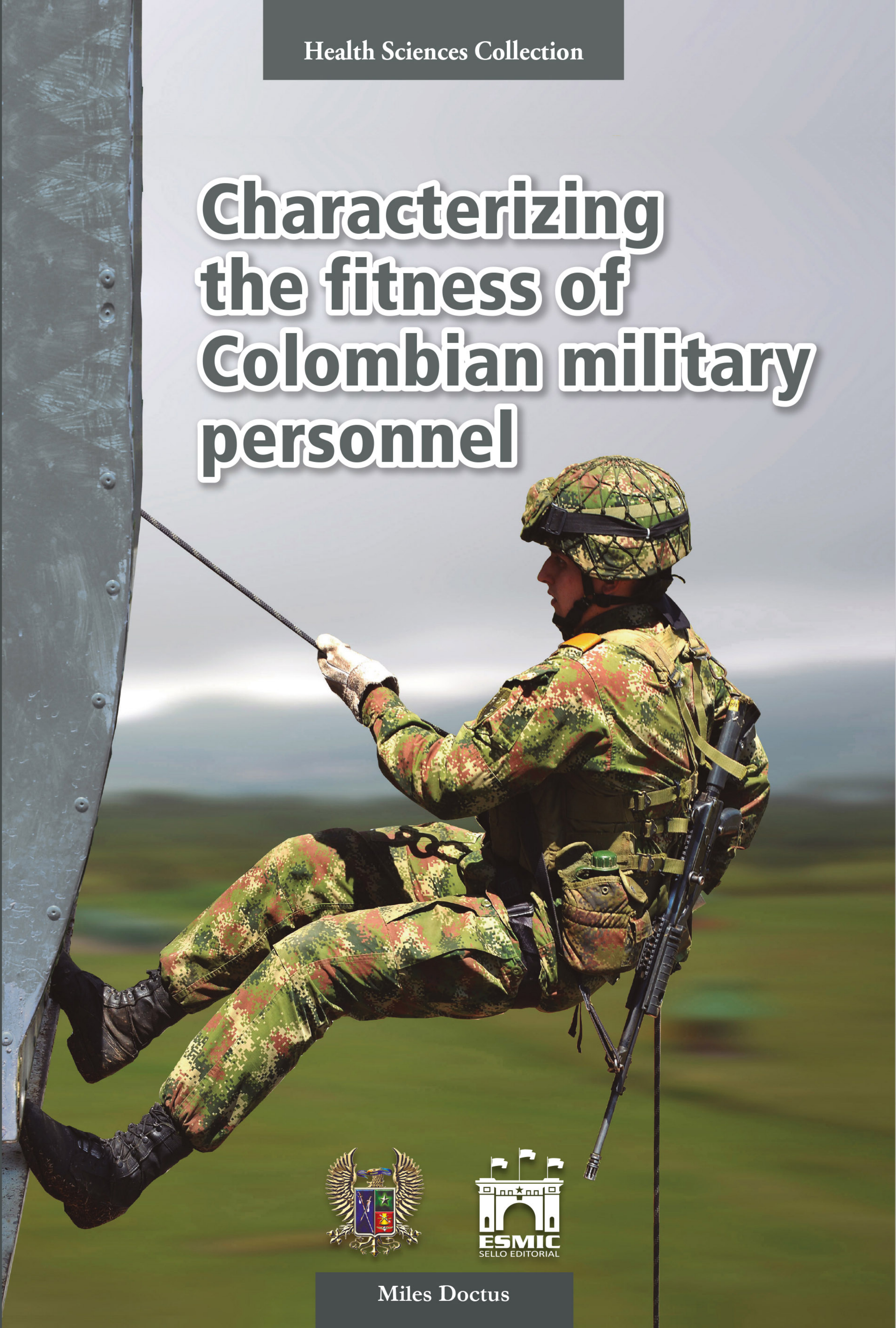
Health Sciences Collection

Characterizing the fitness of Colombian military personnel



ESMIC
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Characterizing the fitness of Colombian military personnel

ESCUELA MILITAR DE CADETES
"General José María Córdova"

Health Sciences (CCS)

This collection includes research that helps define the optimal forms of physical training and sports in the military, following the latest medical and biotechnological advances. Some issues in these sciences concern key concepts such as measurement, performance, and physical culture. Emphasis may be placed on quantitative or qualitative aspects, or both, depending on the object of study to be addressed, the method used, and the sought-after results.

Physical culture and sports

Physical activity sciences study human movement through regular and constant training, whose behavior in sports exercise is subject to periodic controls to improve participants in such training regime's performance, according to their types and specialties. However, the added special note is the specific elements of exercises programmed to face both military operations and athletic competitions in which the members of the National Army participate.

Characterizing the fitness of Colombian military personnel

Jenner Rodrigo Cubides Amézquita
Editorial Coordinator

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Preface

I often hear that as human beings, we are less athletic than other mammals, who mainly use their abilities for the survival and care of their own. However, something very similar is true for military-trained bodies that must endure high physical and mental efforts in various climatic conditions and specific situations in these evolving times. Thus, understanding the impact of military training is a priority in any professional army. This book makes a scientific contribution to explaining and estimating this training's impact on different aspects of the physical condition of our armies. We invite the reader to find in these lines the different aspects of military fitness evaluated in population groups of the Colombian Army.

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Introduction

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Jenner Rodrigo Cubides Amézquita

One of the most important challenges for science is to adequately convey the knowledge arising from research or generated by the interaction of individuals with their environment. The communication and development of knowledge prevents the academic community from falling into repetitive and systematic errors, which cause any type of project to fail. If scientific advances are not communicated, knowledge gaps will persist and, in some cases, will even be perpetuated. Hence, the importance of communicating scientific production, which is the main objective of this work.

One of the limitations in applying research involving the military population is that data are taken from other studies that do not reflect the specific characteristics or conditions of Colombian soldiers. Regardless, they are applied and appropriated as if they were the same sample of study. Therefore, this work presents the results of research involving the physical performance of Colombian military personnel to provide the academic community with descriptions of the variables that make up this population's physical fitness. This is a first attempt to characterize their physical, physiological, and biomechanical capabilities using the best available evidence and state-of-the-art technology.

It should be mentioned that military personnel must endure demanding physical activities during tactical and physical training, in military garrisons, or operations in different areas of Colombia. These activities go from hauling heavy field equipment (including personal items, food, ammunition, and weapons) over long distances in difficult terrains to carrying out common military physical training, including jogging, sprinting, digging, and dodging obstacles. The soldiers' speed and skill in these activities can impact their effectiveness in combat and, certainly, their survival. Therefore, describing, evaluating, and updating the best training programs for military personnel during their active service in the Army are important research objectives to enable the institution to prepare them effectively through activities that resemble military actions in interval, means, and location.

Service personnel must perform specific tasks in military operations in environments where they are exposed to stressors, such as caloric deficit, sleep deprivation, mood disturbances, and continuous physical activity, which can lead to fatigue. Likewise, military operations require the soldier to have high levels of aerobic capacity and muscle strength, making optimal physical conditioning through constant and suitable physical conditioning an important factor in operational performance and the prevention of different musculoskeletal injuries. Therefore, Characterizing the fitness of Colombian military personnel addresses different research results in its eight chapters that contribute, from science, to the evaluation of the physical conditioning of the Colombian military serviceperson. The order of presentation and the topics studied are presented below.

The *first chapter* evaluates the use of the Body Mass Index (BMI) as a mechanism for cleavage and diagnosis of overweight and obesity in military personnel. The objective of the researchers is to correlate the BMI as a diagnostic test with different tools, such as the determination of body composition by bioimpedance. In the *second chapter*, the author determines the changes in the body composition of the students participating in the Advanced Combat Course (ACC) and proposes some inferences about how they happen, since they can affect the physical performance of soldiers. In the *third chapter*, a comparative study is made between the body composition of the students of the three training schools of the National Army (Esmic, Emsub, Espro) and the results are correlated with the intensity and frequency of the training times. In the *fourth chapter*, the correlations between two of the most important variables (see index) are established to determine oxygen consumption through ergo spirometry tests in a population of athletes of Esmic (Escuela Militar de Cadetes General José María Córdova), who in addition to their inherent preparation for military activity are athletes trained for the Inter-school Games of the institutions of the Colombian Military Forces. Likewise, the authors of *chapter five* describe the ventilatory patterns of a group of trained military personnel from the Urban Counter-Terrorism Special Forces Grouping, for which they studied for two consecutive years the oxygen consumption of members of this elite unit of the National Army. Subsequently, the *sixth chapter* characterizes one of the most forgotten, but no less important, components of the military's physical training: flexibility. The researchers conducted a correlational study between three different tests to evaluate flexibility in the pentathletes of the military pentathlon league of the Colombian Military Sports Federation (Fecodemil). Specifically, their findings are based on the «Sit and Reach» test, the Schober test and the passive straight leg lift test. The penultimate parameter in the evaluation of military fitness is addressed in the *seventh chapter*: the power and explosive strength of the lower limbs. The researchers applied the «Squat Jump» test to characterize these aspects in a population of cadets of the Military School and determine important variables involved in the development of injuries in lower limbs, as with asymmetries in the phases of the jump. Finally, *chapter eight* analyzes the medial tibial stress syndrome also known as shin splints, one of the clinical conditions that most afflict the military in formation, in relation to the asymmetries in the gesture of the jump, considered as a risk factor.

These eight chapters present original works that not only describe and characterize each of the components of fitness in different groups of military population, but also provide a scientific basis for the variables associated with military physical performance. However, it is important to note that in order to better determine the variables of physical activity it is necessary in the long term to continue and expand the research of this work, in such a way that the majority of the military population is characterized in all ranks and years of service. In this way, this book reflects the efforts of the Army's training schools to maintain and improve the physical and psychological condition of Colombian military personnel.

Body Mass Index in a Military Population and its Correlation with Other Anthropometric Indicators

1

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Abstract

The Body Mass Index (BMI) has been used to evaluate overweight and obesity in the military population. However, its use as the sole anthropometric indicator is probably inadequate considering this population's specific characteristics. Therefore, there may be both false positive and false negative cases of overweight and obesity. ***Objective.*** This study sought to establish the relevance of the body mass index as an estimator of adiposity (overweight and obesity) in the military population and its relationship with other anthropometric indicators. ***Materials and methods.*** A retrospective transversal study was carried out with 137 military trainees in different Colombian Army schools. Sociodemographic information, such as age, sex, and the army school to which they belonged, was collected. The anthropometric evaluation included height, weight, and waist circumference measurements. Body composition was also evaluated by using electrical bioimpedance (Seca BmCA 550). A description of the prevalence of overweight and obesity, correlation coefficients, and diagnostic concordance was established by using Cohen's Kappa index. Likewise, BMI sensitivity and specificity were described against indicators, like body fat percentage and fat mass index, considered body composition Gold Standards. ***Results.*** The correlation between body weight was higher with fat-free mass weight (FFM) than with the fat mass weight (r = 0.851, p = 0.000, r =

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0.642, p = 0.000), respectively. The correlation between BMI was good and positive with body fat percentage (BFP) (r = 0.750, p = 0.000) and higher with fat mass index (FMI) (0.836, p = 0.000). The waist-to-height ratio (WHtR) showed the best correlation with BFP and FMI. The BMI concordance with BFP (r = 0.750, p = 0.000) and FMI (0.836, p = 0.000) was positive. ***Conclusions.*** While the BMI presented good concordance with the BFP and the FMI, it also overestimated the prevalence of overweight. It underestimated the prevalence of obesity in a smaller proportion, with high sensitivity but low specificity for the diagnosis of overweight and high specificity and sensitivity for obesity. Although the BMI shows a positive correlation with adiposity indicators, it cannot be considered the indicator to diagnose overweight and obesity in the military population. It presents false positives for overweight and false negatives for obesity. In this line, weight in the military population is significantly correlated with muscle and fat-free mass rather than fat, given that this is a physically active population that undergoes specific training favoring muscle mass development. The FMI is the indicator that best predicts body fat, along with the WHtR. Use of the Lean Mass Index (LMI) should be considered a parameter to measure this body component.

Keywords: BMI, body fat percentage, fat mass index, adiposity indicators, electrical bioimpedance, anthropometry, body composition

Introduction

During training, military personnel are subjected to multiple activities and physical efforts related to daily performance, as well as part of the training routines and combat courses. These activities require maintaining good physical condition and adequate body composition, aspects that, according to Castañeda and Caiffa (2015), are closely related with better physical performance (1). In its first program to promote exercise and healthy eating habits in 1981, the U.S. Department of Defense's approach emphasized that maintaining adequate body composition is an integral part of physical condition and plays a vital role in a professional military appearance. Furthermore, it is a good indicator of the military personnel's general health and well-being (2)many Sailors believe the current method fails to accurately predict body fat percentage. As a result, the Naval Health Research Center (NHRC).

Evaluation of physical conditions in the Colombian military context uses the BMI as a reference to classify overweight and obesity (3). Using the BMI as the sole indicator of these conditions is probably inappropriate. Considering the high development of lean mass (LM) resulting from physical training, a high BMI could be reported (overweight or obesity), which, in reality, is a high LM; this is considered a false positive. In other cases, the BMI could report normality and, in reality, the person has a high-fat mass (FM) in their body composition, again, a false negative. Therefore, defining body composition to assess variables that enable BMI identification by high LM or high FM, using easily accessed and used validated methods, like electrical bioimpedance and anthropometry, is essential.

This study's purpose was to establish the relevance of using BMI as the sole indicator of nutritional status in a military population in training. It sought to evaluate using other indicators to differentiate between military personnel with high LM and high FM by correlating BMI with variables, like percentage of fat, FMI, LMI, waist circumference, and waist-to-height ratio.

Body mass index as an indicator of overweight and obesity in the military

The body mass index was proposed in 1832 by Adolphe Quetelet (4) as a global indicator of nutritional status. It establishes a relationship between weight (kg) and the squared height (m) (BMI = weight kg/height m). The BMI is an inexpensive, simple, and fast tool widely used to determine overweight and obesity. The World Health Organization (WHO) establishes the following cut-off points: normal, 18.5 kg/m^2 to 24.9 kg/m^2, overweight 25 kg/m^2 to 29.9 kg/m^2, and obesity >30 kg/m^2 (4). According to this same organization, overweight and obesity are defined as an excessive or abnormal fat accumulation that can be harmful to health. By 2016, 39% of people over 18 worldwide will be overweight and 13% obese (4). In Colombia, according to the figures reported by the 2015 National Food and Nutrition Survey (ENSIN in Spanish), 56.4% of the adult population (18 - 64 years of age) was overweight (37.7% overweight and 18.7% obese), with 59.6% more women than men 52.7% (5). This outlook is not foreign to the military personnel worldwide and in Latin America (6–8)se ha cuestionado su exactitud y apli-cación en diversas poblaciones. Bioimpedance is a method that offers the possibility of knowing the percentage of total body fat, considered a parameter to diagnose obesity. Objective: to analyze the correlation between BMI and total body fat percentage to establish the diagnosis of overweight and obesity. Methodology: an observational, analytical-comparative, prospective, and cross-sectional study carried out in the outpatient clinic of the Hemodialysis Service of the Hospital Central Militar, in May 2015. Healthy volunteers were evaluated. The volunteers were over 18 years of age, of either gender, and consenting to the anthropometric measurements. Bioimpedance equipment was used (InBody770 ®.

For example, in the Colombian context, according to the BMI, a study carried out with pilots identified that 68.9% and 8.7% were overweight and obese, respectively (9). Another study at *Escuela Militar de Cadetes "General José María Córdova"* evaluated the nutritional status of 72 cadets before an advanced combat course and found that 23% and 4.1% of the population had a BMI showing overweight and obesity, respectively (10).

The BMI is the most widely used diagnostic tool to define overweight and obesity, indicating excess fat mass. However, this measurement does not establish a difference between fat and lean mass, which varies widely according to gender, age, race, and level of physical activity, among other aspects (11, 12).

Different studies have concluded that BMI alone is inadequate to assess body composition because it reports false negative or false positive results when assessing body fat (13,14). A study by Carrasco (2004) observed that BMI overestimated overweight in 19% of men evaluated and underestimated obesity in 23%, compared to BFP (15).

Given this evidence, the question arises regarding the relevance of the BMI measurement as the sole estimator of overweight and obesity in the military population, considering that it is a physically active population. A study carried out in the military environment in the Chilean population reported that the BMI overestimated overweight by 23% compared to the percentage of fat, but adequately estimated obesity (16). Similarly, a study conducted in the Mexican military found that some of the individuals classified as overweight according to BMI were normal according to FMI (17). According to Tyson *et al.*, (2015) in an American military population, a BMI between 25 and 27 had a strong correlation, mainly with increased fat-free mass (18)with a BMI of 26.4, and approximately 18% BF. The correlation between BMI and %BF (R = 0.86(19).

Other anthropometric indicators

Abdominal Circumference (AC): along with the BMI, AC is one of the most commonly used indicators to assess body fat. It is an indicator of regional fat distribution and considered the anthropometric measure *par excellence* to diagnose abdominal obesity, cardiovascular risk, and metabolic syndrome (20, 21) because of its association with visceral or ectopic fat deposits. According to a study conducted in a Chilean university population, it seems to be a better predictor of adiposity than BMI in a young population (22). It is also noteworthy that within the U.S. Navy's body composition standards, which has established its own formula to determine BFI%, the AC is considered one of the variables to determine overweight and obesity (23, 24).

The AC has different cut-off points to classify abdominal obesity. According to the WHO, a circumference > 94 cm in men and 80 cm in women is classified as pre-obesity or increased cardiovascular risk. An AC > 102 cm and 88 cm in men and women, respectively, represents abdominal obesity and a very high risk of comorbidity (20). In turn, the 2013 consensus, "Harmonizing the Metabolic Syndrome," adopted values of 90 cm for men and 80 cm for women (25)which occur together more often than by chance alone, have become known as the metabolic syndrome. The risk factors include raised blood pressure, dyslipidemia (raised triglycerides and lowered high-density lipoprotein cholesterol.

Waist-to-Height Ratio (WHtR): is the AC value corrected for height. Its predictive power is given because of its association with cardiometabolic risk (26), with values above 0.51. Thus, and according to results published in the American Journal Clinical Nutrition by Flegan (2009), it was observed that WHtR is a better predictor of adiposity than BMI and AC alone (27).

Body fat percentage (BFP): based on body fat deposits, the Spanish Society of Endocrinology and Nutrition (SEEDO in Spanish) defines a BFP between 12% and 20% and 20% to 30% for men and women, respectively, as normal. It considers a 21% to 25% in men, and 30% to 33% in women limit or overweight, and > 25% in men and >33% in women as obesity (28).

Fat Mass Index (FMI): is the absolute fat corrected for height (fat kg/height m^2) for which there is no consensus on cut-off points. According to Peine *et al.*, (2013) values below 5.60 kg/m^2 and 7.90 kg/m^2 are considered normal. Overweight is between > 5.61 kg/m^2 at 7.08 and >7.91 at 10.30, and obesity is >7.090 kg/m^2 and 10.31 kg/m in men and women, respectively (29). In another study, FMI > 5.4 kg/m^2 and 7.80 kg/m^2 in men and women, respectively, was correlated with overweight and obesity (30).

The LMI or FFMI fat-free mass index: is the fat-free mass corrected for height (LMI or FFMI = FFM (kg)/height^2 (m). It is used to classify individuals with similar body composition but differences in height. The BMI erroneously classifies individuals as overweight at the expense of muscle mass; this may be the case for a percentage of the military population. The FFMI is particularly useful for short individuals with good muscle development, classified as overweight and obese by BMI (31).

Methods

A retrospective, cross-sectional observational study was conducted. The data included in this study was obtained from active students from different military training schools, including *Escuela Militar de Suboficiales* (EMSUB), *Escuela Militar de Cadetes "General José María Córdova"* (ESMIC), and *Escuela de Soldados Profesionales* (ESPRO). The data were taken at each of the schools located in Bogotá and Cundinamarca (Melgar) during August 2018. All male students in each of the schools' last level, available on the day of the data collection, were summoned. The total sample consisted of 137 males between the ages of 19 and 31 years; females were excluded. Individuals with incomplete measurement variables or those failing to comply with the electrical bioimpedance test preparation recommendations (fasting, not having done physical activity in the previous 12 hours, maintaining an adequate state of hydration) were also excluded, as well as those not having signed the informed consent and amputees.

Written informed consent was obtained from each participant. The institution's research, technology, and development area's ethics committee approved the intervention following the Declaration of Helsinki's rules and the legal regulations in force in Colombia that regulate human research (Resolution 008439 of 1993 by the Colombian Ministry of Health).

Measurement variables

Height, weight, and waist circumference were measured and collected by a Level 1 ISAK (International Society for Advancement in Kinanthropometry) certified anthropometrist. The measurement instruments used were a portable stadiometer (Seca 206®, Hamburg, Germany) with a 0 - 220 cm range and 1 mm accuracy for height. For weight, a Seca 813 electronic floor scale (200 kg) with 100-gr accuracy was used. Waist circumference was measured by using a Lufkin W606PM inextensible steel flexible measuring tape. Waist circumference was taken at the midpoint between the lower edge of the last rib and the iliac crest's upper edge.

Body composition was evaluated by using tetrapolar electrical bioimpedance with a Seca mBCA 525 medical Body Composition Analyzer to establish variables, like fat percentage, fat mass index, muscle mass index, and fat-free mass, following the manufacturer's recommendations (no food or drink 4 h prior to the test, no exercise 12 h prior, urination 30 min prior, and no alcohol consumed 24 h prior). Assessments were performed on a stretcher in supine position with arms and legs slightly off the midline.

The waist-to-height ratio was determined by dividing the waist (cm) by the height (cm) measurement using a value of ≥ 0.51 as a reference for the discrimination of abdominal obesity and cardiovascular risk (32). The SEEDO 2000 and 2007 criteria previously described were taken into account to determine the body adiposity level. The following cut-off points were considered for the FMI: normal, <5.60 kg/m^2; overweight, <7.08 kg/m^2; and obesity, >7.09 kg/m^2 (29). Between p25 and p75 (18 to 19.8 kg/m^2) was considered normal for the FFMI, and >p90 >19.9 kg/m^2 was considered high (33).

Table 1. Variables and cut-off points

Variable	Reference	Cut-off point	Interpretation
Body Mass Index (BMI)	WHO	18.5 kg/m^2 to 24.9 kg/m^2	Normal
		25 kg/m^2 to 29.9 kg/m^2	Overweight
		> 30 kg/m^2	Obese
Waist (cm) to Height (cm) Ratio(WHtR)		≥ 0.51	Abdominal obesity and moderate cardiovascular risk
Abdominal Circumference (AC)	Harmonizing the Metabolic Syndrome 2013	> 90 cm	Pre-obesity and cardiometabolic risk
Fat Mass Index (FMI)	Paine *et al.* 2013	< 5.60 kg/m^2	Normal
		> 5.61 and < 7.08 kg/m^2	Overweight
		> 7.09 kg/m^2	Obese
Fat-Free Mass Index (FFMI)	Schutz *et al.*, 2002	P25 and p75(18 to 19.8 kg/m^2)	Normal
		> p90 >19.5 kg/m^2	High
Body Fat Percentage (BFP)	SEEDO 2000 and 2007	12% - 20%,	Normal
		20% - 25%	Overweight
		> 25%	Obese

Source: Material created by the author.

A descriptive analysis was performed to analyze the information to establish the mean and standard deviations and minimum and maximum values.

The SPPSS 25 statistical package was used, applying Kolmogorov-Smirnov normality tests to establish the data's normality to this end. Spearman's Correlation test was used for non-parametric data and diagnostic agreement was established between the BMI and BFP and the BMI and FMI by using Cohen's Kappa Index. The BMI's sensitivity and specificity were calculated against the BFP and FMI, taken as the standard Gold reference.

This research's potential biases are associated mainly with compliance with the electrical bioimpedance evaluation protocol, such as the challenge to guarantee that participants had fully adhered to the recommendations.

Results

The results from 137 males in the Colombian Army's training schools were analyzed. The distribution by school was ESMIC 32.8% (n = 45), ENSUB 34.3% (n = 47), and ESPRO 32.8% (n = 45). The average age of the population was 22 +/-1.8 years. The average weight was 66.5 kg +/-8.04 kg, with minimum values of 46.7 kg and maximum of 90.5 kg. The average BMI was 23.3 +/-2.22 kg/m^2. The summary of the other descriptive data for the anthropometric variables analyzed is shown in Table 2.

Table 2. Description of anthropometric variables in personnel undergoing training in three schools of the Colombian Armed Forces.

	N	MEDIAN	SD	MINIMUM	MAXIMUM	PERCENTILES		
						25	50	75
WEIGHT	137	66.5	8.04	46.7	90.5	60.75	65.8	71.5
HEIGHT		1.69	0.07	1.54	1.84	1.64	1.68	1.74
BMI[1]		23.3	2.22	18.8	29.4	21.8	23.1	24.6
BFP[2]		16.4	5.63	5.9	34.7	12.4	15.7	20.5
FMI[3]		3.9	1.68	1.20	9.8	2.76	3.44	4.9
LMI[4]		19.4	1.13	16.6	22.1	18.6	19.4	20.2
WAIST		78.8	5.72	67.0	96.0	75.0	78.0	82
WHtR[5]		0.47	0.04	0.40	0.60	0.44	0.46	0.49

[1]Body Mass Index, [2]Body Fat Percentage, [3]Fat Mass Index, [4]Fat-free mass index, [5]Waist-to-Height Ratio.

Source: Material created by the author.

According to the BMI, 79.5% (n = 109) of the subjects were normal, 20.4% (n = 28) were overweight (n = 14), and no cases of obesity were reported. According to the BFP, 13.1% (n = 18) of the subjects were classified as overweight and 8% (n = 11) as obese. The FMI reported 11.7% (n = 16) overweight and 4.4% (n = 6) obese (Figure 1).

Of the population with normal BMI, seven individuals had overweight values with BFP and two with FMI (false negatives). Of the 28 individuals classified overweight by BMI, seven had a normal BFP and eight had a normal FMI (false positives). In the obesity classification, the BMI did not report any case. Meanwhile, 11 were presented by BFP and six by FMI (false negatives for obesity) (Tables 3 and 4).

According to the LMI or FFMI, 87% of the population had a normal or high reserve of MM. Therefore, 53% (n = 73) of the individuals were within the 25th to 75th percentiles and 34% (n = 47) were over the 75th percentile. Of all the individuals with BMI in overweight ranges, 71% (n = 20) also had an FFMI above the 75th percentile.

