic modulation measurement. The HRV was monitored with a Polar V800 heart rate monitor (Polar, Kempele, Finland). The R-R series was analyzed using the Kubios HRV software (version 2.0, Biosignal Analysis and Medical Imaging Group, University of Kuopio, Kuopio, Finland) as in previous research with soldiers [18]. HRV values included in the tables were baseline. These were taken in a quiet room free from noise and at an ambient temperature of 23 °C with the participants lie in a stretcher with premise that they breathe in a relaxed and continuous way. A 12-min sample was taken, of which the first 5 min were discarded, using only the subsequent 7 as sample. Participants were instructed to do not consume any drug, alcohol, stimulant, methylxanthines 24 h prior to the analysis and food the 6h prior to the analysis [19]. During the analysis with Kubios software, a very low correction factor (noise reduction) was used in a standardized way for all samples, following previous research [20]. Subsequently, the following parameters of the HRV were analyzed: RMSSD (ms): is the square root of the mean value of the sum of squared differences of all successive R-R intervals. Low values in this parameter indicate low sympathetic modulation during the training, associating with anxiety, depression, and PTSD; and LF/HF ratio: low frequency/high frequency ratio.

Isometric hand strength. It was measured by a maximal hand contraction of the dominant arm with a dynamometer TKK. 5402 (Takei Scientific Instrument CO.LTD).

Lower limbs strength. It was measured trough a maximal horizontal jump test. Subjects performed a standardized warm-up consisted in 10 min of running (light aerobic intensity) [21]. Then, participants performed two maximal horizontal jumps. Both jumps were performed with the hands on the waist, to avoid the arms movement inertia, and the best attempt was used for the statistical analysis.

Anaerobic performance. It was measured by the mean speed of a maximal 50 m run and aerobic performance by the mean speed of a maximal effort around 2000 m, which is associated with the maximal aerobic speed measured in incremental test conducted in laboratory [21]. After a 10-min aerobic standardized warm up and the maximal horizontal jump test, participants were instructed to run the 50 m, rest 10 min and run the 2000 m at maximal speed in a track surface. The heart rate after the 2000 m test was recorded with a Polar V800 heart rate monitor (Polar, Kempele, Finland).

2.3.3. Performance Measures

Melee combat/close-quarter combat. Technical procedures in combat techniques in alert and danger situations were analyzed through a standard evaluation system of the Army. All interventions were filmed by a video camera and analyzed later. Every part

of the maneuver was evaluated with 10, 5 or 0 point by three independent expert judges following previous procedures [22].

2.4. Data Analysis

Data were analyzed using SPSS v 25, (IBM, Madrid, Spain). Normality assumption were tested using Kolmogorov–Smirnov. The following variables failed to meet the normality assumption: melee combat score ($p \leq 0.001$), RMSSD ($p \leq 0.001$), LF/HF ($p = 0.012$), trait anxiety ($p \leq 0.001$), lower limb strength ($p = 0.017$), 50m time ($p = 0.021$), 2000m time ($p = 0.048$). Therefore, a non-parametric Wilcoxon signed rank test was run to examine the differences before and after the training period in each group, and U Mann Whitney to examine the differences between groups (experimental vs. control) after final training. In all these analyzes, the significance level was set at $p \leq 0.05$.

3. Results

The results are reported as mean \pm SD. Psychophysiological, melee combat and performance variables before and after training with the integral operative (IOT) are seen in (Table 1). After IOT, soldiers showed a significant increase in melee combat performance, T-Anxiety reduction, significant decrease in RMSSD and LF/HF values. Also, there was a significant increase in physical performance in 50 and 2000 m run, and lower limbs strength. (Table 1).

Table 1. Summary of Wilcoxon signed rank test experimental group results (Integral Operative pre-mission 6-week training. IOT).

Variable	Pre	Post	Z	p	r
Melee combat score	8.15 \pm 7.13	16 \pm 5.22	−3.109 ^a	0.002 **	0.4916
RMSSD (ms.)	42.7 \pm 18.16	102.06 \pm 76.91	−3.354 ^a	0.001 **	0.5056
LF/HF (ms ² .)	1.83 \pm 1.4	0.83 \pm 0.48	−3.493 ^b	<0.001	0.5266
Trait Anxiety	7.95 \pm 6.8	5.22 \pm 3.61	−2.141 ^b	0.032 *	0.3385
Lower Limbs Strength (cm.)	1.81 \pm 0.3	2.07 \pm 0.28	−3.771 ^a	<0.001 ***	0.5818
50 m time (s.)	8.72 \pm 0.98	8.11 \pm 1.22	−3.372 ^b	0.001 **	0.5203
2000 m time (s.)	625.95 \pm 93.37	562.77 \pm 71.45	−3.876 ^b	<0.001 ***	0.5981

RMSSD: The square root of the mean of the sum of the squares of differences between adjacent. NN intervals, LF/HF: Ratio Low-frequency band/High-frequency band. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. ^a Based on negative ranks. ^b Based on positive ranks.

