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Body Composition and Cardiorespiratory Response of Male and Female Soldiers during a Simulated Attack Maneuver

José Fernando Jiménez Díaz[1,*], Domingo Jesús Ramos Campo[1], Jacobo Ángel Rubio Arias[1], Fernando Martínez Sánchez[1], Paula Esteban García[1], Vicente Javier Clemente-Suárez[1] and José Gerardo Villa Vicente[2]

[1]*Department of Physical Activity and Sports Science, Sports Science Faculty, University of Castilla la Mancha Toledo, Spain*

[2]*Department of Physical Activity and Sports Science, Sports Science Faculty, University of León, León, Spain*

Abstract: The study of organic response during combat is poorly reported in specific literature, despite being essential to improve soldiers training. The aim of the present research was to study the body composition and organic response during a treadmill test simulating the attack maneuver of a light infantry company, studying the differences between soldiers gender. Body composition and organic response in the treadmill test were analyzed in 27 healthy professional soldiers. Body weight was lower and fat mass was higher in female soldiers, and height and muscle mass were higher in male soldiers. In treadmill test, values of maximal oxygen uptake (VO_2), oxygen uptake at anaerobic threshold and maximal heart rate (HR) and HR at anaerobic threshold, were higher in male soldiers (male vs. female: 51.9±1.2 vs. 50.4±1.3 ml/kg/min; 3278.9±93.9 vs. 2721.8 ml/min; 194.2±1.9 vs. 184.0±6.6 bpm; 181.3±1.8 vs. 171.4±1.7 bpm respectively). During simulated attack maneuver female soldiers presented lower VO_2 and higher HR than male soldiers, showing a worse physical fitness level. These data could be used by military coach to improve specific combat training. It is also recommended a decrease in the weigh carried by soldiers and to improve their aerobic performance to maximize the efficiency in last phases of combat maneuvers.

Keywords: Army, body mass index, fat mass, infantry, soldier, maximal oxygen uptake.

INTRODUCTION

Activities that soldiers perform during the standard combat maneuvers require a certain fitness level. However, until 19th century, the physical factor was not taken into account in integral soldier training. The analysis of the physiological profile of soldiers has been less studied in the specific literature, focusing on cognitive aspects as decisionmaking [1], coordination of units during combat [2], the analysis of weapons systems [3], or more related to the present research the study of different physiological variables after carrying out a mission [4]. Another point addressed by the researchers was the analysis of different test and its correlation with combat performance [5, 6] and the fatigue produced in soldiers after maneuver [7] of simulated combat [8].

Other authors focused their studies on the beneficial effects of the intense military exercises on body composition, maximal oxygen uptake (VO_2max) and strength [9-12]. In addition, during the last years some authors tried to delimit the organic response of soldiers in combat simulations. In this line, Clemente and Robles [13, 14] showed that combat is highly stressful, showing soldiers having symptoms of central nervous system fatigue and during combat soldiers being above the anaerobic threshold.

The study of organic response during combat was poorly studied despite being essential for the formation and training of soldiers. Therefore, the aim of this research was to study the differences in body composition and cardiorespiratory response during a light infantry company attack simulation between male and female soldiers.

METHODS

Participants

Twenty seven healthy professional soldiers participated in the present study, 19 men and 8 women, who maintained the same regimen of life, military training and diet. Prior to starting the research, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent in accordance with the Declaration of Helsinki. Descriptive characteristics of the sample are shown in Table **1**.

*Address correspondence to this author at the Avd Carlos III s/n. Campus Tecnológico. Edificio 12.1. Laboratorio de Rendimiento y Readaptación Deportiva. Facultad de Ciencias del Deporte. Universidad de Castilla la Mancha. Toledo, España; E-mail: josefernando.jimenez@uclm.es

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Table 1. Descriptive Characteristics of the sample: Mean (Standard Deviation)

Gender	N	Age (years)	Height (cm)	Body Mass (Kg)	Fat mass (%)
Men	19	21.2 (0.4)	174.7 (1.5)	72.8 (2.9)	15.9 (0.2)
Women	8	20.6 (0.3)	161.9 (0.8)	62.1 (2.4)	27.3 (0.3)