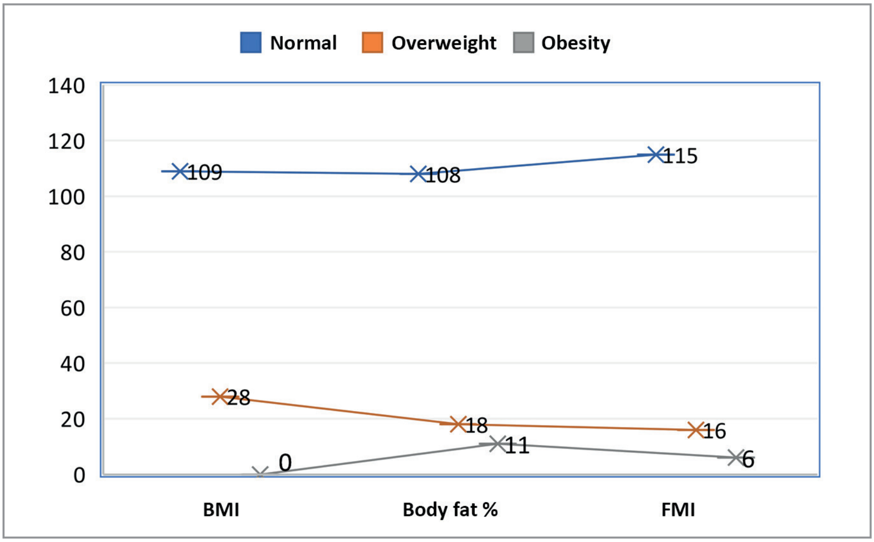

Figure 1. Prevalence of overweight and obesity according to Body Mass Index (BMI) kg/m², body fat percentage (BFP), and Fat Mass Index (FMI) kg/m²

Source: Material created by the author

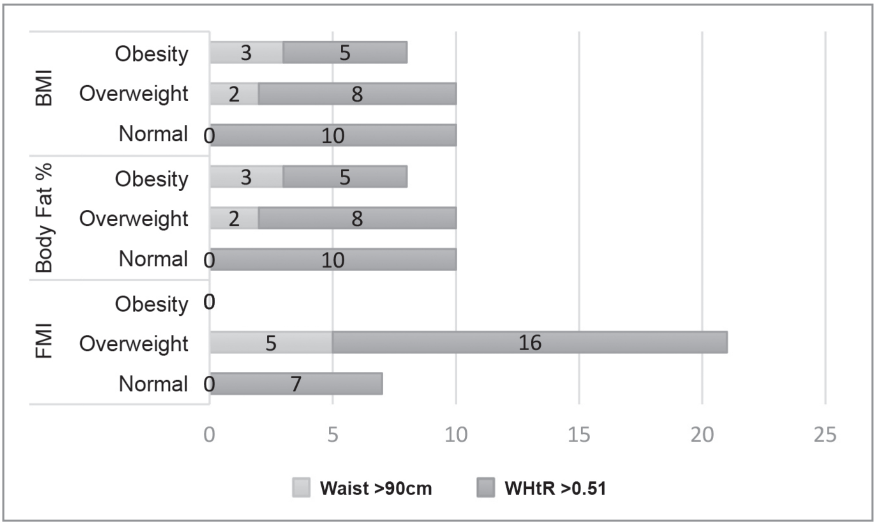

Figure 2. Abdominal adiposity measured by waist circumference and corrected by height to calculate the waist-to-height ratio, compared to adiposity indicators, like BMI, BFP, and FMI.

Source: Material created by the author.

Regarding regional fat distribution, 3.6% (n = 5) of the individuals had an AC > 90 cm or high risk, according to WHO criteria. For their part, 16.7% (n = 23) had moderate cardiometabolic risk according to WHtR (WHtR > 0.51) (Figure 2).

In this population, the most significant positive correlation was among weight and muscle mass (MM) and FFM (r = 0.851, p = 0.00 and r = 0.82 p = 0.00, respectively) followed by the BMI and the FMI (r = 0.836, p = 0.00) and the FMI with the WHtR (r = 0.725 p = 0.000) (Figures 3 and 4). A high positive correlation was also observed among height and MM and the FFM (r = 0.710 p = 0.000 and r = 0.805 p = 0.000, respectively). The WHtR showed better correlation with the BFP (r = 0.691, p = 0.000) and the FMI (r = 0.725, p = 0.000) than the AC (r = 0.650, p = 0.000 and r = 0.698, p = 0.000) (Table 1).

Table 3. Spearman's Rho Correlation Coefficients between the quantitative variables in the Colombian Military Forces' 2018 Formation

		EDAD (años)	PESO (kg)	TALLA (mt)	IMC (kg/mt2)	GRASA (%)	GRASA (kg)	MM (kg)	IMG (kg/mt2)	FFMI (kg/mt2)	CINTURA (cm)	ICA	MLG (kg)
EDAD	Coeficiente de correlación	1,000	0,156	-0,002	,183*	,201*	,206*	0,110	,209*	0,129	,187*	,186*	0,064
	Sig. (bilateral)		0,069	0,982	0,032	0,018	0,016	0,199	0,014	0,134	0,029	0,029	0,457
PESO	Coeficiente de correlación		1,000	,599**	,718**	,441**	,642**	,851**	,517**	,627**	,669**	,275**	,819**
	Sig. (bilateral)			0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,000
TALLA	Coeficiente de correlación			1,000	-0,074	-,174*	0,016	,710**	-0,162	0,104	0,115	-,414**	,805**
	Sig. (bilateral)				0,393	0,042	0,851	0,000	0,059	0,228	0,182	0,000	0,000
IMC	Coeficiente de correlación				1,000	,750**	,833**	,455**	,836**	,680**	,758**	,713**	,338**
	Sig. (bilateral)					0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
GRASA	Coeficiente de correlación					1,000	,966**	0,005	,988**	0,077	,650**	,691**	-0,097
	Sig. (bilateral)						0,000	0,952	0,000	0,368	0,000	0,000	0,261
GRASAkg	Coeficiente de correlación						1,000	,232**	,979**	,232**	,733**	,656**	0,137
	Sig. (bilateral)							0,006	0,000	0,006	0,000	0,000	0,111
MMkg	Coeficiente de correlación							1,000	0,100	,710**	,434**	0,017	,960**
	Sig. (bilateral)								0,244	0,000	0,000	0,841	0,000
IMG	Coeficiente de correlación								1,000	,211*	,698**	,725**	-0,009
	Sig. (bilateral)									0,013	0,000	0,000	0,920
FFMI	Coeficiente de correlación									1,000	,457**	,334**	,651**
	Sig. (bilateral)										0,000	0,000	0,000
CINTURA	Coeficiente de correlación										1,000	,829**	,340**
	Sig. (bilateral)											0,000	0,000
ICA	Coeficiente de correlación											1,000	-0,119
	Sig. (bilateral)												0,168
MLGkg	Coeficiente de correlación												1,000
	Sig. (bilateral)												

Source: Material created by the author

* The correlation is significant at the 0.05 level (bilateral). ** The correlation is significant at the 0.01 level (bilateral).

In assessing the BMI's sensitivity and specificity as a diagnostic test for overweight and obesity compared to BFP and FMI as Gold standard diagnostic tests, a sensitivity of 0.94 and specificity of 0.61 for BFP were observed in diagnosing overweight. For obesity, the sensitivity and specificity were 0.94 and 0.91, respectively. The FMI (height-corrected fat mass as another Gold standard test for adiposity assessment) showed a sensitivity of 0.90 and specificity of 0.87 for overweight and sensitivity and specificity of 0.91 and 1.00 for obesity.

Cohen's Kappa coefficient to calculate diagnostic agreement between BMI and BFP and BMI and FMI as predictors of overweight and obesity, BMI vs. BFP was k = 0.41, and BMI vs. FMI was k = 0.598. Tables 2 and 3 show the presence of false positives and negatives for overweight and false negatives for obesity when compared to BMI.

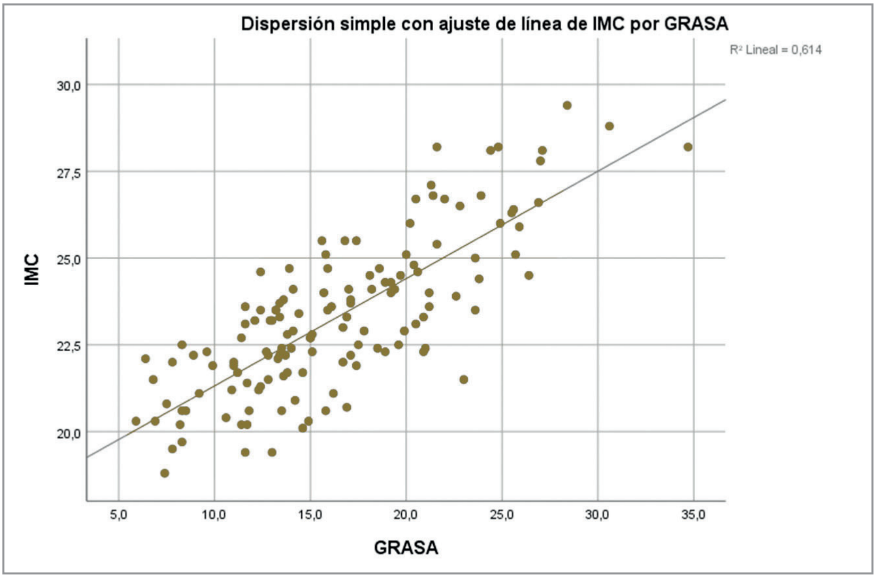

Figure 3. Correlation coefficient between BMI and fat % (CC 0.75, P = 0.00, 95%CI 15.5 - 17.3 kg/m^2).
Source: Material created by the author

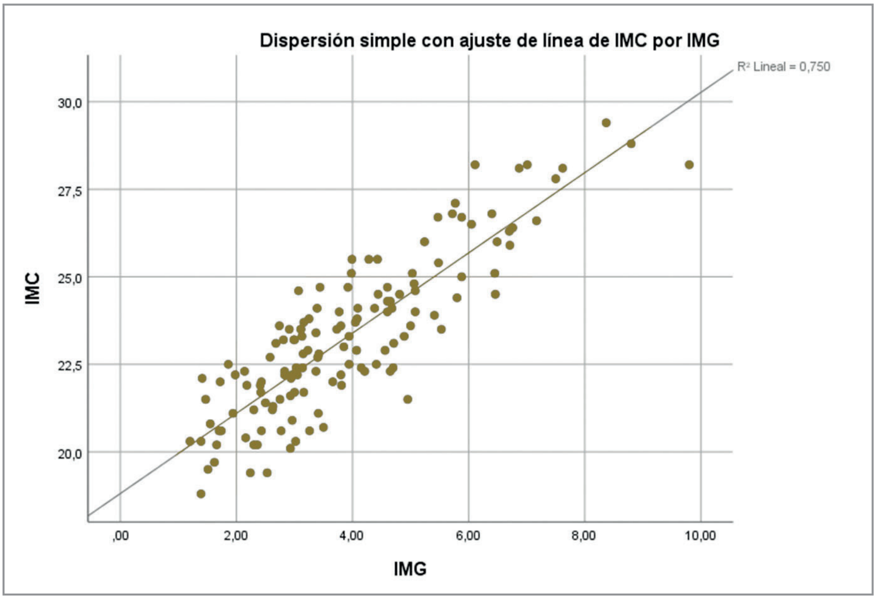

Figure 4. Correlation coefficient between BMI and FMI (CC 0.84, P = 0.00, 95%CI 3.62 - 4.18 kg/m^2).
Source: Material created by the author

Table 3. BMI*BODY FAT (%) cross table

			% BODY FAT			
			Normal	Overweight	Obesity	Total
BMI	Normal	Recount	101	7	1	109
		% of total	73.7%	5.1%	0.7%	79.6%
	Overweight	Recount	7	11	10	28
		% of total	5.1%	8.0%	7.3%	20.4%
Total		Recount	108	18	11	137
		% of total	78.8%	13.1%	8.0%	100.0%

Source: Material created by the author

Table 4. BMI*FAT MASS INDEX (kg/m^2) cross table

			FAT MASS INDEX			
			Normal	**Overweight**	**Obesity**	**Total**
BMI	Normal	Recount	107	2	0	109
		% of total	78.1%	1.5%	0.0%	79.6%
	Overweight	Recount	8	14	6	28
		% of total	5.8%	10.2%	4.4%	20.4%
Total		Recount	115	16	6	137
		% of total	83.9%	11.7%	4.4%	100.0%

Source: Material created by the author

Discussion

The Ministry of National Defense's Permanent Directive of August 2018, "*Physical evidence evaluation parameters for military force officers and non-commissioned officers,*" (3) included as Annex F, lists the normal weight-to-height ranges, according to the BMI by adopting the WHO's cut-off points to diagnose overweight and obesity. However, despite being a user-friendly tool, the BMI incurs into errors in predicting overweight and obesity in the military population (16,17,34), using the BMI and body fat percentage by age group and comparing it with different anthropometric indicators. Material and methods: a cross-sectional study involving 415 soldiers. Sociodemographic information was obtained and an anthropometric evaluation was performed, including height, weight, and body composition measurements. A description of the prevalence of obesity was made, anthropometric measurements were compared according to age using an ANOVA test. Pearson correlations between anthropometric variables were performed and diagnostic agreement between BMI and body fat percentage was determined using the kappa index. Results: The prevalence of obesity in Buin soldiers was 14.3% and 14.0%, using BMI and body fat percentage, respectively. This prevalence increased progressively as the age of the soldiers increased (p<0,05. Although the BMI showed a significant correlation with both the BFP and FMI in this research, it was also observed that in the population studied, the BMI underestimated the prevalence of overweight compared to the BFP and the WHtR by 5.1% and 1.5%, respectively, and obesity by 8% and 4.4%, respectively. In turn, it overestimated overweight by 5.1% and 5.8% compared to BFP and WHtR, respectively. It should be noted that the individuals classified as overweight, according to BMI, and normal, according to BFP and WHtR, were in a BMI range between 25 and 27. This situation was observed in other studies in the military population, suggesting that in individuals with BMI between 25 and 27 in this population body composition should be considered to discriminate whether the overweight condition is at the expense of fat or lean mass (19).

The BMI's behavior in predicting overweight and obesity compared to other adiposity indicators is confirmed by the results reported by Vazquez-Guzman *et al.*, (2015) in a Mexican military population and Duran-Agüero *et al.*, (2015) in a Chilean military population. Therefore, by using the BMI as an indicator in the military population, the cut-off points must be adjusted, and considering that the FMI had the highest sensitivity and specificity and the highest Kappa value, the FMI can be established as the best indicator of adiposity for the military population. Peine (2013) compared the generation of normality ranges for body composition evaluated via electrical bioimpedance to the four-component fractionation method and DEXA, where the BFP overestimated overweight and obesity compared to FMI. This situation is similar to that observed in our research. In turn, the importance of using the WHtR as an indicator of regional adiposity is highlighted by its strong correlation with the FMI.

Moreover, and considering the other important component of body composition, fat-free mass, one of the most important findings was the high positive correlation among weight and muscle mass and fat-free mass, which was higher than the correlation between weight and absolute fat. This suggests important muscle development in this population that contributes to a higher BMI in the presence of normal fat levels. The aforementioned was also identified in Bustamante's (2015) research, which mentions higher-than-average muscle development in Argentinean cadets. This situation is not unrelated to our study in which LMI levels were higher than the 75th percentile identified, according to the table published by Schutz (2002).

Considering Cohen's Kappa Index, which showed moderate diagnostic concordance between BMI and BFP and BMI and FMI, similar to that reported by Durán-Agüero (2017) in a Chilean military population, it can be stated that BMI alone is not an adequate diagnostic tool for the nutritional classification in the military population. It becomes essential to include other adiposity indicators to evaluate military trainees in the Colombian Army.

Within the limitations observed during this research, difficulty is highlighted in controlling compliance with the requirements to carry out bioimpedance, mainly the state of hydration of the population.

Conclusions

The BMI overestimates overweight (false-positive cases) and underestimates obesity in the military population (false-negative cases).

The BMI is not an objective indicator of the military personnel's nutritional status. Therefore, its use is only recommended as a screening tool and should be accompanied by other indicators, like the FMI and WHtR.

In future studies, larger samples are necessary to establish cut-off points for BMI, according to this population's body composition, considering that all schools do not have equipment to assess body composition or personnel trained in anthropometric techniques.

The FMI is a better indicator of adiposity in the military population, even better than the BFP. Taking height into account has less possibility of over or underestimation.

Using the WHtR is also recommended to predict obesity

These results cannot be extrapolated to the military population in exercise.

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Anthropometric Changes in Students Resulting from the Advanced Combat Course at Escuela Militar de Cadetes

2

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Abstract

Background. During military training, students in training schools undergo the Advanced Combat Course (ACC). This course is effective to obtain technical and tactical results for operations. However, there are physical results that cannot be evaluated by using a parameter, such as body mass index, making the understanding of the effects of the ACC on anthropometric conditions necessary to indirectly evaluate the course's components. These results can aid in making potential mid- or long-term adjustments so that training objectives are achieved, without detriment to the participants' well-being. ***Objective.*** This study's objective was to determine the anthropometric changes of the military personnel participating in the Advanced Combat Course and its significant physical repercussions, which can be used as an indicator of the improvement or not of the individual's physical fitness. ***Materials and methods.*** A longitudinal study was conducted with 69 military personnel (56 men and 13 women) in training at the Colombian Army's *Escuela Militar de Cadetes*. The participants signed an informed consent. An anthropometric assessment of height, weight, and waist circumference was performed before and after the ACC. Body composition was also evaluated using electrical bioimpedance (SECA 525), and the behavior of the data was established by using the SPSS Ver. 21 statistical program. The statistical significance of the data was then established by using Student's t-test method for paired data. ***Results.*** The varia-

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bles of WEIGHT, body mass index (BMI), relative fat mass (RFM), absolute fat mass (AFM), visceral adipose tissue (VAT), extracellular fluid (ECF), and phase angle (PhA) had statistically significant changes, meaning that the ACC's physical burden produces changes on these variables. There were no statistically significant changes in the fat-free mass (FFM), skeletal muscle mass (SMM), total body water (TBW), and waist circunference (WC). ***Conclusions.*** While the physical load involved in the 8-week advanced combat course produces changes in all the anthropometric variables evaluated through bioelectrical impedeance analysis, only a few variables present statistically significant changes. However, they are unproved concerning fat-free mass, skeletal muscle, total water, and waist circumference.

Keywords: anthropometry, adiposity indicators, body composition, body fat percentage, body mass index, electrical bioimpedance, fat mass index

Introduction

During one of the training phases of their stay at *Escuela Militar de Cadetes "General José María Córdova",* students must complete the Advanced Combat Course (ACC). This instruction and training program prepares and certifies National Army training school students as troop and field commanders to lead squads and small units in simulated combat environments in the technical, tactical, humanistic, and physical areas (1) (2). It aims to develop the necessary skills for students to preserve their lives, as well as those of their superiors and subordinates, while achieving the mission objective in operational situations that resemble real life as closely as possible. The course involves both academic and physical aspects. It is worth noting that the results achieved determine the students' ascent in military rank, giving the course a high quota of importance.

For eight weeks, the students face situations that test their physiological and physical conditions to test their physical performance. The six levels prior to the course involve elements, like strength, endurance, speed, and conditional abilities, like flexibility, balance, agility, mobility, and coordination skills (3). These skills vary per student and are influenced by the course's high demands, the limited time to achieve them, the course site's hostile climate, the participants' apparel, and the additional weight of the campaign equipment.

It is important to point out that exercise, in general, offers health benefits in non-military populations (4). However, under adverse operational and climatic situations, exercise can produce undesired impacts on those being trained; this has been described in reviews by several military entities concerning short training courses (5). It has also been documented that exercise can produce changes in the subjects' body composition (6) (7) and in other aspects of physical fitness, which are not the subject of this chapter.

The results of this work show the ACC's effects on the students' anthropometric conditions, indirectly evaluating the course's components, so that, in the mid- or long-term, necessary adjustments can be made to achieve the training objectives without detriment to the participants' well-being.

As in many other countries, in Colombia, anthropometric criteria, such as indices based on weight, height, and ratio (body mass index - BMI), have traditionally been used to determine obesity, malnutrition, and eating disorders. This index is calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2). However, these variables have little sensitivity to monitor the response to the process faced by the patient, athlete, or, in this case, the training school student.

To qualify this process, the evaluation of the segmental body composition is ideal. Moreover, understanding the different segments, like body fat, and their distribution needs greater attention concerning the etiology of cardiovascular disease, hypertension, and type 2 diabetes, chronic diseases that are now considered to have their "incubation period" during childhood and adolescence (8).

The BMI provides the fastest measure of overweight and obesity in a population; it is used indiscriminately for both genders and adults of all ages. However, from the point of view of sports medicine, nutrition, among other knowledge lines, is a measure that is too succinct and, in some cases, apparent and inadequate to determine the evaluated subject's nutritional status effectively. Studies have shown that the BMI shows low reliability to estimate adiposity at an individual level, particularly in men and when the BMI is less than 30 kg/m^2 (9).

Thus, the Research Center for Physical Culture (CICFI in Spanish) at *Escuela Militar de Cadetes "General José María Córdova"* set out to determine the effect of the ACC on the military cadet personnel's body composition through a more sensitive method, such as electrical bioimpedance, to understand the course's impact on its structure. The course's protocols and use were exhaustively applied to determine its impact on the subject's different segments before and at the end of the course.

Sensitivity and specificity of bioelectrical impedance analysis in anthropometry

The study of body composition is a topic of growing interest, which can be used for research and clinical purposes. Because changes in body composition are directly related to health and disease, it is important for health science professionals to know the different methods of assessing and analyzing body composition. Body composition analysis methods are currently divided into three groups, direct, indirect, and double indirect. The direct method is the dissection of corpses. The indirect methods include computerized axial tomography (CAT), magnetic resonance imaging (MRI), dual X-ray absorptiometry (DXA), and plethysmography. Anthropometry and bioelectric impedance (BIA) stand out within the double indirect methods (10).

Historically, body composition has been used mostly because of what has been achieved than what has been investigated; this is the fundamental limitation of the different techniques developed (11). The ideal method to study an individual's body composition would be one in which each and every section of the human organism, like fat, bone, muscle, and water, could be analyzed separately. Therefore, to date, the most comprehensive method is cadaver dissection analysis. Between 1945 and 1956, studies on the bodies of five men and one woman were conducted. Although the results showed considerable differences in fat tissue, they all showed relatively constant values in water (73%), protein (approximately 20%), and around 69 mmol K/kg (12). So far, none of the body composition evaluation methods can be conducted directly on living subjects. Instead, it is done by deriving values from body property measurements. The techniques, in practice, present two errors. The first is a methodological error during the collection of the primary data. The second error is in the assumptions made when the primary data is converted into the final result. The relative magnitude of these errors varies between the techniques (13).

Thus, bioelectrical impedance analysis (BIA) is presented as a simple, inexpensive, and easy-to-use method that provides more information for patient monitoring and evaluation in practice. This non-invasive and portable technique has been used for over a decade for body composition analysis. However, bioelectrical impedance does not directly measure body composition; it measures two parameters, body resistance and reactance (14) (15).

Bioelectrical impedance analysis measures the body's resistance or impedance to a small electrical current, undetectable by the subject. It is based on the fact that lean tissue contains high levels of water and electrolytes and, therefore, acts as an electrical conductor and fat acts as an insulator (13), assuming that total body water is a fixed proportion (73%) of the fat-free mass (16). Electrical bioimpedance is based on the opposition of cells, tissues, or body fluids to the passage of an electrical current generated by the device. Fat-free mass, like muscle and bone, have most of the body's fluids and electrolytes.

Once the the fat-free mass value has been obtained, the fat mass is calculated from the total body weight (15). According to the statement by the National Institutes of Health Technology Assessment Conference (Bethesda, Maryland, 12-14 December 1994), regarding the use of BIA in body composition studies, BIA is more accurate than BMI and, perhaps, even more accurate than skinfold measurement for comparative fat mass estimation (17). Therefore, this apparatus provides direct estimation of total body water. From there, fat-free mass and fat mass are estimated indirectly, through pre-established formulas.

This method's reliability and accuracy can be influenced by several factors, such as the type of instrument, electrode placement points, hydration level, feeding, menstrual cycle, ambient temperature, and the prediction equation used, which is generally close to $r^2 = 0.84$, compared to DXA (18). Therefore, some care should be taken before using bioelectrical impedance to avoid errors. These precautions include not eating or drinking four hours before the test, not exercising 12 hours before, urinating 30 minutes before, not drinking alcohol 24 hours before, and not intaking diuretics in the last seven days (19).

Its variables are impedance (Z), resistance (R), and reactance (Xc). Impedance, Z, which is measured in ohms, is the square root of the sum of R and Xc, and it is frequency-dependent; R is the pure opposition of a biological conductor to the flow of an alternating electric current; Xc is the effect of resistance due to the capacitance (storage of electric charge in a capacitor) produced by the tissue and cell membranes' interfaces. Capacitance causes the current to leave the voltage behind, creating a phase shift. This change is quantified geometrically as the angular transformation of the ratio of Xc to R, or the phase angle (20).

The phase angle (PhA) is the most established BIA parameter for diagnosing malnutrition and clinical prognosis, both associated with changes in cell membrane integrity and alterations in fluid balance. The PhA expresses changes in the quantity and quality of soft tissue mass (*i.e.*, cell membrane permeability and hydration). Numerous clinical trials propose the PhA as a useful prognostic marker for clinical conditions, such as liver cirrhosis, as well as breast, colon, pancreatic, and lung cancer. It has also been observed in HIV-positive patients. Surgically, there has been a positive association between the PhA and survival (21). A consensus on normal values has yet to be reached. However, the PhA's general behavior has a negative correlation with age. There has also been a positive correlation between BMI and the phase angle in underweight and normal-weight subjects.

Some examples of research using this method of assessing body composition include a study by Madsen *et al.*, 2014 (22) involving healthy young men in India. The study verified the effects of a cycling program on these subjects' body composition. Another study by Saladin (23), involving patients with eating disorders, evaluated the changes in their body composition during treatment. Camina-Martin *et al.*, 2015 (24) carried out a study with older men with and without dementia, comparing anthropometry and bioelectrical impedance to verify the relationship between dementia and body composition. Esco *et al.*, 2015 (25) assessed female university athletes to evaluate this method's reliability for measuring body composition in different body segments.

In 1994, Núñez *et al.*, studied body composition in young women. They reported a positive correlation between BIA and anthropometry, proposing this technique as an alternative to measuring body composition in homogeneous populations with stable weight. Other authors do not favor its use in obese or very skinny people (26). Available information indicates that bioelectrical impedance is not useful to measure acute body fat changes, although it can characterize long-term changes (17). Currently, some propose that the fundamental value of this technique is in epidemiological monitoring to estimate lean mass (13).

This method's primary advantages are that it allows differentiating between fat and lean tissue and monitors weight loss composition. Some models provide a segmental analysis that is simple and easy to run and highly reliable for large-scale studies. It also allows printing the results immediately. Moreover, most are portable, non-invasive, low risk, and low cost, compared to other high-tech methods, and high predictive value (extensive validations). They also present excellent consistency for repeated measurements (27). Some of its disadvantages are that it is not recommended for use in patients with pacemakers and it is not as accurate as the 4-compartment "gold standard" models. Also, there are no versions available for children under five years of age, patients with hydroelectrolyte balance disorders, and most patients must be able to stand on the platform in the foot models.

It also has application limitations in patients presenting fluid retention, peripheral edema, and hydrostatic problems or using diuretic medication or who have some type of amputation or anatomical deficit of a limb. It is not a suitable method for athletes because it has a 3% error rate, which is too high to provide proper information on the athlete's health status. Furthermore, a minor change in electrode location can produce a 2% variability in the results on different days (27,16).

Methods

This longitudinal study involved seventh-level cadets from *Escuela Militar de Cadetes* who, by the second semester of 2018, were required to participate in the Advanced Combat Course as a graduation requirement for their elective year in 2018. From a universe of 120 cadets, a simple random selection of 80 subjects was made, according to instructions given to the Cadet Group Commander. Ultimately, a total of 69 healthy subjects (13 females and 58 males) between the ages of 18 and 24 (57.5% of the total course population) participated, guaranteeing a statistically representative sample. The inclusion criteria considered healthy men and women between the ages of 18 and 24, students in the seventh-level military training who had taken and passed the Military School's obligatory levels of teaching. The exclusion criteria included cadets who did not sign the informed consent, were withdrawn or did not complete the ACC satisfactorily, or did not have the pre- and post-course anthropometric evaluations. Those with incomplete values or if typing errors were found during data processing, selection, and analysis were also excluded. To avoid bias, the BIA protocol was applied exhaustively, based on the recommendations already mentioned by the authors. Pre- and post-course testing was performed early in the day (between 4:30 and 6:00 a.m.), when the participants had an empty stomach.

The following phases were carried out for this study:

1. Identification of the personnel taking the ACC in the second half of 2018

2. Informing the population, explaining the study's reason and purpose.
3. Subjects were informed individually of the risks and benefits of voluntarily participating in the study.
4. Subjects signed the informed consent form and voluntarily entered the study.
5. Anthropometry by BIA was performed, according to the protocol, before departure to ACC with personnel meeting the inclusion and exclusion criteria.
6. Anthropometry by BIA was performed two to five days after the completion of the ACC. Again, taking into account the protocol.

