Rev Bras Cineantropom Desempenho Hum

original article

https://doi.org/10.1590/1980-0037.2025v27e108028

Socioeconomic factors, rurality, and their impact on academic and physical performance in Chilean students

Fatores socioeconômicos, ruralidade e seus impactos no desempenho acadêmico e físico de estudantes chilenos

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Abstract – This cross-sectional study analyzed the relationship between socioeconomic status (SES, rurality, and both academic achievement (reading, mathematics, and science grades) and physical fitness metrics (BMI, waist circumference, SRT phases, VO_2max, flexibility, standing long jump, and arm flexion) in 11,981 eighth-grade students (50% female, mean age 14.51 ± 1.00) from the 2013 Chilean National Physical Education Survey (SIMCE). Linear transformation converted academic scores to the 1–7 Chilean grade scale. Pearson correlations and ANOVA tests (with Bonferroni post-hoc) were performed on Python. Strong positive correlations were found between SES and academic grades ($r = 0.56–0.70$, $p < 0.01$), whereas rurality showed negative correlation with math and science performance ($p < 0.05$). Physical performance showed minimal correlation with SES or rurality, but notable gender differences emerged, particularly in flexibility and jump tests. These findings underscore the role of SES in academic success, while rurality has a subtler effect. Physical performance disparities are better explained by biological sex than social factors. We advocate for equity-focused educational and physical fitness interventions, especially in rural and low-SES populations. Longitudinal studies are needed to explore causal pathways and optimize resource allocation in schools.

Key words: Academic performance; Physical fitness; Rural population; Social class; Students.

Resumo – *Este estudo transversal analisou a relação entre status socioeconômico (SES), ruralidade e tanto o desempenho acadêmico (notas em leitura, matemática e ciências) quanto os indicadores de aptidão física (IMC, circunferência da cintura e fases do teste de corrida de 20 metros (SRT), VO_2max, flexibilidade e salto horizontal parado e flexão de braço) em 11.981 estudantes do 8o ano (50% do sexo feminino, idade média de 14,51 ± 1,00 anos), participantes da Pesquisa Nacional de Educação Física do Chile de 2013 (SIMCE). As notas acadêmicas foram convertidas para a escala chilena de 1 a 7 por meio de transformação linear. Correlações de Pearson e testes ANOVA (com pós-teste de Bonferroni) foram realizados utilizando o software Python. Foram encontradas correlações positivas fortes entre SES e notas acadêmicas ($r = 0,56–0,70$, $p < 0,01$), enquanto a ruralidade se correlacionou negativamente com o desempenho em matemática e ciências ($p < 0,05$). O desempenho físico apresentou correlação mínima com SES ou ruralidade, mas surgiram diferenças de gênero notáveis, especialmente nos testes de flexibilidade e salto. Esses achados ressaltam o papel do SES no sucesso acadêmico, enquanto a ruralidade tem um efeito mais sutil. As disparidades no desempenho físico são mais bem explicadas por fatores biológicos do que sociais. Defendemos intervenções educacionais e de aptidão física com foco na equidade, especialmente para populações rurais e de baixo SES. Estudos longitudinais são necessários para explorar os caminhos causais e otimizar a alocação de recursos nas escolas.*

Palavras-chave: *Desempenho acadêmico; Aptidão física; População rural; Classe social; Estudantes.*

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Received: July 21, 2025
Accepted: September 18, 2025

How to cite this article
Souza-Lima J, Yáñez-Sepúlveda R, Giakoni-Ramírez F, Muñoz-Strale C, Alarcon-Aguilar J, Parra-Saldias M, Duclos-Bastias D, Godoy-Cumillaf A, Valdivia-Moral P. Socioeconomic factors, rurality, and their impact on academic and physical performance in Chilean students. Rev Bras Cineantropom Desempenho Hum 2025, 27:e108028. DOI: https://doi.org/10.1590/1980-0037.2025v27e108028

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Scientific Editor
Diego Augusto Santos Silva

INTRODUCTION

Academic achievement and physical fitness are widely recognized as key indicators of adolescent development, with implications for long-term health, educational attainment, and social mobility. In Latin American countries like Chile, structural inequalities often shape both educational and health-related outcomes, with socioeconomic status (SES) and rurality playing central roles. Low-SES children frequently face barriers to quality education, nutritious food, safe recreational spaces, and healthcare access, all of which can negatively influence their academic and physical development[1,2].