Table 2 shows psychophysiological, melee combat and performance variables before and after the traditional training (TT). No significant differences were seen excepting a significant increase in the physical performance on the 50 m test.

Table 2. Summary of Wilcoxon signed rank test control group results (Traditional Training program (TT) 6-week training).

Variable	Pre	Post	Z	p	r
Melee Combat Score	7.41 \pm 3.36	9.04 \pm 5.47	−1.382 ^a	0.167	0.2132
RMSSD (ms.)	70.72 \pm 33.65	70.09 \pm 54.86	−0.114 ^b	0.910	0.0184
LF/HF (ms ² .)	2.44 \pm 4.89	2.98 \pm 5.69	−0.227 ^a	0.820	0.0368
Trait Anxiety	5.75 \pm 4.26	5.18 \pm 4.11	−0.935 ^b	0.350	0.1409
Lower Limbs Strength (cm.)	1.95 \pm 0.47	2.12 \pm 0.19	−1.570 ^a	0.117	0.0977
50 m time (s.)	8.16 \pm 0.55	7.84 \pm 0.47	−2.224 ^b	0.026 *	0.3607
2000 m time (s.)	562.36 \pm 62.46	541.57 \pm 50.38	−0.533 ^b	0.594	0.0888

RMSSD: The square root of the mean of the sum of the squares of differences between adjacent, NN intervals, LF/HF: Ratio Low-frequency band/High-frequency band, * $p < 0.05$, ^a Based on negative ranks, ^b Based on positive ranks.

Table 3 shows the comparison between Traditional Training Program and Comprehensive Operational Training after final training. Significant differences were found in combat performance and in the LF/HF parameter of the psychophysiological response.

Table 3. Mann-Whitney U test (Traditional Training program (TT) 6-week training).

	Traditional Training (<i>n</i> = 23)	Integral Operative Training (<i>n</i> = 20)	U	<i>p</i>
	Mdn (Rank)	Mdn (Rank)		
Melee combat score	9 (24)	17 (10)	74	<0.001 ***
RMSSD (ms.)	44.42 (138.65)	66.86 (230.63)	148	0.111
LF/HF (ms ²)	1.29 (24.91)	0.79 (1.87)	131	0.041 *
Trait Anxiety	4.5 (17)	5.5 (12)	236	0.887
Lower Limbs Strength (cm.)	2 (2.5)	1.75 (1.2)	168.5	0.600
50 m time (s.)	7.79 (1.83)	7.9 (4.6)	219	0.980
2000 m time (s.)	545 (206)	548.5 (276)	178	0.418

RMSSD: The square root of the mean of the sum of the squares of differences between adjacent. NN intervals, LF/HF; Ratio—Low-frequency band/High-frequency band. * $p < 0.05$, *** $p < 0.001$.

4. Discussion

The aim of this study was to analyze the modifications on psychological, physiological, and performance variables of soldiers after completing an experimental integral operative training (IOT) and a traditional training (TT) prior to deployment in an international mission. Our initial hypothesis was complied, since the IOT decreased sympathetic activation and increased physical and melee performance more significantly than the TT. Present results showed that the psychophysiological response and adaptations strongly differ depending on the type of training performed. In this line, and according to present data IOT seems an optimum stimuli approach for soldier's preparation prior to deployment in conflict areas.

Analyzing the results in the psychophysiological variables, we first found a significant reduction in trait anxiety in the IOT group. Trait anxiety is considered a relatively stable disposition or tendency to experience anxiety states more frequently and intensely [16]. However, under certain conditions, such psychological interventions, changes have been found in the T-anxiety scores after a certain period of time. There is also strong evidence on the relationship between increasing regular physical activity and improving general mood, as well as reducing psychological and physical reactions to stress [23,24].

The type of physical exercise that has shown the best results in terms of reducing anxiety and other negative emotional states is moderate or high intensity exercise, compared to low intensity physical exercise [25]. Of the two training programs analyzed in the present study, IOT is the one that achieves the greatest psychophysiological activation through the periods of high intensity interval training (HIIT). This psychophysiological response is considered analogous to that registered in simulated combat situations [6]. In line with these findings, our results confirm that it is the IOT group where there is a significant decrease in the trait anxiety variable after the training period.

Regarding the cardiovascular response, several studies have shown the sensitivity of HRV parameters to reflect the changes produced in the autonomic nervous system (ANS) during a stress situation, especially low parasympathetic and high sympathetic activity, considering these parameters as objective indicators of stress and mental health [26]. Our results showed significant differences in HRV measures when comparing results before and after training in the IOT group (lower values in the LF/HF ratio as well as RMSSD increment). This indicates that the sympathetic modulation was higher in this group [4], and therefore the psychophysiological stress response is noticeably lower after the training period; these changes were not replicated in the other group, TT, as there were no significant differences between both evaluation moments in either of the two HRV measures.