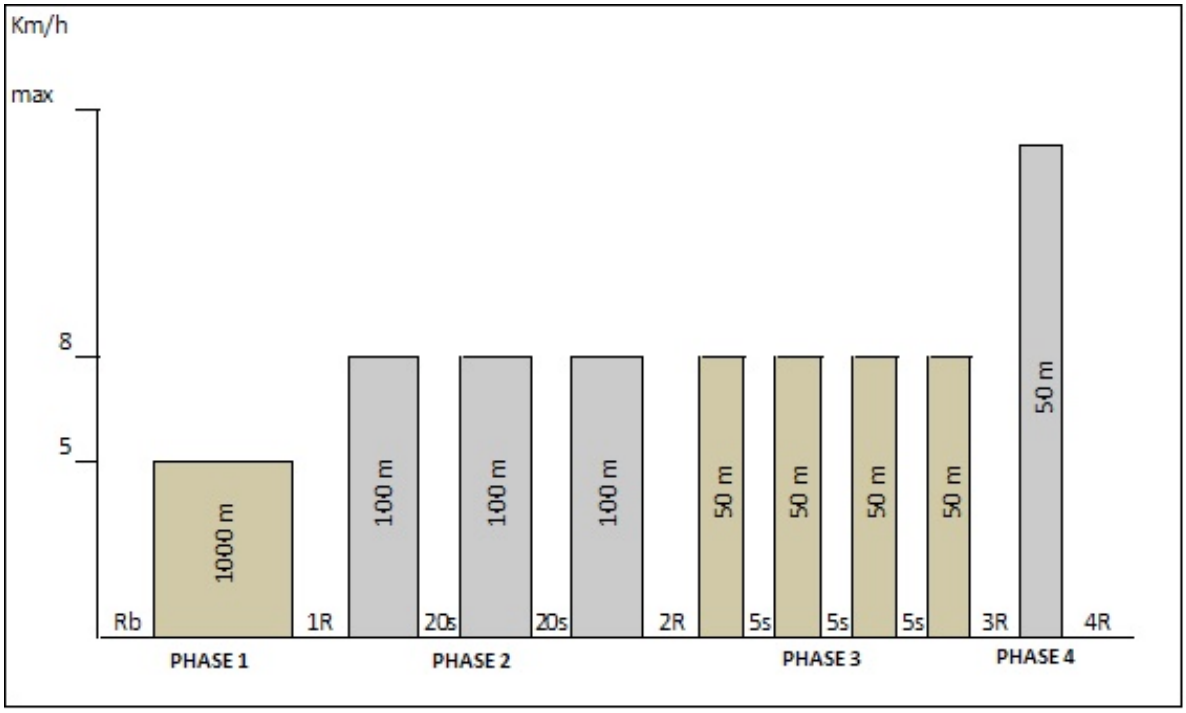

Fig. (1). A schematic representation of the experimental maneuver phases that simulated the combat mode of light infantry company. Rb: basal rest phase, 1R: rest of phase 1; 2R: rest of phase 2; 3R: rest of phase 3. 4R: rest of phase 4.

Protocol

Differences between male and female soldiers were studied in a body composition and cardiorespiratory tests. Firstly, body composition and anthropometric study were conducted according to the previous literature [15]. A stadiometer-scale Sayol (Sayol LTD, Barcelona, Spain), a pachometer Martin (John Bull, British Indicators LTD, England) and a Holtain Skinfold caliper (Crymych, England) were used.

After that, a maximal progressive and continuous treadmill running test was performed. It started at 6 km/h, with increments of 1 km/h per minute until exhaustion and with a 3% constant slope. This maximal test was conducted in sportswear and without armed or personal military equipment. Parameters of VO_2 at anaerobic threshold (AT) and maximum effort (ml/min and ml/kg/min), VCO_2 (ml/min) at AT and maximal effort, maximum heart rate (bpm) AT and maximal effort and maximal ventilation (VE (l/min) were determined in this maximal test.

After one week, a second exercise test was performed. This test reproduced the attack maneuver of a light infantry company that includes the following phases (Fig. **1**):

- Phase 0 (3 min): the soldier stood up resting with all the combat equipments.
- Phase 1: the soldier ran 1000 m at 5 km/h.
- Phase 1R (3 min) recovery period of phase 1 in which the subject remained standing without move.
- Phase 2 consisted on three series of 100 m at 8 km/h resting 20 s. This phase corresponds to the phase II of light infantry company attack protocol, enabling approach to the enemy position from 500 m to 250 m.
- Phase 2R (3 min) recovery period of phase 2 in which the subject remained standing at rest.
- Phase 3 consists of four periods of 50 m at 8 km/h, interspersed with rest breaks of 5 s. This phase corresponds to the phase III of light infantry company attack protocol and allows the approach from 250 m to 50 m to the enemy position.
- Phase 3R (3 min) recovery period of phase 3 in which the subject was at rest.
- Phase 4: 50 m at maximum speed. This phase coincides with the phase IV of light infantry company attack protocol and allows the approximation of troops from the last 50 m to the final assault and melee combat. A researcher was controlling the treadmill and the soldier can increase the velocity moving up his thumb.

