ARTICLE
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Ergonomics for military combatants: an integrative review

Ergonomía para combatientes militares: una revisión integradora

Abstract: Ergonomics aims to prevent injuries and prevent health costs in military personnel. Thus, the aim of this study was to investigate the types of ergonomic assessments and interventions used for the prevention of musculoskeletal injuries in military combatants. An integrative review of observational and experimental studies was carried out. Therefore, a systematic literature search was performed in May 2020 and updated in August 2020 in the MEDLINE, LILACS, Cochrane, CINAHL, Sportdiscus, SCOPUS and Web of Science databases with the DeCS and MeSH military personnel, ergonomics, and load carriage. A total of 955 studies were found in the databases, however 14 studies were included (9 evaluation studies and 5 intervention studies). The following ergonomic assessments were recommended for military combatants: stress level, sedentary lifestyle, activity characteristics, presence of vibrations, posture during operational activities, evaluation of footwear, clothing and the load carried, the ration and the level of satisfaction with the job. As interventions: the realization of ergonomic guidelines and physical exercises, in addition to uniforms and protective equipment that provide a higher level of comfort during operational activities.

Keywords: military personnel; overuse injuries; ergonomics.

Resumen: La ergonomía pretende prevenir lesiones y costos de salud en el personal militar. De esta manera, el objetivo de este estudio fue investigar los tipos de evaluaciones e intervenciones ergonómicas utilizadas para la prevención de lesiones musculoesqueléticas en combatientes militares. Se promovió una revisión integradora de estudios observacionales y experimentales. Con eso, se realizó una búsqueda bibliográfica sistemática en mayo de 2020 y se actualizó en agosto de 2020 en las bases de datos MEDLINE, LILACS, Cochrane, CINAHL, Sportdiscus, SCOPUS y Web of Science con descriptores del DeCS y MeSH military personnel, ergonomics, y load carriage. Se encontraron un total de 955 estudios en las bases de datos, pero se incluyeron 14 (9 estudios de evaluación y 5 estudios de intervención). Se encontraron las siguientes evaluaciones ergonómicas para los combatientes militares: nivel de estrés, sedentarismo, características de la actividad, presencia de vibraciones, postura durante las actividades operativas, evaluación del calzado, vestimenta y carga transportada, ración y nivel de satisfacción con el trabajo. Como intervenciones, la realización de pautas ergonómicas y ejercicios físicos, además de uniformes y equipos de protección que brinden un mayor nivel de comodidad durante las actividades operativas.

Palabras clave: personal militar; lesiones por uso excesivo; ergonomía.

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1. INTRODUCTION

Ergonomics aims at the use of methods and techniques in order to provide improvements in the relationship between the work environment and the individual, and may cover physical and psychological aspects of workers. In addition to adapting jobs, through an ergonomic evaluation of the activity, adjustments of work activities can be made in order to prevent musculoskeletal injuries and occupational diseases. The objective is to prevent workers from acquiring chronic occupational diseases, which can evolve with incapacity for work.

In the military environment, several activities are associated with a higher risk of injury, especially those with higher physical demands.

Combat activities are those carried out on an operational basis, constituting as exercises or employment of activities to combat an enemy (CAMERON; OWENS, 2016). Such operations often require soldiers to carry a high load (individual equipment), nimbly, often on marches on long trajectories and on uneven terrain (KNAPIK *et al.*, 2012), under conditions of need for immediate decision-making.

Combatant personnel often perform as physical training, cargo transportation, marches of 8, 16 and 32 km, and training maneuvers (POPOVICH *et al.*, 2000), making this population susceptible to a high incidence of various types of musculoskeletal injuries (CAROW *et al.*, 2016).

Musculoskeletal injuries are defined as any damage to the musculoskeletal system that promotes the need for medical attention, being related to operational activity and causing withdrawal from sports or work functions (HÄGGLUND *et al.*, 2005). As a result, injuries generate a large health cost, withdrawal from duties causes a reduction in performance (TOMES; ORR; POPE, 2017), premature dismissal of military personnel from active duty (LARSSON; TEGERN; HARMS-RINGDAHL, 2012), as well as reduced operational readiness (HÄGGLUND *et al.*, 2005; TAANILA *et al.*, 2015).

