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Effectiveness of an applied high intensity interval training as a specific operative training.

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ACCEPTED MANUSCRIPT

Abstract

The psychophysiological response due to stress of soldiers in actual combat operations have been determined by recent researchers, but there is a lack of knowledge about the most effective training methodologies to prepare these population for these new psychophysiological and tactical requirements. The aim of this study was to analyze the effect of an operative high intensity interval training (HIIT) in the psychophysiological response and shooting performance of professional soldiers. We analyzed 20 soldiers of the Spanish Army which performed an operative HIIT composed by 3 series of 7 repetitions of exercises based on operative military procedures with 30 s of workload and 30 s of resting between repetitions and 5 min resting between series. Blood lactate, rate of perceived exertion and stress, upper and lower limbs, and respiratory muscle strength, skin temperature, blood oxygen saturation, heart rate, cortical arousal, short-term memory and anxiety response were measured before and after the training. After the training rated of perceived exertion and stress, leg strength, heart rate and lactate presented a significant increase and blood oxygen saturation and cortical arousal significantly decreased. An operative HIIT achieves similar psychophysical response than the evaluated in combat simulations in professional soldiers, producing a decrease in cortical arousal and lactate values over the anaerobic threshold.

Keywords: stress; combat; cortical arousal; soldier; anxiety.

INTRODUCTION

The principal researches in military personnel have been focused in how soldiers can develop post-traumatic stress disorder (PTSD) due to the chronical exposition to the stressful situations of combat [1]. PTSD is an anxiety disorder, which produce different physiological responses as elevated heart rate (HR), increased blood pressure, and a depressed heart rate variability (HRV) [2]. It has shown that there is a big prevalence in military personnel who developed PTSD in Afghanistan and Irak and exist some differences depends of localization and the kind of service deployment [3].

It has shown the acute effect of combat stress in the psychophysiological response of military population. They found increased in lactate, creatinekinase (CK), urea, cortical arousal and legs strength and decreased in isometric strength after combat situations and cortical arousal showing fatigue of Central nervous system (CNS) [4, 5]. In this line, tactical parachute jumps modified the soldier's organic response increasing cortisol, HR, fine motor skills, sympathetic nervous system and leg strength and decreasing somatic anxiety (SA) after the jump [6] and affecting psychophysiological response in posterior combat increasing HR and decreasing fine motor skills [7]. Also, high altitude parachute jumps, (HAHO and HALO), increased sympathetic modulation, creatinekinase and decreased cortical arousal and muscle strength. [8, 9]. Another important factor than influences in different ways the psychophysiological response is previous experience and training, showing higher stress response in novel subjects [5, 10].

Although it is clear the effect of acute exposition to combat stress affects soldier's psychophysiological response and that the chronification of this exposition to combat stress induces PTSD in military personnel, there is a lack of studies that analyzed the

effect of operative training in this population. Actual military training is based in traditional long distance and low intensity training, parameter that do not correspond with the psychophysiological response in actual theater of operations. To the best of our knowledge there are no previous studies that analyzed current training that complied with the combat requirement as is the High-intensity interval training (HIIT), training method recommended by previous specific literature for military training [5, 11, 12]. Then, the aim of this study was to analyze the effect of an operative HIIT in the psychophysiological response and shooting performance of professional soldiers. We considered that an operative HIIT would achieve similar psychophysical response than evaluated in combat simulations by previous studies.

METHODS AND MATERIALS

Subjects

We analyzed 20 soldiers of the Spanish Army (n: 20; Age 36.0 ± 5.7 years; Height 174.4 ± 7.6 cm; weight 74.5 ± 8.3 kg; Military Duty 15.4 ± 5.7 years, Military operation 9.2 ± 11 months). All the procedures, training, and measurements were approved by the medical head quarter of the unit and explained before intervention to all the military personal, who gave the voluntary written informed in accordance with the Declaration of Helsinki.

