Evolutionary analysis of physical strength capacity in Ecuadorian physical education

Abstract

The aim of this literature review was to analyze the evolution of physical strength within the context of school physical education, considering variables such as age, sex, and pedagogical intervention methods. To this end, more than 40 studies published between 2000 and 2024 in specialized databases such as PubMed, Scopus, and SciELO were reviewed. The results show that muscle strength develops naturally, linked to maturational processes, with a significant increase during puberty, especially in boys, due to hormonal factors (increased testosterone) and changes in body composition. In girls, progress is more gradual and less pronounced, although it also improves with appropriate training programs. The study demonstrates that the inclusion of specific strength training methods, adapted to each developmental stage, has a positive effect on both improving strength and preventing injuries, as well as on developing basic motor skills. The literature highlights that strength training at an early age, if properly planned and supervised, does not pose health risks, debunking myths about possible negative effects on growth. It concludes that the didactic treatment of strength in school physical education should consider developmental and gender differences, as well as the individualization of workloads and methods, to promote the student's comprehensive development.

Keywords: Strength, Physical Education, Training, Motor Skills, Physical Capacities

Introduction

Strength is one of the fundamental physical capacities that underpin motor development and physical performance in school-aged children. Its appropriate stimulation from an early age not only contributes to improved performance in sports and recreational activities, but also plays a crucial role in injury prevention, the adoption of active lifestyles, and the promotion of overall health (Stricker et al., 2020; Garthe et al., 2020). In the context of Physical Education, strength

development has been the subject of debate due to the existence of myths related to its impact on the growth and maturation of children and adolescents (Moran et al., 2018; Lesinski et al., 2020).

Several studies have shown that strength development is closely linked to biological factors such as age, sex, hormonal changes, and neuromuscular adaptations, which determine the differences in the development of this capacity throughout childhood and adolescence (Moreno-Torres et al., 2025; Miñanes -Rufo et al., 2023). However, the effectiveness of intervention programs in schools also depends on pedagogical factors, such as the correct dosage of training loads, the choice of appropriate methods, and consideration of each student's individual characteristics (de Souza et al., 2022; Fernández-Chacón & Bayas-Machado, 2021).

Furthermore, the literature has highlighted that well-structured strength training programs not only improve overall physical fitness but also boost self-esteem, adherence to physical activity, and academic performance in schoolchildren (Faigenbaum et al., 2016; Masanovic et al., 2020). Incorporating strength exercises into the physical education curriculum has demonstrated benefits in both body composition and metabolic health parameters, underscoring its importance in preventing chronic non-communicable diseases from an early age (Stricker et al., 2020; García-Hermoso et al., 2018).

Furthermore, it has been shown that the response to strength stimuli varies according to the level of biological maturation of children and adolescents, which implies the need to design adapted programs that respect individual developmental stages to avoid the risk of overload or stagnation of progress (Behm et al., 2017; Moran et al., 2018). Similarly, the integration of playful and motivational methodologies has proven effective in increasing active participation and enjoyment among schoolchildren during training sessions (García-Roca et al., 2020; Marcillo Iza et al., 2022).

Gender differences influence strength development, as males typically reach higher levels of absolute strength after puberty, while girls show more moderate increases due to hormonal and structural factors. However, both sexes improve significantly with well-adapted strength training programs (Lesinski et al., 2020; Miñanes -Rufo et al., 2023).

This literature review analyzes the evolution of physical strength capacity in the educational field, compiling scientific evidence on its development at different school stages and offering didactic guidelines for its appropriate implementation in Physical Education. It highlights the importance of planning strength training based on principles of individualization, progression, and variety, incorporating alternative materials and motor games that promote a holistic approach, encompassing physical, psychological, and social dimensions (Fernández-Chacón & Bayas-Machado, 2021; García-Roca et al., 2020; Moquera Nazareno & Suntaxi , 2024).

Methodology

A systematic literature review was conducted following the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta- Analyses) to ensure rigor, transparency, and reproducibility in the selection and analysis of studies (Page et al., 2021). This approach is widely recognized in sports science and physical education research for its ability to objectively synthesize the available scientific evidence (Moher et al., 2009).

The search was conducted between January and May 2025 in the specialized databases Scopus , PubMed, Web of Science and EBSCO were selected for their relevance in the areas of health sciences, sports, and education. The search strategy included controlled and free-text terms such as: “strength,” “ resistance training,” “ strength training,” “muscular fitness,” “ child ,” “ adolescent ,” and “ physical .” education ”, combined using boolean operators (AND/OR) to optimize the retrieval of relevant articles (Lesinski et al., 2020; Garthe et al., 2020).