The military most exposed to injuries are women (ARMSTRONG *et al.*, 2004; BEDNO *et al.*, 2014; BLACKER; WILKINSON; RAYSON, 2009; FINESTONE *et al.*, 2008), individuals with prior injuries (HENDERSON *et al.*, 2000; KNAPIK *et al.*, 2013; MONNIER *et al.*, 2016), people with obesity or overweight (BMI) (TAANILA *et al.*, 2015), older military (HEIR; EIDE, 1997; HENDERSON *et al.*, 2000), individuals with lower aerobic fitness (MALLOY *et al.*, 2016; ROSENDAL *et al.*, 2003) and those with other risk factors (BOOTH-KEWLEY; LARSON; HIGHFILL-MCROY, 2009; KAZMAN *et al.*, 2015; MALLOY, 2016; ROY *et al.*, 2016; SCHOENFELD *et al.*, 2014).

There are injuries arising from operational activities (combat), and others that do not have direct contact with the enemy. Within this context, non-battle injuries are responsible for a large part (or majority) of time spent on treatment and the number of medical evacuations (CAMERON; OWENS, 2016). In this way, ergonomic strategies have been carried out in order to reduce the incidence of non-battle injuries associated with military combat activities (KNAPIK; REYNOLDS, 2010; LARSSON; TEGERN; HARMS-RINGDAHL, 2012; STEVENSON *et al.*, 2007).

Examples of ergonomic interventions used to reduce the number of injured military personnel include physical training and ergonomic orientations, as well as the recognition of musculoskeletal injuries (LARSSON; TEGERN; HARMS-RINGDAHL, 2012), use of different psychomotor performance materials and thermal comfort (MAJCHRZYCKA *et al.*, 2016) and employment of different vests and backpack adaptations (STEVENSON *et al.*, 2007). There is, therefore, a variety of ergonomic interventions that have been used in the military environment. Considering the importance of maintaining a greater number of individuals with adequate health conditions and physical performance for military activities, knowledge about ergonomic assessments and interventions has the potential to prevent injuries and health costs in military personnel. Thus, the objective of this review was to investigate the types of ergonomic assessments and interventions used in military combatants.

2. METHOD

2.1 Study design

An integrative review of the literature was carried out, in which the ergonomic evaluations and interventions used for the prevention of musculoskeletal injuries in military combatants were investigated.

2.2 Eligibility criteria

For the selection of studies, the PICOS strategy (participant, intervention, comparison, outcome and study design) described in Table 1 was used. In order to investigate the evaluations and interventions used for combatants, studies with military pilots, administrative and health professionals were excluded. It was considered a control group, whose participants do not perform any activity (passive control) or who perform some activity, common to the experimental group (active control). In this case, in addition to the common activity, the experimental group must have undergone some ergonomic intervention: preventive exercises, adaptation of clothing and/or individual load, modification of materials used in uniforms, backpacks and individual equipment, among others.

Table 1 – Inclusion Criteria – PICOS strategy

Acronym	Definition	Description
P	Participants	Military
I	Intervention	Ergonomic assessments or interventions
C	Comparison	Control
O	Outcome/result	Musculoskeletal injuries or symptoms
S	Study design	Not applicable

Source: The authors (2022).

2.3 Search Strategy

A systematic literature search was conducted in May 2020 and updated in August 2020 in the databases MEDLINE, LILACS, Cochrane, CINAHL, Sportdiscus, SCOPUS and Web of Science. The descriptors of DeCS and MeSH were used: military personnel, ergonomics, and load carriage, as well as words obtained in articles on similar topics. Table 2 lists the terms used in the search equations. The Boolean logic operators AND (between descriptors) and OR (between synonyms) were used. There was no language or time filter for the search.