Table 2. Weight of the Equipment Carried by Light Infantry Company Soldier

Combat Team	Weight (Kg)
Clothing and gear position (Kevlar Helmet, uniform, shirt, shorts, socks, boots and jersey)	4.990
Combat bag (bag, cap, gloves, flashlights, individual healing pack, water bottle filled with water, cover, pot, covered, ear protection and emergency food ration)	5.480
Combat gears cover and sash (carrier equipment, four empty magazines, knife-bayonet, 2 instruction grenades, girdle, NBQ protective equipment and personal protective NBQ equipment).	10.085
7.62 *Cetme* rifle with four empty magazines without cartridges.	5.615
Total weight	25.670

Table 3. Body Composition Values of Men and Women Soldiers

Body Mass (kg)	♂	**72.8 (2.9)**	*
	♀	**62.1(2.4)**	
Height (cm)	♂	174.7(1.5)	***
	♀	161.9(0.8)	
Body mass index (kg/cm^2)	♂	23.8(0.5)	
	♀	23,7 (0.4)	
Fat mass (kg)	♂	9.7 (0.4)	**
	♀	15.6 (0.5)	
Fat mass (%)	♂	15.9 (0.2)	**
	♀	27.3 (0.3)	
Muscle mass (kg)	♂	37.4 (0.3)	
	♀	33.8 (0.5)	
Muscle mass (%)	♂	46.6 (0.4)	
	♀	42.8 (0.2)	

Mean (Standard Deviation) and significant differences. Significant level *p<0.05; **p<0.01; ***p<0.001 between male and female soldiers

- Phase 4R (3 min) recovery period of phase 4 in which the subject is at rest.

Both tests were carried out on a treadmill Powerjog M-30 (Birmingham, England), using a gas analyzer CPX Medical Graphics System (Medical Graphics Corporation. St. Paul, Minnesota, USA) and an electrocardiograph Schiller AG AT-6 (M) (Baar, Switzerland): The clothing and equipment with which the soldiers conducted the tests are detailed in Table **2**.

STATISTICAL ANALYSIS

Statistical analysis was conducted using the software SPSS 17.0 for windows. Initially, descriptive statistics of all parameters analyzed were conducted, overall and by groups. After that, a Student t test was used. The significance level was set at $p < 0.05$.

RESULTS

Body Composition

In Table **3**, data of body composition obtained in the anthropometric measurement is presented. Data showed significant differences ($p<0.05$) in total body weight that was 14.72% lower in female soldiers. There were also significant differences ($p<0.01$) in absolute and relative fat mass which was 11.4% higher in women. Finally, significant differences ($p<0.001$) in height were found, showing higher values male soldiers.

Maximal Progressive Treadmill Test

Results are showed in Table **4**. Male soldiers presented a significantly higher values than female soldiers of absolute VO_2max, Maximal HR, VO_2 at AT and VO_2 and HR at AT

Table 4. Cardiorespiratory Values of Men and Women Soldiers

VO_2max (ml/min)	♂	**3677.9 (101.7)**	**
	♀	**3110.3 (43.9)**	
VO_2max (ml/kg/min)	♂	51.9 (1.2)	
	♀	50.4 (1.3)	
VCO_2 (ml/min)	♂	3851.7 (110.1)	
	♀	3089.4 (498.5)	
Maximal HR (bpm)	♂	194 (2)	*
	♀	184 (7)	
Maximal VE (l/min)	♂	136.5 (3.4)	
	♀	109.1 (7.3)	
VO_2- AT (ml/min)	♂	3278.9 (93.9)	***
	♀	2721.8 (66.4)	
AT as % VO_2max	♂	89.2	
	♀	87.5	
VO_2- AT (ml/kg/min)	♂	46.9 (1.3)	
	♀	44.0 (0.9)	
VCO_2- AT (ml/min)	♂	3243.6 (97.4)	
	♀	2857.0 (122.7)	
HR- AT (bpm)	♂	181 (2)	***
	♀	171 (2)	
% HR max – AT	♂	91.99	
	♀	93.2	
VE- AT (l /min)	♂	105.2 (3.0)	
	♀	113.9 (2.5)	

Mean (Standard Deviation). Significant level *p<0.05; **p<0.01; ***p<0.001, between male and female soldiers: VO_2: oxygen uptake. AT: anaerobic threshold HR: Heart rate. VE: Ventilation.

Light Infantry Company Attack Simulation

All the parameters analyzed presented differences between male and female soldiers in the different combat simulation phases, as shown in Table **5**.