Operative high intensity interval training

All the participants performed an operative HIIT composed by 3 series of 7 repetitions of 30 s at maximum intensity, resting 20 s between exercises and 5 min between series, in this rest time soldiers performed a shooting test. Soldiers were equipped with boots, helmet, military uniform and a combat backpack the total weight carried by military personnel was 20 Kg during the intervention. HIIT was composed by seven exercises based on operative military procedures:

- Walking up and down stairs equipped with combat equip.
- Shovel a sand box in a trench with combat equip.
- Carry ammo boxes running in zig-zag with combat equip.
- Overpass obstacles with combat equip.
- Drag a weight disc (20 Kg) with a TRX rope.
- Lifting and throwing over a wall a piece of M113 tank chain (15 kg).
- Simulated assault, combining sprint and “Go to ground”.

Shooting test

After each set of operative HIIT, participants conducted a shooting test in which they shoot three times in three different positions: standing, kneeling ground and sitting with a pneumatic carbine. The sum of punctuation was analyzed by each position.

Procedures

Firstly, we analyzed body composition of participants by an Inbody 270 before the intervention, following previous protocols. [13, 14]

Then, psychophysiological response and shooting performance was measured before and immediately after an operative HIIT as previous researchers in military population [4, 5, 7, 12, 15]. We analyzed the following parameter in this order before and after the HIIT:

1. Blood lactate by a 5µl blood sample in a finger in the Lactate Pro (Arkay, Inc. system, Kyoto, Japan [16].
2. Rating of perceived exertion (RPE), 6–20 scale [17].
3. Legs strength by horizontal jump test and Upper muscular strength (UMS) by the maximum isometric contraction in the dominant hand in a dynamometer.
4. Skin temperature with a digital infrared thermometer (Temp Touch; Xilas Medical, San Antonio, TX).

5. Blood Oxygen saturation (BSO) and HR by a pulsioximeter (PO 30 Beurer Medical).
6. Respiratory muscle strength manifestations by a digital spirometer QM-SP100 (Quirumed, Spain) [18].
7. Cortical activation with the Critical Flicker Fusion Threshold (CFFT), analyzed in a viewing chamber Lafayette Instrument Flicker Fusion Control Unit (Model 12021), by the mean of five incremental flickering light perception from 20 to 100 hz. Increases in CFFT are linked with a decrease in information processing ability and central nervous system fatigue [19, 20].
8. Short-term memory, where participants had to remember a three-digit number showed during one second and say it in reverse after three seconds.
9. Anxiety response by the CSAI-2R, consisting in 17 items who analyze cognitive anxiety (CA), somatic anxiety (SA) and self-confidence (SC), and State Anxiety by the State-Trait Anxiety Questionnaire (STAI) [21, 22].

Finally lactate, HR (by a Polar V800 (Kempelee, Finland)), and shooting performance was measured before and after each series of the operative HIIT.

STATISTICAL ANALYSIS

The IBM SPSS statistical package (version 21.0; SPSS, Inc., Chicago, Ill.) was used to analyze the effect of the HIIT training in the different variables analyzed it was used the paired samples T Test. To analyze differences between before and after each series of the operative HIIT, it was used a General Linear Model to repeated measures, in this method a Bonferroni adjustment was applied. The level of significance for all the comparisons was set at $p < 0.05$.

RESULTS

The results are reported as mean $\pm$ SD. The pre-post results of the psychophysiological variables studied are shown in table 1. RPE, stress perception, CFFT, horizontal jump, HR and lactate presented a significant increase and BOS a significant decrease.

Table 1 over here

The variables measured before and after each series are shown in table 2. The lactate values of each set presented a significant increase in comparison with the pre lactate values. About Δ Lactate in the different series, there was a significant increase in the first series.

Table 2 over here

DISCUSSION

The aim of this study was to analyze the effect of an operative HIIT in the psychophysiological response and shooting performance of professional soldiers. The initial hypothesis was compiled since psychophysiological response evaluated in the operative HIIT was similar than in previous combat simulations studies.

