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The Effects of Sustain Loads on the EMG Activity of the Leg Muscles During Soldier's Quasi-Static Posture Control

Carlos Eduardo Janô Marinho[1] and Runer Augusto Marson[2]*

[1]*Brazilian Army Physical Education School, Brazil*

[2]*Brazilian Army Research Institute of Physical Fitness, Brazil*

***Corresponding author:** Runer Augusto Marson, Brazilian Army Physical Education School, Brazil

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Abbreviations: GNL: Gastrocnemius Lateralis; TBA: Tibialis Anterior; MIVC: Maximum Isometric Voluntary Contraction; MIVC: Maximum Isometric Voluntary Contraction Test

ABSTRACT

Background: The backpack load carriage is a routine activity in the daily life of the military. This can result in injuries, decreased combat capability, and shortened combat duration. The aim of this study was to analyze the activation of the gastrocnemius lateralis (GNL) and tibialis anterior (TBA) muscles in standing position using combat backpack, rifle and machine gun.

Methods: 16 experienced male military personnel participated in the study. Electromyographic analysis was performed for 90 seconds in the orthostatic position. Wireless surface electrodes were placed on GNL and TBA. The test of maximum isometric voluntary contraction (MIVC) was per-formed. Variables were analyzed using the two-way Friedman test for analysis of variance of related samples.

Results: The total body weight was significantly different in all situations. The results of the electromyographic analysis were compared the three conditions were not statistically significant for both muscles collected.

Conclusion: The military carried a statistically significant weight, but that was not enough to present significant differences in the muscle activation of GNL and TBA. These results show that the weight of the carrying items did not require significant muscle activation in addition to the minimum activation to support the backpack in the quasi-static position.

Introduction

During military activity, professionals are sometimes required of their physical capacity to carry out cargo transportation. This activity is performed using basic equipment for the military to last in action, such as: the combat backpack, in which the individual will carry the items needed for personal survival, and his or her weaponry that will pro-vide you with security and protection. The high military physical effort, the specific tasks performed and the great weight transported, the military are subject to a higher risk of suffering some type of injury. The increase of this transported weight reflects in the increase of the tension of the muscles of the lower limbs, which are strictly related to the injuries [1-4]. In the load carriage using packs, the military is subjected to a natural imbalance, at this point he will seek postural control to keep himself balanced. this capacity is defined as the property for maintaining an upright posture, determined by the movement of the human body's pressure center [5]. The most important thing in this activity is the location that the individual will carry such a load in his body. It is precisely in this decision that will reflect how the muscles of the lower limbs will behave to maintain the balance already mentioned above. The way of load carriage using backpacks will also bring reflexes to the military, with regard to biomechanics and human physiology. In this case, showing that distributing the weight in the anterior and posterior part of the body, such as a double backpack, will re-quire less energy from the military; promoting lower inclination of the body, but limiting the movement of the arms and increasing body temperature [3,6].

Another analysis, the high load distribution also alters the ground reaction force, promoting the balance of the body. In its conclusion, it showed the progressive increase of this force in relation to a load of 60% of body weight and with a focus on transportation; also reporting on military weapons [7]. With all this, in our study, to measure this orthostatic equilibrium in the face of a load variation, we used surface electromyography (EMG). This choice was made taking into account that this exam will provide the motor units activated during the individual's overload and the discharge rate produced, showing the muscular behavior [8-10]. In this part of the literature, little has been said about the effect of the support of the military backpack and the armament on the orthostatic position [11,12], analyzed by the electromyographic behavior. This gap needs to be deepened, since it is the basic military activity, it will soon bring a benefit to the Brazilian Army. Generating adaptations, or suggestions, to improve the postural control of our military. All with the purpose of reducing injuries already men-tioned above; thus, improving the combative capacity of the terrestrial force. Therefore, the aim of this study was to evaluate the effects of backpack support and military weaponry on the electromyographic behavior of the leg muscles in maintaining standing position.