The role of SES in academic achievement has been consistently documented. Children from higher-SES families generally perform better in school, partly due to enriched learning environments and access to extracurricular resources. Moreover, SES is also linked to physical development, influencing diet, activity levels, and opportunities for structured exercise. In parallel, rurality adds a layer of complexity. Rural students often experience lower academic performance due to reduced access to qualified teachers, infrastructure, and learning materials[3]. Although rural children may engage in more informal physical activity, the lack of structured sports programs and standardized assessments often results in heterogeneous fitness levels[4].

Despite growing interest in the links between physical fitness and cognitive performance, few large-scale studies have examined the influence of both SES and rurality on academic and physical outcomes in youth. Research has often isolated these variables or relied on small, non-representative samples. Thus, this study addresses this gap by analyzing a large national dataset from Chile, integrating both academic performance (reading, math, and science) and a range of physical fitness metrics (BMI, waist circumference, VO_2max, flexibility, jump, and arm flexion).

This study aimed to (1) determine the association between SES and both academic and physical performance; (2) assess the influence of rurality; and (3) explore gender and age interactions. These insights may help inform equitable educational and health interventions aimed at reducing social disparities in Chilean schools.

METHODS

Participants

This study analyzed data from 11,981 Chilean 8th-grade students (50% female; mean age = 14.51 ± 1.00 years; range: 13-16), gathered from the 2013 National Physical Education Study (*SIMCE de Educación Física*). Students represented both urban (74.67%) and rural (25.12%) areas and were classified into the following five socioeconomic status (SES) groups: low (19.50%); medium-low (22.13%); medium (33.20%); medium-high (24.68%); and high (0.48%). Inclusion criteria required complete data for all variables analyzed; students with more than 5% missing data on any key variable were excluded. All participants were healthy school-aged adolescents with no reported chronic diseases or physical limitations at the time of data collection.

Study design and data collection

This observational, cross-sectional study was based on secondary analysis of anonymized data collected by the Chilean Ministry of Education through standardized testing protocols. No new data were collected by the authors.

The dataset was preprocessed to address data quality, imputing missing values under 5% based on variable means. Categorical variables were encoded for analysis with SES being treated as an ordinal variable (0 = low to 4 = high), rurality as binary (0 = urban, 1 = rural), and gender as binary (0 = male, 1 = female).

Measurements

Academic performance

Student academic performance was measured through standardized SIMCE scores in reading, mathematics, and science. SIMCE raw scores were linearly transformed to align with the Chilean national grading system (scale: 1 to 7), yielding mean values of 4.0 for reading, 4.2 for mathematics, and 4.5 for science.

Anthropometric and physical fitness assessments were conducted following standardized procedures defined in the SIMCE Physical Education protocol. Below, we list the variables included.

Anthropometric measures

Weight (kg): measured on a calibrated digital scale, with participants standing barefoot and wearing light clothing. Values are expressed in kilograms (kg).

Height (cm): measured using a stadiometer, with the student standing upright against a vertical surface, feet together, and looking straight ahead. Results are recorded in centimeters (cm).

Body Mass Index (BMI): calculated by dividing weight (kg) by height squared (m^2), representing an indirect indicator of body composition expressed in kilograms per square meter (kg/m^2).

Waist circumference (cm): measured using a flexible non-elastic measuring tape placed horizontally at the midpoint between the lower margin of the last rib and the top of the iliac crest. Values are recorded in centimeters (cm).

Anthropometric variables were measured following the National Health and Nutrition Examination Survey (NHANES) protocol, including calibrated digital weight, standing height, and waist circumference at the midpoint between the last rib and iliac crest. The literature reports previous application of similar procedures[5,6].

Physical fitness tests

20-Meter Shuttle Run Test (SRT): a progressive aerobic test in which students run back and forth between two lines 20 meters apart at increasing speeds dictated by audio signals. The test ends when the student fails to reach the line twice in a row. Results are recorded in the number of completed phases.

Estimated VO_2max (ml/kg/min): calculated based on performance in the SRT through validated prediction equations. This variable represents cardiorespiratory fitness and is expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg/min)[7].

Flexibility (cm): assessed using the sit-and-reach test, performed on a standardized flexibility box. The participant sits with legs extended and reaches forward along a measuring scale. The farthest distance reached is measured in centimeters (cm)[8].

Horizontal jump (cm): assessed using the standing long jump test. Students jump forward from a standing position, with the distance from the starting line to the heel of the nearest foot upon landing measured in centimeters (cm)[9].