Table 2 – Database search strategy

Military	OR		Ergonomics	OR
Military	OR	AND	Ergonomics	OR
Armed Forces Personnel	OR		Human Factors and Ergonomics	OR
Army Personnel	OR		Human Engineering	OR
Marines	OR		Human Factors Engineering	OR
Marine	OR		Human Factors Engineerings	OR
Soldiers	OR		Cognitive Ergonomics	OR
Soldier	OR		Cognitive Ergonomic	OR
Recruit*	OR		Visual Ergonomics	OR
Recruits*	OR		Visual Ergonomic	OR
Submariners	OR		Organizational Ergonomics	OR
Submariner	OR		Organizational Ergonomic	OR
Sailors	OR		Physical Ergonomics	OR
Sailor	OR		Physical Ergonomic	
Military Deployment	OR			
Recruits*	OR			
Special Forces*	OR			
Special Operation	OR			
Load carriage	OR			
Weight Bearing	OR			
Weightbearing	OR			
Load bearing	OR			
Load-bearing	OR			
Load Bearing	OR			
Load carrying	OR			
Backpacking	OR			
Hiking	OR			
Walking	OR			
Armor	OR			
Armour	OR			
Protective gear	OR			
Rucksack	OR			
Haverstock	OR			
Backpack	OR			
Duffel	OR			
Body protection	OR			
Heavy equipment				

Source: The authors (2022).

Legend: *Added terms in descriptor search

2.4 Data extraction process

The following data were extracted from the studies: sample characteristics (age, gender, armed force, specialty), military activities in which the ergonomic intervention was carried out (cargo loading, anti-aircraft exercises, special operations courses), ergonomic evaluations carried out, intervention protocol and control group, and the results obtained. The studies were categorized into two types: ergonomic assessment or ergonomic intervention.

2.5 Assessment of the quality of individual studies

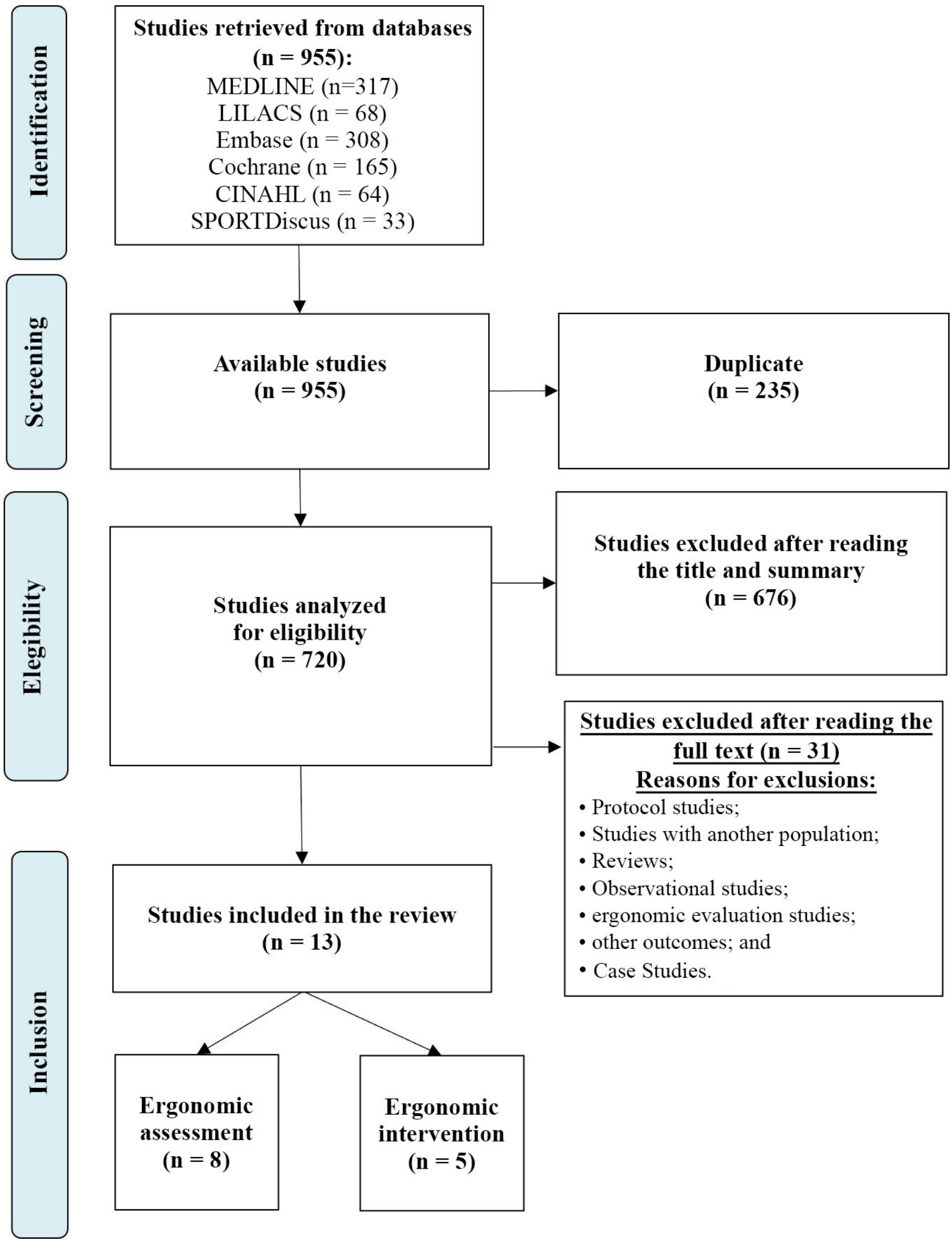
For the evaluation of the quality of the experimental studies, the Jadad scale of methodological evaluation was used (JADAD *et al.*, 1996), which consists of the sum of the score of three domains, namely: 1) randomization of participants; 2) double-blind evaluation; and 3) description of sample losses. Initially, one point was assigned for each question answered. If participant randomization and double-blind evaluation were not appropriate, one point was subtracted from domains 1 and 2. Therefore, the total score on the Jadad scale ranged from 0 to 5 points.

