DOI 10.26773/smj.230202

SportMont

ORIGINAL SCIENTIFIC PAPER

Influence of Tactical Equipment on the Ergospirometric Assessment of Military Parachutists

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Abstract

The military parachutists are responsible of special air operations who require certain capabilities in their physical condition, due to their intense professional career. The analysis of oxygen consumption (VO_2) and heart rate (HR) allows the determination of aerobic (VT1) and anaerobic (VT2) thresholds and used to study the adequacy of the organism to exercise and in the analysis of sporting performance. The aim of this study was to determine the effect of tactical equipment on the stress test performance of elite parachutists. 10 parachutists participated in the study, between 22 and 36 years old with an average of 27.75 years (±4.20). Anthropometric values were determined of: weight 75.69 kg (±8.79), height 173.34 cm (±5.72) and body mass index (BMI) 25.23 (±2.98). Each one, performed 2 maximal treadmill exercise testing: one a conventional stress test (A) and another with the tactical equipment (weight 20 kg) (B). We obtained maximum oxygen consumption (Metalyzer 3B) and monitored the electrocardiogram continuously. The test started at a speed of 6km/h and a slope of 1%. The results of the two test were compared. The average value and standard deviation (SD) of different variables with equipment (B) and without it (A) and p-value were obtained: velocity (A: 14.80±3.29; B: 11.50±1.42 Km/h; p=0.073), HR (A: 182.7±58.62; B: 177.75±9.71 b/m; p=0.038), VO_2 (A: 51.75±13.60; B: 54.00±30.82 ml/Kg/min; p=0.891). Also, the values of ventilatory thresholds: VT1 and VT2 of both tests were obtained, with significant differences. Tactical equipment causes a decrease in stress test performance with changes in VT1 and VT2.

Keywords: *military parachutist, oxygen consumption, ventilatory thresholds, stress test*

Introduction

The Parachute Sapper Squadron (EZAPAC) is one of the military units that require certain physical conditions due to their intense professional career. They are in charge of Special Air Operations, which are defined as "military operations conducted by specially designed, organised, trained and equipped forces to achieve high-value objectives in sensitive or hostile areas through the use of unconventional and innovative means and tactics" (Ejército del aire, 2022).

In order to carry out their missions properly, it is necessary for these professionals to have a good basic physical condition, especially in terms of strength and cardiorespiratory endurance. In addition, this translates into the study of the body's aptitude to exercise and the analysis of sporting performance through the ergospirometry (Taylor, Hernández, Schoenherr, & Stump, 2019).

Ergospirometry studies the global and non-invasive response of the organism during physical exercise by observing oxygen consumption, electrocardiographic analysis and recording metabolic parameters (Stavrou, Tourlakopaulos, Daniil, & Gourgoulianis, 2021; Rosenblant, Granata, & Thomas, 2022). This test is used for the diagnosis, monitoring and prevention of ischaemic heart disease (Contreras-Briceño et al., 2021; Mouine et al., 2021) and the performance of athletes (Álvarez, Campos, Portes, Rey, & Martín, 2016; Paredes, Jódar, Ferrer, & Martínez, 2021(a)).

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The analysis of oxygen consumption and heart rate allows the determination of aerobic and anaerobic thresholds. This data is very useful for studying the organism's suitability for exercise (Beaver, Wasserman, & Whipp, 1985) and in the analysis of sports performance in both healthy subjects (Anselmi et al. 2021) and high-level athletes (Ksoll, Mühlberger, & Stöcker, 2021).

The use of ergospirometry is frequently applied in sports, especially in endurance sports such as cycling (Mina-Paz et al., 2021) or athletics (Alves et al., 2021), allowing the values obtained from the test to be used in different training plans and to be adapted to the different physical capacities of each subject (Mainenti, Vigário, Batista, Bastos, & Mello, 2021; Paredes, Jódar, Martínez, & Ferrer, 2021(b)).

It has been used in other groups whose professional activities require a certain level of demand, such as police officers (Silva et al., 2009), firefighters (Avellaneda & Urbina, 2015) and the military, both to assess the physical condition of soldiers and for incorporation into specific units (Foulis et al., 2015; Perlsweig et al., 2015; Taylor et al., 2019).

