ORIGINAL ARTICLE

Relationship between neuromuscular performance and academic achievement in university students of sports training

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ABSTRACT

This study examined the association between neuromuscular performance and academic achievement in university students enrolled in a sports training program. A cross-sectional study was conducted with 57 physically active university students (45 men and 12 women; age: 19.4 ± 2.1 years) from Bogotá, Colombia. Neuromuscular performance was assessed using the T-Force System during free back squat and bench press exercises, measuring one-repetition maximum (1RM) and mean propulsive velocity (MPV). Academic achievement was obtained from official institutional grade point average (GPA, 1.0–5.0 scale). Partial Pearson correlations adjusted for age, sex, and socioeconomic status were used to examine associations between variables. Significant positive correlations were observed between academic achievement and squat performance variables, including 1RM (r = .620), MPV (r = .611), fast-load MPV (r = .656), and slow-load MPV (r = .642) ($p < .05$). Bench press variables also showed significant correlations with GPA (r = .41–.46; $p < .05$). These findings suggest that greater neuromuscular performance, particularly strength and movement velocity, is associated with higher academic achievement in sports training students. Neuromuscular fitness may represent an important physiological factor linked to academic performance in physically active university populations.
Keywords: Sport medicine, Grade point average, Resistance training, Velocity-based training, Muscular strength, Cognitive performance.

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INTRODUCTION

student success in higher education. It is a multifactorial construct that reflects students' performance in quantifiable terms, such as obtained grades, course completion, and persistence within the educational system (Edel, 2003; Arias, 2013). Its importance lies in the fact that it not only enables assessment of individual performance but also serves as a key criterion for evaluating the quality and effectiveness of educational institutions. In the Colombian context, this variable gains particular relevance given the alarming university dropout rates. According to data from the Ministry of National Education (MEN, 2022), nearly 45% of students entering higher education programs do not complete their studies. This situation has driven numerous investigations aimed at understanding the factors underlying student retention and academic success in universities.

Among the most frequently studied factors related to AA are personal, social, economic, psychological, and pedagogical characteristics. Variables such as socioeconomic status, family environment, learning strategies, intrinsic motivation, institutional support, perceived stress, lifestyle behaviours, and previous academic preparation have been identified as determinants of AA (Restrepo et al., 2006; Luna et al., 2014; Sarmiento & López, 2019; González & Ramírez, 2020). Despite the substantial research in this field, a gap persists regarding how physical and physiological aspects, particularly those linked to muscular fitness and neuromuscular performance, may influence AA, especially among students enrolled in academic programs related to sports training.

Over the last decade, literature has increasingly examined the relationship among physical activity, fitness, and AA, particularly in children and adolescents. Numerous studies have reported positive associations between higher cardiorespiratory fitness, greater muscular strength, and better school performance (Donnelly et al., 2016; Esteban-Cornejo et al., 2014; García-Hermoso et al., 2017). These findings have been explained through physiological and cognitive mechanisms, such as increased cerebral blood flow, enhanced neurotrophins release, and improvements in executive function, working memory, and sustained attention (Álvarez-Bueno et al., 2017). However, within university populations, particularly in young adults, this relationship has received considerably less attention, and current results remain limited and inconsistent.

An emerging line of research proposes evaluating not only overall physical fitness, but also more specific characteristics of neuromuscular performance through the force–velocity profile. This profile, framed by the work of Parejo-Blanco (2014), refers to the individualized representation of the relationship between applied force and movement velocity under different relative loads during specific exercises. Beyond its utility in sports practice, this profile may also be associated with higher-level cognitive functions and, consequently, AA, as it reflects potential links between motor control, decision-making, and the efficiency of the central nervous system (Jiménez-Reyes et al., 2017; Edwards et al., 2022).

Students enrolled in professional sports training programs represent a specific subgroup that warrants special attention. Unlike peers in other academic fields, these students are exposed to substantial physical demands resulting from the practical components of their curriculum. Their academic routines often include training sessions, physical testing, practical classes, exercise laboratories, and, in many cases, additional athletic or fitness-related work outside of school hours. Moreover, many maintain active lifestyles motivated by personal goals or professional involvement in competitive or recreational sports.

This combination of physical, academic, and sometimes occupational demands may yield both positive and negative effects on AA. On one hand, regular physical activity can promote mental health, improve emotional regulation, and optimize cognitive functions. On the other hand, excessive physical workload or poor time and recovery management may lead to chronic fatigue, disrupted sleep, and reduced time available for studying. Despite these distinct characteristics, there is a notable lack of studies investigating how specific indicators of neuromuscular performance relate to AA in this population.