We found a significant increase in lactate after the first HIIT series, maintaining the levels before the following series. These data reached values over the anaerobic threshold, as well as previous studies conducted in close quarter, urban, symmetrical and asymmetrical combats and tactical parachute jumps [4, 5, 7, 23]. This significant increase in lactic metabolic system during the training means that the effect of operative HIIT was effective since elicits a metabolic response similar than the monitored in previous combat and tactical situations [4, 5, 7, 23]. In this line, joining the anaerobic metabolic activation we have found a significant increase in HR, as previous researches conducted in different combat scenarios [7, 10, 24-26]. This physiological activation

was due to the stress produced by the operative HIIT, which increased the sympathetic nervous system modulation, reaction previously found in combat situations where the fight-flight system was activated due to the combat stress [7, 23, 27]. This activation also produced a decrease in the BOS, probably due to an increase of temperature during the training [28].

Regarding cortical resources, we found a decrease in cortical arousal, symptom of fatigue in central nervous system, reflected by the increased in CFFT values [29]. This reaction has been previously observed in military population in simulated combat and tactical parachute jumps [5, 8]. Despite the decrease in cortical arousal, the lower body strength manifestation (horizontal jump) was not affected, increasing after the operative HIIT. Probably, this increase was due to the increase in sympathetic nervous system activation produced in the HIIT, which produce a greater number of cortex eferences to muscles [30]. By contrary, upper body and respiratory strength manifestation were not significantly modified; showing how fatigue could affect different body muscle depending on the cortical arousal, level of muscle implication and exertion time, but future research might explain this.

About the rating of perceived exertion during the operative HIIT, we found a significant increase in RPE. This result was similar than previous combat [5, 23]. Nerveless, these values were lower than the evaluated metabolic response, probably due to soldiers were not aware of the physiological requirement of the training, as well as the response found in combat simulations [5, 7]. In the same line, stress perception increased after the training, not affecting memory capacity of soldier, in contras of previous studies conducted in asymmetrical combat [30]. This could be due to the lack of combat stress, since present research only analyze an operative training not combat simulation. Besides

this, we found no relation between the stress perceived and the anxiety response, probably by the lack of combat stress in the training.

The shooting performance was not significantly affected by the psychophysiological fatigue measured. This fact showed a good shooting performance skill in fatigue conditions in this military group. In this line, shooting performance was minimal modified by different intensity of exercise in biathlon athletes [31]. Furthermore, shooting accuracy under pressure decreased in police officer [32]. The training involved in increased pressure context produced a shooting performance acclimatization [33]. In these previous studies the stress and fatigue levels were different than the present, but it was highlighted that the use of realistic conditions of training is a basic tool to improve shooting performance. The present operative HIIT could be an important tool to keep the psychophysiological and operative conditions of military and police population.

Limitation of the study

The principal limitations of the present study were the lack of control of stress hormones as cortisol, the no analysis of woman, the lack of control of heart rate variability to asses directly the autonomous nervous system modulation, and the low number of the sample. Future research might seek to address these specific issues.

CONCLUSION

An operative high intensity interval training achieves similar psychophysical response than the evaluated in combat simulations in professional soldiers, producing a decrease in cortical arousal and lactate values over the anaerobic threshold.