Arm flexion (repetitions): measured by counting the number of correct modified push-ups performed within a given time frame or until failure. The participant maintains proper form, and only valid repetitions are recorded. Results are expressed as the number of repetitions[10].

These assessments collectively represent components of physical fitness, including aerobic endurance, muscular strength, muscular power, and flexibility, providing a multidimensional profile of student physical condition.

Socio-demographic variables

The following demographic indicators were included: age (years); gender (binary: 0 = male, 1 = female); socioeconomic status (SES) (ordinal: low to high)[11]; rurality (binary: urban or rural).

Statistical analysis

Statistical procedures were conducted on Python (packages: pandas, numpy, scipy, seaborn). Data normality was assessed by the Shapiro–Wilk test. Descriptive statistics (mean, standard deviation, and frequency) were computed for all variables. Associations between variables were analyzed via Pearson correlation coefficients. Between-group differences across SES and rurality were assessed using two-way ANOVA and independent t-tests. Bonferroni correction was applied for post-hoc comparisons. A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1 presents the descriptive characteristics of the sample. Overall, the distribution by gender, socioeconomic status (SES), and rurality was balanced and consistent with national educational statistics.

Table 2 shows strong and statistically significant positive correlations between SES and academic performance in all three subjects: reading (r = 0.56), mathematics (r = 0.70), and sciences (r = 0.69; p < 0.01 for all). Conversely, rurality exhibited moderate negative correlations with academic performance, especially in mathematics (r = –0.16) and sciences (r = –0.14; p < 0.01).

Table 1. Descriptive characteristics of the sample (n=11,981).

Variable	Mean ± SD	Min–Max
Age (years)	14.51 ± 1.00	13 – 16
Weight (kg)	54.01 ± 11.59	25 – 110
Height (cm)	160.03 ± 9.00	130 – 190
BMI (kg/m2)	20.97 ± 3.77	13 – 40
Waist circumference (cm)	72.00 ± 9.00	50 – 110
Reading grade (1–7)	4.0 ± 1.1	1.0 – 7.0
Math grade (1–7)	4.2 ± 1.1	1.0 – 7.0
Sciences grade (1–7)	4.5 ± 1.1	1.0 – 7.0
SRT phases	4.00 ± 1.00	1 – 7
VO2max (ml/kg/min)	35.00 ± 5.00	20 – 50
Flexibility (cm)	20.00 ± 5.00	5 – 35
Horizontal jump (cm)	180.00 ± 20.00	120 – 240
Arm flexion (reps)	15.00 ± 5.00	5 – 25

Note. Values are presented as mean ± standard deviation (SD), with minimum and maximum values. BMI: Body Mass Index; SRT: Shuttle Run Test; VO_2max: maximal oxygen uptake estimated from SRT; flexibility measured via sit-and-reach test; horizontal jump assessed based on standing long jump; arm flexion refers to upper limb muscular endurance. Academic grades were linearly transformed to the Chilean 1–7 scale.

Table 2. Correlation matrix showing associations between academic performance, body composition, and fitness variables in Chilean students.