3. RESULTS

The flow diagram of the included studies is in Figure 1. The results of this review show that there are several ergonomic variables related to military activity. A total of nine studies involving firefighters, army soldiers, military police, armored personnel carriers, and others investigated the ergonomic variables associated with musculoskeletal discomfort in military combatants (Table 1). On the other hand, ergonomic orientations, use of insoles, exercises and cervical collars were interventions used in order to reduce painful symptoms, increase comfort and acceptability of the military (Table 2).

Among the studies, the activities of infantry, armored personnel carriers, cargo loading (backpack, personal protective equipment, clothing, weapons, etc.), missions in Iraq etc. were analysed. Despite the diversity of samples and activities, some factors were repeated in different studies.

Figure 1 – Flow diagram of the studies included in the Integrative review



Source: The authors (2022).

Table 1 - Characteristics of the studies included in the review that investigated ergonomic evaluations in military personnel

Study	Sample characteristics	Activity	Evaluation	Result
McCaig e Gooderson (1986)	n=2000 Soldiers.	Military operations in cold and humid climates.	Interviews: assess reasons for dissatisfaction.	Prolonged combat boots time; total weight loaded; physical fatigue.
Daniels *et al.* (2005)	n=279 Army servicemen (men and women).	Infantry, driver, construction equipment operator and repairman, vehicle mechanic, systems operator and nurse.	Factors associated with low back pain in Air Force activities.	Frequency of movements, such as bending, twisting, standing and sitting, is associated with low back pain.
Leyk *et al.* (2006)	n=1337 healthy Army candidates (301 women).	Environments with integration with machines, seated.	Anthropometry, hand grip test and isometric strength test for dominant forearm flexors and knee extensors in the sitting position.	There were differences between the sexes in all tests. Only 26% (knee extensors) and 3% (forearm flexors) of women generate forces greater than the corresponding 5 percentiles of men.
Rozali *et al.* (2009)	n=159 Drivers of armored vehicles.	Armored missions.	A self-administered questionnaire on specialty, low back pain symptoms and human vibration meter were used in this study.	The prevalence of low back pain among drivers of tracked armored vehicles was higher (81.7%) compared to drivers of wheeled armored vehicles (67.0%). Driving in a sitting posture with a forward tilt and exposure to vibration increased the chance of low back pain.
Vitari, Francisco e Mello (2012)	n=208 Military firefighters.	Military firefighter activities.	Questionnaire (age, gender, education, BMI, time of service, frequency of health tests, practice of physical activity, work environment and demands of the activity performed.	Most of the military were sedentary, with high BMI, with musculoskeletal symptoms and mental work overload, complained of the demands of work, environment and comfort.
Majchrzycka *et al.* (2013)	n=10 Military	Ergonomic evaluation of bulletproof vests and fragments.	An obstacle course and subjective ergonomic assessment questionnaires were used in the tests. Thermal discomfort and psychological evaluation.	The tests did not show any decrease in comfort wearing the new pads with better ballistic resistance compared to the currently used pads.