DISCUSSION

The aim of this research was to study the differences in body composition and cardiorespiratory response during a light infantry company attack simulation between women and men soldiers. We found significant differences between male and female soldiers in both parameters. Theoretically, these differences should be due to the morphological differences between genders, but the military training should decrease these differences to adapt the soldiers' response to the combat requirement.

Data showed the low fitness level and high fat percentage of both female and male soldiers. It is known that the actual life style of population in developed countries is sedentary, with a low percentage of sports practice and a poor nutrition, this fact was confirmed by Blair [16] that showed the decrease in physical level and the increase in weight of youth people during the last decades, and specifically in American youth population [17]. Values of % of fat mass measured in male soldiers were similar to previous studies conducted with soldiers with ages between 19 and 21 years old [18]. Moreover, female soldiers presented higher values of % of fat mass comparing with the study of Wood *et al.* [19] (27.3 vs. 10.2% respectively). Regarding data of body weight of male soldiers, values obtained were similar than values of

Table 5. Cardiorespiratory Values of Men and Women Soldiers During the Simulated test

		Phase 0		Phase 1		Phase 2		Phase 3		Phase 4	
VO_2 (ml/min)	♂	**301.3 (27.4)**	*	**1529.4 (81.8)**		**1780.7 (108.5)**		**2061.2 (119.3)**		**1493.1 (92.2)**	
	♀	**214.8 (17.4)**		**1395.2 (97.9)**		**1476.2 (94.5)**		**1712.9 (93.9)**		**1135.1 (186.0)**	
%VO_2max (%)	♂	8.2		41.6		48.4		56.0		40.6	
	♀	6.9		44.9		47.5		55.1		36.5	
VO_2 (ml/kg/min)	♂	5.8 (1.2)		21.2 (1.0)		24.8 (1.2)		28.5 (1.1)		20.3 (0.7)	*
	♀	3.4 (0.2)		19.5 (0.4)		23.5 (0.7)		27.5 (1.0)		17.5 (1.1)	
VCO_2 (ml/min)	♂	272.3 (29.9)	*	1413.2 (84.8)	*	1739.8 (137.5)		2039.6 (125.8)		1439.6 (99.9)	
	♀	183.7 (12.8)		1118.2 (47.7)		1521.7 (76.0)		1850.0 (103.8)		1284.3 (105.9)	
HR (bpm)	♂	88 (2)		125 (6)		150 (3)	**	159 (4)	***	152 (4)	***
	♀	89 (2)		113 (2)		168 (3)		177 (3)		173 (3)	
VE (l/min)	♂	15.5 (0.68)		36.2 (1.4)		59.9 (5.2)	*	68.1 (1.2)	**	60.7(5.8)	
	♀	10.6 (0.85)		31.4 (0.9)		44.9 (3.7)		51 (1.6)		43.1 (1.5)	

Mean (Standard Deviation) and significant differences. Significant level *p<0.05; **p<0.01; ***p<0.001 between male and female soldiers: VO_2: Oxygen uptake. HR: Heart rate. VE: Ventilation.

American soldiers, values of height were exactly the same than American Armed Group and values of body fat percentage were slightly higher than USA soldiers (15.9 vs. 15.6 % respectively) [20]. Moreover, values of total body weight of women soldiers were higher than female soldiers of US Army (62.1 vs. 58.6 kg respectively) and height values were practically equal (161.9 vs. 162.0 cm respectively) [20]. However, the body fat percentage of Spanish female soldiers was lower than that of US female soldiers (27.3 vs. 28.4 % respectively), this difference could be related principal with the different type of diet and different life style between USA and Spanish soldiers. The similar results provided by USA and Spanish soldiers in body composition variables make us think about a possible professional soldier biotype, although more studies in this area would be needed to clarify.

Aerobic capacity of soldier has been repeatedly studied, but the cardiorespiratory response of soldiers during combat was poorly studied, although the originality of the present study was that we analyzed the different phases of specific offensive infantry maneuver. The anaerobic threshold of soldiers (male and female) obtained in the maximal progressive treadmill test was 45.4 ml/kg/min, which is the 88.2% of VO_2max. These values correspond to moderately trained young athletes [21]. Values of VO_2max measured in the present research were higher than in Canadian recruits with the same age (51.9 male and 50.4 female vs. 47.0 ml/kg/min respectively) [22]. Moreover, Vogel [23] analyzing US recruits found values similar to the data obtained in the present research (51.0 ml/kg/min). On the other hand, Song & Moore [24] evaluated a lower value (39.1 ml/kg/min), possibly because of the training program conducted did not provide an adequate stimulus to improve the VO_2max. These results provide evidence that in some cases the military daily training is not enough to improve the physical performance of soldier, that is vital in military action as maneuvers and close quarter combat. Several studies [25-27] have researched the effect of different training programs on soldiers VO_2max, showing an increase in VO_2max after the military physical training just in subject with lower VO_2max values. Another study found that military walk training was an effective method of instruction, increasing the average velocity during maneuvers, but to increase the VO_2max running training was necessary [28]. Depending on the military training conducted the improvements in physical fitness were different, but the higher improvements always were reached by soldiers with the lower initial level [22-28].

