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

7

https://doi.org/10.21830/9789585380240.07

María Alejandra Díaz Pinilla[1]
Rodrigo Argothy Buchelli[2]

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

1 MSc. Biomedical Engineering. CICFI Research Group, Escuela Militar de Cadetes "General José María Córdova" Bogotá, Colombia

2 F.T CICFI Research Group, Escuela Militar de Cadetes "General José María Córdova" Bogotá, Colombia

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.

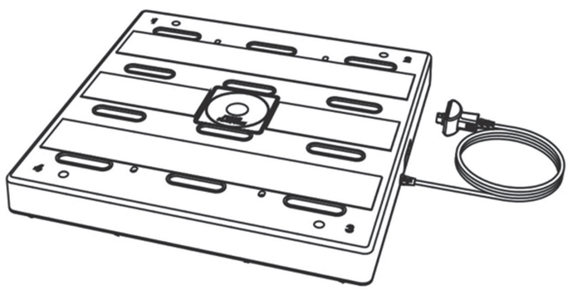

Figure 1. PASCO uniaxial platform.
Source: Taken from PASCO CI-6461 Force Platform - Manual

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.

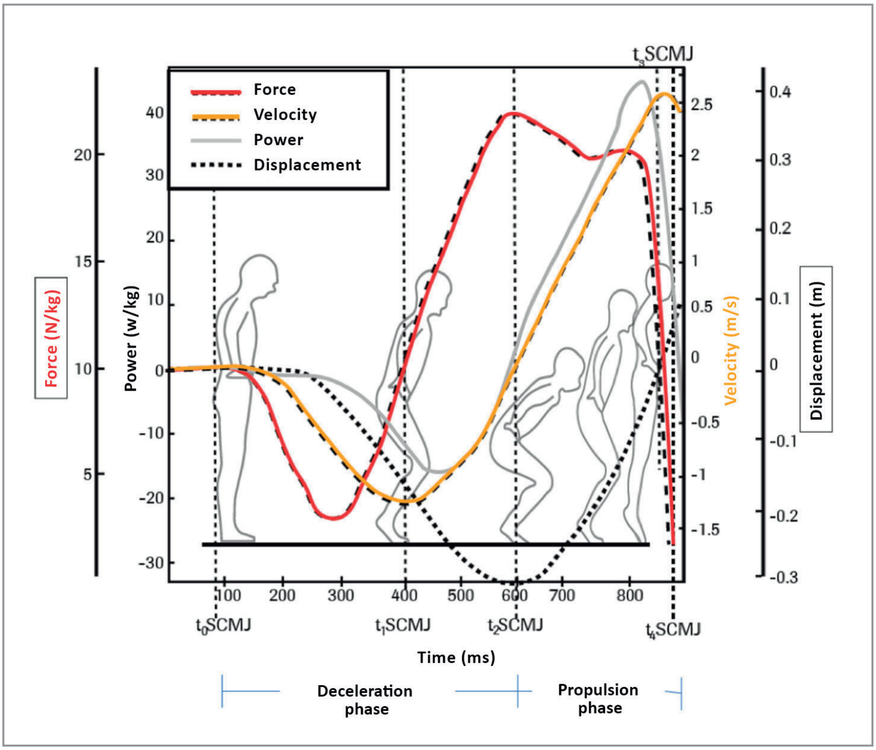

Figure 2. Countermovement vertical jump, illustrating two of its phases.
Source: Taken from (18).

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.

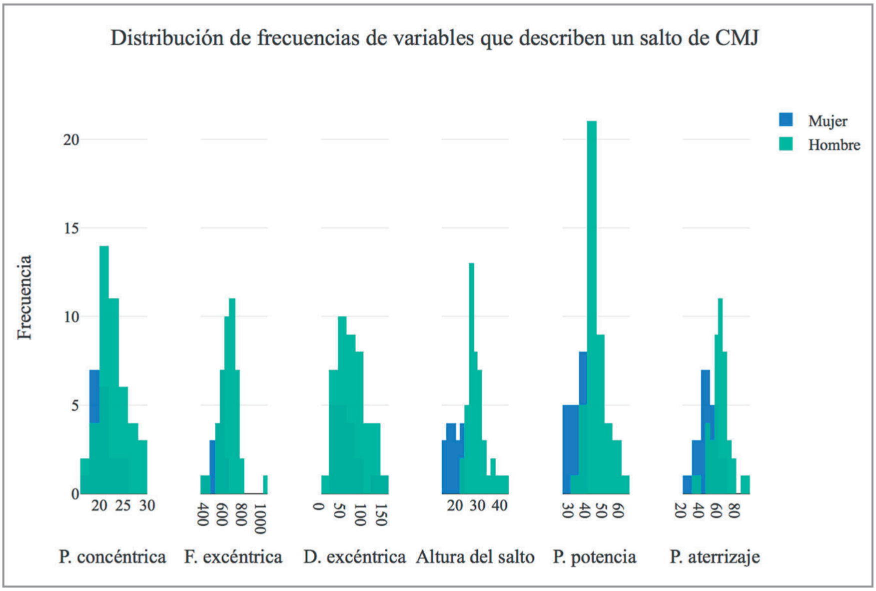

Figure 3. Frequency distribution of study variables, a comparison between men and women. Order of histograms from left to right: Peak concentric force (P. concentric), mean eccentric force (F. eccentric), eccentric deceleration (D. eccentric), jump height, peak power (P. power), and peak landing (P.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