The sappers must possess optimum physical qualities to face the different missions they face during their professional career. It is an elite team, which carries tactical equipment with: military clothing, boots, protective waistcoat, regulation pistol, magazines, backpack with supplies and specific material. All of this, in order to face complicated situations within a mission. For this reason, their physical form must be maintained throughout the years within this group and their training and repeated practice must be the basis so as not to compromise their health (Ejército del aire, 2022). Since it is unclear how tactical equipment affects the physical performance of parachutists, the aim of this paper was to determine the effect of tactical equipment on the stress test performance of elite parachutists.

Methods

Participants

A total of 10 members of the Air Force Parachute Sapper Squadron (participants in a training course), aged between 22 and 36 years (27.7±4.2) formed the sample for the study. They presented a mean of number of years of service for the entire group of 14.0±5.2 and the mean number of jumps was 1061.2±2204.3. In terms of the anthropometric values, we obtained a mean weight of 75.7±8.6 kg, 173.34±5.7 cm in height and 25.2±2.9 kg/m2 with respect to body mass index (BMI).

The participants who were selected according to the inclusion criteria were the sappers who were at the Air Base taking the training course on the dates of the study. The exclusion criterion was that the participants had injuries or pathologies that interfered with the correct performance of the stress test. All persons involved were informed of the objectives and procedures, their informed consent was obtained, as well as permission from the military authorities and a favorable report from the University's Research Ethics Committee with approval number: 1034-2015 (Approval date: 11/03/2015). The research was carried out at the Biomedical Research Laboratory of the University of Murcia.

Measurments

The general protocol was organized into two tests A and B: in test A, each subject in shorts and sports shoes completed a maximal exercise test on a Run 7411 treadmill (Runner®) with continuous recording of the 12 standard leads of the electrocardiogram using the Cardioline® electrocardiograph, model Click ECG and the Cortex® gas analyser, model Metalyzer 3B for VO_2 measurement. All tests were performed according to the standard protocol (Pollock et al., 1976).

FIGURE 1. Conventional stress test

In test B, each skydiver carried his specific equipment with a total weight of 20 kg: boots, protective waistcoat, regulation pistol, magazines, and backpack with supplies. They performed the same test as described in test A. However, on this occasion the electrocardiographic recording was not collected and was replaced by an F10 polar pulsometer, because it was easier to carry the equipment with the latter device. The order of the visits was randomised.

FIGURE 2. Stress test with specific equipment

Before starting the first test, body weight, blood pressure, cardiac auscultation and resting ECG were obtained for each participant. The test started at a speed of 6 km/h and a gradient of 1% with ramp increases of one kilometer per hour and one grade of gradient every minute. During exercise, heart rate was recorded every minute as well as during recovery. Similarly, blood pressure was taken at the beginning of the recovery period, after three and five minutes (Howley, 1995).

The test ends when the subject is exhausted and gestures with his hand to start the recovery phase at 3 km/h for 3 minutes and at rest for another 2 minutes. The tests were considered to be maximum and valid when they exceeded 85% of the theoretical maximum heart rate (220-age) and the respiratory exchange ratio (RER) was greater than 1.15. (Howley, Bassett, and Welch, 1995).

During exercise testing, subjects breathed through a mask connected to the gas analyser (Metalyzer 3b*, Cortex) to determine: physiological ventilatory (thresholds aerobic (VT1); anaerobic (VT2)), velocity, RER, VO_2, VO_2max, HR and percentage HR max. All gas exchange parameters were measured during breathing and averaged every 30 seconds. The method used to determine VO_2max was to reach the oxygen consumption plateau (Fletcher 2009). All tests were conducted under similar environmental conditions.

Statistics

The data was analysed with Statistical Package for Social Science (SPSS v.24). The description of the results is presented by the value of the mean and standard deviation for quantitative variables. The coefficient of variation (CV = mean/SD*100) of each variable and the percentage decrease between both tests (PD = (B-A)/A*100) have been calculated. Samples were tested for normality using the Shapiro-Weils test. The means of independent variables were compared using the Student's t-test and those related with the paired t-test. A minimum level of significance of $p<0.05$ was established.

Results

Table 1 shows the statistical values for basic anthropometry and body composition.