Analyzing the simulated attack maneuver, during phase, where soldiers remain at rest, it is logical to find oxygen uptake and heart rate values being low compared to the maximum data while the heart rate is higher due to the contribution of the equipment, the stress prior to the effort (increase in sympathetic activity). Moreover, during the different phases of the maneuver we found that oxygen consumption, ventilation and heart rate values increased. Values measured indicated that the effort conducted by soldiers was not too stressful (moderate effort) performing the short running exercises with the combat equipment, but soldiers presented a heart rate percentage higher than expected, perhaps influenced by limited recovery periods, the low fitness level and the stress of the effort carrying the equipment on the treadmill. However during the last phase of the maneuver (phase 4) values of oxygen consumption were lower representing 37.2% (average of male and female values) of maximal oxygen uptake, this decrease was due to the lower duration of effort performed after the last recovery step. The influence of combat stress, even being a simulation, could produce the symptom of fatigue as previous researches conducted in combat simulations with combat equip [13, 14]. It seems likely that the continuous increase in metabolic parameters, ventilatory and cardiac

during the first three phases of the maneuver, is clearly related to the increase in the intensity of the exercise. Heart rate of female soldiers was above the anaerobic threshold in the last two combat phases since the heart rate of male soldiers during all the maneuvers was below the anaerobic threshold, it is evident that female soldiers presented a worse physical fitness than male soldiers and more aerobic training is needed to improve their aerobic performance, the fact that would improve the efficiency in the last phases of the attack maneuver and the posterior melee combat. On the other hand, if we compare the relative load carried by male and female soldiers, female soldiers were carrying the 41% of their body mass and male soldiers just the 35% of their body mass, this factor could influence the organic response of the soldiers making the female organic response higher because of the higher relative intensity that they had to perform in the test, but we also have to consider that female soldiers conduct all their training and maneuvers with this load, then they should be better prepared for this load, and the organic response should be more similar to male soldiers. More studies are needed to clarify this fact in the future.

The weight reduction and the improvement of physical fitness are essential for combat maneuver specially in continued military operation in which soldiers increase the energy consumption above to the 4000 kcal/day [29], these maneuvers conducted with full military equipment during prolonged periods of time with short periods of recovery should be improved with specific aerobic training taking into account the values obtained in the present research to perform better and more specific trainings. Overweight derivate to the transport of armament and combat equipment produces an increase in oxygen consumption that causes a decrease in fighter performance [19]. Also, to try to reduce fatigue, the reduction of combat equipment and weight seems to be justified giving to the soldier a garment with breathable materials to prevent dehydration and risk situations of "heat stroke" during combat exercises especially when environmental conditions are unfavorable [30]. For many years, gender differences in physical performance and performance in military tasks among soldiers have been researched. The literature showed that there are differences in body composition18 presenting male soldiers to have higher values of muscle mass as well as technical and military performance [31] than female soldiers. The differences in physical performance depend on different factor related with the subject environment (training, nutrition) and constitutional factor (genetic, age, gender) [32]. Relative to the gender differences, those are closely related with the body composition factors [33], we found a higher VO_2max in male soldiers due to differences in body composition (higher fat percentage and lower muscle mass in women) and possibly due also to the lower hemoglobin concentration in women and other factors related with the life style and the performance level [32]. The present study also found a higher muscle mass, less fat mass and a higher aerobic performance of male soldier in a maximal oxygen treadmill test and also in the attack maneuver analyzed. Data obtained in the present research could be used by military coach to improve specific combat training to improve the efficiency in combat maneuvers.

CONCLUSIONS

The light infantry company offensive maneuver protocol should be modified, either by decreasing the distances of running periods or increasing the recovery time between them to facilitate a reduction of soldiers fatigue, a fact that would improve the performance of soldiers during the last part of the maneuver, the melee combat.

We found differences between genders in the organic response; female soldiers conducted the test above the AT, while male soldiers working below the AT, this difference could be related with the different relative load carried.

Female soldiers should lose the fat mass to values more close to sportswomen to improve their physical fitness and to improve the combat efficiency in the maneuvers.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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