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Table 1. Psychophysiological variables measured before and after the operative training
(M±SD)

	PRE	POST	T	Sig	D Cohen
Stress (0-100 scale)	11.55±12.96	37.85±22.92	-5.36	0.00	2.03
RPE (6-20 scale)	6.6±1.31	14.55±1.96	-16.81	0.00	6.05
Skin Temperature (°C)	37.15±1.09	37.59±0.74	-1.94	0.07	0.40
Heart Rate (bpm)	74.5±16.61	121.1±18.55	-17.28	0.00	2.81
BOS (%)	98.35±0.99	95.9±1.02	8.08	0.00	-2.48
UMS (N)	46.73±7.4	48.05±8.31	-1.33	0.20	0.18
Horizontal Jump (cm)	193.03±19.43	205.25±21.41	-5.66	0.00	0.63
FVC (l)	4.91±0.88	5.24±0.96	-1.63	0.12	0.38
FEV1	3.90±0.66	3.96±0.69	-0.53	0.60	0.08
PEF (l/min)	9.50±2.67	9.60±2.14	-0.23	0.82	0.04
CFFT (Hz)	34.45±3.15	35.90±3.16	-2.94	0.01	0.46
AC	5.1±3.24	4.00±3.26	1.93	0.07	-0.34
AS	5.3±4.74	6.1±4.76	-0.75	0.46	0.17
ACF	17.55±3.79	17.45±5.05	0.09	0.93	-0.03
Estate Anxiety	4.35±5.25	4.00±4.12	0.42	0.68	-0.07
Lactate (mmol/L)	2.38±1.51	12.37±4.23	-9.95	0.00	2.36
Memory	1.00±0.00	0.95±0.22	1.00	0.33	0.00

RPE (Rating of Perceived Exertion); BOS (Blood oxygen saturation); UMS (Upper Muscular Strength); HJ (Horizontal jump); FVC (Forced Vital Capacity); FEV1(Forced Expiratory Volume in 1 Second); PEF1 (peak expiratory flow); CFFT (Critical Flicker Fusion Threshold); CA (cognitive anxiety); SA (somatic anxiety); SC (self-confidence).

Table 2. Heart rate, lactate and shooting performance in each training series (M $\pm$ SD).

	Series 1	Series 2	Series 3	F	POST HOC
HRBS (bpm)	161.4 $\pm$ 17.69	168.9 $\pm$ 19.92	174.5 $\pm$ 22.91	2001.28	-
HRAS (bpm)	127.5 $\pm$ 22.83	133.6 $\pm$ 22.43	134.8 $\pm$ 26.01	862.29	-
SST	11.7 $\pm$ 3.37	13.1 $\pm$ 3.91	13.5 $\pm$ 2.78	582.92	-
KST	14.2 $\pm$ 2.78	14.0 $\pm$ 2.44	15.4 $\pm$ 2.35	2221.41	-
SIST	15.5 $\pm$ 2.80	15.2 $\pm$ 3.30	15.6 $\pm$ 1.88	1544.34	-
TST	41.4 $\pm$ 6.80	42.2 $\pm$ 8.04	44.4 $\pm$ 4.96	1575.40	-
Δ Heart Rate					
intraserie (bpm)	-33.9 $\pm$ 21.55	-35.35 $\pm$ 13.04	-39.65 $\pm$ 18.26	139.06	-
Δ Heart Rate					
interserie (bpm)	86.90 $\pm$ 24.61	94.40 $\pm$ 25.07	99.95 $\pm$ 27.26	331.38	-
Δ Lactate (mmol/L)	7.6 $\pm$ 5.56	0.7 $\pm$ 4.36	1.72 $\pm$ 2.81	98.97	1>2,1>3
Lactate (mmol/L)	9.95 $\pm$ 5.36	10.64 $\pm$ 4.58	12.37 $\pm$ 4.23	153.60	3>1, 2>1

HRBS (Heart rate before shoot); HRAS (Heart rate after shoot); SST (Standing shoot test); KGST (Kneeling ground shoot test); SIST (Sitting shoot test); TST (Total shoot test).

The psychophysiological response due to stress of soldiers in actual combat operations have been determined by recent researchers, the aim of this study was to analyze the effect of an operative high intensity interval training (HIIT). An operative HIIT achieves similar psychophysical response than the evaluated in combat simulations in professional soldiers, producing a decrease in cortical arousal and lactate values over the anaerobic threshold.