Table 1. Basic anthropometric and body mass index data

	Min	Max	Mean	SD	VC%
Age (years)	22.0	36.00	27.75	4.20	15.14
Weight (Kg)	63.10	88.80	75.69	8.79	11.61
Height (cm)	163.50	185.50	173.34	5.72	3.30
BMI Kg/m^2	20.20	31.60	25.23	2.98	11.81
Waist (cm)	73.00	88.00	79.82	5.22	6.54
Relative Fat Mass (%)	15.40	24.36	20.40	3.13	15.34

Note_ SD: standard deviation; BMI: body mass index; %: percentage; VC%: variation coefficient.

Table 2 presents the pairwise comparison of the maximum values of both tests, the conventional test (A) and the test with equipment (B) and the percentage of decrement between the two tests ((B-A)/A%). Statistically significant differences were found in all the variables described, with $p<0.05$, with higher values for all variables in the conventional test. No correlation was observed between anthropometric variables and percentage decrement ($p>0.05$).

Table 2. Comparison of peak values in the conventional stress test (A) and with tactical equipment (B).

	Test	Means	SD	VC (%)	T-student	p-value
Velocity (km/h)	A	14.17	0.67	4.73	33.00	0.001*
	B	11.52	0.60	5.21		
	(B-A)/A%	-18.72	1.97	-10.52		
Slop (%)	A	7.80	0.68	8.72	21.17	0.001*
	B	5.13	0.52	10.14		
	(B-A)/A%	-34.09	5.10	-14.96		
Total time (min)	A	9.19	0.61	6.64	31.22	0.001*
	B	6.54	1.74	26.61		
	(B-A)/A%	-28.85	3.18	-11.02		
HR (Beat/min)	A	188.67	9.39	4.98	7.88	0.001*
	B	179.67	11.15	6.21		
	(B-A)/A%	-4.81	2.42	-50.31		
HR% (Beat/min)	A	98.08	4.12	4.20	7.84	0.001*
	B	93.40	5.14	5.50		
	(B-A)/A%	-4.81	2.43	-50.52		
VO_2(ml/kg/min)	A	54.20	5.88	10.85	3.57	0.003*
	B	51.53	6.84	13.27		
	(B-A)/A%	-5.00	5.29	-105.80		
RER	A	1.16	0.03	2.59	2.50	0.025*
	B	1.14	0.04	3.51		
	(B-A)/A%	0.00	0.00			
Ventilation (l/min)	A	139.07	16.85	12.12	3.52	0.004*
	B	125.18	11.30	9.03		
	(B-A)/A%	-9.19	10.26	-111.64		

Note_ HR: heart rate; VO_2: consumption oxygen; A: conventional test B: with the tactical equipment test; (B-A)/A%: percentage decrease between the two tests; *p<0.05.

Table 3. Comparison of aerobic thresholds (VT1) of both tests.

		Means	SD	T-Student	p-value
Velocity(km/h)	A	9.51	0.63	7.39	0.000*
	B	8.27	0.50		
HR(beat/min)	A	144.40	10.76	-1.04	0.318
	B	147.47	14.80		
% HR Max(beat/min)	A	76.53	4.17	-3.72	0.002*
	B	81.95	4.43		
VO_2(ml/kg/min)	A	33.80	3.71	-0.69	0.500
	B	34.40	2.90		
%VO_2 Max (ml/kg/min)	A	62.67	5.38	-2.64	0.019*
	B	67.30	5.99		

Note_ %HR Max: maximum heart rate; %VO_2 Max: maximum oxygen consumption; *p<0.05.

As for the comparison of the aerobic thresholds (VT1) shown in Table 3, we found statistically significant differences in the variables velocity, percentage of maximum heart rate and maximum oxygen consumption. Thus, it has been found that in test B, the aerobic threshold is reached at a lower velocity and lower percentage in the maximum oxygen consumption, on the contrary, it is obtained with a higher percentage of maximum heart rate compared to test A.

Similarly, the variables obtained in the anaerobic threshold (VT2) are shown in Table 4. It can be deduced that statistically significant differences are again obtained in the values of velocity and percentage of oxygen consumption, observing as before, in the velocity this threshold is reached earlier in test B. However, in the percentage of maximum heart rate this threshold was reached later.

Table 4. Comparison of anaerobic thresholds (VT2) of both tests.