Materials and Methods

It is an experimental, applied study, cross-sectional and quantitative data. The participants were composed of experienced service members and were submitted to three conditions: The first, supporting only the combat backpack (CTRL), the second condition sup-porting the combat backpack with the machine gun simulator (MAG) and the third condition supporting the combat backpack with the rifle (FZL). These moments were compared based on the electromyographic signal variables of gastrocnemius lateralis (GNL) and tibialis anterior (TBA) muscles.

Subjects

The sample was of the non-probabilistic type of voluntary character and consisted of 16 participants (male sex; age: 27.5±4.9 years; total body mass: 77.2±9.3 kg; height: 176.8±5.1 cm), experienced service members (> 6 years of service and experience in cargo support). All participants were students in the instructor course of the Brazilian Army Physical Education School. The study protocol was approved by the Ethical Committee of the Salgado de Oliveria University (file: CAEE 48000321.3.0000.9433). All participants were fully informed about the content of the study and gave their written consent.

Equipment's and Instruments

In the reference condition, the participants wore t-shirts, shorts, boots, socks, and a military backpack. Afterward, all subjects added a rifle and a machine gun according to the test. The individual combat equipment that was used by the 16 volunteers was composed of: 01 (one) large capacity Alice campaign backpack with two liter pet bottles with sand, totaling the weight of 15kg, 01 (one) Mauser carbine model 1935 with two shin guards, one of 3kg and another of 4 kg, weighing on average 10.8kg (simulating the weight of the MAG machine gun), together with a bandolier to assist in weight control), 01 (one) Model 1935 Mauser carbine with a 1kg shin and an extra weight of 0.5kg, weighing on average 4.8kg (simulating the weight of the FAL 7.62 rifle), along with a bandolier to assist in weight control) and 01 (one) personal boot, shirt and shorts.

Procedures

Data were collected from June to September of 2021 in the Biosciences laboratory of the Brazilian Army Physical Education School. The volunteers were scheduled to only collect 4 individuals per day. At first, the ICF and anamnesis were completed. After completing the mandatory documents, each military member had his or her stature (EST) and total body mass (MCT), measured using the military physical training uniform. It was then asked that the military put the boots, for a new conference of MCT and EST. They were then instructed on the procedures to be carried out. On the days of collection the MCT was again measured, but in the control conditions with backpack (MCT_CTRL), with backpack and rifle (MCT_FZL) and with backpack and machine gun (MCT_MAG). For the acquisition of biological signals (surface electromyography - sEMG), wireless surface electrodes (Trigno Wireless System, Delsys Inc., USA) were used, amplified by a signal acquisition module ((Delsysinc., USA, 2.4GHz transmission frequency, 1kHz sam-pling frequency, common rejection mode >80dB, 10Hz high pass filter and 450Hz low pass, total gain 1000 times). The electrodes were positioned on both sides of the lower limbs in the anterior tibialis (TBA) muscle, one-third to one-fourth of the distance from the knee to the ankle, in the largest palpable muscle mass, we palpated the area while the individual performed the dorsi-flexion of the foot. In the gastrocnemius lateralis muscle (GNL), the electrodes were

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positioned approximately two centimeters laterally in relation to the midline of the gastrocnemius muscle [9,12,13].

Myoelectric activity recorded from: gastrocnemius lateralis (GNL) and anterior tibialis (TBA) normalized for the maximum amplitude of myoelectric activity obtained during the maximum isometric voluntary contraction test (MIVC). The CIVM was performed with the individual seated on a stretcher with the trunk at 80º flexion in relation to the hip and with the knee positioned at 90º flexion and suspend-ed on the side of the table. After positioning, the participants performed the dorsi-flexion and plantar flexion against resistance imposed by the evaluator. This resistance was maintained for 5 seconds for each movement in both lower segments. After that, they climbed onto the power platform and looked for the upright and static posture, staring at a target on the wall in front of them, at a distance of 3 meters. The positioning of the feet, on the platform, was standardized, using a plastic wedge with an angle of 30º, making the heels stick together and the tips of the feet distant. Each participant was submitted to three conditions of estabilometric evaluation, being sustaining the combat backpack, sustaining the combat backpack and the Mauser carbine and sustaining the combat backpack and the MAG machine gun, in each of these positions were made 3 collections. Each measurement lasted 90 seconds, with 30 seconds (15 initial seconds and 15 final seconds) being discarded where sEMG analyses occurred in 60 seconds. The sEMG signals of the muscles and the platform of force were sincronized by means of an accelerometer positioned in the dorsal region of the boot (Table 1).