The search limits included publications between 2018 and May 2025, in English and Spanish, in order to incorporate recent studies that reflect current trends in strength training in school populations (Moran et al., 2018; de Souza et al., 2022).

Inclusion criteria:

Studies with school population between 6 and 18 years old.

Direct (dynamometry, 1RM, vertical jump) or indirect (physical test batteries) assessments of strength capacity.

Methodological design of the type meta-analysis, systematic review or experimental/intervention study.

Studies developed in school contexts or whose applicability is directly to school Physical Education.

Exclusion criteria:

Research with adult populations (>18 years) or focused on high-performance athletes, because their physiology and training contexts differ substantially from the school population (Faigenbaum et al., 2016).

Articles without access to full text, which prevents a comprehensive evaluation of the methodology and results.

Observational studies that did not include intervention or that did not specifically evaluate the strength variable (Masanovic et al., 2020).

The study selection process included the reading of titles, abstracts, and full texts by two independent reviewers, with discrepancies resolved by consensus or consultation with a third reviewer, following the recommendations of Moher et al. (2009). The methodological quality of the included studies was assessed using the PEDro tool for clinical trials or AMSTAR-2 for systematic reviews and meta-analyses (Shea et al., 2017), ensuring the internal validity of the integrated evidence.

Population and sample

The target population consisted of scientific studies related to the development of strength capacity in schoolchildren. The final sample comprised 30 key studies selected after an initial screening process of over 1000 records. The sample included:

- 4 international meta-analyses on strength training in schoolchildren.

- 2 systematic reviews (one global and one Ibero-American).
- 24 original studies of intervention or strength assessment in a school context.

Additionally, 3 studies conducted in Ecuador were considered, which provided specific data on the national context.

Methods, techniques and procedures

The methodological process was developed in the following phases:

Systematic bibliographic search in the indicated databases, applying the descriptors and filters of date, language and school population.

Screening of titles and abstracts to discard irrelevant studies (n=1000 initial records).

Full text review to assess the methodological and thematic relevance of the preselected articles (n=85).

Application of PRISMA criteria for the final selection (n=30 studies), ensuring methodological quality and thematic relevance.

Data extraction from each selected article: study design, sample size, age and gender of participants, duration and intensity of interventions, variables evaluated (maximum strength, muscle endurance, power, VO2max), main findings and pedagogical recommendations.

Narrative and comparative synthesis of results, differentiating by age groups (6–11 and 12–18 years), sex and type of intervention.

Results and discussion

- The evolution of strength follows a pattern of progressive increase associated with neuromuscular maturation in childhood (6–11 years) and hormonal factors (especially in males) in adolescence (12–18 years).

- Calisthenics interventions and motor games in children showed significant improvements in strength-endurance without requiring specialized equipment.
- Structured strength programs (HIIT, progressive loads) of 6–12 weeks demonstrated improvements in maximum strength and power in adolescents, with notable increases in VO_2max and speed.
- A sustained global decline in muscle strength and endurance was observed since the 1990s, associated with sedentary lifestyles and less time spent on physical activity at school.
- The differences between the sexes were minimal in prepuberty , widening after puberty in favor of males in absolute strength, but not in relative strength.
- No negative effects on growth, epiphyseal plates, or bone health were reported when the interventions were supervised and well-dosed.
- Cognitive (attention, working memory) and emotional (self-esteem) improvements were evident after 8-week strength programs.
- Ecuadorian studies confirmed these global trends, with specific findings such as a positive correlation between frequency of physical activity and strength, and a decrease in strength-endurance in sedentary schoolchildren.

Table 1. Summary of Effects of Force Interventions by Age Group

Age Group	Type of Intervention	Main Results	Additional comments
6 – 11 years (childhood)	Calisthenics (push - ups, planks , curl - ups), motor games, recreational activities	Improved strength-endurance, coordination, neuromuscular activation	No changes in muscle mass; cognitive benefits observed (attention, concentration)
12-18 years (pre-adolescence and adolescence)	Calisthenics + HIIT + strength training with progressive overload (40-60%	Increase in absolute strength (greater in males), muscle power, VO_2max ,	Hormonal changes (testosterone/estrogens) make a difference in absolute strength gains

Age Group	Type of Intervention	Main Results	Additional comments
	1RM)	speed	

Table 2. Effects of Strength Training on Physical, Metabolic, Cognitive and Psychosocial Variables