		Means	SD	T-Student	p-value
Velocity(km/h)	A	12.05	1.10	7.36	0.000*
	B	10.13	0.89		
HR(beat/min)	A	172.60	7.98	1.85	0.086
	B	168.93	10.91		
% HR Max(beat/min)	A	91.53	2.85	-50.50	0.000*
	B	180.89	6.29		
VO_2(ml/kg/min)	A	46.87	6.35	1.46	0.167
	B	45.07	6.02		
%VO_2 Max (ml/kg/min)	A	86.47	6.17	-0.65	0.524
	B	87.62	6.05		

Note_ %HR Max: maximum heart rate; %VO2 Max: maximum oxygen consumption; *$p<0.05$.

Discussion

The purpose of this study was to analyse the influence of tactical equipment on the performance of elite parachutists in stress tests. Participants took part in the study, and during the two sessions data were collected for the stress tests with equipment (20 kg) and without equipment. It is important to note that this is a new topic and that the literature consulted is scarce in terms of works referring to stress tests performed on soldiers with equipment.

In our study, the "overweight" BMI value (25.23 kg/m2), which shows the mean of the population, is not due to excess fat but to the muscle mass of the participating subjects. Thus, we found similarities with a study published by Pihlainen, Santtila, Häkkinen, and Kyröläinen (2018), in which we obtained similarities with respect to the anthropometric data of their military population in Finland (their results: mean ± SD of: age, height, weight and BMI of the soldiers was 29.8±8.0 years, 179.8±6.3 cm, 79.2±8.5 kg and 24.5±2.3 kg/m2, respectively) and despite having a larger sample size than ours, there are no works in the literature that encompass our aim of this study.

When comparing the maximum values obtained in both stress tests, we found that there is a statistically significant decrease in all physiological (HR, HR%, VO_2, RER, ventilation) and non-physiological (velocity and slope) variables analysed during test B. As the study by Mainenti et al. (2022) shows, the decrease in speed and VO_2max during the stress test is directly related to sports performance. In other words, the greater the load supported by the subject (test B), the lower the values obtained for cardiopulmonary variables such as VO_2max, HR or ventilation during the test.

The mean VO_2max obtained during the exercise test was 54.00±30.82 ml/kg/min in the exercise test without equipment and 51.75±13.60 ml/kg/min in the test with load. These values are lower if we compare them with the study by Ceballos et al. (2021), in which third-year cadets of the military high school (ESMIL), who after performing high-intensity intervallic training (HIT) modified their VO_2max values from 57.26 ml/kg/min to 62.30 ml/kg/min. On the other hand, if we compare these results with other studies where the population is composed of elite athletes, such as professional footballers, we obtain that our VO_2max results are above theirs with a value of 45.90±2.24 ml/kg/min, as reflected by Metaxas (2021). The fact that the latter may be due to the specific training that our military group carries out in comparison to professional footballers.

Furthermore, these results are in line with those obtained by Looney et al. (2018) where a group of 9 military personnel had this variable determined on two occasions: firstly, on a treadmill with light clothing and trainers; secondly, evaluating a walk in difficult terrain with clothing and backpack on. In our study, we compared two similar situations, except for one difference, and that is that the tests were conducted entirely in a laboratory with a treadmill. Both situations were not conducted in a laboratory with a treadmill, in contrast to our work. In which we compared two similar situations.

Furthermore, in the study by Looney et al. (2018) we see how VO_2max decreases considerably with the tactical equipment on, as in our work. The measurement of this variable is considered one of the best predictors of an athlete's aerobic performance and one of the main indicators of cardiorespiratory health.

In this same study, they concluded that the HR is significantly lower with the load than without it, as in our study. When we increase the load on the subject (Test B), we are increasing their cardiorespiratory demand considerably. This can limit sporting performance over long distances on several occasions. Also, from the VO_2max and HR in our study, you tend to have a higher running velocity in the stress test without equipment (A), (14.80 ±3.29 km/h), than with tactical equipment (B) (11.50±1.42) as in the Looney et al., study (2021). As the load on the individual increases, both the velocity and the slope on the treadmill decrease, leading to an earlier stress situation during test B than A in the military.