A total of 11 (dependent) variables were evaluated before and after the ACC (Table 1). Each variable was assigned a number corresponding to the period in which it was evaluated: (1) corresponds to the pre-course measurement and (2) corresponds to its measurement post-course. Example: BMI1 - value taken before the start of the course and BMI2 - value after the end of the course.

Table 1. Variable Matrix

Name	**Abbre-viation**	**Conceptual Definition of the Variable** (28)	**Indicator**	**Measurement Scale**
Independent Variables				
Age	-	No. Years old	Years of service	Continuous, in years
Size	-	Distance from the measuring plane to the vertex in a standing position	Centimeter distance	Continuous, in centimeters
Gender	-	Biological distinction between men and women	M: Male F: Female	Nominal
Dependent variables				
Weight	Weight	Mass in kilograms	Grams of weight	Continuous, in kilograms

Continuous table

Name	Abbre-viation	Conceptual Definition of the Variable (28)	Indicator	Measurement Scale
Body Mass Index	BMI	Relationship between weight and height used as an indicator of nutritional status	Weight / Size^2	Continue, decimal number
Relative Fat Mass	RFM	Measurement calculated using size and waist circumference.	Grams of weight	Continuous, in kilograms
Absolute Fat Mass	AFM	Mass in kilograms	Grams of weight	Continuous, in kilograms
Visceral adipose tissue	VAT	Absolute value in litres	Volume in litres	Continuous, in liters
Fat Free Mass	FFM	Mass that includes bone, muscle, extracellular water, nerve tissue, and all other cells that are not fat or adipocytes	Grams of weight	Continuous, in kilograms
Skeletal Muscle Mass	SMM	Muscle mass in kilograms	Grams of weight	Continue, in kilograms
Total Body Water	TBW	Absolute value in liters	Volume in liters	Continuous, in liters
Extrace-llular fluid	ECF	Relative value in %	Percentage	Continuous, in percentage
Waist Circum-ference	WC	Measurement in centimeters of the largest perimeter around the abdomen between the lower edge of the rib cage and the iliac crest	Centimeters	Continuous, in centimeters
Phase angle	PhA	Changes in cell membrane integrity and alterations in fluid balance	Whole number	Continuous, decimal number

Source: Material created by the author.

Results

A total of 69 subjects belonging to *Escuela Militar de Cadetes "General José María Córdova"* were evaluated. The distribution by gender was 13 women (18.5%) and 56 men (81.5%). The mean age of the general population was 21.15 ± 1.14 years. Their average height was 1.68 ± 0.67 centimeters (1.51 centimeters minimum and 1.81 maximum).

Table 2 shows the 11 anthropometric variables analyzed with their respective descriptive data.

Table 2. Description of anthropometric variables of ESMIC cadets. Pre (1) and post (2) advanced combat course values

Variable	Average	N	Standard deviation	Typical error of the average
Weight 1	66.574	69	8.8313	1.0632
Weight 2	64.323	69	7.7093	0.9281
BMI1	23.3165	69	2.16537	0.26068
BMI2	22.5168	69	1.80848	0.21772
RFM1	17.9713	69	7.47749	0.90018
RFM2	15.3980	69	6.37592	0.76757
AFM1	12.0994	69	5.40873	0.65113
AFM2	9.9172	69	4.13968	0.49836
VAT1	1.4096	69	0.42321	0.05095
VAT2	0.9961	69	0.25037	0.03014
FFM1	54.4745	69	7.66051	0.92222
FFM2	54.4059	69	7.42892	0.89434
SMM1	26.3086	69	4.58379	0.55182
SMM2	25.7114	69	4.09703	0.49322
TBW1	39.645	69	5.5256	0.6652
TBW2	39.646	69	5.3657	0.6460
ECF1	15.749	69	2.0971	0.2525
ECF2	16.070	69	2.1561	0.2596
WC1	0.7414	69	0.04806	0.00579
WC2	0.7410	69	0.04766	0.00574
PhA1	7.561	69	0.6411	0.0772
PhA2	7.226	69	0.6646	0.0800

N: subjects of the sample.
Source: Material created by the author.

The table shows a weight difference between the pre-ACC intake of 66.57 ± 8.8 kg and a post-ACC of 64.32 ± 7.7 kg, with an average difference of 2.25 kg less after the course. It also shows a pre-ACC BMI value of 23.32 ± 0.26 and a post-ACC BMI of 22.5 ± 0.21, a difference of 0.79 less at the end of the course.

In general, it can be observed that there is a decrease in all the variables, with the exception of the values of total water and extracellular fluid.

The first step was to determine the data normality by applying the Kolmogorov –Smirnov and Shapiro-Wilk tests, with 95% confidence interval. The results are shown in Table 3. We checked the significance level; the distribution was considered not normal if it was < 0.05 and normal if it was > 0.05.

Table 3. Summary of processing of normality test cases

	Kolmogorov-Smirnov			**Shapiro-Wilk**		
	Statistical	N	Sig.	Statistical	N	Sig.
Age	0.189	69	0.000	0.914	69	0.000
Weight1	0.075	69	0.200*	0.983	69	0.486
Weight2	0.083	69	0.200*	0.989	69	0.804
Height	0.081	69	0.200*	0.983	69	0.457
BMI1	0.065	69	0.200*	0.978	69	0.266
BMI2	0.076	69	0.200*	0.985	69	0.552
RFM1	0.068	69	0.200*	0.972	69	0.123
RFM2	0.108	69	0.045	0.945	69	0.005
AFM1	0.074	69	0.200*	0.970	69	0.092
AFM2	0.094	69	0.200*	0.974	69	0.155
VAT1	0.108	69	0.046	0.952	69	0.010
VAT2	0.070	69	0.200*	0.992	69	0.948
FFM1	0.130	69	0.006	0.972	69	0.128
FFM2	0.140	69	0.002	0.973	69	0.139
SMM1	0.167	69	0.000	0.945	69	0.004
SMM2	0.123	69	0.012	0.959	69	0.025
TBW1	0.106	69	0.052	0.980	69	0.337
TBW2	0.119	69	0.016	0.979	69	0.290
ECF1	0.056	69	0.200*	0.991	69	0.904
ECF2	0.099	69	0.091	0.984	69	0.497
WC1	0.092	69	0.200*	0.973	69	0.149
WC2	0.097	69	0.183	0.974	69	0.162
PhA1	0.100	69	0.085	0.979	69	0.291
PhA2	0.096	69	0.191	0.982	69	0.431

* This is a lower limit of true significance.
Source: Material created by the author

Based on the results of the tests conducted, it can be confirmed that the statistics of all the variables analyzed were > 0.05. Therefore, they are considered of normal distribution.

Following the aforementioned, we decided to use Student's t test for a related sample, with a 95% confidence interval; that is, a 5% error. We started with a null hypothesis, H0, where no significant difference in the values was determined. An alternative hypothesis, H1,was used where there was a significant difference (Table 4).

Table 4. Application of Student's t test

	Related Differences					t	Significance
	Average	Common deviation	Typical average error	95% Confidence interval for the difference			
				Lower	Higher		
Weight1 - Weight2	2.2507	2.4313	0.2927	1.6667	2.8348	7.690	0.000
BMI1 - BMI2	0.79971	0.84063	0.10120	0.59777	1.00165	7.902	0.000
RFM1 - RFM2	2.57333	2.78233	0.33495	1.90494	3.24172	7.683	0.000
AFM1 - AFM2	2.18217	2.26404	0.27256	1.63829	2.72606	8.006	0.000
VAT1 - VAT2	0.41348	0.35192	0.04237	0.32894	0.49802	9.760	0.000
FFM1 - FFM2	0.06855	1.39951	0.16848	-0.26765	0.40475	0.407	0.685
SMM1 - SMM2	0.59710	1.71169	0.20606	0.18591	1.00829	2.898	0.005
TBW1 - TBW2	-0.0014	1.0825	0.1303	-0.2615	0.2586	-0.011	0.991
ECF1 - ECF2	-0.3203	0.6298	0.0758	-0.4716	-0.1690	-4.224	0.000
WC1 - WC2	0.00043	0.00361	0.00043	-0.00043	0.00130	1.000	0.321
PhA1 - PhA2	0.3348	0.3584	0.0432	0.2487	0.4209	7.758	0.000

Source: Material created by the author

The interpretation of Table 4 shows that if the p (value) or significance was < 0.05, the null hypothesis, Ho, is rejected. Thus, the alternate hypothesis, H1, is true.

It can be stated that the variables of Weight, BMI, RFM, AFM, VAT, ECF, and PhA had statistically significant changes. In other words, the ACC's physical burden produces changes in the above variables. On the other hand, there were no statistically significant changes in the FFM, SMM, TBW, and WC.

Discussion

After taking the Advanced Combat Course, the values that decreased significantly from the initial ones were weight, body mass index, relative and absolute fat mass, visceral adipose tissue, extracellular fluid, and phase angle. These results are positive from a medical, nutritional, and general health perspective, contributing to the reduction of cardiovascular risk and ideals according to anthropometric parameters.

The variables with the most significant percentage of change were those related to fat mass, in percentage, and total weight within the organism. This change is fundamentally due to the students' aerobic training (29), which has lipids as its main source of energy. The variables of body weight and BMI also underwent a significant decrease. On the one hand, because weight was lost, reducing the total amount of body fat, on the other, because of the amount of extracellular water. No increase was found in muscle mass and fat-free mass.

The variables that did not present changes, such as fat-free mass, skeletal muscle, total water, and waist circumference respond to the course's most significant conditions and objective, which involve the soldier's technical, tactical, psychological, and, to a lesser degree, physical preparation for military operations, especially in the sites of these operations, which are generally hostile combat zones that present climate, food, hydration, and adverse psychological condition-related hardships. These are truly the conditions that the Colombian soldiers face in their theaters of operations after graduating and going out to exercise their careers; the ACC seeks to improve their conditions of resistance and tolerance to these types of noxas. From the physical point of view, its objective is not to gain muscle mass or power of any kind.

It should be noted that muscle mass increase is largely determined by predominance of protein synthesis over its destruction (29); predominance, which in strength-training athletes can be 3.9% higher than the amount of protein measured in post-training (30). However, in the case of the military students' training, it is possible that because of the high protein anabolism resulting from the resistance training and associated with high temperatures and low nutritional intake, increased protein synthesis may be surpassed by the catabolic processes that lead to the accumulation of continuous aerobic work sessions throughout the course; this could explain why no changes are seen in these variables.

Concerning the phase angle, it is considered that acute exposure (eight weeks) in healthy subjects without previous pathological conditions does not impact the values significantly. Therefore, not unlike the previous, they were not reflected in the final effects.

This study's results indicate that the objectively elaborated and acutely applied structured training content allows participants in this type of course to present body variations, despite the inclement climate, emotional load, and stress of the simulated operation areas. Moreover, it produces anthropometry improvements, secondary to the types of imposed loads associated with the nutritional models that accompany these processes.

The study shows that the body variations were adequate and are not harmful to the individual's health. They are also a fundamental part of the military personnel's training and reality in their areas of operations.

These results will be beneficial in the future in the short, medium, and long term, as long as the application of the loads in this type of course can be technologically advanced and objective, oriented more and more towards improving the anthropometric conditions of our soldiers.

Conclusions

It can be concluded that after the eight weeks of training, the variables of weight, body mass index, relative and absolute fat mass, visceral adipose tissue, extracellular fluid, and phase angle presented statistically significant changes. In other words, the physical load by the ACC affects changes in the variables mentioned.

There were no statistically significant changes found in fat-free mass, skeletal muscle, total water, and waist circumference.

Future studies should try to establish, in addition to anthropometric parameters, evidence of nutritional and water inputs to try to strengthen these variables, if necessary.

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Electrical Bioimpedance to Determine Body Composition in Students from the Colombian National Army's Training Schools

3

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Abstract

Determining the components of body composition is a necessity when evaluating the fitness of the Colombian military personel. Therefore, a cross-sectional observational study was proposed in which each of the body composition variables of students in the last level of military training was determined and compared. The study was carried out in three of the Colombian Army's schools where officers, non-commissioned officers, and professional soldiers are trained. The indirect method of electrical bioimpedance was used to measure body composition. The students' ages ranged from 18 to 25 years, with an average of 21 ± 1.5 years. Their average weight was 66.3 ± 7.9 kg, and their average body mass index was 23.2 ± 2.16 weight kg/height^2. The results showed a prevalence of 19.3% (n = 26) overweight (BMI ≥ 25) in the sample; 80.1% (n = 109) of the participants were of normal weight, according to WHO criteria. The Body Mass Index (BMI) was similar in students from the three training schools (ESMIC 23.65 ± 2.3 kg/m^2; EMSUB 23.41 ± 2.4 kg/m^2; and ESPRO 22.57 ± 1.4 kg/m^2). The absolute value of fat mass in the ESPRO students showed lower weight in fat than the

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ESMIC and EMSUB students (ESMIC 12.16 ± 5.04 kg; EMSUB 11.67 ± 4.61 kg; and ESPRO 9.20 ± 4.07kg). Compared to *Escuela Militar de Cadetes*, the skeletal muscle mass presented variation in the two schools (ESMIC 28.52 ± 2.79 kg; EMSUB 25.82 ± 2.85 kg; and ESPRO 26.83 ± 2.88 kg). The differences found in the students' body composition in the three schools were due to factors, like load, intensity, frequency, and training duration in each of the military institutions.

Keywords: body composition; electrical impedance; military personnel

Introduction

Military activities involve a series of specific tasks in different theatres of operation. Military personnel are exposed to environments and conditions considered stressors, including caloric deficit, sleep deprivation, altered moods, continuous physical activity, and even cases of fatigue (1)8, and 17, as well as the Workshop on Optimizing the Performance of Women in the Armed Forces of NATO, there remained open questions concerning mission-related testing and training. The Research and Technical Organization (RTO. Military operations require soldiers to have high levels of aerobic capacity, energy reserve, and muscular strength. Therefore, good fitness (aerobic resistance, muscular endurance, strength, flexibility, and body composition) and adequate physical conditioning, in general, are important "*performance*" factors and aid in preventing musculoskeletal injuries (2).

In Western countries, fitness and aerobic capacity have declined in young people over the last few decades. Obesity in both civilian and military personnel has increased. Physical activity is essential to improve fitness and prevent obesity (3). This phenomenon is a great challenge for current military training, where logistic and technological developments reduce certain physical activities (4). Obesity has increased globally. It is currently considered an epidemic with increased morbidity and mortality rates stemming from preventable health-related causes, followed by tobacco use. Prevention and strategies to control this pathology must be initiated from childhood and adolescence to avoid adult obesity. Adults who were obese during childhood have increased risk of morbidity and mortality regardless of their weight during adulthood (5).

In the military field, the original intention of using variables, such as weight and height as parameters to decide on incorporating an individual with chronic malnutrition issues or inadequate weight for height has taken a radical turn. Currently, it focuses more on the prevention of overweight and obesity in the personnel to be incorporated. Now, the determinants of body composition are used to ensure acceptable physical abilities and rapid strength development through adequate nutrition and regular physical activity (6), in some cases, including predictors of strength performance (7). Although obesity in the military is, overall, below the average for the general population, inadequate body composition negatively impacts health care costs. It reinforces the need for policies and programs to reduce the prevalence of overweight and obesity (8).

Assessing body composition is an indispensable requirement to monitor obesity, nutritional status, training objectives, and general health (9)triceps, subsapular and supra-iliac - and total body density (by underwater weighing. In activities requiring the body mass to repeatedly overcome gravity during locomotion or jumping, excess adipose tissue acts as dead weight; this decreases military and sports performance and increases energy demand. On the other hand, fat-free mass contributes to energy production during high-intensity activities by improving absolute strength and resistance to static and dynamic loads (10). Components, like fat mass and fat-free (lean) mass are used to identify the body's nutritional requirements and energy expenditure (11). Sports nutrition experts use body composition data to develop specific dietary interventions and guide coaches and trainers to optimize and evaluate sports training programs.

Body composition assessment is frequently used in military fitness training to evaluate the effectiveness of programs for individuals considering weight loss or starting functional (strength, endurance, and body shape definition) or sports training (12). In the different training types, bodyweight control is one of the key problems during military and sports activities. Not surprisingly, some military personnel and athletes tend to increase and accelerate the training process; this can affect negatively health or performance in the field or competition. Therefore, technological efficiency in military and sports training systems must be improved, always through controlling processes that lead to optimizing the desired results.

In recent years, bioimpedance analysis (BIA) has been widely used in sports medicine. More and better methods to determine body structure and segments are being developed (13). Bioimpedance involves a flow of an alternating electric current of one or more radio frequencies transmitted by an electrode attached to the skin surface to characterize the tissues with or without good conduction, as well as the fluids that make up the body (14). Different speed current flows depend on the body's composition. Water is an excellent current conductor, as are tissues rich in electrolytes, such as muscle. Fatty tissue, bone, and pneumatic body spaces are poor current conductors (15).

We can briefly define some basic concepts to understand the fundamentals of bioimpedance. Impedance (Z) is the frequency dependent on the opposition to the current flow by the conductor (*e.g.*, the body). Geometrically, impedance is the vector composed of two frequency-dependent parameters (resistance [R] and reactance [Xc]). Resistance is the opposition to the current flow when passing through the body. Reactance is the delay in the electrical conduction caused by cell membranes, tissue interfaces, and non-ionic substances. Capacitance is a function of reactance that is increased when the cell membranes store a portion of the current for some time. This temporary storage of current charges creates a phase shift or phase angle (PhA), quantified as the ratio of the arctangent of the reactance to the resistance expressed in degrees (Xc/R) x (180°/π) (15).

The PhA is a measure provided directly by bioimpedance equipment. It is used as a marker of cell membrane integrity and body cell mass, as well as a predictor of morbidity and mortality from chronic diseases, like renal failure (16) congestive heart failure (17), oncological pathologies (18), or malnutrition (19). The PhA is the ratio of the calculation between the resistance (R) of the tissues to the passage of current (which depends on the state of hydration) and the reactance (Xc) of the tissues associated with cellularity, their size, and the cell membrane's integrity.

A decreased PhA is consistent with cell death or an alteration in cell membrane selectivity. Increased PhA values are associated with the cell membrane and body mass integrity and vitality. In healthy populations, gender, age, and body mass index are the main PhA determinants (20). In these populations, the typical PhA ranges from 5° to 7°. In athletes, the PhA can reach as high as 9.5°. There is very little literature on the determination of body composition by BIA concerning military training, less so in Colombia. Therefore, this study sought to make a general characterization of the bioelectric parameters of the body composition of students in the last level of training in the Colombian National Army's training schools.

Methods

The study's design was observational, descriptive, and transversal, with an analytical component in which BIA was used to evaluate the body composition of 135 students in the final level of military instruction. The study was carried out in three Colombian military training centers. The first was *Escuela Militar de Cadetes "General José María Córdova"* (ESMIC) in Bogotá, where National Army officers are trained. The second center was *Escuela de Suboficiales "Sargento Inocencio Chinca"* (EMSUB - Non-Commissioned Officers School) in Melgar, in the department of Tolima. The third was *Escuela de Soldados Profesionales "Pedro Pascasio Martínez Rojas"* (ESPRO - Professional Soldiers School) in the municipality of Nilo in Cundinamarca. This work was approved by the Social and Exact Sciences Ethics Committee (CECSE in Spanish) at *Escuela Militar* under Act 4363 REG-AL-FOL-71/02-2018. The study subjects participated in a meeting before beginning the data collection in which the study objectives and methodology were explained. They were provided all the information on the study and assured of the data's confidentiality with the signature of the informed consent. Participants remained anonymous, and withdrawal from the study had no consequences for their military career.

The body composition variables were taken by an ISAK 1 (International Society for the Advancement of Kinanthropometry) nutritionist-anthropometrist, according to the "pre-test" protocol. Data collection was done in the morning, at the same time for all groups. The participants were weighed in their underwear and shoeless. Before the test, none had participated in physical exercise in the previous 24 h or eaten in the last 4 h. They were all in good state of hydration, and their last urination was 30 min before the start of the tests. A SECA mBCA 525 Medical Body Composition Analyzer (Hans E. Ruth S.A, Hamburg, Germany) was used to measure body composition by electrical bio-impedance. We used the 8-point bio-electrical impedance analysis measurement method, with 19 measurement frequencies ranging from 1 to 1,000 kHz and measuring values of impedance (Z), resistance (R), reactance (Xc), and phase angle (Φ). The impedance measuring area of 10 Ω to 1,000 Ω and current measurement of 100 μA allowed multisegment recording of the body and phase angle (0°-20°). Height was measured by using a hand-held platform stadiometer (Seca 274, Hamburg, Germany). Waist circumference was measured at the midpoint between the last rib and the iliac crest using a tape measure (Ohaus® 8004-MA, Parsippany, MJ, USA). The data obtained were analyzed and stored by using Seca Analytics 115® software.

Statistical analysis

Data were analyzed by determining central tendency (means and medians), dispersion (standard deviations, standard deviation absolute error, and upper and lower limit of 95% confidence interval) measurements. Normal data distribution was assessed by using Kolmogorov-Smirnov tests. A one-factor variance (ANOVA) analysis with *post hoc* tests (Bonferroni and Games-Howell) for multiple comparisons was performed to determine differences among body composition variables in study participants at each training school, accounting for the assumptions for the test. Non-parametric statistics were used through the Kruskal Wallis test in the type of data that required it. The correlation between the sample's BMI and body composition variables was determined by using Spearman's test. The statistical software used in the data analysis was the Statistical Package for the Social Sciences® V.24 (SPSS 24) and Graph Pad Prism 7 to diagram the results. The level of statistical significance was defined by a 95% confidence interval and the lowest probability value of $p \leq 0.05$.

Results

The sample comprised 135 male cadets from the three Colombian Army's military training schools during the last level of military training (ESMIC - eighth semester, EMSUB - third semester of military training, and ESPRO - after six months of the basic military training phase). The students' ages ranged from 18 to 25 (21 ± 1.5 years). Their weight was 66.3 ± 7.9 kg, and their average body mass index was 23.2 ± 2.16 height^2/weight. Average height was 1.68 ± 0.07 m, and waist circumference for bioimpedance analysis yielded 0.786 ± 0.056 m. The prevalence of overweight (BMI ≥ 25) in the sample was 19.3% (n = 26); 80.1% (n = 109) of the participants were of average weight, according to WHO criteria. Once the analyses of body composition, anthropometric characteristics, and bioelectrical variables was performed, it was established that the BMI had similar values in the students from the three training schools (ESMIC 23.65 ± 2.3 kg/m^2; EMSUB 23.41 ± 2.4 kg/m^2; ESPRO 22.57 ± 1.4 kg/m^2). The data obtained in fat mass absolute value showed that ESPRO students had a significantly lower volume of fat than the ESMIC and EMSUB students (ESMIC 12.16 ± 5.04 kg; EMSUB 11.67 ± 4.61 kg; ESPRO 9.20 ± 4.07 kg). Similar values for fat-free mass were found in ESMIC and ESPRO. Meanwhile, the value was significantly lower for EMSUB (ESMIC 57.68 ± 5.31 kg; EMSUB 52.54 ± 5.23 kg; ESPRO 56.25 ± 5.77 kg). Compared to ESMIC, the skeletal muscle mass varied for the two other (ESMIC 28.52 ± 2.79 kg; EMSUB 25.82 ± 2.85 kg; ESPRO 26.83 ± 2.88 kg), reflected in the calculation of the kilocalories yielded by the individuals' total energy expenditure (ESMIC

3138.73 ± 247.79 kcal; EMSUB 3018.05 ± 207.87 kcal; ESPRO 3005.55 ± 164.74 kcal). Finally, in the PhA value analysis, EMSUB students had a lower PhA compared with the ESMIC and ESPRO students (ESMIC 7.78° ± 0.52°; EMSUB 7.56° ± 0.55°; ESPRO 7.19° ± 0.66°). However, they were considered outside the expected values for this young and physically active population (Table 1).

Table 1. Variables of body composition by bioimpedance of the students from the three National Army's training schools

Variable	ESMIC x sd		EMSUB x sd		ESPRO x sd	
AGE (years)	22.58	1.234	21.38	1.775	21.24	1.26
WEIGHT (kg)	69.846	8.667	64.220	7.7595	64.9244	6.0784
SIZE (m)	1.7173	.06340	1.6553	.06244	1.6953	.07288
BMI (kg/m^2)	23.651	2.3576	23.411	2.4618	22.578	1.34137
WAIST CIRCUM-FERENCE (cm)	0.8078	0.0613	0.7902	0.0594	0.7609	0.0346
FAT MASS (kg)	12.1633	5.04370	11.6736	4.6163	8.6667	2.5304
FAT-FREE MASS (kg)	57.6833	5.3164	52.5464	5.2335	56.2578	5.7722
SKELETAL MUSCLE (kg)	28.5216	2.7909	25.8207	2.8538	26.8389	2.8802
TOTAL BODY WATER (kg)	41.8756	4.0355	38.0689	3.9346	40.8978	4.3203
EXTRACELL FLUID (kg)	16.3311	1.8115	15.1467	1.7238	16.6756	2.0061
ENERGY EXPENDITURE (Kcal)	3138.73	247.791	3018.05	207.875	3005.55	164.746
RESPONSE EXPENDITURE (Kcal)	1739.83	130.337	1657.24	114.965	1669.75	91.526
ANGLE (º)	7.78	.522	7.56	.553	7.19	.6643

* Median (x) and standard deviations(sd); Escuela Militar de Cadetes "General José María Córdoba" (ESMIC); Escuela de suboficiales "Sargento Inocencio Chinca" (EMSUB); Escuela de Soldado Profesionales "Pedro Pascasio Martínez Rojas" (ESPRO).
Source: Material created by the authors.

In the subsequent set of figures, the comparisons of some of the body composition variables for the three schools are presented. For the multiple comparisons, a one-factor analysis of variance (ANOVA) was perfomed with Bonferroni or Games Howell tests, as the case may be, for data with normality in its distribution. An Inter-group comparison was also performed for data with non-parametric distribution using the Kruskal Wallis statistician. Statistically significant differences were found in the BMI between ESMIC and ESPRO (p = 0.029) (Figure 1). Figure 2 shows the statistically significant differences in fat mass between ESMIC and ESPRO (p = 0.0001), and between EMSUB and ESPRO (p = 0.001). Figure 4 shows differences in skeletal muscle mass between ESMIC and EMSUB (p = 0.0001), and between ESMIC and ESPRO (p = 0.0001). Figure 3 shows the fat-free mass comparison between ESMIC and EMSUB (p = 0.0001), and between EMSUB and ESPRO (p = 0.005). Figure 6 shows the total energy expenditure between ESMIC and EMSUB (p = 0.021), and between ESMIC and ESPRO (p = 0.009). Figure 4 shows the PhA statistically significant differences between ESMIC and EMSUB (p = 0.0001), and between EMSUB and ESPRO (p = 0.009). Figure 5 shows the comparison of total body water between ESMIC and EMSUB (p=0.0001), and BETWEEN EMSUB and ESPRO (P=0.0004). Figure 7 shows the comparison of the phase angle between ESMIC and EMSUB students (p=0.0001), and between EMSUB and ESPRO students (p=0.009). Figure 8 presents the correlation analysis between BMI and bioelectrical variables, which showed a significant relationship with the fat mass value (r = 0.83; p = 0.0001), and the skeletal muscle mass (r = 0.45; p = 0.0001) (Figure 9).