Table 1: Descriptive statistics with mean, standard deviation (SD), minimum (Min.) and maximum (Max.) of the total body mass (kg) in the conditions with backpack, backpack and rifle and with backpack and machine gun.

	Mean	SD	Min	Max
MCT_CTRL (kg)	93,56	9,16	72,40	106,90
MCT_FZL (kg)	98,36[1]	9,16	77,20	111,70
MCT_MAG (kg)	104,36[2]	9,16	83,20	117,70

Note:

[1]Significant difference between MCT_CTRL and MCT_MAG condition.

[2]Significant differences between MCT_CTRL and MCT_FZL condition.

The signals were analyzed in specific software in which the test parameters consisted of continuous collection and thus initially stored in files on the computer hard drive for the processing of digital signals in MATLAB environment (R2015a) version 8.5.0 (The Math works Inc Natick, Massachusetts, USA) that provided root Mean square (RMS) and full-time analysis (iEMG) related time domain data. The RMS values are summed on each side according to the analyzed muscle. This sum generated a unique value for the TBA and GNL muscle in the respective conditions (CTRL, FZL and MAG). The same calculation was made for iEMG. After these values were normalized by the peak of the RMS and iEMG of the MIVC of each muscle.

Statistical Analysis

All data were stored and analyzed using the statistical program Statistical Package for the Social Sciences for Windows (SPSS) version 20.0 (SPSS Inc. Chicago, Illinois, USA). Shapiro Wilk's normality test rejected the hypothesis of equality of EMG variables for different load conditions, and Friedman's two-way test was performed to analyze the variance of related samples. All significance values (p value) were determined as <0.05. Descriptive statistics (mean, standard deviation, maximum and minimum) were calculated for each data set if presented in graphic form using Graphpad Prism software version 8.0.1 (Graphpad Software Inc. San Diego, California, USA).

Results

The total body mass (MCT) obtained initially was that of the control condition (93.56±9.16 kg). Then we obtained the MCT of the FZL condition, with the military carrying the simulacrum of the Rifle (98.36±9.16 kg), in which already presented a statistically significant difference between the CTRL condition (p=0.014). Finally, the MCT of the MAG condition, with the military carrying the MAG machine gun weight (104.36±9.16 kg), finally, this last condition was demonstrated with a statistically significant difference, both from the CTRL condition (p=0.0001), and from the FZL condition (p=0.014).When performing the maximum voluntary isometric contraction (CIVM), we obtained the measure adopted as 100% of the RMS (1.0 in u.a.), represented in the ordinal axis of Figures 1 & 2. When performing the sEMG analysis in the time domain, In Figure 1, we used the square root of the mean signal obtained (RMS) to quantify our muscle activation in relation to the maximum military activation, all of the two muscles under analysis, anterior tibialis (TBA) and gastrocnemiuslateralis (LNG). With this, we found that the CTRL condition (TBA: 0,204 [0,062 - 0,366]; LNG: 0,209 [0,067 - 0,371]) did not present a significant difference.

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The RMS values in the FZL condition (TBA: 0,195 [0,008 - 0,381]; LNG: 0,204 [0,013 - 0,385]) and in the GAM condition (TBA: 0,221 [0,072 - 0,293]; LNG: 0,225 [0,077 - 0,298]) were not statistically significant differences. However, there is a low-er maximum variation of this muscle activation in the latter condition. Another form of sEMG quantification is the integral of the entire area, in the frequency spectrum filled by the signal [7]. In this condition of Figure 2, we obtained for CTRL condition the result of 0.225 (0.064 - 0.368) for TBA and 0.231 (0.069 - 0.373) for GNL, both muscles without significant differences. For FZL condition, the results were 0.213 (0.012 - 0.382) for TBA and 0.218 (0.015 - 0.387) for LNG, also without significant differences for both muscles. Finally, in the GAM condition, the results were 0.219 (0.074 - 0.295) for TBA and 0.224 (0.079 - 0.300) for GNL, as well as the previous ones without significant difference. Results similar to Figure 1 with the treatment of MRH, corroborating the reliability of the data obtained in the time domain.