Nissen *et al.* (2014)	n=680 Soldiers on mission in Iraq	Mission in Iraq.	Questionnaire with demographic and personal characteristics, characteristics of missions, lifestyle and pre-employment health; aspects of leadership at work and relationship at work.	Age, poor support from leaders, psychological stress, inappropriate work postures and working in warehouses were associated with low back pain.
Ramstrand *et al.* (2016)	n=21 Police officers.	Loading cargo.	Biomechanical and self-report data were collected on two test occasions, comparing situations without and with loads (standard belt and ballistic protective vest; or a load-bearing vest with ballistic protective vest).	The load-bearing vest was associated with a significant reduction in the range of motion of the torso, pelvis and hip joints. Biomechanical changes associated with the load-bearing vest seemed to reduce with longer time of use. Self-report data indicated a preference for the load-bearing vest.

Source: The authors (2022).

Caption: BMI = body mass index.

Table 2 - Characteristics of the studies included in the review that investigated the effects of ergonomic interventions on military

Study	Sample characteristics	Activity	Evaluation	Intervention	Outcome	Result	Jadad Score
Larsen, Weidick e Lebo-euf-Yde (2002)	n=249 Recruits Age=21±1.5 years.	Military service.	Complaint of back pain.	EG: ergonomic orientations and passive spine extension exercises in the prone position daily. CG: no interventions.	Number of recruits with back pain.	GE: menor número de recrutas com dor nas costas em 3 meses (RR = 0,6 (0,5–0,9), 1 ano RR = 0,7 (0,4–1,1); e na busca pelo atendimento na enfermaria (RR = 0,3 (0,2–0,7).	3
House, Dixon e Allsopp (2004)	n=38 Marine Corps recruits.	Military service.	Comfort questionnaire.	Recruits were matched in pairs according to body mass and then randomly given a pair of shock-absorbing insoles with a thickness of 3mm (CG) or 6mm (EG).	Comfort level of footwear.	Both insoles promoted comfort in the military, but there was worsening in damp conditions.	1
Breeze *et al.* (2011)	n=71 Army cadets and marines.	Movement under fire.	Rifle shooting; simulation of movement under fire and climbing a 20 m firefighter lift carrying a simulated victim.	Six kinds of cervical collars from different countries.	Comfort and potential restriction of military performance.	Higher and stiffer collars showed the worst overall and designs with overlapping segments were the most comfortable when shooting.	1
Breeze *et al.* (2013)	n=10 Infantrymen.	Armed and equipped treadmill test.	Troop acceptability, heart rate, tympanic and skin temperatures.	6 kinds of protective collars for cervical: no neck protection; three-piece collar; two-piece collar; nape pad; ballistic scarf; EP-UBACS.	Comfort.	The ballistic scarf showed a comfort of 30%, while the other five types had a comfort of 90%.	0
Breeze *et al.* (2014)	n=20 Soldiers on mission in Afghanistan.	Mission in Afghanistan.	Comfort.	Three configurations of a combat shirt with neck protection (EP-UBACS) compared to the standard (UBACS) were compared.	Comfort, heat dissipation and overall acceptability.	Silk fabric was the most comfortable, but the collars did not hold up after repeated use. Crossover collars incorporating UHMWPE or felt had similar acceptance to standard UBACS.	0
EG = experimental Group; CG = control group; RR = relative risk; UBACS = body armour combat shirt; UHMWPE = a layer of ultra high molecular weight polyethylene							

Source: The authors (2022).