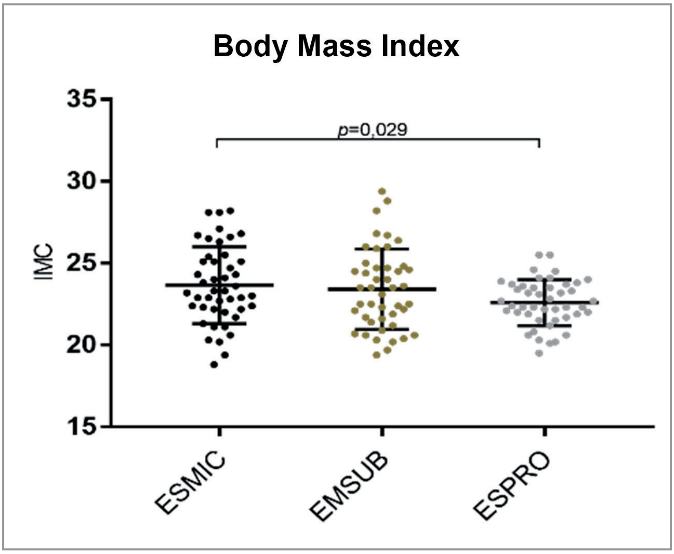

Figure 1. Comparison in the Body Mass Index among the students of the three schools (Games-Howell test).
Source: material created by the authors.

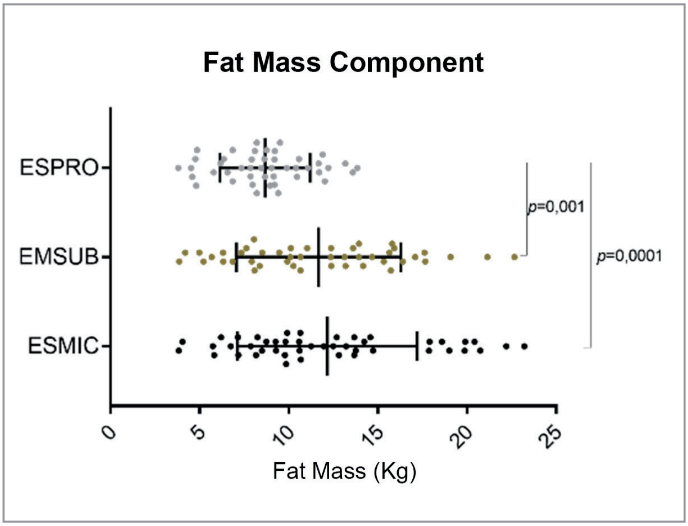

Figure 2. Comparison of the fat mass component among the students of the three schools (Games-Howell test)
Source: material created by the authors.

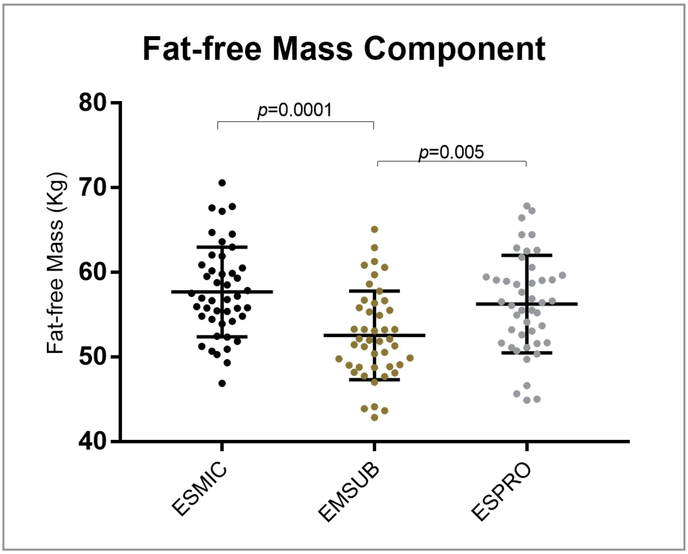

Figure 3. Comparison of the Fat-free Mass component among students in the three schools (Bonferroni test).
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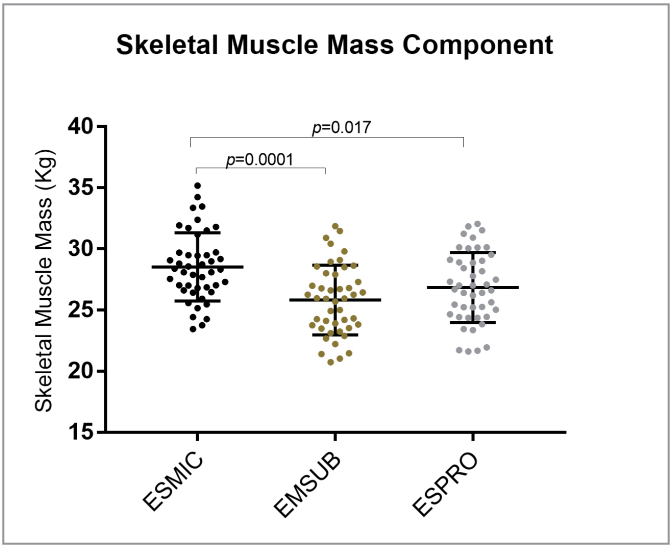

Figure 4. Comparison of the Skeletal Muscle Mass component among the students of the three schools (Bonferroni test)
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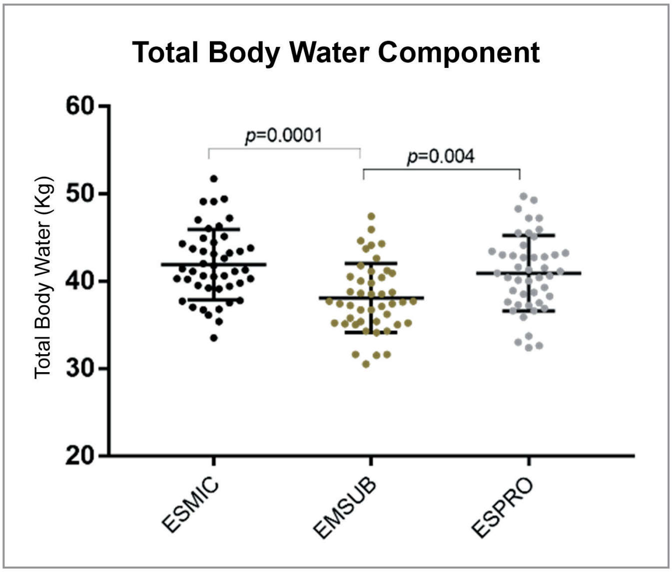

Figure 5. Comparison of the Total Body Water component (hydration status) among the students of the three schools (Bonferroni test)
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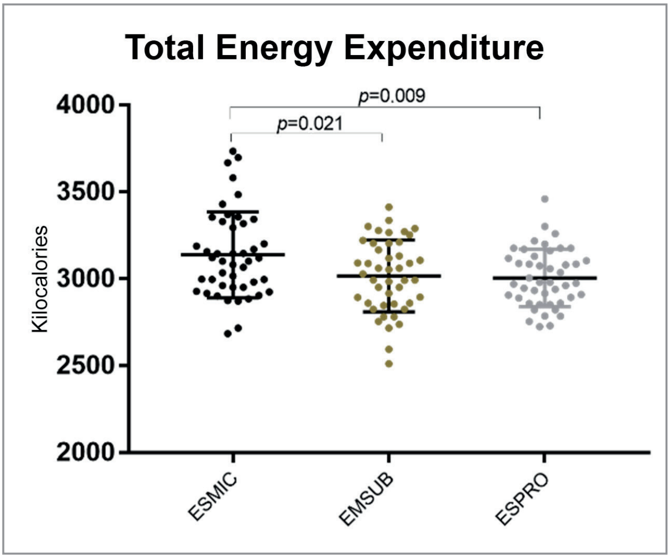

Figure 6. Comparison in the prediction of the total energy expenditure among the students of the three schools (Bonferroni test)
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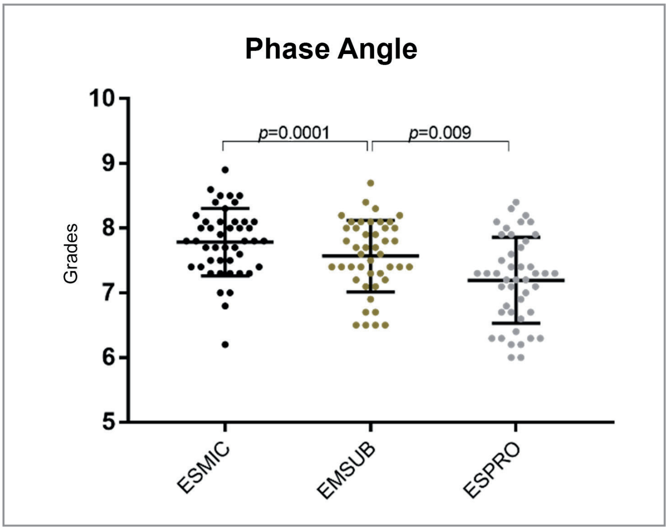

Figure 7. Comparison of the phase angle between the students of the three schools (Bonferroni test)
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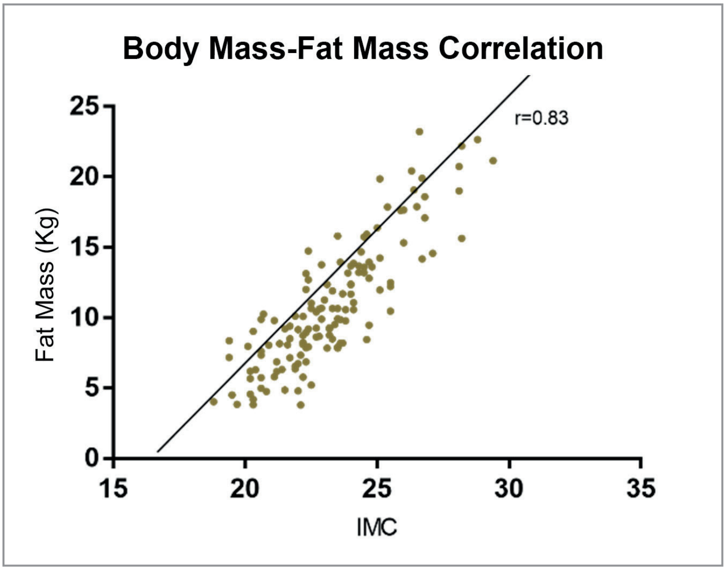

Figure 8. Correlation between Body Mass Index (BMI) and Fat Mass of study participants (Spearman's test).
Source: material created by the authors.

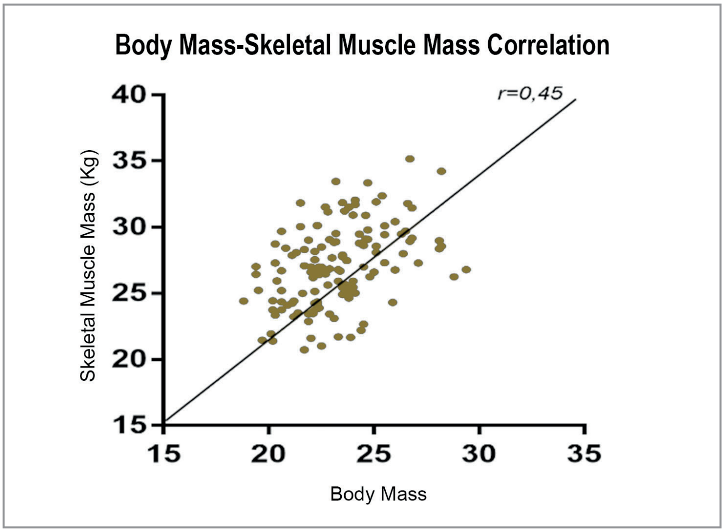

Figure 9. Correlation between Body Mass Index (BMI) and Skeletal Muscle Mass of study participants (Spearman's test).
Source: material created by the authors.

Discussion

Maintaining adequate levels of fitness and body composition in military personnel has been a selection criterion for carrying out tasks typical of the physical demands of military service, assuming that adequate body weight is synonymous with good health, adequate physical and mental condition, and suitable military appearance (21) Advances in health services, technological and computer developments, and improved nutritional requirements in recent decades have led to an increase in the general population's average weight, height, and fat-free mass. However, excessive consumption of food quantity and quality and physical inactivity cause risks of overweight issues that impact military health and performance. One of the most relevant questions by the organizations in charge of evaluating physical training and military plans is how to evaluate the physical performance (fitness) of its members. Four components have been proposed in the evaluation, *i.e.*, aerobic capacity, muscular power, resistance, and body composition (22).

The body composition of military personnel undergoing technical and tactical training in the Colombian National Army's training schools had not been previously characterized comprehensively. This work allowed contrasting this description with studies abroad and among the three schools.

The BMI, which is an indicator of population screening for overweight and obesity using weight-for-height analysis, in the entire sample for this study was 23.21± 2.16 kg/height^2. In 2017, Maldonado *et al.*, found similar BMI values of 22.7 ± 2.7 weight kg/height^2 in a study of 153 students at an army soldier training school in Ecuador. However, the body composition data were obtained via skin folds (23) Another study by Cortés *et al.*, (2017) of military personnel in Colombia determined BMI values of 24.4 ± 2.22 weight kg/length^2 in 72 cadets attending a 12-week combat course. These values were collected through electrical bioimpedance prior to the combat course training (24). In 2016, a study by Duran-Agüero *et al.*, found BMI values in military men under 30 years of age of 25.4 ± 2.9 weight kg/height^2 in a sample of 415 soldiers of a Chilean military parachute brigade (25). Gómez *et al.*, (2016) used bioimpedance to determine a BMI of 26.90 ± 0.80 weight kg/height^2 for 288 Mexican service personnel (26). In a study conducted in the United Kingdom, during the Gulf War, Blacker *et al.*, (2011) evaluated different parameters in 119 members from different military forces (Navy, Air Force, and Army), finding a BMI of 22.2 ± 2.6 weight kg/height^2 (27). Overall, the average BMI in the different armies evaluated did not show major differences, except for the study in Chile assessing subjects over 25 years of age, which is related to increased BMI associated with age.

In this study, in the three Colombian Army's training schools, significant differences were found in BMI between the students from *Escuela Militar de Cadetes* (ESMIC) and those from *Escuela de Soldados Profesionales* (ESPRO). These differences are closely related with lower values in the fat mass component of the ESPRO soldiers, which is explained by several reasons. The first reason is the intensity of a shorter training program (12 weeks of constant training and field equipment load). The second is altitude;

training occurs at 336 meters above sea level, whereas Bogotá is at 2600 masl. Given its location, sensible and insensible fluid losses are higher at ESPRO; this affects the weight assessment and fat mass component, making it lower in this population, which directly influences a lower BMI.

This study's fat mass component was estimated at 10.83 ± 4.45 kg. These results are similar to those in studies by Cortés *et al.*, (2018) who found values of 6.27 ± 4.88 kg, Duran-Agüero *et al.*, (2017) in Chile, where the fat mass values were 16.1 ± 5.6 kg and Vásquez Guzmán *et al.*, (2016) in Mexico who reported values of 19.32 ± 3.07 kg. When observing the latter populations, higher BMI values could be attributed to increased fat mass, age-related overweight issues, and low physical activity levels. In our comparison of the three schools, ESPRO showed lower fat mass values than the other two Army training schools.

The average fat-free mass component for the three schools was 55.49 ± 5.82 kg. In a previous study by Cortés *et al.*, (2017) values of 66.3 ± 6.12 kg were found for their sample of Colombian military personnel. Meanwhile, in Chilean military personnel, the fat-free mass was 57.8 ± 6.0 kg. Finally, in the Mexican military population, this value was estimated at 57.55± 5.09 kg. In our comparison of the training schools, significant differences were found in the fat-free mass values. The group at EMSUB had the lowest component of fat-free tissue.

No strong correlation was found between BMI and fat mass ($r = 0.33$; $p = 0.001$). These values were similar to those obtained in the Mexican military population ($r = 0.33$) and very different from the correlation of the Chilean population's components ($r = 0.61$). Regarding the average skeletal muscle mass component in this study's population, it was 27.06 ± 3.03 kg. These values were unlike those reported by Cortés *et al.*, (2017) in a similar population, where the value of skeletal muscle mass was 63 ± 5.09 kg. Based on the comparison, the EMSUB military personnel had lower skeletal muscle component. Significant differences were found between the military personnel at ESMIC and at ESPRO. The correlation obtained between BMI and skeletal muscle mass was positive between these two variables ($p = 0.45$).

Although values were obtained in this study for body composition variables, such as total energy expenditure, energy expenditure at rest, total body water, extracellular fluid, and phase angle, no military-related literature was found to contrast them. However, having a baseline of the bioelectrical characteristics of body composition is essential to describe this population, given that, when comparing the results obtained in the three schools, significant differences were found, which could be explained in terms of training times, intensity, and frequency. However, in general terms, they do not present alterations regarding the standards determined in other studies for a military population.

Conclusions

Although very few studies exist of body composition analysis by electrical bioimpedance in young people, and more so in a military population, this work determined the body composition variables most commonly used in sports nutrition and military training. This pilot study showed specific statistical differences in body composition components and bioelectrical variables according to the training school. Although the sample is homogeneous, we can evidence that ESPRO has a lower percentage of fat mass than ESMIC and EMSUB, which could be explained by the intensive and continuous training process during the four months of the instruction phase. Moreover, the skeletal muscle mass was higher for ESMIC and ESPRO than for EMSUB. This study is a first step to studies that will allow better characterizing the variables of interest with more representative samples of all the National Army's units.

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Maximum Ventilatory Equivalents and Oxygen Pulse in the Pre-competitive Phase of Military Athletes. An Observational Study

4

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Abstract

The ventilatory equivalents for oxygen (VE/VO_2), carbon dioxide (VE/VCO_2), and oxygen pulse ($PulO_2$) influence exercise response. **Objective.** To analyze the precompetition ventilatory equivalents and maximum oxygen pulse in a group of military athletes. **Methodological design.** A retrospective research assessing $PulO_2$, VE/VO_2, and VE/VCO_2 in relation to other physiological variables through ergoespirometry. Descriptive statistics were applied. Levene's test was used to assess variance homogeneity. Data distribution was verified by using the Shapiro-Wilk test. The Kruskal-Wallis H test, Student's t test, and Pearson's coefficient were also applied. **Results.** Sixty athletes aged 21 ±2 years, 80% (n = 48) men and 20% (n = 12) women, participated in the study. The ventilatory equivalents showed no differences by gender ($p > 0.05$). However, they did differ by type of sport (p 0.02). The $PulO_{2max}$ showed differences by gender and type of sport ($p > 0.01$). The VE/VCO_{2max} and the VO_{2max} were related with the test duration, and the $PulO_{2max}$ with speed. **Conclusions.** The VE/VCO_{2max} and $PulO_{2max}$

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should be part of the military physical training, given the differences by gender and type of sport.

Keywords: ergoespirometry; oxygen pulse; sports; VE/$VCO_{2max;}$ ventilatory equivalents

Introduction

Cardiopulmonary exercise testing (CPET), or ergospirometry, is a diagnostic procedure to assess the function and capacity of the cardiovascular, pulmonary, and metabolic systems. It provides information on the body's response to dynamic stress and is routinely used in stress testing laboratories (1), monitoring and evaluating respiratory functions, and gas analysis during physical activity and, at the same time, cardiac function under load. The CPET is a diagnostic and prognostic tool, useful in assessing the cause of shortness of breath (dyspnea) and providing a prognostic assessment of patients with cardiovascular and pulmonary diseases, such as coronary disease, chronic obstructive pulmonary disease (COPD), pulmonary embolism, and hyperventilation syndrome, as well as exercise-induced asthma, among others (2) (3).

This non-invasive and objective method provides a very accurate assessment of the function of the cardiovascular, pulmonary, muscular, and metabolic systems during exercise in quantified manner. It is commonly calculated based on the treadmill or cycloergometer's working speed and is considered the gold standard for cardiopulmonary functional assessment. Therefore, many medical specialties, like cardiology, pneumology, and sports medicine or sports science, have benefited from this test (4) (5) (6) (7).

The CPET is an important method in functional evaluation in Colombia and globally. Its most frequent uses involve applying an intensity exercise that gradually increases until exhaustion or until limiting symptoms or signs occur (8). The test is based on measuring exhaled gases during exercise. Among other things, it estimates pulmonary ventilation (PV), oxygen consumption (VO_2), carbon dioxide production (VCO_2), VO_2 maximum (VO_{2max}), VCO_2 maximum (VCO_{2max}), and the ventilatory equivalents for oxygen (VE/VO_2) and carbon dioxide (VE/VCO_2). In some special situations, it measures pulse saturation both during and after exertion (9) (10).

Oxygen consumption (VO_2) is defined as the volume of oxygen (O_2) extracted from the air inhaled during pulmonary ventilation (PV) over a time span. In practice, the maximum VO_2 (VO_{2max}) is the highest value achieved, despite the progressive increase in the applied load (4). It is calculated from the difference between the volume of O_2 in the inhaled and exhaled air during exercise per time unit. The VO_2 is determined by the cellular O_2 demand. In healthy people, it increases linearly as external work increases (11).

Carbon dioxide (VCO_2) production is the difference between the volume of CO_2 in the air inhaled and exhaled during exercise per unit of time and represents the metabolic production of carbon dioxide. This VCO_2 is affected by the same factors as VO_2; however, it is more dependent on ventilation because of the greater solubility of CO_2 in the blood.

Several variables in CPET, including the respiratory quotient (RER) and ventilatory equivalents, are derived from VCO_2 (12). The RER expresses the relationship between CO_2 production and O_2 consumption (VCO_2/VO_2). It is currently the best non-invasive indicator of maximum or near-maximum exercise intensity. Values >1.0 may reflect intense exercise. However, in a CPET, those ≥ 1.10 are sought (2) and have been accepted as a parameter of exhaustion or near-exhaustion (13). Lactic acid production nearing exhaustion results in an RER > 1 because additional CO_2 is introduced into the system from a bicarbonate buffering (HCO_3). Thus, an RER substantially > 1 in maximum exercise is a maximum effort marker. Hyperventilation can also cause an RER >1 (12). Some authors maintain that a person has reached maximum testing when they reach at least two of the following criteria: reaching and maintaining the VO_{2max} plateau, even if the workload increases, to reach the maximum predicted heart rate and reaching an RER ≥ 1.15 (14). Figure 1 shows the expected behavior of VO_2 and VCO_2, rising linearly, with VO_2 greater than VCO_2 until the VO_2 plateau is reached.

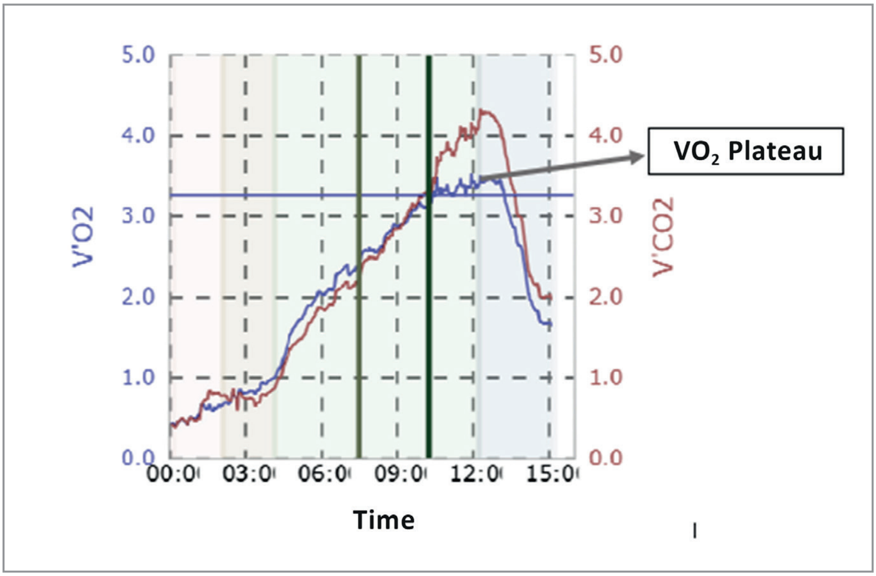

Figure 1. VO_2 and VCO_2 behavior
Source: Research data

Pulmonary ventilation (PV) is expressed in liters per minute and represents the air volume entering and leaving the lungs. It is defined as the product of the breathing frequency (BF) by the current volume exhaled in each cycle depending on: 1) the process of cellular respiration, 2) interaction between sensors and receptors that capture physical or chemical changes, 3) the central control that triggers the frequency and depth of each breath, sending stimuli to the respiratory muscles, and 4) the mechanical effectors that facilitate inhalation and exhalation. In this sense, sensors located in the central nervous system (CNS) capture changes in pH and central temperature. Outside the CNS, there are carotid and aortic bodies that are sensitive to changes in $PaCO_2$, PaO_2, and pH. Some receptors located in the upper airway (nose, pharynx, and larynx) and the lung receptors (stretch receptors, irritation receptors, and juxtacapillary receptors) are also involved. Finally, the respiratory muscles' (neuromuscular and Golgi tendon organ uses) receptors also modulate ventilation by conditioning the muscles' level of stretching and shortening. Regarding central control, the pneumotaxic center located in the pons is responsible for inhibiting inspiration and increasing the respiratory rate. The apneustic center does the opposite, increasing inspiratory time. The bulbar centers are in charge of stimulating the respiratory muscles (15).

At rest, 7 to 9 L/min of air are ventilated; however, in athletes, this value can reach 200 L/min with maximum effort (16) (7). Ventilation increases continuously during progressive stress in CPET and undergoes additional increases influenced by anaerobic metabolism resulting from the accumulation of lactic acid, defined as the first and second ventilation thresholds (17).

MOreover, the oxygen pulse (pulse of O_2) is the ratio of VO_2 to heart rate (HR) and is expressed in ml/beat (18). Low oxygen pulse during exercise may indicate decreased systolic volume or an abnormality in the extraction of oxygen from the skeletal muscle. Low HR during exercise, caused by Beta-blocker medications, may raise the O_2 pulse by lowering the denominator (18).

The VE/VO_2 and VE/VCO_2 are indicators of respiratory efficiency. They are defined as the relationship between pulmonary ventilation and oxygen consumption (VE/VO_2) or between pulmonary ventilation and carbon dioxide production (VE/VCO_2) during an incremental exercise test (7) (19). Both decrease from rest to sub-maximal exercise intensities, reaching minimum values before the anaerobic threshold (AT), when there is a progressive increase caused by increased ventilation to eliminate the additional production of CO_2, which results in a bicarbonate-in-blood lactate buffer (6). Figure 2 shows a graphic example of the behavior of the VE/VO_2 and the VE/VCO_2 in which a gradual increase in the former and a progressive decrease in the latter can be observed.

In different types of sports training, the CPET is a useful and valuable test to evaluate athletes and monitor their progress. Like athletes, military personnel must also have good physical condition to perform optimally to meet operational requirements in stressful and rigorous environments and life-threatening conditions associated with their work (20). The Armed Forces have historically invested in preparing elite and Olympic-level athletes

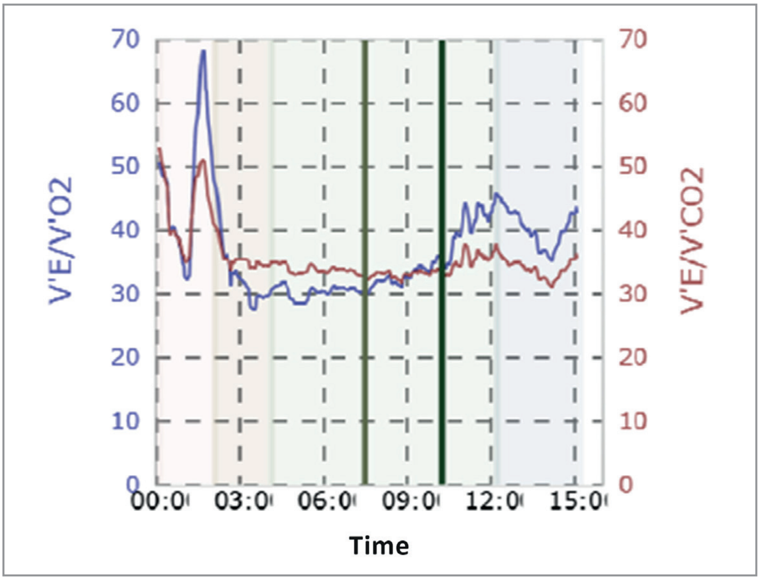

Figure 2. Behavior of VE/VO_2 and VE/VCO_2
Source: Research data

worldwide (21). There is little evidence of studies involving the military athlete population and, to our knowledge, this is the only study that focuses primarily on this analysis in Colombia. Therefore, this study's objective was to analyze the ventilatory equivalents and the maximum oxygen pulse of a group of military athletes in the pre-competitive phase.