Variable evaluated	Observed effects	Level of evidence*	Comments
Muscle strength	↑ Maximum strength, strength-endurance, power	High	Best results with programs ≥6 weeks, 2-3 sessions/week
Body composition	↓ Body fat, ↑ lean mass	Moderate	Associated with progressive overload and calisthenics programs
Bone mineral density	↑ Bone density without epiphyseal plate involvement	High	Supervised training does not pose a risk to growth
Metabolic health	↑ Insulin sensitivity, improved lipid profile	Moderate	More consistent effects in adolescents; lack of longitudinal studies
Cognition	↑ Attention, working memory	Moderate	8-week strength + endurance programs show improvements
Emotional state	↓ Anxiety, ↑ self-esteem	Low to moderate	Need for more specific controlled studies
Academic performance	Trend towards improvement in executive functions	Low	Insufficient longitudinal school studies

Table 3. Main Differences by Sex and Biological Maturation

Variable / Age	Prepuberty (6–11 years)	Puberty (12–18 years)	Key comments
Relative strength (relative to body weight)	Minimal differences between the sexes	Marked increase in post-pubertal males	Influence of testosterone in men
Absolute strength	Similar in boys and girls	Higher in males	Related to muscle mass and bone mass
Response to training	Primarily neuromuscular	Obvious hypertrophy in men	The girls are improving, but to a lesser extent.
Motivation and adherence	No clear differences reported	Few studies differentiated by sex	It is recommended to investigate self-efficacy and motor perception.

Level of evidence (according to a synthesis of reviewed studies):

- High: Consistent results in ≥3 high-quality studies.
- Moderate: Consistent results, but with methodological limitations or heterogeneity.
- Low: Limited or inconsistent evidence.

The findings of this review reaffirm the importance of integrating strength training into school physical education from an early age, as an essential strategy for the comprehensive development of children and adolescents. Numerous studies agree that well-structured and supervised strength training programs not only increase physical capacity (Moran et al., 2018; Lesinski et al., 2020), but also provide benefits in metabolic terms (reduced risk of obesity and insulin resistance), bone health (increased bone mineral density), cognitive function (improvements in executive functions), and psycho-emotional well-being. (increased self-esteem and intrinsic motivation) (Faigenbaum et al., 2016; Stricker et al., 2020).

Scientific evidence confirms that strength training in school-aged children is safe and effective with proper supervision, even in pre-pubertal and pubescent children. Its planning should be

tailored to the level of biological maturation, also considering socio-environmental factors that affect their development. However, gaps remain in the research, such as the lack of longitudinal studies and standardized protocols. A playful, progressive and individualized approach is recommended , with the involvement of families and continuous training of teachers to ensure the adherence and effectiveness of these programs (Behringer et al., 2010; Myer et al., 2013; Lloyd & Oliver, 2012; Marcillo Iza et al., 2022; Frómeta et al., 2019; Garthe et al., 2020; Moran et al., 2018; Rodríguez-Rodríguez et al., 2022; de Souza et al., 2022; Miñanes -Rufo et al., 2023; González-Cutre et al., 2019; Stricker et al., 2020; Moquera Nazareno & Suntaxi , 2024).

Conclusions

Recent literature confirms that strength is an essential capacity that can be effectively developed from school age through supervised and adapted training (such as calisthenics, HIIT or resistance training), with a minimum frequency of 2-3 times per week for at least 6 weeks, contributing comprehensively to the physical, cognitive and metabolic health of students.

The findings of this review highlight the importance of systematically and strategically including strength-building activities in school physical education programs. These activities not only contribute to improving specific physical abilities but also have a positive impact on students' bone, metabolic, and psychological health, reducing the risk of chronic diseases in adulthood. This demonstrates that strength training extends beyond mere athletic pursuits, establishing itself as a cornerstone of holistic health and well-being during the school years.

Despite scientific evidence, myths persist about the risks of strength training in school children. Therefore, it is essential to update the training of physical education teachers, integrating the latest advances in this area to implement safe, effective, and motivating strategies that promote the holistic development of students.

The analysis shows that the effectiveness of strength training in school-aged children depends largely on personalizing programs according to individual characteristics, such as biological age, level of maturation, gender, and initial physical condition. Adapting the load, volume, and intensity

is crucial to maximizing benefits and minimizing risks, underscoring the need for an individualized pedagogical approach in Physical Education.

In addition to program design, extrinsic factors such as family support, school culture, and access to suitable facilities play a crucial role in motivating and ensuring the continuity of strength training in children and adolescents. Interventions should involve the educational and family community to promote active and healthy lifestyles, facilitating the incorporation of strength training as a long-term habit.

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