This gap in the literature underscores the need to analyse potential associations between neuromuscular performance and AA in sports training students. Such research can contribute to the existing body of knowledge on determinants of academic success by incorporating an integrative perspective that connects physical fitness, performance physiology, and the educational context of a scientifically underrepresented population. Based on this rationale, the objective of this study was to evaluate the relationship between AA and neuromuscular performance in a sample of university students enrolled in a sports training program.

MATERIAL AND METHODS

Study design and participants

This descriptive cross-sectional study was conducted between 2020 and the first semester of 2021 with a sample of 57 university students (45 men and 12 women) enrolled in a sports training program at a higher education institution in Bogotá, Colombia. A non-probabilistic convenience sampling approach was used, which is common in exploratory studies within exercise sciences (Sedgwick, 2013).Inclusion criteria required participants to be between 18 and 30 years old, actively enrolled with at least three consecutive semesters completed, and classified as physically active based on the International Physical Activity Questionnaire (IPAQ), showing a weekly energy expenditure ≥1500 MET·min (Craig et al., 2003; Arango-Vélez et al., 2020). Participants were excluded if they responded affirmatively to any item on the PAR-Q questionnaire (Warburton et al., 2011) or presented any physical or neuromuscular condition that could compromise safe participation in testing. The study received approval from the Institutional Ethics Committee of Fundación Universitaria del Área Andina (Andean Area University Foundation) (code: CVF2020-IM-B02), complying with the Declaration of Helsinki and Colombian Ministry of Health Resolution 008430 of 1993. All participants signed informed consent documents and completed three evaluation sessions addressing body composition, force–velocity profiling, and academic performance data collection.

Instruments and procedures

Body Composition: segmental bioelectrical impedance was assessed using a Tanita IRONMAN BC-1500 analyser, validated for physically active adults (Sillanpää et al., 2014). Participants arrived in a fasting state (≥8 hours), with controlled hydration and bladder emptying at least one hour before measurement. Waist and hip circumferences were taken using a SECA 203 anthropometric tape following ISAK technical procedures (Silva & Vieira, 2020).

Neuromuscular Performance: force–velocity profiling was conducted in free back squat and bench press . exercises. A progressive loading protocol was employed to determine one-repetition maximum (1RM), while measuring mean propulsive velocity (MPV) using the T-Force System (Ergotech, Spain), a linear velocity transducer with proven validity and reliability for resistance training assessments (Sánchez-Medina et al., 2010).The protocol began with 20 kg and increased by 10 kg until MPV fell below 0.80 $m \cdot s^{-1}$. Thereafter, load increments of 5 kg and 2.5 kg were used to refine 1RM estimation. MPV from the fastest attempt in each set was recorded. Three repetitions were performed when MPV ≥ 0.8 $m \cdot s^{-1}$, two repetitions between 0.8 and 0.5 $m \cdot s^{-1}$, and one when <0.5 $m \cdot s^{-1}$, with 2-minute recovery intervals. A controlled eccentric phase and maximal-velocity concentric execution were required, aligned with recommended procedures for valid force–velocity assessment (González-Badillo & Sánchez-Medina, 2010; Banyard et al., 2017).Warm-up consisted of 5 minutes of joint mobility and specific submaximal lifts. Bench press was tested first, followed by squat, to maintain protocol standardization.

Academic Achievement Academic achievement was operationalized as the students' cumulative GPA on a 1.0–5.0 scale. Students accessed their institutional platforms (BANNER or SIRENA) to download official academic records, under evaluator supervision to ensure accuracy and transcription quality, in line with recommended registry-based procedures for academic performance research (Martínez-Abad & Chaparro, 2020).

Statistical Analysis: normality was assessed using the Kolmogorov–Smirnov test. Sex differences in continuous variables were evaluated with the independent-samples t-test and chi-square analyses for categorical variables. Neuromuscular indicators included: 1RM in squat and bench press, Overall MPV, MPV under fast-load conditions (≥0.1 $m \cdot s^{-1}$), MPV under slow-load conditions (≤0.1 $m \cdot s^{-1}$). Associations between neuromuscular variables and AA were examined using partial Pearson correlations adjusted for age, sex, and socioeconomic status. Statistical significance was set at $p < .05$. Analyses were performed using IBM SPSS Statistics version 24.0 (Chicago, IL, USA).

RESULTS

Table 1. General characteristics of the sample.