Methods

This retrospective, observational study analyzed 76 ergospirometry tests conducted with military athletes in the 2018 pre-competitive phase of different disciplines, including sprints, long-distance running, orienteering, triathlon, pentathlon, and soccer and basketball. Only 60 maximum tests were considered (respiratory quotient ≥ 1.10) (22). The subjects were evaluated in the Research Center of Physical Culture (CICFI in Spanish) at *Escuela Militar de Cadetes "General José María Córdova"* (ESMIC). Testing was performed by using an HP Cosmos treadmill with a Metalyzer 3B-R2 spiroergometry device, at 22.6 °C and barometric pressure of 560 mmHg. All of them followed an aerobic power protocol, starting with a 4-minute warm-up at 4 km/h. The initial treadmill's speed was 7 km/h; it increased by mile, every minute, until exhaustion, with a constant inclination of 1%. Ventilation (VE), carbon dioxide production (VCO_2), maximum ventilatory equivalent for oxygen and carbon dioxide, maximal oxygen pulse (VO_{2max}/HR_{max}), respiratory quotient (VCO_2/VO_2), maximum breathing rate (BR_{max}), maximum current volume (VC_{max}), and oxygen consumption (VO_{2max}) were considered ventilatory variables. Maximum heart rate (HR_{max}) was analyzed among the cardiac variables.

The data were aggregated into an Excel matrix for further analysis by using the SPSS v. 21 statistical package. Use of the data was approved by the military school's ethics committee.

Results

Sixty subjects were analyzed retrospectively; 80% (n = 48) were men and 20% (n = 12) women. The mean age was 21 ± 2 years, weight was 68 ± 10 kg, height was 1.71 ± 10 m., and BMI was 23.1 ± 1.8 kg/m^2. Body surface area was 1.8 ± 0.18 m^2, HR_{max} was 1.84 ± 9 L/min. Furthermore, VO_{2max} was 45.6 ± 6.6 ml/kg/min., VO_{2max} was 3.11 ± 0.63 L, VCO_{2max} was 3.6 ± 0.7 L, VE_{max} was 148.2 ± 27 L, VE/VO_{2max} was 52.6 ± 10.2 **(unit of measure?)**, VE/VCO_{2max} was 41.17 ± 4.6 **(unit of measure?)**, RF_{max} was 68.9 ± 10 r/min, VC_{max} was 2.1 ± 0.48 L. Oxygen pulse was 17 ± 3.5 ml/heartbeat, and the respiratory quotient was 1.2 ± 0.10 **(unit of measure?)**. Ten percent (n = 6) of the population practiced pentathlon, 22% (n = 13) soccer, 12% (n = 7) long-distance running, 20% (n = 12) orienteering, 8% (n = 5) triathlon, 16% (n = 10) sprints, and 12% (n = 7) basketball. The differences by gender are presented in **Table 1** and the differences by type of sport are presented in **Table 2**.

Table 1. Behavior of cardiopulmonary variables by gender

Variable	Median and SD		*P*
	Men	Women	
Age (years)	20.7 ± 1.7	20 ± 1.9	*2.01*
Weight (kg)	71.19 ± 8.5	56.07 ± 6.4	*0.00*
Height (m)	1.74 ± 0.08	1.58 ± 0.05	*0.00*
BMI (kg/m^2)	23.37 ± 1.85	22.24 ± 1.58	*0.05*
Test duration (minutes)	15.39 ± 2.96	14.28 ± 3.14	*0.25*
Body surface area (m^2)	1.85 ± 0.15	1.57 ± 0.12	*0.00*
Speed (km/h)	18.83 ± 1.63	15.66 ± 1.06	*0.00*
HR Rest (BPM)	79 ± 10	83 ± 8	*0.14*
HR_{max} (BPM)	183.5 ± 8	186.8 ± 12	*0.26*
VO_{2max} (L)	3.34 ± 0.48	2.21 ± 0.26	*0.00*
VO_{2max} (ml/kg/min)	47.16 ± 6.15	39.66 ± 4.9	*0.00*
VCO_{2max} (L/min)	3.89 ± 0.48	2.56 ± 0.32	*0.00*
VE_{max} (L/min)	157.53 ± 20.33	111.3±17.98	*0.00*
VE/VO_{2max}	51.32 ± 10	57.90 ± 9.85	*0.45*
VE/VCO_{2max}	40.62 ± 4.52	43.36 ± 4.58	*0.66*
BR_{max} (rpm)	70.22 ± 9.94	64 ± 9.34	*0.05*
VE_{max} (L/min)	2.27 ± 0.36	1.75 ± 0.27	*0.00*
O_2 pulse (ml/beat)	18.25 ± 2.77	12.08 ± 1.44	*0.00*
Respiratory Quotient	1.20 ± 0.11	1.16 ± 0.1	*0.23*

* Significance level ($p < 0.05$).
Source: Created by the authors from research data.

Table 2. Behavior of cardiopulmonary variables by type of sport

Variable	Median and SD		P
	Individual	Group	
Age (years)	21±2	21±1	*0.54*
Weight (kg)	64.9±8.4	74.6±10.4	*0*
Height (m)	1.70±0.1	1.80±0.1	*0.01*
BMI (kg/m^2)	23.0±1.9	23.4±1.7	*0.43*
Test duration (minutes)	15.9±3.3	13.8±1.5	*0.11*
Body surface area (m^2)	1.7±0.2	1.9±0.2	*0*
Speed (km/h)	18.3±2.3	18.1±1.4	*0.74*
HR Rest (BPM)	80.5±10.8	78.9±9.7	*0.57*
HR_{max} (BPM)	186.6±9.2	179.4±7.5	*0.03*
VO_{2max} (L)	3.0±0.7	3.3±0.5	*0.18*
VO_{2max} (ml/kg/min)	46.6±7.5	43.9±3.9	*0.13*
VCO_{2max} (L/min)	3.4±0.7	4±0.6	*0.01*
VE_{max} (L/min)	144.7±28.3	155.4±23.9	*0.15*
VE/VO_{2max}	55.5±8.5	47±11.3	*0.02*
VE/VCO_{2max}	42.4±4.6	38.4±3.6	*0.02*
BR_{max} (rpm)	70.9±11.1	65.1±6	*0.03*
VE_{max} (L/min)	2.1±0.4	2.4±0.4	*0.01*
O_2 pulse (ml/beat)	16.4±3.7	18.4±3	*0.03*
Respiratory Quotient	1.18±0.1	1.2±0.1	*0.04*

Source: Created by the authors from research data

The VE/VO_{2max} and VE/VCO_{2max} showed no significant differences by gender. However, differences were found by type of sport. For individual sports, the VE/VO_{2max} was 55.5 ± 8.5 and 47 ± 11.3 in team sports; VE/VCO_{2max} was 42.4 ± 4.6 and 38.4 ± 3.6, respectively, p = 0.00 in both cases.

The $PulO_{2max}$ showed differences by gender. It was 18.25 ± 2.77 ml/beat for men and 12.08 ± 1.44 ml/beat for women, with p =0.00. For individual sports, it was 16.4 ± 3.7 ml/beat and 18.4 ± 3 ml/beat for team sports, with p = 0.01. The VE/VCO_{2max}, was related to the VE/VO_{2max} (r = 549, p = 0.00), with the VO_{2max} (0.342 ± 0.00), with the test duration (r = 0.385, p = 0.00). In turn, test duration was related with the VO_{2max} (r = 0.518, p = 0.00). The VE/VO_{2max} was related with weight (r = -373, p = 0.00), with the body mass index (r = -317, p = 0.00), and with the VCO_{2max} (r = -317, p = 0.00). The $PulO_{2max}$ was related with length (r = 0.693, p=0.00), weight (r = 732, p=0.00), BMI (r = 335, p = 0.00), speed (r = 414, p = 0.00), VCO_{2max} (r = 0.781, p=0.00), with the VE_{max} (r = 0.828, p = 0.00), and with the VO_{2max} (r = 0.661, p = 0.00). The VO_{2max} was related with the RF_{max}. (r = 0.474, p = 0.00).

Discussion

This study's main objective was to evaluate the athletes' physical and functional conditions in the pre-competitive phase to implement training plans to optimize performance during competition. It was evidenced that the maximum ventilatory equivalent for carbon dioxide, maximum oxygen consumption, and oxygen pulse showed a significant impact on the duration of the test and, therefore, on the performance of the athletes evaluated.

Herdy and Uhlendorf established VO_{2max} scales in 2,388 Brazilian men and 1,534 women. The subjects included healthy, sedentary, and physically active individuals. The authors reported average values in the active population of 50.6 ± 7.3 ml/kg/min for men and 38.9 ± 5.7 ml/kg/min for women (4). In our study, slightly higher values were found in women and lower in men. These differences could be due to the type of population, race, and age. The comparison of our results with Herdy and Uhlendorf's study corresponds to their 15 to 24-year-old group, given that our study's minimum age was 18.

It has been reported that *VE*/VCO_2 is unrelated with the athlete's ability to use oxygen or achieve high performance (23). However, in this study, a positive correlation was found between this variable and the test duration in the pre-competitive phase. Therefore, it is recommended to monitor it during training, as suggested by Sauer, Pérez, and Cartelli (24). It should be noted that these authors reported weak correlations between *VE*/VCO_2 and VO_2, based on previous studies. Conversely, in this work, a statistically significant moderate correlation was found between both variables, suggesting an association between ventilation and performance. Here, it must be indicated that the subject can intake oxygen and eliminate carbon dioxide through ventilation and that according to the hemoglobin dissociation curve's behavior, decreased plasma pH, increased $PaCO_2$ or temperature, among others, cause decreased hemoglobin affinity for oxygen, favoring its delivery to tissues (25). This fact could explain the relationship found in the athletes assessed at the maximum phase.

In the same sense, a work by Nalbandiano *et al.* (26), which also considered test duration as a performance indicator, documented that breathing rate influenced neither VO_{2max} nor resistance in a group of 10 male athletes. In this work, however, a significant relationship was found between VO_{2max} and BR_{max}. Although no relationship was found between BR and test duration, it could be considered that if BR is related with VO_{2max}, it could also be related with performance. This aspect could be addressed in future studies. In this case, the breathing rate's exaggerated increase, in the maximum phase, causes a reduction in the tidal volume and an increase in $PaCO_2$, generating, as described by Minas from physiology, enhancement of the Bohr effect, optimizing O_2 delivery (27) (28). This situation would also explain the relationship found between VE/VO_2 and VCO_2.

Considering that VO_2 partially depends on the correct diffusion of gases, influenced by time constants (29), and that the HR reaches maximum levels that shorten the red blood cell's exposure time in the hematogaseous membrane during intense activities of high metabolic demand, it is possible to explain that the maximum frequencies reached by the athletes could reduce the VO_{2max}, in comparison to values found in other athletes of the same age, in the pre-competitive phase (28). Here, it is important to note that, in our study, not all athletes belonged to the same discipline and that there was no data to establish how long they had been in it. Therefore, it is recommended that future studies take these aspects into account.

Finally, Padilla's work with Mexican endurance athletes reported a positive relationship between $PulO_{2max}$ and absolute VO_{2max}. However, it also reported a negative relationship between $PulO_{2max}$ and HR_{max} (18). These findings are similar to those found in this work and corroborate that oxygen pulse complements the cardiorespiratory evaluation, as concluded by Padilla himself.

Conclusions

The ventilatory equivalent for maximum carbon dioxide (VE/VCO_{2max}) influences upon test duration, thus, breathing technique and respiratory muscle training may influence sports performance.

The $PulO_{2max}$ allows identifying cardiopulmonary resistance and, therefore, sport performance; this was reflected in its direct relation with the speed of the athletes evaluated. Therefore, training should aim to enhance $PulO_{2max}$, and strengthen ventilation, differentiating by gender and type of sport.

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Characterization of Oxygen Consumption in a Special Population: AFEAU (Urban Anti-terrorist Special Forces Group)

5

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Abstract

Cardiovascular endurance is one of the health-related components of fitness. A reliable way of evaluating it is by measuring the maximum oxygen consumption, "which represents the maximum amount of oxygen that the body is capable of absorbing, transporting, and consuming per unit of time" [2]. This parameter allows assessing adaptations to cardiovascular resistance training. It facilitates the comparison among individuals and populations based on factors, such as genetics, age, gender, body mass, and composition.

In this chapter, a cross-sectional study analyzes the results of oxygen consumption tests carried out with personnel from the Urban Antiterrorist Special Forces Group (AFEAU, for the term in Spanish) to characterize their cardiovascular condition. Subtle differences were found among the groups evaluated. The population from 2018 showed better results than in 2016; this generates new proposals for monitoring this population and options for expanding research in this field.

Keywords: ergospirometry, maximum oxygen consumption, cardio vascular resistance

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Introduction

This chapter shows how oxygen consumption is measured to determine cardiovascular endurance, one of the health-related components of fitness (1), through treadmill ergo-spirometry in a specific population within the armed forces, namely, the Urban Anti-terrorist Special Forces (AFEAU) group. The most important variable obtained from the physical test, maximum oxygen consumption, "which is the maximum amount of oxygen that the body is capable of absorbing, transporting and consuming per unit of time," must be clear (2). It is the product of maximum cardiac output (liters blood · minute -1) and the difference in arteriovenous oxygen (mL of oxygen per liter of blood) (1).

Characterizing this population provides an objective measurement of its cardiovascular condition. It can also be used to compare with the results of oxygen consumption by ergo-spirometry in other military populations, given that the maximum oxygen consumption has been considered a means to evaluate adaptations to cardiovascular endurance training (3). Characteristics, like age, height, and weight, were included in the data analyzed to better understand this population. Ergospirometry reports served to evaluate oxygen consumption, heart rate, and maximum speed during the test. This data helped to evaluate the population's cardiovascular condition at different levels of training and provided valuable information for training programs.

Peak oxygen consumption is an indicator of an individual's functional capacity, which depends on several factors. Up to 70% depends on genetics, making it the most significant determinant. Other variables, like age, gender, and body mass and composition, can affect up to 50%, and up to 20% can be improved by the degree of training or physical conditioning (2, 3). Expected values for men between 20 and 40 years of age were 35 to 45 ml/kg/min, and, depending on the type of training, the range could be from 40 to 80 ml/kg/min (2). Cardiac output is one of the components of oxygen consumption. It is the product of heart rate and systolic volume, both of which increase with physical activity. The heart rate response depends on age and training; the more training, the more significant the response (4). This was one of the variables measured during the ergospirometry test.

Methodology

This study is a retrospective description of the results of a treadmill ergospirometry test with a progressive and incremental protocol, performed on two different groups during two different periods. The first four participants were measured in December 2016, the second group of five individuals in May 2018. These ergospirometry tests were performed in the laboratory of the Centro de Investigación de la Cultura Física (CICFI, for the term in Spanish) by the staff in the research group at Escuela Militar de Cadetes "General José María Córdova" in the city of Bogotá D.C. and interpreted by the sports physician in the research center. The tests completed fully by the members of the urban anti-terrorist special forces group (AFEAU) were included. One partially completed test from the 2018 group was excluded. The following variables were evaluated in these tests: oxygen consumption and heart rate at the threshold and maximum, and the maximum speed reached in the test. The equipment used was a Metalyzer 3B-R2 ergospirometer and an HP Cosmos treadmill. The Stata 13 statistical program was used to perform a descriptive analysis of the data. The data are shown as medians and interquartile ranges, given the small sample size.

Results

The oxygen consumption of nine members of the urban anti-terrorist task force during 2016 and 2018 was measured by using treadmill ergospirometry. Figure 1 shows the distribution of the number of individuals included.

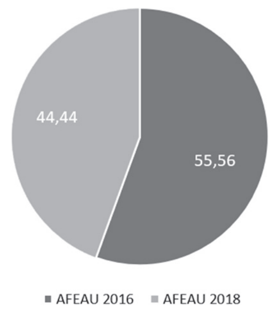

Figure 1. Distribution of the number of persons included in the percentages
Source: Material created by the author.

The median age of the participants was 34 (Interquartile range [IQR]: 31-34), their median height and weight were 1.69 meters (IQR: 1.66-1.72), and 69 kilograms (IQR: 66-72), respectively. Table 1 shows a summary of the basic characteristics of the study population, separated by year (2016 and 2018).

Table 1. Population characteristics

Year	Variable	Median	IQR*	Minimum	Maximum
2016	Height (m)	1.68	1.63 – 1.73	1.6	1.76
	Weight (kg)	67.5	62.0 – 70.5	58	72
	Age (years)	34	31.5 – 36.5	29	39
2018	Height (m)	1.69	1.66 - 1.72	1.65	1.76
	Weight (kg)	69	67.0 - 74.0	61	75
	Age (years)	33	31.0 - 34.0	29	36
Total	Height (m)	1.69	1.66 - 1.72	1.6	1.76
	Weight (kg)	69	66.0 - 72.0	58	75
	Age (years)	34	31.0 - 34.0	29	39

*IQR: Interquartile range. Source: Material created by the author.

The individuals measured in 2018 had a lower median age (Figure 2), but a higher median height (Figure 3) and weight (Figure 4).

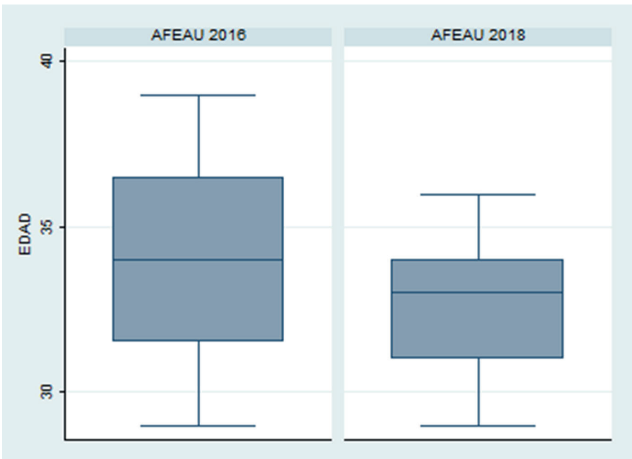

Figure 2. Age distribution (years) according to the year of the study.
Source: Material created by the author.

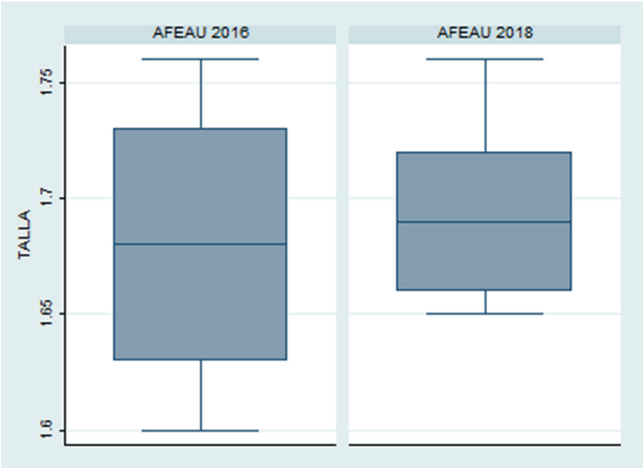

Figure 3. Height distribution (meters) according to the year of the study.
Source: Material created by the author.

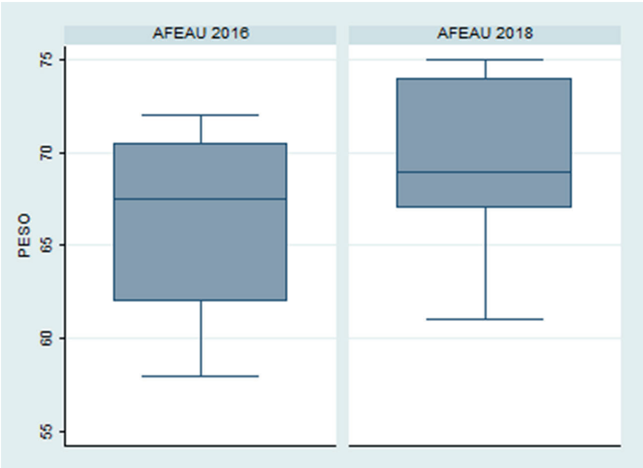

Figure 4. Weight distribution (kilograms) according to the year of the study.
Source: Material created by the author.

Table 2 presents the results of oxygen consumption by ergo-spirometry respiratory condition measurement by clinical characteristics. Note here that the participants' average oxygen consumption at the threshold and maximum was 39 (IQR: 37-45) and 45 (IQR: 43-50) mL/min/kg, respectively. The median heart rate at the threshold was 155 bpm (IQR: 152-158). Meanwhile, the median of the maximum frequency reached 174 bpm (IQR: 166-176). The maximum speed in the test was a median of 18.5 km/hr (IQR: 18.5-20.1).

Table 2. Clinical Characteristics

Year	Variable	Median	IQR	Minimum	Maximum
2016	VO_2 threshold (mL/min/kg)	38	36.5 - 40.5	36	42
	VO_2 Maximum (mL/min/kg)	44.5	43.0 - 48.0	42	51
	CF threshold (Ipm)	158.5	152.0 - 169.0	152	173
	CF Maximum (Ipm)	176.5	166.5 - 179.0	159	179
	Max. speed (km/h)	18.5	18.5 - 19.3	18.5	20.1
2018	VO_2 threshold (mL/min/kg)	45	37.0 - 46.0	36	46
	VO_2 Maximum (mL/min/kg)	48	43.0 - 50.0	41	53
	CF threshold (bpm)	155	152 - 158	152	158
	CF Maximum (bpm)	168	166.0 - 175.0	159	176
	Max. speed (km/h)	20.1	18.5 - 20.1	16,9	20.1
Total	VO_2 threshold (mL/min/kg)	39	37.0 - 45.0	36	46
	VO_2 Maximum (mL/min/kg)	45	43.0 - 50.0	41	53
	CF threshold (bpm)	155	152.0 - 158.0	152	173
	CF Maximum (bpm)	174	166.0 - 176.0	159	179
	Max. speed (km/h)	18.5	18.5 - 20.1	16.9	20.1

*IQR: Interquartile range. Source: Material created by the author

Compared with the 2016 participants, the 2018 group of participants had higher median values of oxygen consumption at the threshold (Figure 5) and maximum (Figure 6).

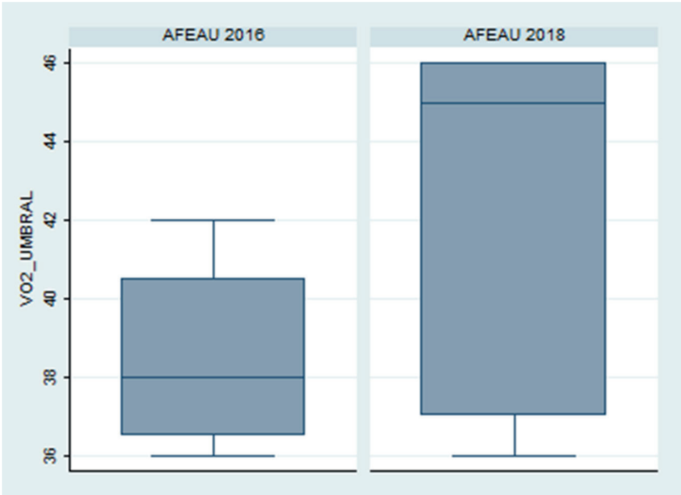

Figure 5. Distribution of threshold oxygen consumption (mL/min/kg) according to the year of the study
Source: Material created by the author

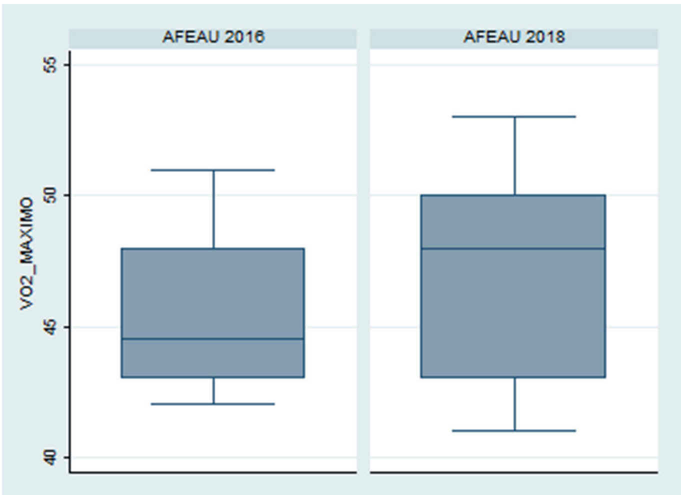

Figure 6. Distribution of maximum oxygen consumption (mL/min/kg) according to the year of the study
Source: material created by the author

Additionally, the group of participants in 2016 obtained higher heart rate median values at the threshold (Figure 7) and maximum (Figure 8).

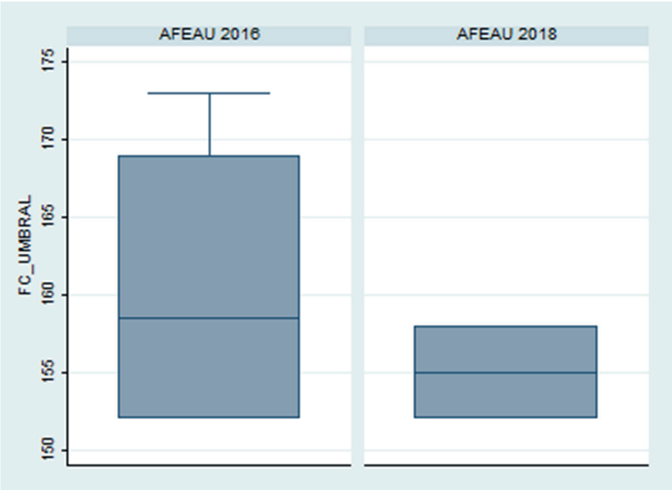

Figure 7. Threshold cardiac frequency (BPM) distribution according to the year of the study
Source: Material created by the author

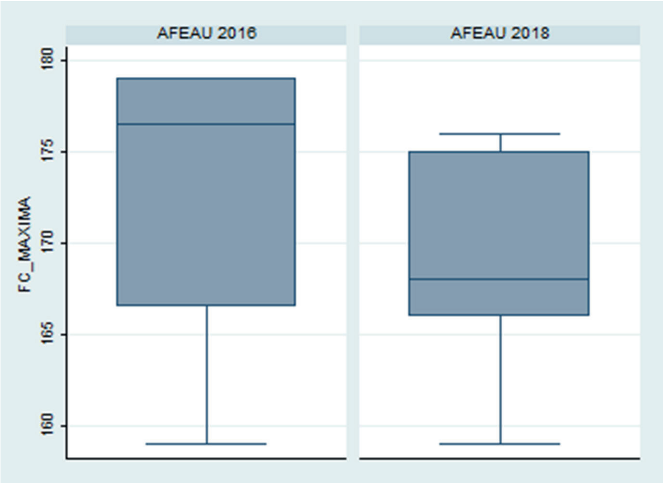

Figure 8. Distribution of the maximum heart rate (MHR) according to the year of the study
Source: Material created by the author

Another parameter evaluated with the data obtained from oxygen consumption and heart rate is the percentage of the maximum values at which the threshold was reached; this information helps in recommending training work to improve cardiovascular endurance.

In this study, the values of percentages of threshold oxygen consumption were all >81%. In the cardiac frequency variable, which is the most widely used to modify training because of its easy monitoring, the percentages of the maximum frequency in which the threshold was achieved were >86%; six of the nine measurements were > 90%.