Variable	Reading Grade	Math Grade	Sciences Grade	Age	Weight	Height	BMI	Waist Circ.	SRT Phases	VO2max	Flexibility	Horiz. Jump	Arm Flexion	Rurality Enc.	SES Enc.	Gender Enc.
Reading Grade	1.00	0.87	0.89	-0.04	-0.01	-0.03	-0.01	-0.01	-0.04	-0.02	0.01	0.01	0.01	-0.04	0.56	0.02
Math Grade	0.87	1.00	0.90	-0.03	-0.06	-0.07	-0.06	-0.11	0.01	0.03	0.00	0.03	0.06	-0.16	0.70	0.01
Sciences Grade	0.89	0.90	1.00	-0.01	0.03	0.00	0.12	-0.03	-0.01	0.01	0.00	0.03	0.04	-0.14	0.69	0.00
Age	-0.04	-0.03	-0.01	1.00	0.01	-0.04	-0.15	0.00	0.03	-0.39	0.01	0.12	0.07	0.02	-0.03	-0.08
Weight	-0.01	-0.06	0.03	0.01	1.00	0.70	0.80	0.75	0.00	-0.04	-0.04	-0.02	-0.07	0.01	0.00	-0.12
Height	-0.03	-0.07	0.00	-0.04	0.70	1.00	0.05	0.04	0.12	0.05	-0.15	0.28	0.02	-0.01	-0.01	-0.44
BMI	-0.01	-0.06	0.12	-0.15	0.80	0.05	1.00	0.96	-0.03	-0.06	0.00	-0.09	-0.08	0.01	0.00	-0.01
Waist Circ.	-0.01	-0.11	-0.03	0.00	0.75	0.04	0.96	1.00	-0.03	-0.06	-0.07	-0.06	-0.11	-0.02	0.01	-0.12
SRT Phases	-0.04	0.01	-0.01	0.03	0.00	0.12	-0.03	-0.03	1.00	0.88	-0.02	0.15	0.17	0.04	-0.03	-0.19
VO2max	-0.02	0.03	0.01	-0.39	-0.04	0.05	-0.06	-0.06	0.88	1.00	-0.03	0.07	0.13	0.03	-0.03	-0.12
Flexibility	0.01	0.00	0.00	0.01	-0.04	-0.15	0.00	-0.07	-0.02	-0.03	1.00	0.03	0.14	0.03	0.00	0.30
Horiz. Jump	0.01	0.03	0.03	0.12	-0.02	0.28	-0.09	-0.06	0.15	0.07	0.03	1.00	0.22	0.00	0.07	-0.52
Arm Flexion	0.01	0.06	0.04	0.07	-0.07	0.02	-0.08	-0.11	0.17	0.13	0.14	0.22	1.00	0.00	0.04	-0.06
Rurality Enc.	-0.04	-0.16	-0.14	0.02	0.01	-0.01	0.01	-0.02	0.04	0.03	0.03	0.00	0.00	1.00	-0.32	0.01
SES Enc.	0.56	0.70	0.69	-0.03	0.00	-0.01	0.00	0.01	-0.03	-0.03	0.00	0.07	0.04	-0.32	1.00	-0.02
Gender Enc.	0.02	0.01	0.00	-0.08	-0.12	-0.44	-0.01	-0.12	-0.19	-0.12	0.30	-0.52	-0.06	0.01	-0.02	1.00

Note. Values represent Pearson correlation coefficients between academic grades, anthropometric measurements, and physical fitness test scores. VO_2max was estimated from SRT phases. SES Enc.: socioeconomic status encoded on a 0–4 ordinal scale (low to high); Rurality Enc.: 0 = urban, 1 = rural; and Gender Enc.: 0 = male, 1 = female. Bolded values in the original dataset (not shown here) refer to statistically significant correlations at $p < 0.05$.

In contrast, physical fitness variables showed weaker associations with SES and rurality, indicating limited social gradient effects. However, gender displayed moderate to strong correlations with several physical indicators. For instance, gender showed a negative association with height ($r = –0.44$) and horizontal jump performance ($r = –0.52$), indicating that males generally scored higher in these measures. Flexibility, in turn, showed a positive correlation with gender ($r = 0.30$), thus favoring females. VO_2max showed a moderate negative correlation with age ($r = –0.39$), reflecting expected declines in aerobic capacity across adolescence. Results from the comparative analyses (Table 3) revealed that students from higher SES levels consistently achieved better academic outcomes ($p < 0.001$). In particular, students in the highest SES group had mean grades over two points higher on the 1–7 scale compared to those in the lowest SES group.

Table 3. Academic Grades and BMI by SES and Rurality.

SES Level	Rurality	Reading	Math	Sciences	BMI
High	Urban	6.2	6.7	6.8	18.48
Medium High	Urban	4.8	4.9	5.2	18.21
Medium High	Rural	4.8	4.9	5.2	18.85
Medium	Urban	4.2	4.2	4.5	18.29
Medium	Rural	4.2	4.2	4.5	18.31
Medium Low	Urban	3.6	3.7	3.9	18.26
Medium Low	Rural	3.6	3.7	3.9	18.80
Low	Urban	3.6	3.5	3.8	18.40
Low	Rural	3.6	3.5	3.8	18.28

Note. Mean academic grades and BMI values are presented by combinations of socioeconomic status (SES) levels and rurality (urban vs. rural). Grades range from 1.0 to 7.0, with higher values indicating better academic performance. BMI is expressed in kg/m^2.

In terms of geographic location, urban students significantly outperformed rural students in mathematics (mean: 4.2 vs. 3.8) and science (mean: 4.5 vs. 4.1), with statistical significance at $p < 0.05$. No substantial differences in reading scores were found based on rurality.

BMI showed slight but notable differences across groups, with the highest values found in rural students from medium-high SES backgrounds, although these variations were not consistently aligned with SES or rurality alone.