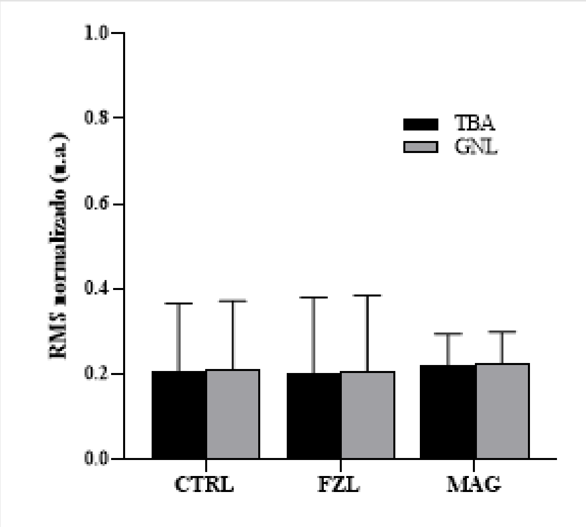

Figure 1: Root mean square (RMS) of the electromyographic signal in arbitrary unit (u.a.) comparing the conditions with backpack (CTRL), backpack and rifle (FZL) and backpack and machine gun (MAG) of the anterior tibialis (TBA) and gastrocnemius lateralis (GNL) muscles.

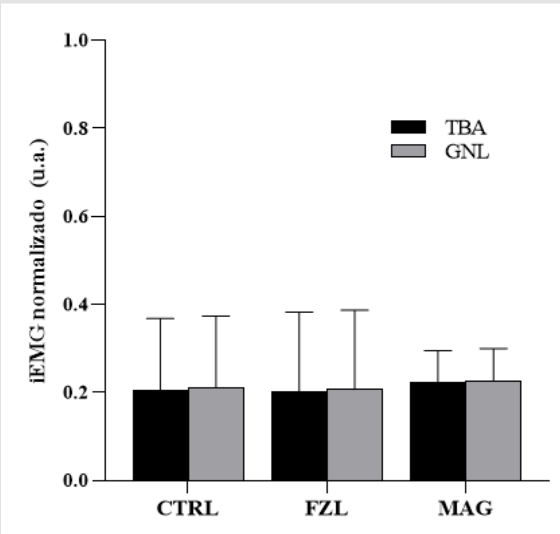

Figure 2: Electromyographic signal integral (iEMG) in arbitrary unit (u.a.) comparing the conditions with backpack (C-TRL), backpack and rifle (FZL) and backpack and machine gun (GAM) of the anterior tibialis (TBA) and gastrocnemius lateralis (GNL) muscles.

Discussion

Military activity requires the transportation of heavy cargo, whether backpack, equipment, or weaponry, for extended periods of time. We have shown in our study that the addition of the rifle and the MAG machine gun were statistically significant for the difference in total body mass (MCT), this is a potential risk factor for the occurrence of lesions in the locomotor system [14]. However much this difference in weight, when we add the MAG and compare it with the CTRL situation, it is significant, it is an increase of less than 20% of the MCT. The backpacks with less than 20% of body weight were not sufficient to activate the lower limbs muscles in the static position, noting a significant difference only in the rectus abdominis [15-17]. With the results of our sEMG, we observed that there was no statistically significant difference when comparing the three situations tested. All of them had about 20% of the muscular activation when compared to the total maximum voluntary isometric contraction. Several may be the reasons for this event, first we performed the measurement in the static position, while Simpson, et al. [18] collected these variables in displacement and found an increase in gastrocnemius lateralis activity, suggesting that a possible collection in displacement be more reliable the real employment situation of military troops [19].