Discussion

The two groups evaluated shared similar ages, heights, and weights. Their results for maximum oxygen consumption by interquartile ranges were also similar; 43 - 48 mL/kg/min for the AFEAU 2016 group and 43 - 50 mL/kg/min in the AFEAU 2018 group. The values were slightly above the expected ranges (35 - 45 mL/kg/min) for healthy men from 20 to 40 years of age (2). However, differences existed in the medians, 44.5 mL/kg/min for the AFEAU 2016 group and 48 mL/kg/min for the AFEAU 2018, showing improved cardiovascular fitness in the 2018 group. Concerning the oxygen consumption at the threshold, which is the point of metabolic change between stable and unstable (5), a difference was evident in both medians and interquartile ranges. The 2016 AFEUA group had a median of 38 mL/kg/min and IQR of 36.5 - 40.5 mL/kg/min, and the 2018 AFEUA group had a median of 45 mL/kg/min and IQR of 37 - 46 mL/kg/min. This data supports the conclusion that the 2018 group had a superior cardiovascular condition. This quality is of utmost importance, given that this population's effective performance of its tasks involves different skills and capacities at the mental and physical levels. Therefore, it is acknowledged that adequate physical fitness at the cardiovascular level, as well as strength development programs (6, 7 , 8), can help them to fulfill their roles and objectives, challenging their training both in common tasks and in military competitions at international level (7, 8, 9).

The maximum and threshold oxygen consumption data are just one measurement in this population with already implemented specific training. However, without initial measurements prior to this type of training, the evaluation of the impact of the physical preparation received is limited. The results of before-and-after measurements used in a study involving a population performing compulsory military service showed that training could be deficient if resistance is to be improved in military personnel. It found that the VO_2 maximum increased by 5% only in subjects with low initial VO_2 maximum. No change was found in subjects with the median VO_2 maximum, and it tended to decrease in those with a higher initial level (10). Unlike the aforementioned, another study reported significant improvement in VO_2 maximum among 72 recruits when combining eight weeks of basic training with resistance or strength training (11).

Characterization of the military population and their training, as well as the importance of adequate physical condition, have been carried out in different countries, such as Canada, the Netherlands, the United Kingdom, and the United States (7). Therefore, describing the cardiovascular condition by measuring the maximum oxygen consumption through ergo-spirometry of a special population, like the Special Anti-Terrorist Forces Group, AFEAU, contributes to understanding the military population.

In conclusion, the results showed that, overall, the AFEAU has an adequate cardiovascular condition that exceeds the average values of the general population, the 2018 group slightly outperforming the 2016 group. However, the impact of the training they received is unknown because no measurements were taken prior to training. Better information could be obtained if the type and loads of training were also known to compare the results with other parameters, like body composition and oxygen consumption measurements before the start of training and subsequent follow up; this would be of great importance in future characterizations.

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Relationship between Lumbar and Ischiotibial Flexibility in Pentathletes from Escuela Militar de Cadetes "General José María Córdova" in Bogotá D.C., Colombia

6

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Abstract

Flexibility is a critical physical component in sports performance. It must be trained, planned, and quantified to improve the range of motion of joints. Therefore, measuring the posterior muscle chain longitudinally, emphasizing the ischotybial and low lumbar areas, has become common-use in clinical practice. Assessment is conducted by using the sit and reach test, which has become a preferred element for sports-related professionals because of its easy application and high relative intra-examiner reliability (0.89 - 0.99). Given that the posterior chain involves a postural component and the trunk's posterior region, a single test for this chain can produce a false positive, considering that this chain is complemented in the lower limb from the hip joint. On account of the aforementioned, this research sought to examine the relationship among the results of applying the sit and reach, Schober, and passive straight leg raise tests (PSLR) in pentathletes from *Escuela Militar de Cadetes "General José María Córdova"* in Bogotá, Colombia. This descriptive study of association and transectional design set out to determine the relationship among the results of applying these tests at a given time

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in a convenience sampling of seven participants. Based on the sample measured in this study, there is no relationship among the flexibility tests, except for the sit and reach test and left leg flexibility, which have a negative correlation. Thus, characterization of flexibility requires several complementary measures to analyze and justify dysfunctions in the posterior chain.

Keywords: muscle flexibility, sport, range of motion, hamstring muscles

Introduction

Flexibility is a determining physical trait in sports performance. Like strength, power, and endurance, it must be trained in planned and quantified spaces to improve the range of joint movement (1). The literature includes reports on the benefits of flexibility work, including, thermal changes in the connective tissue, pain reduction, and injury prevention. It is even the favored strategy in various sports for activation and returning to calm. However, these benefits are currently being debated. Diverse positions exist concerning the understanding of the concept. Thus, the extrinsic and intrinsic characteristics that influence the joint motion range and the therapeutic strategies used to improve such have become unclear (1, 2).

In everyday life, concepts of flexibility and stretching are used synonymously. It should be clarified that flexibility refers to an individual's characteristic intrinsic factors that involve various intra- and extra-articular components (bones, cartilage, ligaments, muscles, tendons, fascia, and skin). Stretching is a modifiable extrinsic factor commonly involved in warming up and cooling down in sports; it is also involved in injury prevention and improving an athlete's performance (3).

However, stretching should be addressed within the topic of flexibility. Stretching generates acute effects called viscoelastic effects. They are associated with changes in the range of motion and resistance to stretching related to changes in stress relaxation, creep, and tissue hysteresis, as well as neural effects resulting from decreased motor neuron excitability rates. As a magnet effect, they produce relaxation and a decreased ability to produce power during a sporting activity, despite generating a temporary lengthening of the muscle (3, 4).

Considering that muscle injury is cited as the most frequent in sports practice, different positions also exist regarding the benefits of stretching. Epidemiological studies have reported that decreased flexibility is a risk factor for acute muscle injury; therefore, it should be trained as a protective element (5). Some *in vitro* studies have been used to argue the changes in myotendinous viscoelasticity because of excessive temperature increase in the muscle prior to activity, which decreases the muscle's ability to absorb energy and may result in injury. Although the information found differs among authors, it is necessary to specify the modality that corresponds to each response (5).

Based on the previously stated, the literature shows that the most referred variants of stretching are static and dynamic, which report different effects. For example, in static stretching, the movement's eccentric phase is mainly affected by a change in the lengthening-cutting cycle in which the elastic recoil and rigidity of the myotendinous junction are decreased. The latter is necessary for storage of elastic energy. The result obtained, added to the inhibition of the motor neurons by depression of the H-reflex, is the decrease in the stretched muscle's ability to produce power; this also favors the antagonist muscle's imbalance because of reciprocal inhibition (4).

Authors, like Alikhajeh *et al.*, also mention that decreased performance due to passive stretching occurs because said stretching increases compliance of the muscle-tendon unit that reduces its stiffness, reducing the development of strength. Moreover, this response produces neural inhibition and decreased neural impulses to the muscle, ultimately resulting in reduced power production (4).

Other studies have found that static stretching has negative implications in performing activities that require power, such as jumping, where evidence exists of a 4.4% to 7% decrease in height for drop jumping, 4.3% to 4% in squat jumps, and a 9.5% decrease in maximum voluntary contraction force. However, the parameters and techniques used to approach flexibility are unclear. Therefore, its justification remains controversial (6).

In contrast, dynamic stretching before activity produces an increase in the central temperature. The movements involved prepare and stimulate coordination of movement patterns associated with the sports gesture; in turn, the nerve receptors' sensitivity is increased, boosting the nerve impulse's speed, thus, generating faster and more efficient muscle contractions that provide important inputs to adopt simple and complex postures, typical of sports (4). Considering that athletes are exposed to musculoskeletal injuries from the moment they are exposed to sports, this stretching can provide preventive benefits (7).

Because flexibility requires complex coordination between connective tissue structures, understood as a conditional physical quality, it must be stimulated through a planned process with specific objectives. For instance, Ayala *et al.*, reported improved hip range motion after a 12-week program of active stretching three times per week with daily doses of 180 seconds in people with and without hamstring retraction (8). However, to identify flexibility training's true impact through stretching, it is indispensable to use the right measurement tools to ensure corrective therapeutic strategies in professional practice.

Thus, measuring flexibility as a conditional physical quality is fundamental to identify risk factors that influence the sports gesture within the different processes of sports characterization and pre-participation assessments. Accordingly, in clinical practice, the longitudinal measurement of the posterior muscle chain, emphasizing the ischiotibial and lower lumbar area, is often included by using the sit and reach test. This test's easy application and high relative intra-examiner reliability (0.89-0.99) have made it a preferential element for professionals involved in sports (9, 10).

Although the sit and reach test has moderate mean validity to estimate ischiotibial flexibility (rp = 0.46 - 0.67) and low mean to estimate lumbar flexibility (rp = 0.16-0.35) (11), in professional practice, confusion can arise regarding the test's yield of low quantitative results, produced by the involvement of the postural component and stimulation of the trunk's posterior muscular chain. A limitation of this chain can produce a false positive based on the examinees' difficulty in positioning themselves and executing the test, considering that this chain is complemented in the lower limb from the hip joint (12).

An objective and quantitative discrimination of which component of the chain presents the dysfunction will also likely be necessary to more accurately assess such with the least possible bias. This is indispensable for the prescription of stretching to improve flexibility in athletes and the general population. Different tests are reported in the literature that can corroborate the results obtained in the sit and reach test. The Schober test measures mobility in the lumbar spine, for example (13), and the PSLR or the 90:90 test measure ischiotibial elasticity from knee flexion at 90° to full extension (14).

Accordingly, the aim of this research was to estimate the relationship among the results of applying the sit and reach test, the Schober test, and the PSLR tests in pentathletes from *Escuela Militar de Cadetes "General José María Córdova"* (ESMIC) in Bogotá, Colombia.

Methods

This descriptive study of association and transectional design sought to determine the relationship among the results of applying the sit and reach test, the Schober test, and the PSLR tests at a given time in pentathletes from ESMIC in Bogotá, Colombia. The convenience sampling included seven participants. The inclusion criteria were male subjects in the pentathlon selection process at ESMIC, complying with the informed consent provided by the researcher. The exclusion criteria considered all those factors that could bias the tests' results, such as individuals presenting musculoskeletal lesions in the dorsolumbar area and the lower limbs that would make it difficult to adopt the position and perform the tests, and those practicing another sport in parallel to pentathlon.

The Schober test was used to measure the lumbar spine's flexibility according to the protocol established in the literature (13). The PSLR test was used to measure ischiotibial elasticity, following the criteria developed for its correct execution (14). The standard sit and reach test was used to measure the joints at the lumbar and ischiotibial levels, following the necessary considerations and requirements for its correct application described in the literature (8, 11).

The data analysis initially involved processing the descriptive results by using the R program version 3.6.0. The information was placed in tables and the average and standard deviation were calculated for each variable. Pearson's linear correlation coefficient was used for the variables' correlation analysis to statistically identify the degree of relationship between two variables measured at an interval level (15).

The ethical considerations were based on the Colombian Ministry of Health's Resolution No. 008430 of 1993, Article 11, which classifies this study as minimum risk, where routine and common procedures do not involve manipulating the subjects' conduct (16). The ethical principles of the Helsinki Declaration for medical research involving human subjects were also considered (17).

Results

Application of the tests showed that for lumbar flexion, the subjects obtained an average value of 4.14 cm with a standard deviation (SD) of 0.87, indicating that most of the sample was within the normal range, except for one subject who only achieved 2.5 cm of flexion. For lumbar extension, all subjects were below the normal parameters, with an average of 1.21 cm and SD of 0.58.

When measuring ischiotibial elasticity, it was observed that, with the exception of two subjects, the sample showed moderate-to-severe muscular shortening, considering that the literature accepts a knee flexion angle of 20° starting from 90° as a limit value. The average result was similar in the right and left extremities with averages of 33.1° and 33.3°, respectively. However, the SD value provides evidence of result variabilities among the subjects, finding angles of up to 50°.

Finally, the average result of 9.91 cm was found when applying the sit and reach test. This value is below the minimum accepted range. According to the American College of Sports Medicine's classification, all the subjects would require flexibility training. Moreover, one test subject obtained a value of 0 cm during the test, producing an SD of 5.60.

The data correlation analysis was also performed by using Pearson's linear correlation coefficient to measure the degree of relationship between the Schober test and the sit and reach test, and the PSLR test with the sit and reach test.

According to the analysis performed between the variables, the result to determine the degree of association between the Schober and sit and reach tests was very weak. This result allows inferring that no association existed between the lumbar flexion-extension range of motion measured with a tape measure and the lumbar flexion measured in conjunction with the ischiotibial group.

Although the hypothesis tests for the correlations' statistical significance were performed using $t=r\sqrt{n}\text{-}2\ /\sqrt{1}\text{-}r^2$, which was distributed as a Student's t with n-2 degrees of freedom under the non-correlation hypothesis, the correlation between sit and reach and Schober bending, the p value was 0.5552. This result shows that the null hypothesis cannot be rejected and, therefore, there is no statistical association between these two variables.

The same hypothesis test was performed to observe if the correlation between the sit and reach and Schober's tests during the extension measurement was significant, obtaining a p value of 0.9655; this does not allow rejecting the hypothesis of no association.

A significant negative linear association between the PSLR and the sit and reach test relationship analysis was found through hamstring elasticity measurement. This indicates that when the subjects obtain a higher result in the sit and reach test, the PSLR test result will be lower in terms of the degrees of knee flexion.

The same hypothesis test was performed to determine whether the correlation between the sit and reach and PSLR was significant, obtaining a p value of 0.1132. This result does not allow concluding an association between these two measurements. The hypothesis test for the correlation between the sit and reach and the left leg generated a p value of 0.0567, which is significant at 10%. This negative correlation indicates that a lower value should be expected for the left leg elevation variable when the sit and reach results are higher.

Discussion

As previously stated, flexibility is an important conditional physical quality for adequate movement and performance in sports. However, its development requires adequate strategies according to the person or athlete's requirements. Therefore, correct measurement and evaluation are fundamental (1, 9). This research's objective was to estimate the relationship among the results of the sit and reach test, the Schober test, and the passive straight leg raise test in pentathletes from ESMIC in Bogotá, Colombia.

The results obtained during the Schober test showed that the sample of pentathletes has lumbar spine extension movement limitations. These limitations may be associated with shortening of the trunk's posterior muscular chain, which, under normal conditions, maintains correct crown-rump positioning and functioning, following Busquet's three laws of the body: equilibrium, economy, and comfort (12). Furthermore, when considering tensegrity, shortening of this chain can directly affect the muscle chains' functioning in the lower limbs, involving the ischiotibial group that functions as rear support when the rear trunk chain attempts to stabilize the pelvis during the bipedal position (12). Tensegrity explains why one group of muscle chains affects another group of distant chains. The body is a closed chamber with a set of forces seeking balance within the body structure. Tensegrity refers to a self-balancing system composed of a continuous set of information-transmitting cables that resist the force of tension (muscles, tendons, fascia, and ligaments) and are supported by a set of struts or bars (bones) (18).

Although *in vitro* studies have shown continuity between fascia and muscles anatomically located away from each other, there is lack of literature on the *in vivo* behavior of these connections (19). By applying tensegrity on a large scale outside of tissue samples in laboratories, the explanation of tensegrity in practice – shown in recent studies – has provided evidence of great advances in postural alterations affected by structurally distant origins, including alterations in the postural alignments of the lower back due to hamstring injuries, as shown in a study of 34 rugby players compared to a control group (20).

In the present study, the ischiotibial elasticity test showed that the pentathletes present moderate-to-severe shortening, a sign of a mechanical dysfunction associated with the lower limbs' flexing chain, which may trigger forced postural changes to compensate for the antagonistic chain's (extension muscle chain) mechanical disadvantage. Li indicates that stretching the hamstring muscles can affect movement during forward-bending, perceiving the agonist-antagonist relationship supported by tensegrity in the human body chamber (21).

The sit and reach test results corroborate the data obtained in the previous measurements, demonstrating that the sample presents a decrease in overall flexibility at the global lumbar and hamstring levels, given that the participants were unable to perform maximum lumbar flexion with knee extensions. A recent study has demonstrated the direct relationship between lumbar and hamstring function. The study, which involved 30 subjects with clinically diagnosed lumbar pain, showed a significant decrease in the hamstring muscles' length with no alteration to the pelvic tilt, demonstrating compensation within the body chamber by force compensation without significant postural alterations (22). Returning to the concept of tensegrity, it can be argued that the deficit in the sit and reach test results from myofascial dysfunctions that together limit the individuals' adequate selection, execution, and maintenance of complex postures, typical of their sporting gesture. Thus, they are forced to develop compensatory movements at the expense of excess energy consumption to meet the sporting demand and compensate for the stress balance (23).

In summary, it has been shown that flexibility is not only dependent on the musculoskeletal system, it also depends on the surrounding tissues, like fascia, tendons, and ligaments, that form a holistic system affecting posture or movement in the human body (the closed chamber composed of compression and tension forces) (24).

Conclusion

As a conditional physical quality, flexibility is critical for movement and adopting and maintaining complex postures during sports practice. Therefore, it must be measured with quantitative and valid parameters that truly depict a real panorama of the athlete's current condition to propose therapeutic alternatives to obtain and develop standard flexibility parameters.

Based on the sample measured in this study, no relationship exists among the different flexibility tests, except for the sit and reach test and the left leg flexibility, which had a negative correlation. However, considering the human body as a tensegrity system, characterization of its flexibility requires complementary measurements to analyze and justify the dysfunctions that may occur in sports practice.

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Jumping Test Lower Limb Neuromuscular Characterization in First-level Students from Escuela Militar de Cadetes

7

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Abstract

Introduction. As in other military contexts, high incidence of injuries has been observed at *Escuela Militar de Cadetes "General José María Córdova."* Tibial stress has been observed in 4% to 10% of the military population during basic training. Resistance, strength, flexibility, and mobility are among the most important physical traits required for the new cadets' proper military training. Therefore, biomechanical evaluations are essential to monitor the neuromuscular system's maximum mechanical capacities; in this case, the lower limbs. The countermovement jump (CMJ) is among the most commonly used tests to indicate lower extremity muscle strength and anaerobic power. **Objective.** This study employs the countermovement jump test to characterize the lower limbs' neuromuscular component in the military population entering *Escuela Militar de Cadetes*. **Materials and methods.** A cross-sectional study was conducted on 63 first-level students (45 men and 18 women) from the military school in the second semester of 2017. Jump tests were measured by using two uniaxial force platforms (PASCO frequency of acquisition 1,000 Hz). The data was processed using ForceDekcs software. **Results.** Peak landing, concentric force, power, and eccentric deceleration were significantly higher (p value < 0.05) in men than in women. The

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variable with the most significant difference between genders is the jump height, with a 35% difference. Despite these significant differences, asymmetry percentages do not differ between genders. It was found that jump height, peak power, and peak concentric force generate a neuromuscular profile of lower limbs that allows distinguishing between men and women.

Keywords: countermovement jump, neuromuscular characteristics, lower limb

Introduction

The Colombian National Army is made up of military schools to prepare those aspiring to military life, training them to take on each challenge in the best way possible (1). Throughout the military profession, the students are exposed to high physical demands, not only because of their intense military training but also their academic routine, which requires dedication, effort, and many hours of study (2). However, they are not only exposed to physical fatigue. They manage high emotional and psychological loads, generating high energy demands and risk of fatigue.

As in other military contexts, high incidence of injuries has been observed at *Escuela Militar de Cadetes "General José María Córdova,"* (ESMIC), more specifically in the lower limbs. Medial tibial stress, sprains, and fissures stand out among these injuries (Table 1). The most frequent injury associated with the military career is medial tibial stress. It is produced by increased physical activity at different intensities, frequently without specialized guidance, which causes overuse (3). Thacker *et al.*, (4) point out that injuries to the lower extremities associated with military training are between 60% and 80% and are highly related to overuse of the locomotive system. The most concerning is that 4% to 10% of the military population in basic military training (8 to 12 weeks) are diagnosed with medial tibial stress (5, 6). A significant number of new students entering from civilian life show symptoms of medial tibial stress. However, it is unclear whether military training is directly responsible for this type of injury or related to the physical and physiological characteristics with which the students enter their military careers.

Table 1. Injuries ocurring at *Escuela Militar de Cadetes "General José María Córdova"**

	Tibial stress (%)	Fissure (%)	Sprain (%)	Total (%)
Level 3	15	6.1	1.2	22.3
Level 4	6.9	5.4	3.6	15.9
Level 5	12.4	11.2	2.2	25.8
Total	34.3	22.7	7	64

Source: Table taken from (1)*.

A new cadet requires a certain fitness level to meet the physical demands required to begin military training. Among the most important physical traits required are endurance, strength, flexibility, and mobility (7). Military training includes dynamic movements that involve the muscles making eccentric and concentric contractions successively. Therefore, conducting biomechanical evaluations to monitor the maximum mechanical capacities of the neuromuscular system is essential, in this case of the lower limbs, where the most significant number of injuries occur. Among the tests most used as indicators of strength and anaerobic power of the muscles of the lower extremities are various jumping tests (8), using force platforms. The most used in studies are the countermovement jump (CMJ) and the squat jump (SJ) because of their quantitative measurements (9). Some devices use linear velocity transducers to measure muscle power. However, several studies claim that these devices overestimate speed, force, and power (3).

Jumping tests are the most used because jumping is an activity that requires motor coordination between the upper and lower body segments (10). Welsh *et al.*, (11) cite that this activity does not require much skill; it is very safe and reproducible. The CMJ is used more than the SJ to monitor an individual's neuromuscular state (12), given that it is a dynamic movement that involves concentric and eccentric muscular actions. In contrast, the SJ is only a concentric action (13). The CMJ is used because of its ability to identify fatigue, asymmetries, and compensations (14, 15) and because it is positioned as one of the most straightforward, effective, and popular tests (11, 12). Moreover, this test does not generate any fatigue, which can happen in other tests, affecting the subjects' performance and altering the results (11).

Beyond the CMJ test's practicality, Markov *et al.*, (10) state that it facilitates studying the jump's biomechanical characteristics, allowing analysis of the lower limbs' contractile characteristics. Furthermore, it permits evaluating the effectiveness of the stretch-shortening cycle from the height reached in the jump (10,15). However, the most interesting thing to analyze in the CMJ is how the jump is related to the lower limbs' neuromuscular abilities. This is seen in two very simple ways. On the one hand, as mentioned by Jiménez (15), the jump's height is proportional to the take-off speed, which, in turn, is proportional to the speed of muscle shortening. On the other, if there is muscle-tendon stiffness or fatigue, less force will be generated, which is related to loss of speed and height when executing the jump (16).

Therefore, this work's objective was to carry out a neuromuscular characterization of the lower limbs in a first-level military population to determine the students' performance upon entering the military school. It establishes the lower limb neuromuscular differences between men and women and their asymmetries based on a jumping test. This study will determine whether the basal characteristics trigger the student's injuries or whether they are due to the initiation of their military careers, considering that during training they are exposed to different loads.

Methods

This research was based on quantitative results. The research design is cross-sectional, and the scope is descriptive.

Study design

Participants

The participants were cadets entering the first-level in all of the ESMIC faculties during the first semester of 2017, present at the time of the test data collection. All the participants were previously invited to enter the study voluntarily. The study's objectives, methodology, and details were explained to the participants in a meeting before the protocol's start, and confidentiality of the data was assured. This study's exclusion criteria were subjects who had not signed the informed consent, had neuropathies in the lower limb, hip dysplasia, or any pathology affecting the cadets' physical performance during military training and the CMJ measurements. Thus, 63 healthy cadets (45 men and 18 women) were part of the study.

Procedure

The study was conducted at the ESMIC's Center for Physical Culture (CICFI in Spanish). Each session was about 15 minutes long. Before performing the proposed tests, the cadets performed a warm-up consisting of jogging and lower limb activation, as well as some practice counter jumps (CMJ) before performing the test.

At the beginning of the study, the participants' age, gender, and background were recorded. They were also asked about their physical activity habits. A questionnaire (not validated) was created containing various questions from the Global Physical Activity Questionnaire (GPAQ) to know about their history of orthopedic material use and lower limb injuries. The basic anthropometric measurements (height, weight, and BMI) were taken using pre-calibrated instruments (an mBCA 515/514 SECA height meter and a BC-1500 ANT+Wireless TANITA scale). Jump height (cm), eccentric deceleration (ED [N/s* kg]), the average eccentric force (EF [N/kg]), peak concentric force (PCF [N/kg]), peak landing force (PLF [N/kg]), power surge (PS [W/kg]), and PLF (%), ED (%), and PCF (%) asymmetries were evaluated through the bilateral CMJ at the baseline. The neuromuscular function of the lower extremities in the different phases of the CMJ was evaluated by using these variables.

Before its execution, the jump technique was explained and the cadets had the opportunity to practice. The subject is in a bipedal position to perform the CMJ, hands placed on the waist, and the jump is performed.

The descent phase is completed at the subject's comfort. The descent and ascent movement should be done as fast and powerfully as possible. Finally, when falling from the jump, the subject regains the position and remains in a bipedal position. Each participant made three valid attempts, and the average was taken for each of the variables. The results were then matched according to the subjects' body weight (N/s or N divided by the weight in kg).

Instruments

Jump ability tests were measured by using two PASCO uniaxial platforms (one for each leg), as shown in Figure 1. The data obtained were processed by using ForceDekcs software.

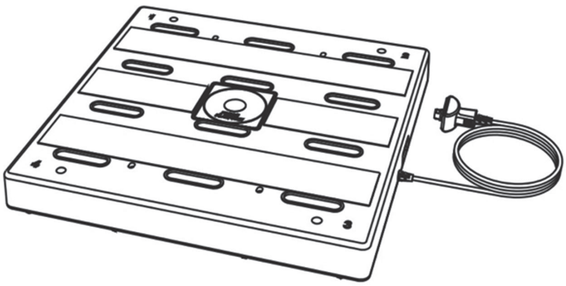

Figure 1. PASCO uniaxial platform.
Source: Taken from PASCO CI-6461 Force Platform - Manual

Data analysis

The CMJ's phases are defined in Figure 2, including the flight phase and landing phase. The variables used in the study, which allow analysis of the jump's complete movement, are summarized in Table 2.

Statistical analysis

The analysis was carried out by using SPSS Statistics version 25 (IBM). First, descriptive statistics were used to verify that the dependent variables met the normal distribution assumption. The normality test showed that the variables met a normal distribution. Then, a one-factor ANOVA was performed to evaluate the differences between genders.

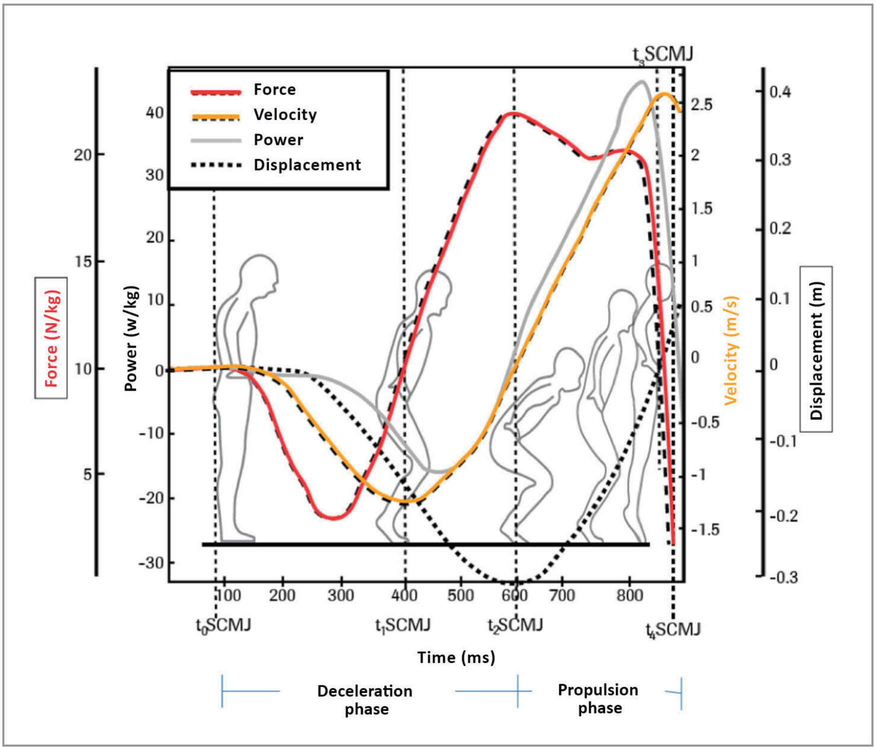

Figure 2. Countermovement vertical jump, illustrating two of its phases.
Source: Taken from (18).