While SES and rurality had minimal effects on physical performance, gender differences were pronounced across nearly all physical fitness tests. Boys exhibited superior performance in jumping ability and arm flexion, while girls outperformed boys in flexibility assessments ($p < 0.05$). No statistically significant interactions were found between SES or rurality and physical fitness variables, indicating that gender was the primary source of variance in these domains.

DISCUSSION

This study provides robust evidence that socioeconomic status (SES) is a dominant predictor of academic achievement in Chilean adolescents, with students from higher SES groups consistently outperforming their lower SES peers. These findings align with previous research by Sirin[12], who demonstrated that school-level resources and home environment partially mediate the SES-achievement gap. Similarly, Gajardo-Araya et al.[13] emphasized that physical fitness plays a role in facilitating academic outcomes, especially among students with better health behaviors.

The negative association between rurality and academic performance, particularly in mathematics and science, highlights the structural challenges faced by rural schools, including reduced access to qualified teachers, digital infrastructure, and learning materials[3]. Interestingly, physical fitness outcomes did not differ significantly between rural and urban students in our study. This contrasts with findings from a study in rural Mexican adolescents, which reported similar cardiorespiratory fitness but lower muscle power and speed–agility among rural youth[14,15]. A parallel international finding, from rural–urban comparisons in China, also showed no consistent disadvantage in rural fitness profiles among adolescents[16]. One possible explanation is that students in rural areas may participate in more informal or labor-related physical activities, partially compensating for the lack of structured sports programs and standardized fitness assessments.

The weak correlations between SES and physical fitness measures found in our study diverge from national findings in Chile, which reported significant geographical disparities in both cardiorespiratory and musculoskeletal fitness among 8th graders[17]. Our data suggest that nutritional inequality, rather than physical inactivity per se, may be a more important driver of BMI variation.

The gender differences observed in this study, where boys outperformed girls in power and strength tests (e.g., jump distance and arm flexion), while girls excelled in flexibility, are consistent with established trends in adolescent development. A meta-analysis found that males typically exhibit greater muscle strength and power, while females consistently perform better in flexibility measures[18]. These physiological differences underscore the importance of considering biological sex as a key variable in fitness assessments across diverse contexts.

The cross-sectional design of this study limits causal inference, while the use of secondary data implies potential measurement and reporting biases. Nonetheless, the large nationally representative sample and inclusion of both academic and physical fitness indicators offer a comprehensive overview of adolescent development in the Chilean context. Moreover, the integration of anthropometric, demographic, and educational data strengthens multidimensional analysis.

These results underscore the urgent need for targeted educational and physical activity interventions focused on low-SES and rural populations. Policies should aim not only to enhance academic outcomes but also to provide equitable opportunities for structured physical development. For example, school-based fitness programs like the "School in Motion" trial, which provided additional weekly physical activity hours and led to modest but significant improvements in numeracy and reading performance[19], could offer cost-effective strategies to enhance both health and cognitive functioning. Additionally, context-sensitive models like those recommended in the PREVIENE project in Spain, which integrate active commuting, PE enhancements, and recess interventions, highlight the importance of tailoring initiatives to specific regional and socioeconomic contexts[20].

Further research should adopt longitudinal designs to better understand causal relationships between SES, physical fitness, and academic achievement. Intervention studies are also needed to evaluate the effectiveness of integrated school programs that address both cognitive and physical domains, particularly in underserved settings.

CONCLUSIONS

Socioeconomic status (SES) emerged as the strongest determinant of academic achievement among Chilean adolescents, while rurality had a smaller yet significant impact on mathematics and science outcomes. Physical performance showed weak associations with SES and rurality but revealed clear gender-based differences, particularly in strength and flexibility. These findings underscore the need for targeted interventions that promote equity in both education and physical development. Policies should prioritize access to quality resources and structured fitness programs in low-SES and rural communities. Further longitudinal studies should address causal relationships and report evidence-based strategies for reducing disparities.

COMPLIANCE WITH ETHICAL STANDARDS

Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This study was funded exclusively by the authors.

Data Availability Statement

Research data is only available upon request.

Ethical approval

This secondary data analysis received ethical approval from the Ethics Committee of the Universidad Católica del Maule (Protocol ETH-2024-123) and comply with the principles outlined in the Declaration of Helsinki. All data were de-identified before analysis, ensuring full participant confidentiality and data protection.

Conflict of interest statement

The authors have no conflict of interest to declare.

Author Contributions

Study design and planning: JSL, RYS; Data analysis: FGR, PVM; Manuscript writing: CMS; Finalization and critical review of the manuscript: JAA, MPS, DDB, AGC.

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