Characteristics	**Men (n = 45)**	**Women (n = 12)**	***p*-Value**
Socioeconomic status			
1	18 (40.0%)	6 (50.0%)	.523
2	15 (33.3%)	4 (33.3%)	.342
3	12 (26.7%)	2 (16.7%)	.464
Body composition			
Weight (kg)	66.2 (9.4)	54.06 (4.5)	.001*
Height (m)	172.0 (6.2)	156.8 (4.4)	.001*
BMI ($kg \cdot m^{-2}$)	22.28 (2.28)	22.00 (2.04)	.696
Body fat (%)	13.2 (4.0)	20.4 (4.2)	.001*
Visceral fat	1.73 (1.3)	1.00 (0.0)	.11
Metabolic age (years)	15.08 (6.4)	12.00 (0.0)	.14
Waist circumference (cm)	75.02 (6.3)	70.2 (4.7)	.019*
Hip circumference (cm)	93.2 (5.2)	90.68 (4.2)	.13
Age (years)	19.57 (2.2)	18.66 (0.77)	.177
Neuromuscular performance			
Squat 1RM (kg)	73.11 (13.7)	53.33 (9.8)	.001*
Squat MPV ($m \cdot s^{-1}$)	0.89 (0.22)	0.75 (0.09)	.001*
Squat MPV – fast loads	1.08 (0.22)	0.94 (0.09)	.022*
Squat MPV – slow loads	0.74 (0.22)	0.60 (0.09)	.043*
Bench press 1RM (kg)	39.3 (21.06)	21.6 (7.1)	.001*
Bench press MPV ($m \cdot s^{-1}$)	0.73 (0.22)	0.59 (0.09)	.032*
Bench press MPV – fast loads	0.92 (0.22)	0.78 (0.09)	.021*
Bench press MPV – slow loads	0.58 (0.22)	0.44 (0.09)	.031*
Academic achievement			
GPA (1.0–5.0 scale)	4.12 (0.3)	4.45 (0.4)	.006*

*Note. Data presented as mean ± standard deviation. *p < .05 indicates statistical significance. MPV: mean propulsive velocity; 1RM: one-repetition maximum.*

Regarding socioeconomic status, most participants belonged to strata 1 and 2, with no statistically significant differences between men and women in any category (p > .05). Concerning body composition, men showed significantly higher values for body weight (p = .001), height (p = .001), and waist circumference (p = .019), while women presented a significantly higher body fat percentage (p = .001). No significant differences were observed in BMI, visceral fat, metabolic age, hip circumference, or chronological age (p > .05). In terms of neuromuscular performance, men significantly outperformed women in squat 1RM (p = .001) and bench press 1RM (p = .001), as well as in mean propulsive velocity (MPV) across both exercises (p = .001 and p = .032, respectively). Significant differences were also observed in MPV under fast and slow loads in both squat and bench press exercises (p < .05 for all comparisons). Finally, academic achievement was significantly higher in women (4.45 ± 0.4) compared to men (4.12 ± 0.3; p = .006). (Table 1).

Partial correlations adjusted for age, sex, and socioeconomic status between AA and neuromuscular performance variables in the squat exercise showed a positive association of moderate to strong magnitude (Figure 1). Specifically, significant correlations were observed between AA and squat 1RM (r = .620), overall MPV (r = .611), MPV under fast loads (r = .656), and MPV under slow loads (r = .642), all statistically significant (p < .05).