A principal component analysis (PCA) was performed on the data obtained from the 63 subjects. Important information was extracted from the database and expressed in a new set of variables called Principal Components. This technique was used to reduce the database's dimensionality while maintaining as much variance as possible and finding correlations in a multivariate database. The variables used for this analysis, covering all the jump's phases, were selected to find correlations between them. The variables are described in Table 2.

Table 2. Variables used with their respective measurement units and phase in which the variable was measured

Variables	Units	Description	Jump phases
Eccentric deceleration	Newton/ Seconds (N/s)	Force of the eccentric period generated during the antagonistic muscle elongation within the jump performed.	Deceleration phase
Peak power	Watts (W)	Maximum force generation by speed during the jump.	Propulsion phase
Concentric peak force	Newton (N)	Force that allows to surpass the force of gravity and this related to the muscular activity (Maximum force).	Propulsion phase
Jump height	Centimeter (cm)	Jump length measurement.	Flight phase
Peak landing	Newton (N)	Force of action of the ground where the force generated at the moment of the fall is divided by the weight of the subject.	Landing phase

* Source: Material created by the authors to explain Figure 2. The descriptions of the variables were taken from (17).

Results

The sample consisted of 63 healthy cadets (45 men and 18 women); none had any injury or discomfort in their lower limbs. Table 3 summarizes the study group's main physical characteristics.

Table 3. Study group's general anthropometric and statistical data. Mean and (standard deviation).

	Age (years)	Height (m)	Weight (Kg)
Women	18.3 (1.5)	1.62 (0.06)	54.50 (6.54)
Men	18.9 (1.1)	1.73 (0.07)	65.18 (8.26)

Source: Material created by the authors.

Table 3 shows the distribution of the selected variables evaluated through the CMJ for men and women entering the military school in the first semester of 2017. They all show a normal distribution (Kolmogorov-Smirnov; p value > 0.05). The frequency values are higher for men because this population was larger than the female population. However, these graphs' relevance is that the distributions of the variables for both genders are homogeneous. Moreover, the distribution among men has higher values, which always generates a higher mean and median in all the variables in this population. It should be noted that more atypical values are seen in women because the number of the population is lower than that of the male population.

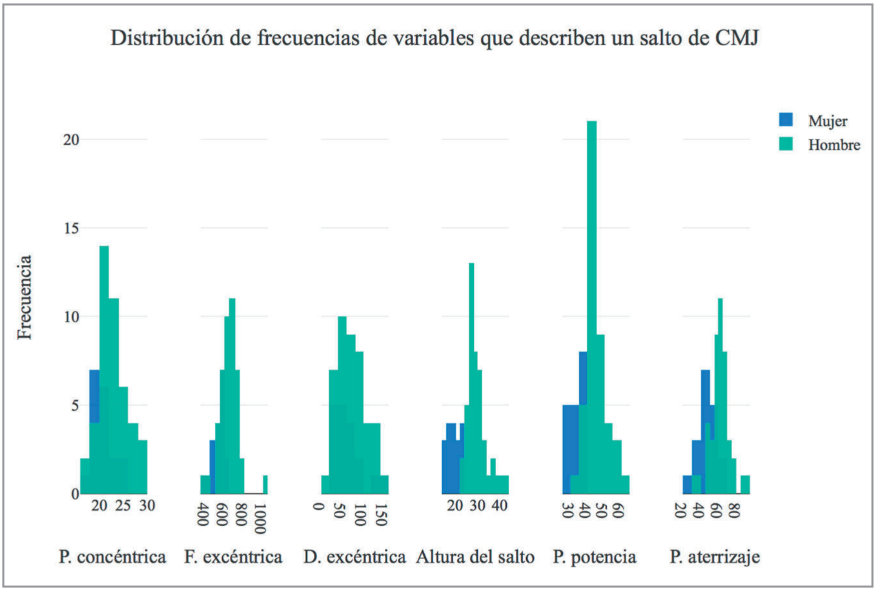

Figure 3. Frequency distribution of study variables, a comparison between men and women. Order of histograms from left to right: Peak concentric force (P. concentric), mean eccentric force (F. eccentric), eccentric deceleration (D. eccentric), jump height, peak power (P. power), and peak landing (P. landing).
Source: Material created by authors.

Table 4 shows more detailed values from the study. Male participants jumped 35% higher than the females (29.68 ± 4.45 cm vs. 19.08 ± 2.64 cm). The peak landing, peak concentric force, and mean eccentric force values were also significantly higher (p value < 0.01) in men than in women. Furthermore, the percentages of asymmetry in eccentric deceleration, concentric force, and peak landing were calculated to explain the asymmetries in three phases of the jump: the deceleration phase, propulsion phase, and landing phase. Although these values do not differ between genders (Table 5), it is evident that the highest values of asymmetries for both genders occurred in the deceleration phase, followed by the landing phase.

Table 4. Values of the variables studied (mean and standard deviation) in men and women

	Women	Men	Difference	Minimum	Maximum
Peak power (W/Kg)	32.88 (4.56)	45.14 (5.99)	27,16%	25.5	62.4
Jump height (cm)	19.08 (2.64)	29.68 (4.45)	35,71%	14.9	43.5
Peak landing (N/Kg)	48.22 (10.32)	61.04 (11.16)	21,00%	28	93
Peak concentric force (N/Kg)	20.61 (2.28)	22.76 (2.86)	9,45%	17.6	28.9
Eccentric deceleration-RFD (N/s*Kg)	64.77 (30.33)	73.19 (32.75)	11,50%	23	154
Median eccentric force (N/Kg)	525.72 (65.42)	640.27 (97.78)	17,89%	376	1000

Source: Material created by the authors. Decimals should be expressed with periods

A principal component analysis was then used to reduce the data's dimensionality, find variable correlations and patterns to differentiate between genders. Because PCA is a transformation of the original coordinate system into a new coordinate system (PCs), the coefficients represent vectors that allow visualizing relationships between the original variables with the new coordinate system. At the same time, to estimate how much each variable contributes to the formation of the principal components (PCs) and how strong the correlations between the different variables and the components are, in this study, peak power, jump height, peak landing, peak concentric force, and eccentric deceleration were included in the PCA.

Table 5. Asymmetry percentages for men and women calculated for three variables

	% Assymetry	
	Men	Women
Peak landing	12.17	7.47
Peak concentric force	7.3	6.13
Eccentric deceleration	14.53	17.65

Source: Material created by the authors.

Three of the five components were selected from this new system of coordinates because they explain 95.7% of the data's variance. Figure 4 shows that the coefficients of the first principal component for peak power, jump altitude, and peak concentric force is greater than or close to 0.5. This PC represents how the propulsive force (P. concentric), which explains the muscular force, is correlated with the efficiency of the jump obtained by the height and power. It also explains equation 1, mentioned by Prada (19), where the muscular power of the lower limbs is directly proportional to the height (h) reached in the jump. The first PC explains the CMJ's propulsion and flight phases, explaining 60.09% of the data variance. The second component defines 23% of the data variability and the third PC, 12%. The second component illustrates the jump's descent/ascent, resulting in a strong correlation between concentric force and eccentric deceleration. Finally, the third component is defined by the jump's landing phase.

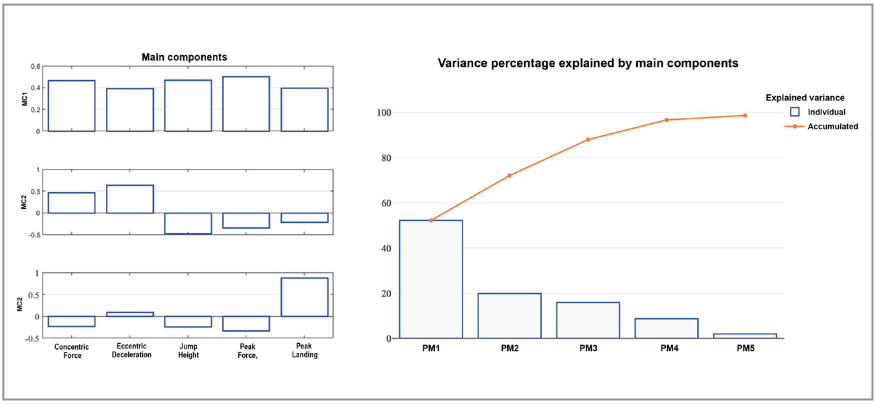

Figure 4. Results of the data principal component analysis using concentric peak force, eccentric deceleration, jump height, peak power, and peak landing. Left: Coefficients of the first three principal components for the five variables. Right: Percentage of variation explained by the principal components.

Source: Material created by authors.

$$Power = \sqrt{\left(\frac{g}{2}\right)} * m * \sqrt{h} \ (1)$$

Finally, all the tests or observations were passed to this new system of coordinates. The data was grouped according to gender. This new system of coordinates reveals the differences between genders mainly provided by the first PM. In other words, the jump's power, height, and concentric force are the main characteristics that allow the lower limb neuromuscular differentiation between genders (Figure 5).

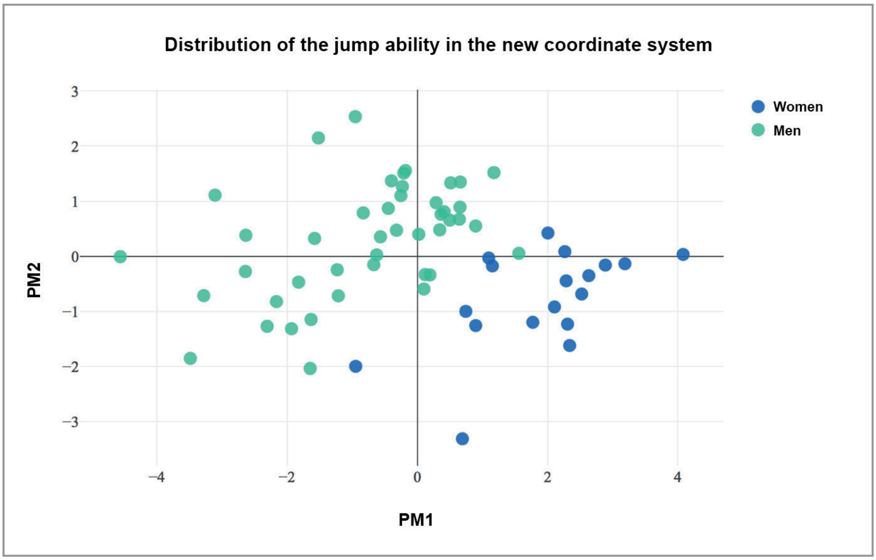

Figure 5. Distribution of the jump ability in the new coordinate system: men and women. Each subject is a point in the new coordinate space, which is determined by the principal component 1 (PM1) and the principal component 2 (PM2).
Source: Material created by the authors.

Discussion

The countermove jump is one of the tests most commonly used for neuromuscular analysis (10, 12, 15, 20). This project's objective was to carry out a lower limb characterization in first-level students of the Colombian Military School using CMJ tests. The concept of neuromuscular characterization using CMJ has been mentioned in other research, especially to evaluate athletes' performance (15, 17, 20, 21). However, some studies have also used the CMJ test in the military field (7, 11, 22). Most of these studies have focused on comparing how strength, speed, and power vary when performing a countermovement jump after specific training. In other words, the CMJ is used to evaluate the effectiveness and incidence of training. These studies have been based on two main variables: peak power and jump height.

The present study's innovation is the characterization of muscle by using not only the variables of peak power and jump height but also eccentric deceleration, peak concentric force, and peak landing. The aim was to cover all the phases of the jump to conduct a comprehensive analysis and find reference values to describe the muscular condition of the lower limbs of military school first-level students in Colombia.

Gender differences

Figure 3 and Table 4 indicate that the differences in lower limb strength and power between men and women are significant, with differences of no less than 10%. The most evident difference is in the jump height. This 35% difference is produced by the greater concentric force, which explains the propulsion force and, in turn, is highly correlated with a greater eccentric deceleration. These results are similar to those found by Lafaye *et al.*, (20). They stated that a greater concentric force, accompanied by a greater eccentric force, provides a greater capacity to accelerate the body when performing a countermove jump.

In jump 2, the force that defines each phase (eccentric deceleration, peak concentric force, and peak landing) is lower in women than in men. Some studies suggest that a low rate of force development in women is due not only to differences in the muscles' elastic properties (23) but also body dimensions and muscle architecture, which modify how force is produced (20).

Articles studying military populations and using jump ability tests have focused on determining how a CMJ or SJ is relevant to measuring a military person's physical performance after short (8 - 21 days) military training (7, 11, 22). These studies do not differentiate between genders and only use peak power and jump height as comparison variables. It is worth noting that, even if the subjects are exposed to the same training with the same duration, not distinguishing between genders could bias the results. Table 4 shows that the differences during the execution of a CMJ jump are significant.

Evaluation of asymmetries

In a vertical jump, both limbs are expected to contribute the same in strength and power; otherwise, performance decreases, and the probability of injury increases (24). However, this is not true. Most of the time, asymmetries occur according to the dominant limb. It is important to be aware of asymmetries greater than 10% in subjects who, although having a high level of physical activity, are not adequately trained (25). Thus, it can be said that the military school's first-level students of 2017 have very high percentages of asymmetry in the deceleration and landing phases. Most likely, these subjects have always been physically active but have never developed training that allows them to compensate for these asymmetries. A high probability of injury may occur if adequate supervised training is not carried out in this population. In this case, this population's injury rate is unknown and may not have been high. However, it could be due to compensatory mechanisms, including alteration of movement technique or posture modification (26) that can cause long-term injuries.

Although the differences by gender in the jump phases are evident, it is important to highlight that the differences in the asymmetries were not significant in the incoming population. However, it would be interesting to see how these asymmetries vary throughout the military training.

Neuromuscular profile

The final report of a CMJ jump is associated with kinetic and kinematic variables, including jump height, power, force, speed, eccentric force, and concentric force. At the same time, some variables are more sensitive than others when it comes to determining an athlete's neuromuscular profile (12). To date, there is not much literature where models using the variables of a CMJ report to differentiate between interest groups, even less focused on distinguishing the neuromuscular profiles of the lower limbs between men and women. The studies that propose models from reports derived from a CMJ test have focused on creating profiles that allow for differentiation between athletes according to their discipline (20) or propose simpler models that describe the force/speed and power/speed relationships of a jump (27).

One of this study's objectives was to find correlations to define a neuromuscular profile differentiated between first-level military school students' genders. A high correlation was found among jump height, peak power, and peak concentric force in this study, as many authors have reported (11, 15, 17, 20, 21, 22). The innovation here is how these three variables generate a profile that is the main way to differentiate between men and women in a countermove jump (Figure 5). This study highlights that a subject's muscular activity is correlated with the maximum generation of force by speed during the jump; in turn, these neuromuscular characteristics alter the height of a jump.

Conclusion

Many first-level students enter *Escuela Militar de Cadetes* each year, where they are exposed to demanding military routines that can lead to injuries. Most injuries occur in the lower extremities; however, the exact causes are not known.

This study used a countermovement jump test to produce a lower limb neuromuscular profile for students entering the military school. This was done to determine the students' main lower limb characteristics and possible injury causes during military training. The lower limbs' neuromuscular behavior was established by gender, and some parameters of comparison were established.

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Risk Factors for Medial Tibial Stress Syndrome Associated with the Kinetics of the Countermovement Jump in Cadets Undergoing Training

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Abstract

Medial Tibial Stress Syndrome (MTSS) is one of the most-often reported and incapacitating pathologies in military personnel. Given that the muscles of the lower limb conduct an important task in attenuating impact forces when running and landing, deficiency and asymmetries in the neuromuscular function are associated with greater risk of having musculoskeletal injuries (MSI). **Objective:** the work sought to determine the risk factors for MTSS associated with the kinetics of the *countermovement jump* (CMJ) in cadets undergoing training. **Methodology:** a cohort of 164 cadets was monitored prospectively during 24 weeks. Upon starting the research, the study recorded the anthropometric and demographic data of the participants and inquired on some of their life habits and antecedents in using orthopedic material, injuries in lower limbs, and MTSS. Jump height (cm), eccentric deceleration of rate force development (EDRFD

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[N/s*kg]), EDRFD asymmetry (% and %/NV), concentric mean force (CMF [N*kg]), CMF asymmetry (% and %/NV), peak landing force (PLF [N*kg]), and PLF asymmetry (% and %/NV) were assessed through the Bilateral CMJ with a pair of uniaxial force platforms. Upon ending the follow up, it was possible to identify cadets who had MTSS through the clinical history. **Results:** at the end of the study, 91 men and 32 women (n = 123) remained. The MTSS incidence was at 13% (n = 16). Female sex (RR = 2.84; 95% CI = 1.16-6.94), rural origin (RR = 2.65; 95% CI = 1.04-6.72), and MTSS antecedent (RR = 5.71; 95% CI = 2.23-14.62) were associated significantly with MTSS (p ≤0.05). For the EDRFD asymmetry (%/NV), significant differences were found among cadets with and without MTSS (9.4% vs. -3.4%; p = 0.016). In the binary logistic regression, female sex (OR = 4.91; 95% CI = 1.38-13.37), rural origin (OR = 4.82; 95% CI = 1.04-6.72), and EDRFD asymmetry (OR = 1.03; 95% CI = 1.00-1.07) were associated significantly with MTSS (p ≤0.05). The MTSS antecedent was significant in p ≤0.1 (OR = 8.95; 95% CI = 0.68-118.73). The prediction model was significant for MTSS (p ≤0.01), with sensitivity of 31.3% and specificity of 99.1% (global prognosis at 90.2%). **Conclusions:** female sex, rural origin, MTSS antecedent, and large asymmetry in the EDRFD are important risk factors for the development of MTSS. These findings will permit better predicting MTSS in military personnel, being especially useful to classify the risk and implement a primary prevention program aimed at cadets who begin their military training upon entering the ESMIC.

Key words: risk factors, military personnel, medial tibial stress syndrome, biomechanical phenomena, kinetics, countermovement jump

Introduction

Medial Tibial Stress Syndrome (MTSS) is one of the most-often reported and incapacitating pathologies in military personnel (1-5), being the principal cause of pain in the lower part of the leg related with physical exercise (3). Although not of serious nature, if not treated adequately, it can cause injuries, like tibial stress fracture (6). The incidence reported in military personnel for this pathology ranges between 7.2% and 35% (3, 4).

The MTSS is characterized by diffuse pain in the middle third of the posteromedial border of the tibia (1-3, 5, 7), which increases when engaging in physical exercise (7). Although the symptoms are perceived at subcutaneous level between the crural fascia and bone, MTSS is associated with specific bone changes (1). In most cases, this pathology involves cortical bone microfractures (5). The most sensitive way for the clinical diagnosis of MTSS is palpation (2, 7).

During physical exercise, the mechanical stress endured by the tibia provokes microtrauma necessary to construct, strengthen, and adapt the bone; in fact, the tension produced by the muscle during muscle contraction stimulates osteogenesis (3, 4, 6). Nevertheless, exceeding the microtrauma threshold (due to excessive workloads), can lead to injury, like MTSS (3, 4, 6). Bone stress generates overload in bone remodeling (imbalance between bone matrix resorption and synthesis) that results in osteopenia (6, 8). It has been observed that subjects with MTSS have lower bone mineral density (23% ± 8% less) compared with healthy athletes in the zone where the pain is located (9).

The average duration of the rehabilitation treatment for MTSS is three months, even reaching from 4-5 months (10). According to data reported by the *Australian Defense Force Academy*, the time of disability for this pathology is of 57.5 days on average per individual, which translates into costs for the state of AUD $6,410 per case (11). In summary, MTSS – like the rest of musculoskeletal injuries (MSI) – results in a high number of medical encounters (12-16), high costs in medical care and rehabilitation (12, 14, 17, 18), a high loss of work days (14, 16, 19-23), limitation in the physical and operational/tactical preparation (18, 19, 24, 25), diminished military personnel deployed and operational performance during combat situations (13, 25, 26), functional impairment and physical disability (20, 27-29), and a high percentage of premature desertion (30, 31).

According with the most recent systematic reviews with meta-analysis, only 10 risk factors evidenced a significant association with MTSS development: female sex (odds ratio [OR] = 2.35; 95% confidence interval [CI] = 1.58-3.50; $p < 0.05$) (1), increased body mass index (BMI/weighted mean difference [WMD] = 0.79; 95% CI = 0.38-1.20; $p < 0.001$) (4), greater range of motion in the hip external rotation (standardized mean difference [SMD] = 0.44; 95% CI = 0.23-0.65; $p < 0.05$) (1), greater navicular drop

(SMD = 0.44; 95% CI = 0.21-0.67; $p < 0.05$) (1), greater range of motion in the plantar flexion of the ankle (WMD = 5.94°; 95% CI = 3.65-8.24, $p < 0.001$) (4), MSI antecedents (OR = 2.18; 95% CI = 1.00-4.72; $p < 0.05$) and MTSS (relative risk [RR] = 3.74; 95% CI = 1.17-11.91; $p = 0.03$) (1, 8), increased weight (SMD = 0.24; 95% CI = 0.03-0.45; $p < 0.05$) (1), lower experience in athletic practice (SMD = 0.74; 95% CI = 1.26-0.23; $p = 0.005$) (8), and prior use of orthopedic material (RR = 2.31; 95% CI = 1.56-3.43; $p < 0.001$) (8).

Although some kinematic biomechanical variables have been associated with the MTSS, evidence is limited with respect to kinetic variables. Particularly, the association has not been examined between the kinetic variables implicit in jumping and the MTSS (in athletes, civilian or military population), although some of these have been associated with diverse MSI (32-44).

Jumping is a functional movement (given that it resembles different sports gestures) (45) and permits evaluating easily and cost effectively the neuromuscular function in comparison with other methods (like isokinetic strength tests) (46). Specifically, the *countermovement jump* (CMJ) is a widely used tool to monitor neuromuscular status in military personnel (47). Because the muscles of the lower limb perform an important task in attenuating impact forces when running and landing (48), deficiency and asymmetries in the neuromuscular function are associated with higher risk of having MSI (32, 45, 49-51).

The principal objective of this study was to determine the risk factors for MTSS associated with the CMJ kinetics in cadets undergoing training. The secondary objective sought to establish the actual MTSS incidence in a sample of cadets from the Colombian military population, on which nothing has been reported to date.

Materials and methods

In this observational study (descriptive with analytic component), a cohort of 164 first-semester cadets belonging to Escuela Militar General

José María Córdova (ESMIC-Bogotá, Colombia) was followed up prospectively during 24 weeks. This cohort included subjects from both sexes and from all regions of the country. Although a convenience sample was taken, it included the entire target population at the beginning of the research. All the participants were previously invited to participate voluntarily. During a prior meeting at the start of the protocol, they were explained the objectives, methodology, and all the details of the study, as well as assuring them of the confidentiality of the data.

The exclusion criteria proposed *a priori* for this study were subjects who had not signed the informed consent, had MSI or lower-limb neuropathies, hip dysplasia, or any pathology affecting the physical performance of the cadets during the military training and the CMJ measurements. All the subjects were subjected to a medical revision and to the pertinent clinical tests, according to the criteria of the health professional in charge, to confirm said assumptions. Lastly, the research excluded those with incomplete data (*a posteriori*).

Voluntary withdrawal from the study had no repercussions on the cadets' military career, or on the timely management of the MTSS when it was diagnosed. This research was approved by the Ethics Committee in Social and Exact Sciences (CECSE, for the term in Spanish) at ESMIC, according to act # 4363 REG-AL-FOL-71/02-2018.

Measurements

At the start of the research, age, sex, and origin of the participants was recorded, and they were asked about their physical activity habits, smoking habits, and alcohol consumption habits. This was carried out through the Global Physical Activity Questionnaire (GPAQ) and the Global Adult Tobacco Survey (GATS). Likewise, they were asked about their antecedents in using orthopedic material, lower-limb injuries, and MTSS. Basic anthropometric measurements (height, weight, and BMI) were taken by using calibrated instruments (SECA mBCA 515/514 height rod and Tanita BC-1500 ANT + wireless scale).

The jump height (cm), eccentric deceleration of rate force development (EDRFD [N/s*kg]), EDRFD asymmetry (%), concentric mean force (CMF [N*kg]), CMF asymmetry (%), peak landing force (PLF [N*kg]), and PLF asymmetry (%) were evaluated through the Bilateral CMJ at the base line. Through these variables, the study assessed the neuromuscular function of the lower limb during the different CMJ phases: impulse (EDRFD), rise/take off (CMF) and landing (PLF). Before its execution, the jump technique was explained and the cadets had the opportunity to rehearse it.

During the CMJ, the hands are placed on the waist, a 90° squat is performed and without pausing during the impulse, carry out the rise/take off (vertical jump). Each participant conducted three valid attempts and the average was taken for each of the variables. Thereafter, these were adjusted according to the subject's body weight (N/s or N divided between weight in kg). In case of asymmetries, the absolute value (N/s or N) was taken of the lower limbs separately and the relative difference (percentage) was determined between these (% asymmetry= [right absolute value-left absolute value /highest absolute value]*100).

A pair of uniaxial force platforms (PASCO®) was used, with capacity to measure force vectors > 4,400 N or 1000 Lb. The data obtained were processed through the ForceDekcs® software. It should be highlighted that, for asymmetries, normalized data were obtained (disregarding the dominance of the asymmetry) and negative values (NV), as were designated the values that considered the dominance of the asymmetry (left dominance = negative [-]), with this variable being analyzed in different ways (% and %/NV, respectively).

At the end of the follow up, the study identified cadets with MTSS through the electronic clinical history based on the health information system of the Colombian military forces. The dispensary doctors were in charge of making the clinical diagnosis of the pathology and including such in the Salud.SIS® software.

At the onset of the research, the health professionals were trained to standardize the protocol for the clinical diagnosis of the MTSS. Based on an exploration procedure proposed by Yates et al., the study included the history of the pain (that the pain was induced by engaging in physical exercise and remained for some hours or even days), location of pain (diffuse pain along the posteromedial border of the tibia), performing the palpation test (manifestation of discomfort and pain in the zone mentioned when proceeding with the palpation), and identification of symptoms associated with other MSI (52), like cramps, paresthesia, focal pain, immediate cessation of pain upon ending the practice of physical exercise, among others (common in the tibial stress fracture and the compartment syndrome) (2, 5).

Statistical analysis

The study determined measurements of absolute and relative frequency (categorical variables) and measurements of central tendency and dispersion (continuous variables). For the categorical variables, independence (with respect to the presence of the MTSS) was evaluated through the Chi-squared test and the relative risk (RR). In the case of continuous variables, the difference of means/medians among the groups (with and without MTSS) was determined, which called for the evaluation of the data distribution and the variance homogeneity. Data normality was established with the Kolmogorov-Smirnov test (>50 subjects) and the variance homogeneity with the Levene test. For variables with $p \leq 0.05$ in any of these two assumptions, nonparametric statistics (Mann-Whitney U/difference of medians) was used; on the contrary, parametric statistics (Student's t test for independent samples/difference of means) was used.

The significant variables in the bivariate analysis were used to create a prediction model. This was carried out through a binary logistic regression (multivariate analysis), which determined the significant variables for the MTSS based on $p \leq 0.05$, with their respective OR (exp[B]). The study determined the model's goodness of fit by Hosmer and Lemeshow, Nagelkerke's R squared, sensitivity and specificity, and significance (Omnibus test).

The data were organized in Excel (Microsoft Office 2016) and exported to the *Statistical Package for Social Science* (SPSS version 25.0) software for their statistical analysis.