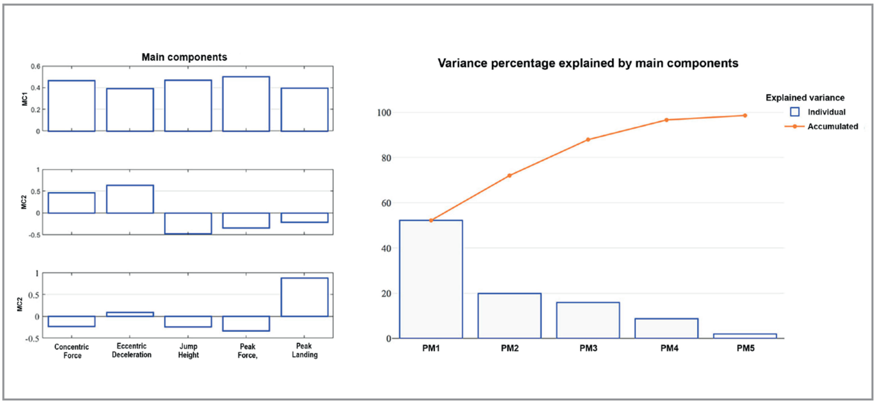

Figure 4. Results of the data principal component analysis using concentric peak force, eccentric deceleration, jump height, peak power, and peak landing. Left: Coefficients of the first three principal components for the five variables. Right: Percentage of variation explained by the principal components.

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).

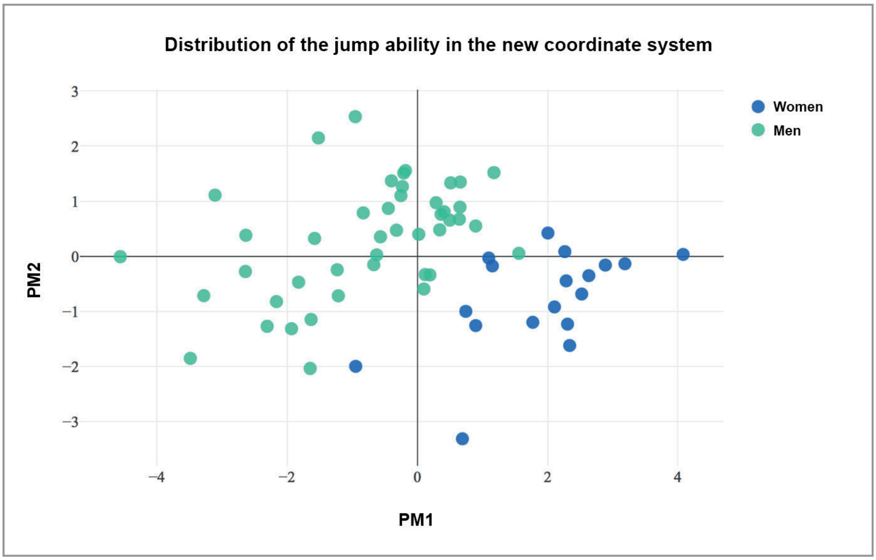

Figure 5. Distribution of the jump ability in the new coordinate system: men and women. Each subject is a point in the new coordinate space, which is determined by the principal component 1 (PM1) and the principal component 2 (PM2).
Source: Material created by the authors.

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.

Acknowledgements

The data analyzed in this study are part of the unfunded institutional project on "risk factors associated with the presence of tibialis medialis stress syndrome in students in training at *Escuela Militar*." This project was carried out in cooperation between *Escuela Militar de Cadetes "General José María Córdova"* and the Physical Activity Measurement Center (CEMA in Spanish) at Universidad del Rosario.

References

1. Rodríguez Gómez J, Valenzuela Pinzón J, Velasco Rodríguez J, Castro Jiménez L, Melo Buitrago P. Caracterización de las lesiones derivadas del entrenamiento físico militar. Revista CUIDARTE. 2016;7(1):1219.
2. Castro Solano A, Casullo M. Predictores del rendimiento académico y militar de cadetes argentinos. Universidad de Murcia; 2004.
3. Gómez García S. Actualización sobre el síndrome de estrés tibial medial. Revista Científica General José María Córdova. 2016;14(17):225.
4. Deuster P, Jones B, Moore J. Patterns and Risk Factors for Exercise-Related Injuries in Women: A Military Perspective. Military Medicine. 1997;162(10):649-655.
5. Heir T. Musculoskeletal Injuries in Officer Training: One-Year Follow-Up. Military Medicine. 1998;163(4):229-233.
6. Jackson D, Bailey D. Shin Splints in the Young Athlete: A Nonspecific Diagnosis. The Physician and Sportsmedicine. 1975;3(3):44-51.
7. Heinrich K, Spencer V, Fehl N, Carlos Poston W. Mission Essential Fitness: Comparison of Functional Circuit Training to Traditional Army Physical Training for Active Duty Military. Military Medicine. 2012;177(10):1125-1130.
8. CORMIE P, MCCAULLEY G, TRIPLETT N, MCBRIDE J. Optimal Loading for Maximal Power Output during Lower-Body Resistance Exercises. Medicine & Science in Sports & Exercise. 2007;39(2):340-349.
9. Klavora P. Vertical-jump Tests: A Critical Review. Strength and Conditioning Journal. 2000;22(5):70-75
10. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and Factorial Validity of Squat and Countermovement Jump Tests. Journal of Strength and Conditioning Research. 2004;18(3):551-555.
11. Welsh T, Alemany J, Montain S, Frykman P, Tuckow A, Young A *et al*. Effects of Intensified Military Field Training on Jumping Performance. International Journal of Sports Medicine. 2008;29(1):45-52.