4. DISCUSSION

Factors such as stress and sedentary lifestyle were associated with musculoskeletal symptoms (VITARI; FRANCISCO; MELLO, 2012). At the same time, individuals with high physical demand had higher rates of low back pain (DANIELS *et al.*, 2005). In older individuals, under stress, and in inappropriate work positions, there were higher incidences of low back pain (NISSEN *et al.*, 2014). Factors such as model of footwear and excessive load carrying were reasons for dissatisfaction with work (MCCAIG; GOODERSON, 1986). In armored vehicle drivers, low back pain was associated with excessive vibration conditions (OR=1.95 and 95% CI = 1.02-3.69) and a sitting posture with anterior torso inclination (OR = 3.63 and 95% CI = 1.06-12.42).

Regarding prevention strategies (ergonomic interventions), a total of five studies were included, with 388 military participants. In this case, the samples were composed of marines, army cadets and marines, conscripts and soldiers on mission in Afghanistan. Interventions occurred during military service activities, cargo loading and crawling (Table 2).

For recruits, the risk of back pain was significantly decreased with interventions based on ergonomic guidelines and spinal extension exercises in the prone position. The interventions occurred in a period of 3 months (RR = 0.6 (0.5–0.9), 1 year RR = 0.7(0.4–1.1), in which search for care in the ward reduced considerably (RR = 0.3 (0.2–0.7) (LARSEN *et al.*, 2002).

The use of shock-absorbing insoles in military recruits marines seems to increase the comfort of the military, although there was no difference between the groups (thickness of 3 or 6 mm). In addition, there was worsening discomfort in conditions of increased foot dampness (HOUSE; DIXON; ALLSOPP, 2004).

The uniform and protective equipment were investigated in three studies (BREEZE *et al.*, 2011, 2013, 2014) in crawling tests, equipped armed cargo loading and in ordinary combat activities. The use of shorter and thinner cervical protectors were classified as more comfortable and the ballistic scarf presented a comfort of 30%, while the other five types had a comfort of 90%.

The results of the present study corroborate the high incidence of musculoskeletal symptoms in military combatants, whether related to risk factors (NISSEN *et al.*, 2014) or to the activity itself (MCCAIG; GOODERSON, 1986). In addition to a strong need for the regular practice of physical exercises, the control of stress, the loaded load, clothing care and factors related to organizational ergonomics (worker suitability for the activity, considering their expectations and qualifications) and cognitive ergonomics (in particular, stress), or in the employment of activities to combat an enemy (CAMERON; OWENS, 2016). It was also found that in situations related to training, injuries of the type non-battle are responsible for a large part (or majority) of musculoskeletal symptoms (CAMERON; OWENS, 2016).

Thus, strategies based on ergonomic orientations, exercises and adaptation of shoes and uniforms seemed to be effective.

However, this study is not free of limitations. First, despite the fact that all the military personnel included were combatants, there was a great diversity among the samples of the included studies. Thus, the heterogeneity between studies is great. There have been a small number of studies that objectively performed ergonomic interventions. At the same time, the studies showed low methodological quality. Of the five studies, only one (LARSEN *et al.*, 2002) presented a good evaluation by the jadad scale (three points), which demonstrates that the level of confidence that can be had as a result of the present study is low. Despite the difficulty in performing double blinding in ergonomic intervention studies, most studies failed because they did not perform adequate randomization of participants, with a consequent risk of selection bias. As strengths, this study conducted an extensive search of databases, including the main ones related to ergonomics and related areas.

5. CONCLUSION

The present review concludes that the following ergonomic evaluations have been performed for military combatants: stress level, sedentary lifestyle, activity characteristics, presence of vibrations, posture during operational activities, evaluation of footwear, clothing and the load carried, the ration and the level of satisfaction with the work. Regarding interventions, strategies of ergonomic orientations, use of insoles, physical exercises and cervical collars seem to reduce painful symptoms, increase comfort and acceptability of the military. Considering the low methodological quality of most of the included studies, these results should be extrapolated with caution. Thus, it is suggested to conduct new experimental studies with greater methodological rigor, especially in order to minimize selection biases and confusion.

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