Results

Of the 164 cadets comprising the initial sample, at the end of the follow up, 91 men and 32 women (n = 123) remained. The MTSS incidence was 13% (n = 16), specifically for the men it was 8.8% (n= 8) and for the women it was 25% (n = 8). The mean age was 18.15 ± 1.17 years. In turn, average weight, height and BMI was 61.8 ± 9.9 kg, 1.71 ± 0.08 m and 21.1 ± 2.9 kg/m^2, respectively. No significant differences were noted for BMI between the groups with and without MTSS (21.3 ± 2.7 vs. 21.1 ± 2.9; p = 0.636).

It was found that sex, origin and MTSS antecedent were associated significantly with the MTSS (Table 1). Women were at greater risk than men of suffering this pathology (RR = 2.84), as well as cadets from rural zones (immediately prior to entering the military training) and who had suffered MTSS in the past in comparison with their counterparts (RR = 2.65 and 5.71, respectively) (Table 1).

Table 1. Relative risk for the MTSS according to demographic and lifestyle variables

	n	MTSS incidence (%)	RR	95% CI	p-value†
Sex					0.019**
Male	91	8.8	REF	-	
Female	32	25.0	2.84	1.16-6.94	
Origin					0.044**
Urban	105	10.5	REF	-	
Rural	18	27.8	2.65	1.04-6.72	
Current cigarette consumption					0.698
No	122	13.1	-	-	
Yes	1	0.0	-	-	
Prior cigarette consumption					0.768
No	113	13.3	1.32	0.19-9.03	
Yes	10	10.0	REF	-	

	n	MTSS incidence (%)	RR	95% CI	p-value†
Prior alcohol consumption					0.861
No	9	11.1	REF	-	
Yes	114	13.2	1.18	0.17-7.97	
Alcohol consumption in the last three months					0.77
Never	47	12.8	1.03	0.37-2.88	
1 or 2 times	57	12.3	REF	-	
Monthly	16	12.5	1.01	0.23-4.42	
Weekly	3	33.3	2.71	0.47-15.53	
Current practice of physical exercise or sports					0.593
No	11	18.2	1.45	0.37-5.58	
Yes	112	12.5	REF	-	
Weekly frequency of physical exercise or sports					0.122
≤ 2 days	26	7.7	1.3	0.19-8.67	
3-5 days	63	19.0	3.23	0.76-13.63	
≥6 days	34	5.9	REF	-	
Daily time of physical exercise or sports					0.413
< 1 h	34	14.7	2.35	0.49-11.27	
1-2 h	57	15.8	2.52	0.58-10.98	
> 2 h	32	6.3	REF	-	
Prior use of orthopedic material					0.918
No	116	12.9	REF	-	
Yes	7	14.3	1.1	0.16-7.20	
MTSS antecedent					0.005***
No	120	11.7	REF	-	
Yes	3	66.7	5.71	2.23-14.62	
MSI antecedent in the lower limb					0.593
No	112	12.5	REF	-	
Yes	11	18.2	1.45	0.37-5.58	

** Significance of p ≤0.05; *** Significance of p ≤0.01; † Chi-squared test. Material created by the authors.

Based on the kinetic variables evaluated, only the EDRFD asymmetry (%/NV) was significant when comparing cadets with and without MTSS (Table 2). In individuals with said pathology, right dominance (positive) prevailed for the EDRFD asymmetry unlike healthy subjects (left dominance [negative]) (Table 2). Upon evaluating the risk of having MTSS based on the dominant lower limb, it was found that cadets with right asymmetry for the EDRFD had 2.06 (95% CI = 0.79-5.31; p = 0.125) times greater risk of suffering MTSS than those with left asymmetry.

Table 2. Difference of the groups with and without MTSS for the CMJ kinetic variables

	MTSS (n = 16)		No MTSS (n = 107)		p-value†
	$\bar{x}$ (SD)	95% CI	$\bar{x}$ (SD)	95% CI	
Jump height (cm)	26.1 (7.4)	22.2-30.1	28.6 (5.8)	27.5-29.7	0.129
EDRFD asymmetry (%)	19.4 (14.5)	11.7-27.1	15.7 (11.0)	13.6-17.8	0.417
EDRFD asymmetry (%/NV)	9.4 (22.8)	-2.8-[21.5]	-3.4 (18.9)	-7.0-[0.3]	0.016**
EDRFD (N/s*kg)	43.8 (11.1)	37.9-49.7	41.4 (15.2)	38.5-44.3	0.314
CMF asymmetry (%)	5.8 (4.0)	3.7-7.9	7.3 (5.4)	6.2-8.3	0.434
CMF asymmetry (%/NV)	1.1 (7.1)	-2.6-[4.9]	-2.3 (8.8)	-4.0-[-0.6]	0.138
CMF (N*kg)	9.7 (1.3)	9.0-10.4	9.3 (1.2)	9.1-9.6	0.636
PLF asymmetry (%)	12.1 (8.6)	7.5-16.7	18.4 (14.4)	15.7-21.2	0.139
PLF asymmetry (%/NV)	0.8 (15.1)	-7.2-[8.9]	3.6 (23.2)	-0.8-[8.1]	0.642
PLF (N*kg)	29.3 (5.6)	26.3-32.3	29.9 (7.8)	28.4-31.4	0.774

** Significance of p ≤0.05; † Student's t or Mann Whitney U tests; EDRFD= eccentric deceleration of rate force development. Material created by the authors.

When analyzing separately the group with right dominance for the EDRFD asymmetry (n = 55), significant differences were found between the groups with and without MTSS (Table 3). Asymmetry for those injured was found above 20%, while for the healthy subjects it was below 15% (Table 3). Cadets with asymmetries ≥ 20% had 2.84 (0.91-8.86; p = 0.061) times greater risk of suffering MTSS than those with asymmetries < 20%.

Table 3. Difference of the groups with and without MTSS based on dominance for the EDRFD asymmetry

	MTSS (n = 10)		No MTSS (n = 45)		p-value†
	x̄ (SD)	95% CI	x̄ (SD)	95% CI	
Right dominance for EDRFD asymmetry (%)	23.0 (14.0)	13.0-33.0	14.7 (9.8)	11.7-17.6	0.029**
	MTSS (n = 6)		**No MTSS (n = 62)**		**p-value†**
	x̄ (SD)	**95% CI**	**x̄ (SD)**	**95% CI**	
Left dominance for EDRFD asymmetry (%)	-13.4 (14.4)	-28.5-[1.8]	-16.5 (11.8)	-19.4-[-13.5]	0.552

** Significance of p ≤0.05; † Student's t test. Material created by the authors.

Of the 10 subjects with MTSS who had right dominance for the EDRFD asymmetry, 20% suffered this pathology in the right lower limb, 20% in the left, and 60% in both legs. Of the six cadets with MTSS who had left asymmetry for the EDRFD, 16.7% suffered this pathology in the left lower limb, 50% in the right, and 33.3% in both legs. These data reveal that MTSS affected in lesser proportion the dominant lower limb against the non-dominant lower limb (18.3% vs. 35%); however, the most common was the bilateral MTSS (46.7%).

The variables included in the logistic regression and which contribute most to predicting MTSS were sex, origin, MTSS antecedent, and EDRFD asymmetry (%/NV). The model was significant for MTSS (p = 0.001), had 31.3% sensitivity and 99.1% specificity (global prognosis of 90.2%), goodness of fit of 0.57 (Hosmer and Lemeshow test), and Nagelkerke's R squared of 0.26.

All the variables incorporated in the model had a significance of p ≤0.05, except for the MTSS antecedent (p ≤0,1) (Table 4). Women were at greater risk than men of suffering this pathology (OR = 4.91), as well as cadets from rural zones (immediately before entering the military training) and who had suffered MTSS in the past compared with their counterparts (OR = 4.82 and 8.95, respectively) (Table 4). Similarly, a 1% increase in the EDRFD asymmetry (right) increases the risk of enduring MTSS (OR = 1.03) (Table 4).

Table 4. Risk factors associated with the MTSS in the multivariate prediction model

	B (coefficient)	Standard error	Wald	p-value	OR (Exp[B])	95% CI
Sex	1.590	0.65	6.08	0.014**	4.91	1.38-13.37
Origin	1.572	0.69	5.18	0.023**	4.82	1.24-18.66
MTSS antecedent	2.192	1.32	2.76	0.097*	8.95	0.68-118.73
EDRFD asymmetry (%/NV)	0.034	0.02	4.49	0.034**	1.03	1.00-1.07
Constant	-3.037	0.53	32.57	0.000	0.05	

* Significance of $p \leq 0.1$; ** Significance of $p \leq 0.05$. Material created by the authors.

Discussion

The MTSS is one of the MSI of higher incidence in military personnel (3, 4). This pathology impacts negatively on the military career of the cadets, their short- and long-term health, and the health costs of the military institutions (11, 12, 14, 25, 27, 30). Numerous risk factors have been related with MTSS (1, 4, 8); however, the kinetic variables implicit in jumping have not been associated with this pathology unlike other MSI (32, 45, 51). This study focused on determining the risk factors for MTSS associated with the CMJ kinetics in cadets undergoing training.

The findings show that the BMI is not associated significantly with the MTSS in this study, contrary to that observed in other research. Two systematic reviews with meta-analysis found that increased BMI is associated significantly with MTSS (WMD = 0.79, 95% CI = 0.38-1.20, p

<0.001; SMD = 0.24, 95% CI = 0.08-0.41, p = 0.003) (4, 8). Moreover, research conducted in the German army found significant differences for BMI between the groups with and without MTSS (p = 0.04), but when this variable was examined in the multivariate analysis, it was not significant (p = 0.3) (53). In a prediction model developed by Garnock et al., the BMI was not significant for MTSS in navy recruits (11). Yates and White also found no significant differences for the BMI between the groups with and without MTSS (p = 0.917) in a sample of Australian navy recruits (52). Another two studies evidenced that the BMI is not associated significantly with the pathology reported in the military personnel (p >0.05) (54, 55). One of the reasons for the differences found is that the systematic reviews with meta-analysis showed heterogeneity in the samples evaluated (athletes, civilian or military population).

Plisky et al., indicated that subjects with a BMI ≥ 20.2 had 5.3 times greater risk of suffering MTSS than their counterparts (p <0.05); nevertheless, said study was conducted in a population of *runners* with a mean age of 16.0 ± 1.0 years (56). In turn, Grier et al., found that subjects with a BMI ≥ 25 and ≥ 30 had 1.77- and 2.72-times greater risk of suffering MSI in a combat brigade in comparison with those with a BMI < 25 (p <0.01) (57). Although the previous study did not discriminate directly the MTSS, another explanation for the results obtained in this research is that the average BMI in the cadets with or without MTSS was < 25.

In spite of the increased BMI being a risk factor for MTSS – given that it represents a greater load on bone system in the lower limbs (4, 8), in the military personnel the evidence is not clear. Considering that the BMI has important limitations because it does not permit discriminating the distribution of fat and lean mass (58), it is indispensable to use different tools to assess body composition.

This is the first study relating origin (rural and urban) with MTSS. One of the possible explanations for the results found is the socioeconomic status. In Colombia, the National Administrative Department of Statistics (DANE, for the term in Spanish) indicated higher monetary and multidimensional poverty in the country's rural zones (59). A study carried out with Tunisian adolescents evidenced that those with low socioeconomic status had significantly lower results in the CMJ height and power compared with those with higher socioeconomic status ($p < 0.01$) (60). Said same research also found that poorer subjects had lower lean mass unlike their counterparts ($p < 0.05$) (60). El Hage et al., found that the hip BMD (Bone Mineral Density) was correlated positively with the performance of the vertical jump ($r = 0.78$, $p < 0.01$) and longitudinal jump ($r = 0.67$, $p < 0.05$) (61). Although many hypotheses exist regarding the results obtained, further research is needed to interpret the association between rural origin and MTSS.

Female sex and MTSS antecedent were also associated significantly with the MTSS, agreeing with existing evidence. Two systematic reviews with meta-analysis demonstrated that female sex is associated significantly with the MTSS (OR = 2.35, 95% CI = 1.58-3.50, $p < 0.05$; RR = 1.71, 95% CI = 1.15–2.54, $p = 0.008$) (1, 8). Likewise, a systematic review with meta-analysis found that the MTSS antecedent se associated significantly with this pathology (RR= 3,74, 95% CI= 1,17-11,91, p= 0.03) (8).

Women are more prone to suffering diverse MSI in the lower limbs in comparison with men, due to important anatomical, hormonal, and biomechanical differences (8, 62, 63). The most important of these include increased Q angle/width of pelvis, decreased intercondylar notch of the femur, increased articular laxity, increased flexibility of the hamstrings, increased anterior translation of the tibia, increased pronation of the foot and navicular drop, effects of estrogens in the neuromuscular control and function, decreased H:Q ratio (hamstrings/quadriceps), the magnitude and altered timing of muscle activation, decreased proprioception, imbalance of the medial-lateral muscle contraction patterns of the quadriceps, and greater dynamic knee valgus among others (62).

Different studies have also shown that women had lower physical condition, unlike their counterparts (19, 20, 64). This makes them more vulnerable to suffering any type of injury within the military context, where requirements are equal for men and women. In the case of the MTSS antecedent, it is felt that subjects injured again have had incomplete bone healing; however, the hypothesis also exists that after the first episode there is loss of BMD for up to eight years (8).

From the biomechanical analysis, it was found that jump height is one of the variables most associated with diverse MSI. A study conducted on professional soccer players found that greater height in the *squat jump* was associated significantly with greater risk of suffering any type of hamstring injury (OR = 1.47; 95% CI = 1.02-2.12; $p \leq 0.05$) (33). Research by Gómez-Piqueras et al., also with professional soccer players, reported significant differences in the CMJ height (during the preseason) between injured subjects and those not injured ($p \leq 0.05$), being lower in healthy soccer players (35.56 ± 3.94 vs. 40.43 ± 4.42) (36). Contrary to the aforementioned, Iguchi et al., found that a height ≤ 66 cm (in contrast with > 66 cm) in the *vertical jump* was related significantly with greater risk of suffering hamstring strain (HR = 0.15; 95% CI = 0.03-0.74; $p \leq 0.05$) (34). Orr et al., evidenced that subjects who reached a height between 30 and 34 cm in the *vertical jump*, in contrast with those who reached a height ≥ 55 cm, had 2.12 (95% CI = 1.07-4.20) times greater risk of suffering diverse MSI ($p \leq 0.05$) (35).

Although the EDRFD, CMF, and PLF have less evidence than the jump height, existing studies have been determinant for the development of this analysis. Hewett et al., found that women athletes with rupture of the anterior cruciate ligament (ACL) had – at the start of the follow up – a 20% increase in the vertical ground reaction force (vGRF) during landing in the *drop jump* (DJ) test, compared with those not injured ($p \leq 0.05$) (32). A systematic review with meta-analysis reported no differences in the vGRF (during the impact and propulsion phases) between subjects with antecedents of stress fracture (tibial and metatarsal) and those with no such antecedents, however, the load rate in the vertical ground reaction force (LRvGRF) during landing was significantly higher in the injured population ($p \leq 0.01$) (37). Powell et al., found that subjects with prior Achilles tendon rupture exhibited higher LRvGRF during the landing phase in the *drop countermove-*

ment jump ($p \leq 0.01$), unlike their counterparts (38). Research conducted with volleyball players reported that subjects with antecedents of patellar tendinopathy (in contrast without such) had a higher knee moment development rate (KMDR) during the eccentric phases (during impulse and landing) during the *spike jump* ($p \leq 0.05$) (39). Another study by Bisseling et al., reported that subjects with prior patellar tendinopathy had higher LRvGRF in the DJ during landing, in comparison with individuals without this condition ($p \leq 0.01$), however, no significant differences were found in the peak vGRF (40).

In contrast, another research evidenced that subjects with ACL reconstruction had lower LRvGRF during landing and takeoff in the DJ, in contrast with healthy individuals ($p \leq 0.05$) (41). A cases and controls study found that injured basketball players had significantly lower eccentric activity in the *jump-shot* during landing in comparison with those not injured ($p \leq 0.01$) (42). Research conducted on subjects with patellar tendinopathy reported that those with complete recovery of their injury (score >80 in the *Victorian Institute of Sport Assessment* [VISA]) had significantly higher values in the LRvGRF ($p \leq 0.01$) and the RMDK ($p \leq 0.05$) in the DJ during landing than their counterparts (40). One of the hypotheses for the results found in these studies is that subjects with recent lesions (or which were not treated adequately) develop a protection mechanism on the affected lower limb, thus, having a lower LRvGRF (39). Unfortunately, the studies examined did not evaluate lower-limb asymmetries in injured individuals.

Considering the findings presented, it is believed that greater LRvGRF (during any of the jump phases) in subjects with injury antecedents may be contraindicated if the tissue affected has not had adequate rehabilitation. If so, this would represent greater load during a shorter period of time on tissue that has not recovered completely (43). Likewise, it is presumed that a lower LRvGRF (in any of the jumping phases) manifests a greater risk of injury (in healthy subjects or who have MSI antecedents), given that the muscle's responsiveness to a motor stimulus is diminished. Greater load rate (LR, also known as rate of force development [RFD]) is translated into the capacity to decelerate more rapidly during the impulse phase by activating the quadriceps and, thus, obtaining increased muscle strength and power during the concentric contraction (65, 66). During landing, greater LR will permit maintaining equilibrium and knee stability, and attenuating the impact forces (energy absorption) through the deceleration of the lower limb (39, 42, 67).

Evidence regarding the kinetic variables and risk of suffering MSI seems contradictory; nevertheless, the findings are reasonable because the studies cited analyzed different MSI and were conducted on diverse populations. Moreover, these were conducted during different moments after the injury. Merely two longitudinal studies found that increased vGRF and diminished eccentric activity during landing are associated significantly with different MSI (32, 42).

Jump height, EDRFD, CMF, and PLF are not associated significantly with the MTSS in this study. Compensatory strategies (in injured subjects), which take place through the different muscle groups of the lower limb, may be the cause for the findings reported. This was denoted in a study by Siegmund et al., in basketball players with patellar tendinopathy (68). Nonetheless, further research is warranted to elucidate this hypothesis.

The CMF and PLF asymmetry (disregarding dominance [%]) were not associated significantly with the MTSS in this research. It is believed that these results are due the average asymmetry for the variables mentioned being < 15%, which is the reference clinical value to evaluate the risk of injury and the return to sports activity in the case of athletes who have suffered MSI (43-45, 69, 70). For the EDRFD asymmetry (%),individuals with MTSS had values > 15%, but were not significant with respect to healthy subjects.

Bearing in mind the asymmetry dominance (%/NV), the EDRFD was the only variable associated significantly with the MTSS. Upon analyzing the results, it was possible to denote that in the subjects with MTSS, the right dominance prevailed for the EDRFD – in contrast with individuals not injured (left dominance prevailed), becoming a factor de risk for developing this pathology, presenting right dominance for the variable mentioned. A study indicated that right-handed people have greater have greater hemispheric asymmetry on the cortical surface (of the sensory cortex) and activation of primary motor cortices, in comparison with left-handed people (71). It is presumed that said cerebral asymmetries are directly related with the motor asymmetries of the lower limb, with right-handed subjects being the most vulnerable to suffering diverse MSI. Given that it was not the objective of this study, it is necessary for this hypothesis to be analyzed carefully and be an incentive to carry out new research.

A secondary analysis examined the group of cadets with right and left dominance separately to clarify this phenomenon. The group with left dominance for the EDRFD showed no significant differences between subjects with and without MTSS, finding the group of those injured below 15%. In the group with right dominance for the EDRFD, the injured cadets had a significantly higher asymmetry percentage than the healthy cadets (23.0% ± 14.0% vs. 14.7% ± 9.8%; $p = 0.029$). Subjects with MTSS exhibited asymmetry > 15% (reaching above 20%), while individuals not injured were below this value. These data agree with the clinical reference point reported in the literature and with results from other research.

Paterno et al., found that a group of athletes with ACL reconstruction had 37% asymmetry, in contrast with a group of healthy athletes, which exhibited 7.7% asymmetry for the LRvGRF during landing in the DJ (43). The injured lower limb had a lower LRvGRF, in comparison with that not injured ($p \leq 0.01$) (43). In another study, a group of subjects with acute ankle sprain exhibited asymmetry of 15.02% ± 13.09%, while the control group had asymmetry of 5.76% ± 4.16% for the RFD during phase 1 (rise/takeoff) of the DJ ($p = 0.001$) (44). During phase 2 (landing), injured people also exhibited asymmetry significantly greater than their counterparts for the variable indicated (10.62% ± 8.64% vs. 4.35% ± 3.49%; $p = 0.001$) (44). During both phases, a lower RFD was observed in the injured lower limb, in comparison with that of the controls, however, this difference was only significant during phase 2 ($p = 0.01$) (44). These studies support the idea that asymmetries above 15% for the EDRFD are associated with higher risk of suffering MTSS.

According with the research cited herein, it is observed that the dominant leg in jumping for the variables reported was the uninjured leg. Although the results cannot be comparable due to the type of study, population, and type of injury examined, in the present research the cadets mostly injured the non-dominant lower limb (35%) in contrast with the dominant (18.3%), based on the EDRFD. One of the hypotheses employed for the results obtained is that the injured non-dominant leg has a diminished neuromuscular function that influences negatively on the capacity to quickly decelerate during the impulse and landing phases, affecting the achievement of greater muscle strength and power, and attenuation of the impact forces when running and jumping, among others (39, 42, 65-67). Furthermore, it is believed that the injuries that occurred in the dominant lower limb are due to the overload exerted on the musculoskeletal tissue by deploying a force stimulus rapidly and repeatedly. This is especially common in cadets, who undergo an abrupt change of life (26, 72), where they are exposed to great training volume and intensity, and sudden increases in any of these two aspects (73).

From sex, origin, MTSS antecedent, and the EDRFD asymmetry (%/NV), a prediction model was proposed for the MTSS, which had 31.3% sensitivity and 99.1% ($p = 0.001$) specificity. The model proposed in this study is quite similar to that developed by Garnock et al., for the MTSS (11). Said model included sex, MTSS antecedent, and hip external rotation ($p < 0.001$) and had 82% sensitivity 82% and 84% specificity (11). It is expected that future research can study diverse biomechanical variables (kinetic and kinematic), which permit creating a more-robust prediction model for the MTSS.

The principal strength of this study is that it is the first to analyze the association of diverse kinetic variables implicit in the CMJ with the MTSS. Unlike most cross-sectional investigations and which were conducted after the injury, this was a prospective longitudinal study. The design of the present study permitted establishing the principal risk factors associated with the MTSS, prior to starting the military training of the cadets. Bearing this in mind, a significant prediction model was obtained for the MTSS, which will serve to identify subjects at greater risk of suffering this pathology upon entering the ESMIC. This Will permit creating a primary prevention program for said population. Another strength of this study was that it took a representative sample of the population at greater risk of having MTSS and the controlled conditions in which the cadets were found, given that during the follow-up period all the subjects were exposed to similar feeding, training, and resting conditions among others.

The most important limitations were the short follow-up period, high percentage of sample loss, and not having examined other biomechanical variables. As perspectives, it is expected for future research to measure different kinetic and kinematic variables, through tools, like 3D movement analysis, linear dynamometry (linear encoder) and isokinetic tools (isokinetic force machines), among others. The aforementioned to obtain broader knowledge about the biomechanical risk factors (kinetic and kinematic) that can impact on the development of MTSS.

Conclusions

Based on the prediction model proposed, it was found that female sex, rural origin, MTSS antecedent, and greater EDRFD asymmetry are important risk factors for the development of MTSS. These findings will permit better prediction of the MTSS in military personnel, being especially useful to classify the risk in cadets starting their military training. Given that sex, origin, and MTSS antecedent are non-modifiable risk factors, a large EDRFD asymmetry becomes a fundamental element to treat to reduce the risk in a physical training program when entering the ESMIC.

These results may also be potentially beneficial for any type of population exposed frequently to this pathology (like, for example, athletes). Because the results found herein are only recently being described in the literature, it is necessary to conduct new research to elucidate the role of kinetic variables implicit in jumping on developing the MTSS. Likewise, it is necessary to contemplate the evaluation of different variables (biomechanical, anthropometric, sociodemographic, among others) for the MTSS to be analyzed in multifactorial manner, arriving at the creation of a more-robust prediction model than that introduced in this study.

Conflict of interests

The authors declare no conflict of interests in this research.

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General Conclusion | 9

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The physical training of a soldier is conditioned by both environmental and genetic factors, but the most striking factor in health conditions and that is influenced by habits, is represented by lifestyles. Therefore, maintaining adequate physical preparation becomes an important factor of well-being and health. The military member of any State security force needs to have a good level of preparation, given the high demands of physical and mental activity during the performance of the tasks of his profession, either during training periods or in different theatres of operation. The monitoring of the level of physical conditioning in any military must be a fundamental milestone, which must be evaluated and analyzed in the operational performance, as well as the mechanisms to ensure the skills of the combatant personnel. An adequate physical condition can protect the soldier from stressful situations during the development of his activity, at the same time can reduce other complications in the face of any type of injury. It is commonly known that intensive training decreases risk factors for cardiovascular diseases, leading to a loss of body weight by reducing the percentage of visceral fat and an increase in cardio-respiratory level. These findings also translate into a reduction in the risk of morbidity and mortality, after obtaining improvements in well-being related to the quality of life. Because physical preparation has been conceptualized as a multidimensional construct (cardio-respiratory endurance, muscle power, muscle endurance, flexibility, body composition), its evaluation includes multiple tests that have been developed in laboratories and high-performance centers, but adapted to the specific fields of military-physical training. This book mentions and implemented some measurement tools of the research centers in physical activity, such as the use of electrical bioimpedance in the determination of body composition, the use of force platforms and inertial accelerators for the quantification of the propulsive force and muscle power of the upper and lower limbs, as well as the determination of asymmetries in the different phases of the jump. Specific tests such as the «Sit and Reach» test, 90-90 and the ELY test were also used to evaluate the flexibility of groups of military athletes. In addition, field tests adapted to the military and sports environment were used, which are an indirect reflection of what happens in a laboratory equipment (the use of the Cooper test in relation to some ventilatory variables obtained by means of an ergospirometer). Among the contributions of this work in the knowledge about military physical training, it can be mentioned that it is the first approximation initiative in the evaluation of the level of physical preparation of the Colombian military. All the studies in this compilation are based on scientific accuracy from a methodological perspective, which also allows the reproducibility of the tests, that is, their external validity. This is the basis for other researchers to determine the scales of the physical, physiological and biomechanical variables of the state and physical capabilities of the military population in the country. The authors are aware that within the execution of the works that compose the book are limited in some studies in terms of the number of the sample, but correspond to small population groups. Also, bear in mind that this opens the possibility for new studies with more representative samples to be contrasted with the results obtained here, in order to improve the internal validity of the same. This book is the first step in a series of investigations into military physical performance and factors associated with health in active members of the National Army, which will first aim to characterize, evaluate and determine training plans that optimize the pillars of doctrine at the institutional level. The ultimate goal is to achieve better physical conditions for the combatant, for a better quality of life and safety in operational performance.

ESMIC
SELLO EDITORIAL

Characterizing the fitness of Colombian military personnel

One of the great limitations in applying research involving the military population is that data are taken from other studies that do not reflect the specific characteristics or conditions of Colombian soldiers. Regardless, the outcomes are applied and appropriated as if these soldiers were, in fact, the sample of the study. In response to this situation, this work publishes the results of research involving the physical performance of Colombian military personnel to provide the academic community with descriptions of the variables that make up this population's physical fitness training. This work is a first attempt to characterize their physical, physiological, and biomechanical capabilities using the best available evidence and state-of-the-art technology. One of this book's main contributions to military physical training knowledge is that it is the first initiative to evaluate Colombian military personnel's level of physical training. The scientific rigor of the studies in this compilation allows the reproducibility of the tests (external validity). It paves the way for a series of studies in military physical performance and health-related factors concerning active members of the National Army, seeking to characterize, evaluate, and determine training programs to optimize the institution's pillars of doctrine. The ultimate goal is to drive the improvement of soldiers' physical conditions, favoring a better quality of life and safety in operational performance.

ESCUELA MILITAR DE CADETES
"General José María Córdova"

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