12. Claudino J, Cronin J, Mezêncio B, McMaster D, McGuigan M, Tricoli V *et al.* The countermovement jump to monitor neuromuscular status: A meta-analysis. Journal of Science and Medicine in Sport. 2017;20(4):397-402.
13. Jiménez-Reyes P, Samozino P, Cuadrado-Peñafiel V, Conceição F, González-Badillo J, Morin J. Effect of countermovement on power–force–velocity profile. European Journal of Applied Physiology. 2014;114(11):2281-2288.
14. Jiménez-Reyes P, González-Badillo J. Control de la carga de entrenamiento a través del CMJ en pruebas de velocidad y saltos para optimizar el rendimiento deportivo en atletismo. (Monitoring training load through the CMJ in sprints and jump events for optimizing performance in athletics). Cultura_Ciencia_Deporte. 2011;6(18):207-217.
15. Jiménez-Reyes P, Cuadrado-Peñafiel V, González-Badillo J. Aplicación del CMJ para el control del entrenamiento en las sesiones de velocidad. (Application of the Counter Movement Jump Test to Monitor Training Load in Sprint Sessions). Cultura_Ciencia_Deporte. 2011;6(17):105-112.
16. Toumi H, Poumarat G, Best T, Martin A, Fairclough J, Benjamin M. Fatigue and muscle–tendon stiffness after stretch–shortening cycle and isometric exercise. Applied Physiology, Nutrition, and Metabolism. 2006;31(5):565-572.
17. Yánez Constante C. VARIABLES BIOQUÍMICAS Y DEL DESEMPEÑO DEL SALTO CONTRAMOVIMIENTO PARA MONITORIZAR LA FATIGA NEUROMUSCULAR EN DEPORTISTAS DE RESISTENCIA [Master]. Universidad Nacional de Colombia; 2016.
18. Rodríguez Zárate N, Argothy Bucheli R, Acero Jáuregui J, Gómez Salazar L, Menzel H, Cohen D. Lineamientos de Política Pública en Ciencias del Deporte en Biomecánica. 1st ed. Bogotá: COLDEPORTES; 2018.
19. Centeno Prada R. Valores de referencia para saltos en plataforma dinamométrica en una población de deportistas andaluces [Ph.D.]. Universidad Pablo de Olavide; 2013.
20. Laffaye G, Wagner P, Tombleson T. Countermovement Jump Height. Journal of Strength and Conditioning Research. 2014;28(4):1096-1105.
21. Chamari K, Chaouachi A, Hambli M, Kaouech F, Wisløff U, Castagna C. The Five-Jump Test for Distance as a Field Test to Assess Lower Limb Explosive Power in Soccer Players. Journal of Strength and Conditioning Research. 2008;22(3):944-950.
22. Loturco I, Ugrinowitsch C, Roschel H, Lopes Mellinger A, Gomes F, Tricoli V *et al.* Distinct Temporal Organizations of the Strength- and Power-Training Loads Produce Similar Performance Improvements. Journal of Strength and Conditioning Research. 2013;27(1):188-194.
23. KOMI P. Physiological and Biomechanical Correlates of Muscle Function. Exercise and Sport Sciences Reviews. 1984;12(1):81-122.
24. Bell D, Sanfilippo J, Binkley N, Heiderscheit B. Lean Mass Asymmetry Influences Force and Power Asymmetry During Jumping in Collegiate Athletes. Journal of Strength and Conditioning Research. 2014;28(4):884-891.

25. Benjanuvatra N, Lay B, Alderson J, Blanksby B. Comparison of Ground Reaction Force Asymmetry in One- and Two-legged Countermovement Jumps. Journal of Strength and Conditioning Research. 2013;27(10):2700-2707.
26. Menzel H, Chagas M, Szmuchrowski L, Araujo S, de Andrade A, de Jesus-Moraleida F. Analysis of Lower Limb Asymmetries by Isokinetic and Vertical Jump Tests in Soccer Players. Journal of Strength and Conditioning Research. 2013;27(5):1370-1377.
27. Rahmani A, Viale F, Dalleau G, Lacour J. Force/velocity and power/velocity relationships in squat exercise. European Journal of Applied Physiology. 2001;84(3):227-232.