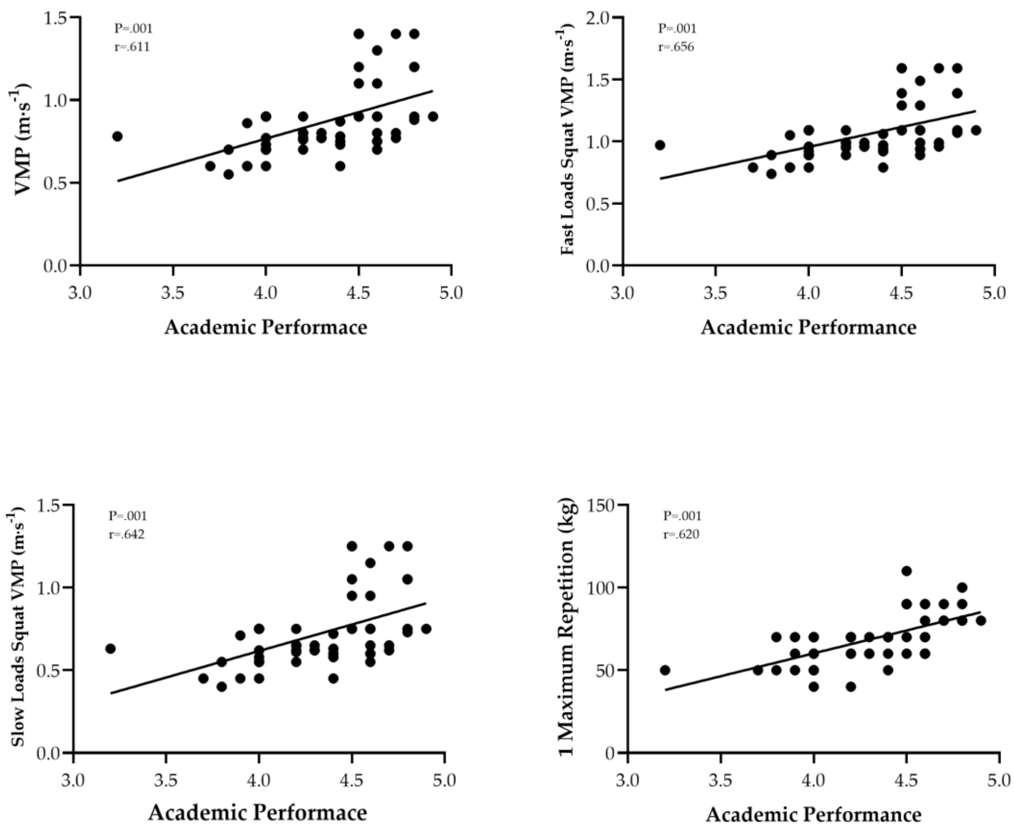

Figure 1. Squat.

Similarly, adjusted partial correlations between AA and neuromuscular performance variables associated with the bench press revealed positive associations (Figure 2). Significant correlations were identified between AA and bench press 1RM (r = .46), overall MPV (r = .41), MPV under fast loads (r = .45), and MPV under slow loads (r = .43), with all results reaching statistical significance (p < .05).

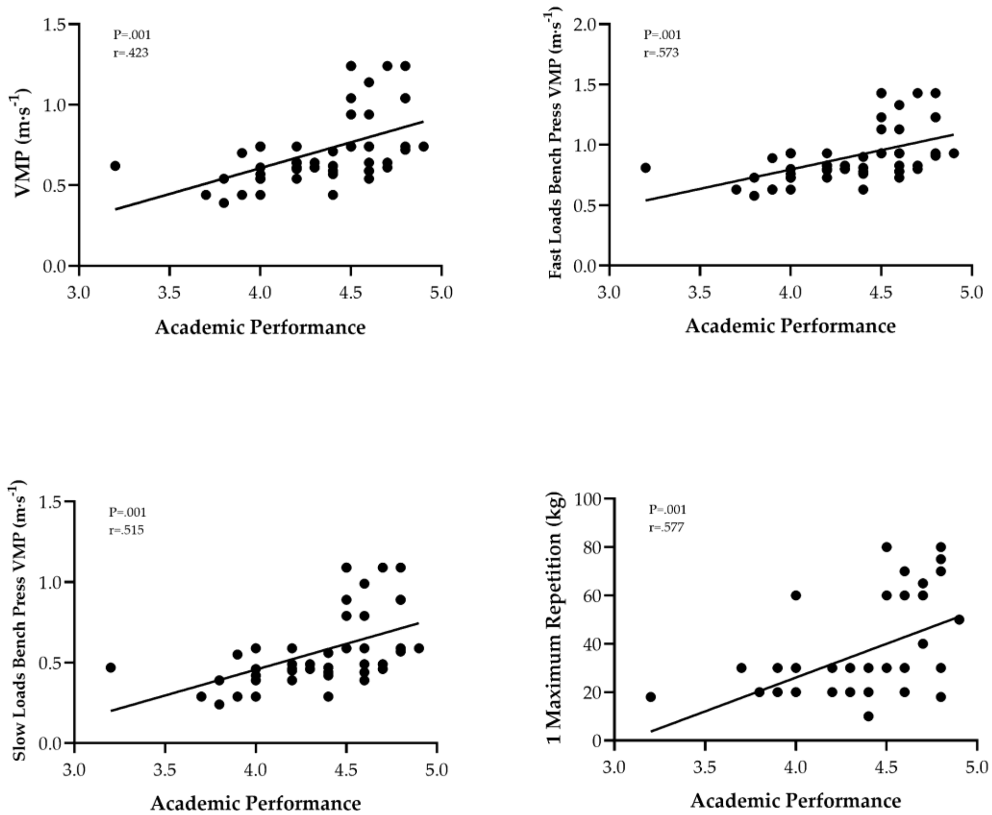

Figure 2. Bench press.