The coefficients of variation show that in test A, our population presents homogeneous results in all the ergometric variables and that the dispersion increases slightly in test B. Furthermore, in the percentages of decrease we have observed that in the non-physiological variables (velocity, slope and exercise time) the decrease in values is more homogeneous than in the physiological variables (HR, VO_2max, RER and ventilation) where the inter-individual variability is greater. This may suggest that there are individual factors involved in the response to increased load that we have not been able to relate to anthropometric data.

Comparing test, A and B, the aerobic threshold (VT1) was reached with statistically significant differences in speed data (lower in test B), HR max percentage (higher in test B) and VO_2max percentage (higher in test B). This is possible because carrying the weight during test B at a lower speed took longer for VT1 to appear than in the conventional test (A). In the rest of the variables such as HR and VO_2 no significant differences were observed between the two tests. This may be due to the fact that, during the exercise, the subject maintained the same pace with and without load. This is probably due to the level of training experience, physical fitness and aerobic fitness of the participants in this study (Looney et al., 2018).

In our results, the anaerobic threshold (VT2) was reached at a lower speed and at a higher percentage of HR max during test B, these values being statistically significant. These data agree with those of Mainenti et al. (2022): 14.8 km/h, 191.0 beats/min, 40.2 ml/kg/min. In this study, the velocity at which the ventilatory threshold is reached was found to be an excellent indicator for the prescription of exercise intensity and its relation to sports performance.

When relating the maximum value of VO_2 in tests A and B with the appearance of the ventilatory thresholds VT1 and VT2, we observed that the first ventilatory threshold took longer to appear in test B than in test A, with values of 34.40 ml/kg/min (67.30%) and 33.80 ml/kg/min (62.67%) respectively. The second ventilatory threshold, however, appears earlier in test B with 45.07 ml/kg/min than in A with 46.87 ml/kg/min. This suggests that, on the one hand, in the conventional test the subjects stay longer at VT1 threshold without reaching the maximum exercise intensity, maintaining an aerobic metabolism. On the other hand, in test B, although the appearance of the VT1 threshold is delayed, as the organism is undergoing an increase in intensity, the subject fatigues earlier and anaerobic glycolysis begins to cover the energy demands and VT2 appears quickly, increasing the production of lactate in the blood (Maté-Muñoz, Domínguez, Lougedo, and Garnacho-Castaño, 2017).

A subject with a higher VT2 value, as is the case during test A, will be able to sustain a longer period of time at a higher rate than during test B, thus achieving a higher performance. Therefore, training work based on ventilatory thresholds could be effective in modifying the intensity of an exercise during training that requires high endurance, as in the case of the soldier carrying the 20kg rucksack, as it takes into account individual metabolic responses (Anselmi et al., 2021).

There is no literature available on the Parachute Sapper to be able to compare our results of both tests directly with other authors. Nor are there any studies on the influence on performance of load carrying during the stress test in athletes at any level.

The main limitations of this study is that it has been carried out in a laboratory test, not in their outdoor activities, and also small sample size.

This study is original and innovative, so it is interesting to expand the field of study, as it would be essential to have references that allow us to ensure adequate physical conditions for this elite team. This study has made a series of important contributions in terms of novel data on variations in ventilatory thresholds by comparing conventional stress tests with equipment in a specific population that is difficult to access. It is therefore necessary to analyse their physical capacity in order to be able to maintain strict control in situations that require it.

The contributions of this work are necessary because we are providing basic reference data so that other populations with similar characteristics can be compared and improve physical capacity and performance.

Conclusion

The tactical equipment of the soldier has a negative influence on the physical performance during the exercise test, decreasing the maximum values of velocity and oxygen consumption. It is also observed that the change from VT1 to VT2 is obtained earlier when carrying the load (B) than without it (A). Therefore, during test B, a stress situation is generated in the organism previous, in which there is insufficient capacity to supply oxygen to the muscles that are active. Also, comparing tests A and B, VT1 is reached at significantly higher values of HR max percentage and VO_2max percentage; in VT2, it is achieved at a higher percentage of HR max.

Acknowledgements
We acknowledge the Parachute Sappers Squadron for their participation in this study.

Conflict of interest
The authors declare that there are no conflicts of interest.

Received: 12 Aprile 2022 | **Accepted:** 15 December 2022 | **Published:** 01 February 2023

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