In our research we analyzed the tibialis anterior and gastrocnemius lateralis muscles, in both results they were similar and did not present significant statistical differences. Corroborating with Lindner, et al. [1], in his study, found that these muscles, already mentioned above, also did not demonstrate significant muscle activation when transporting military equipment, however, in this same research, the greatest increase in electromyographic activity was in the rectus femoris muscle after adding the backpack. Birrel, et al. [7] presented in their research that there are statistically significant differences in the ground reaction force when walking with a rifle, but when dealing with muscle activation measured by sEMG. We are talking about the recruitment of muscle fibers to perform a certain activity, that is, the greater the difficulty of the task required, the greater the recruitment of muscle fibers. In our research, when we added the rifle or the MAG machine gun, the activation was similar to the CTRL moment, which would be the individual with only the backpack, it is worth noting that both the rifle and the MAG were inserted with the bandolier wrapping behind the neck with the armament resting in front of the body which suggests a greater demand of the upper back muscles due to the location closest to which weight was supported, thus requiring little muscle recruitment of the lower extremities, the previous statement is confirmed by the study by Lindner, et al. [1] which showed that the weight of the rifle showed no significant difference in muscle activation in the lower limbs, when the weight of the armament is carried by the upper limbs. Confirming our thesis Thuresson, et al. [18] showed that the weight of a helmet placed on the head did not reflect on the lower limbs, but on the muscles of the neck and upper back due to its proximity to the place of weight inserted.

Contributing to the findings of our research, Majumdar, et al. [20] in his study on the transport of loads in military personnel, found that the body adopts some postural changes to decrease muscle overload, but that if this load is carried is low, between 6.5% and 27.2% of body weight will not cause orthostatic changes, confirming our results, since the load we added in the military was well below 25% of the MCT. Our sample was composed of experienced service members, all with at least seven years of military service, with good physical fitness, being a very restricted and specific sample. Therefore, also attributed this factor to one of the causes of low muscle activation and concluded that experienced service members supported larger loads due to better training, physical condition and greater strength, supporting loads between 47% and 64% of your body weight while maintaining a normal gait pattern [21,22]. The present study has limitations such as: the small sample collected; the evaluation only in the static position; the weight of the additional transported load is relatively low; the collection time is small. The study did not evaluate other possible factors that contributed to the low electromyographic activity found in the research, such as: muscle strength of the lower limbs, and a strength test of this muscle group may have been performed previously; activity of other synergetic muscles, which may be collected in later studies, adding sEMG in the biceps femoris for example; finally, postural changes of individuals, and photogrammetry software may be used to quantify these changes. It is suggested to carry out more studies in the area, a cross-sectional survey with military personnel during a march, with the continuous monitoring of the electromyographic activity of the lower limbs. Another suggestion would be a longitudinal study, analyzing the sample with the manipulation of the transported load variable and verifying the behavior of the military with the increase of this variable.

Conclusion

The body mass of the total FZL and MAG condition were significantly different. The sEMG of the TBA and GNL muscles in the CTRL condition showed about 20% of muscle activation in relation to VSD, the other two conditions resembled the control condition and did not present a statistically significant difference for both muscles measured. A similar result was observed in iEMG, in which the CTRL condition was not significantly different from the FZL and MAG condition, both of TBA and GNL, serving to corroborate with sEMG. These results indicate that the addition of the rifle load and the MAG machine gun, were not sufficient to significantly activate the muscles of the lower extremities, during the maintenance of the quasi-static posture with combat backpack.

Author Contributions

Conceptualization, R.A.M.; methodology, R.A.M. and C.E.J.M.; software, R.A.M.; formal analysis, R.A.M. and C.E.J.M.; investigation, R.A.M. and C.E.J.M.; resources, R.A.M.; data curation, C.E.J.M; writing-original draft preparation, R.A.M. and C.E.J.M.; writing—review and editing, R.A.M. and C.E.J.M.; visualization, R.A.M.; supervision, R.A.M.; project administration, R.A.M. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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