DISCUSSION AND CONCLUSIONS

The main finding of this study was that university students with better neuromuscular performance, understood as a greater ability to move relative loads rapidly and efficiently, demonstrated higher academic achievement. This result is particularly relevant because it provides novel evidence on the relationship between neuromuscular performance and academic achievement in sports training students, a population that has been scarcely addressed in the scientific literature. Most previous studies have focused on school-aged populations or general university students without considering specific neuromuscular performance indicators such as maximal strength and movement velocity.

The positive associations observed between academic achievement and neuromuscular performance variables, including one-repetition maximum and mean propulsive velocity, suggest that neuromuscular fitness may be linked to cognitive and academic functioning. These findings are consistent with previous research indicating that physical fitness and muscular strength are positively associated with academic performance and cognitive outcomes (Esteban-Cornejo et al., 2014; García-Hermoso et al., 2017). These relationships may be explained by physiological adaptations that improve neural efficiency, motor coordination, and central nervous system function, which may contribute to enhanced cognitive processes involved in learning and academic performance.

From a physiological perspective, exercise capable of improving neuromuscular performance has been shown to increase brain plasticity and levels of brain-derived neurotrophic factor (BDNF), facilitating neurogenesis and synaptic plasticity in brain regions involved in memory and learning, such as the hippocampus (Erickson et al., 2011; Voss et al., 2013). Additionally, resistance training stimulates the release of neurotransmitters such as serotonin and norepinephrine, which are associated with improved attention, mood, and cognitive processing (Cigarroa-Cuevas & Zapata-Lamana, 2016). These mechanisms may partially explain the positive associations observed between neuromuscular performance and academic achievement in the present study.

Furthermore, the use of velocity-based indicators such as mean propulsive velocity provides a more specific and sensitive measure of neuromuscular function compared to traditional strength assessments alone. This is particularly relevant because movement velocity reflects the efficiency of neuromuscular activation and coordination, which are influenced by neural factors associated with motor control and central nervous system efficiency (González-Badillo & Sánchez-Medina, 2010; Jiménez-Reyes et al., 2017). Therefore, the ability to produce force rapidly may represent an important physiological characteristic associated with academic performance in physically active university students.

These findings are also consistent with previous studies conducted in university populations that have reported positive associations between muscular strength and academic performance (Peña et al., 2019). However, the present study extends previous knowledge by incorporating both maximal strength and velocity-based neuromuscular indicators, providing a more comprehensive assessment of neuromuscular performance. This approach allows for a better understanding of the potential relationship between neuromuscular function and academic achievement in sports training students.

From an educational and practical perspective, these findings suggest that neuromuscular performance may represent an important physiological factor associated with academic success in sports training students. Strength and velocity-based training strategies may contribute not only to physical performance improvements but also to cognitive and academic functioning. Given the physical and academic demands faced by students enrolled in sports training programs, optimizing neuromuscular performance may support both their physical development and academic performance. Universities and sports training programs may consider integrating structured neuromuscular training strategies as part of comprehensive educational and performance development programs.

From a public health perspective, promoting neuromuscular development during early adulthood may contribute to healthier lifestyles and improved long-term health outcomes. Physical exercise has been shown to improve overall physical and mental health and reduce the risk of chronic diseases (Warburton et al., 2006), while also supporting cognitive function and academic performance. Therefore, neuromuscular fitness may represent an important component of student well-being and academic success.

This study presents several limitations that should be acknowledged. First, the cross-sectional design does not allow causal relationships to be established between neuromuscular performance and academic achievement. Second, the relatively small sample size and the imbalance in sex distribution may limit the generalizability of the findings to broader university populations. Third, other factors known to influence academic achievement, such as sleep quality, psychological stress, cognitive abilities, academic workload, and study habits, were not controlled in this study. Additionally, differences in training experience and lifestyle behaviours may have influenced both neuromuscular performance and academic achievement. Future longitudinal and experimental studies are needed to confirm these findings and to determine whether improvements in neuromuscular performance can directly contribute to improvements in academic achievement.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. William Felipe Martin-Aleman contributed to data collection, statistical analysis, and manuscript drafting. Angie Carolina Tovar Quintero contributed to study design and epidemiological supervision. Yordan Rene Pardo Daza and John Fredy Rodriguez contributed to data acquisition and interpretation. Luis Andres Tellez contributed to methodological supervision. Jhonatan Camilo Peña conceived the study, supervised the research process, and critically revised the manuscript. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

ETHICS APPROVAL

This study was approved by the Institutional Ethics Committee of Fundación Universitaria del Área Andina (Approval Code: CVF2020-IM-B02) and conducted in accordance with the ethical standards established in the Declaration of Helsinki. All participants provided written informed consent prior to participation.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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