Both results—the reduction in the HIIT group of trait anxiety and the cardiovascular response—are congruent with the findings obtained in training based on stress inoculation or training in exposure to stress. In these studies, the military participants train under conditions that simulate common stressors in combat situations, resulting in a decrease in anxiety and an improvement in performance [27,28]. This is consequent with previous studies that compared different approaches to control and regulate the autonomous nervous system, suggesting that HIIT is an optimal non-pharmacological tool [29]. Repeated exposure to the same situation in which high stress is induced has a habituation effect, progressively reducing the magnitude of the stress response as training progresses. In this case, habituation has a behavioral immunization effect that is greater especially when the levels of the stressor have been of high intensity [30,31].

In this line, PTSD is a common symptom after being deployed in combat. With a health cost of approximately \$ 45–50 billion dollars per year only in the United States, and with ratios ranging from 16.7% of the active troops, and even higher among reservists at 24.5% [32]. One of the factors in common in patients with PTSD and other is a dysregulation in autonomic modulation, related to hyperarousal and over sympathetic activation. Thus, controlling the autonomous nervous system can be a protective factor for stress, PTSD and mental health [26,32]. Indeed, authors report that pre-deployment HF in the context of higher pre-deployment PTSD symptom severity appears to be a significant physiological predictor of post-deployment PTSD [7]. In this line, the IOT is presented as an effective strategy prior to soldier's deployment to improve autonomic modulation of soldiers. Furthermore, the improvement of the autonomous nervous system and vagal tone is close related to a reduction in anxiety and stress levels [33]. In addition, this fact was in line with the present data, since there was a significant reduction of the T-Anxiety values after the IOT. This modification of the psychological profile of participants could be related with the fact that regular physical exercise has proven to be a powerful regulator of autonomic modulation. It improves general mood, reducing psychological and physical reactions to stress [23,24]. Yet, authors conclude that terms of reducing anxiety and other negative emotional states, HIIT exercise seems the most appropriate tool [6,25].

Along with improving autonomous nervous system and reducing stress, reverse periodization and HIIT have been shown to be more effective in improving athletic performance than traditional programs [21,34]. This result was also found in the present military sample since after the IOT, significant performance improvements were found in the time of 50 and 2000m, and lower limb muscular strength. These improvements are related with physiological demands of actual combats, speed, endurance, and strength. HIIT increases cardiac output and maximal oxygen uptake due to improvements in oxygen delivery [35], fact shown in the increased performance in 50 and 2000m tests. Furthermore, given the nature of HIIT and that most of the exercises were based on dragging, jumping and sprinting, it would explain the improvement in lower body strength observed, as in previous research [13]. Also, other authors found similar results in HIIT protocols of 6 and 8 weeks, when compared to traditional approaches of moderate or low intensity [36–38].

Finally, after training, significant changes were found in the scores of a test of combat techniques procedures in the IOT group. This improvement was not found in the TT group. The IOT group received specific technical training in combat procedures during training, including practically applied immobilization, strike and control techniques from martial arts following previous operative training methods [39–41]. In addition, we can relate this result to the findings of previous studies that indicate the negative influence of the stress response on the learning and performance of relevant military skills, both physical and mental, negatively influencing cognitive performance and decision-making, and skills. such as shooting precision [5,42]. In this way, a lower stress response facilitates the performance of the technical and practical skills put into practice in a test such as the one carried out.

Results of this study should be considered with caution, since the study focuses on the pre-post training differences, but other relevant factors could have affected the psychophysiological status of military athletes throughout the training.

4.1. Limitations of the Study

One of the limitations of the present research was the low sample size, but the limitations, restrictions, and COVID-19 health protocols precluded recruitment of a larger sample. The lack of control for stress hormones such as cortisol or alpha amylase due to a lack of funding constituted another limitation.

4.2. Practical Application

Physical preparation in tactical athletes is a complex process given the nature of their duty and the number of elements that interfere with it. This work shows the effects of a training program which meets all the requirements for the performance optimization and the perseverance of the physical and mental health of the soldier prior to deployment.

4.3. Future Research

Future studies should focus on training processes and protocols such as the IOT, adapted to the unit and characteristics of the military group to which they belong.

5. Conclusions

An integral operative training produced an improvement in autonomic regulation by improving vagal tone, essential for the prevention of mental illnesses and PTSD before being deployed in combat. Additionally, it produced lower levels of perceived stress, which translates to better learning of melee and close quarter combat techniques. Finally, the integral operative training was a better stimulus for improving aerobic and anaerobic performance and lower body strength than the traditional training.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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