

Cross-sectional relationships between motor coordination and change-of-direction and jumping performance in primary schoolchildren

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Abstract:

Motor coordination and physical fitness interrelated throughout childhood, although the magnitude of this association may differ according to age, sex, and the motor demands imposed by the assessment tasks. This study investigated the relationships between motor coordination and three indicators of physical performance in children aged 6–11 years: the 4 × 10 m shuttle run, standing long jump (SLJ), and countermovement jump (CMJ). The sample comprised 636 children recruited from two public primary schools. Motor coordination was evaluated using the 3JS test. The analyses included prespecified Pearson correlations, multiple linear regression models adjusted for age and sex, and comparisons among coordination groups were defined relative to the sample. Global motor coordination was associated with SLJ performance ($r = 0.405$), 4 × 10 m time ($r = -0.756$), and CMJ performance ($r = 0.438$; Holm-adjusted $p < 0.001$ for all three). In multivariable models, motor coordination remained independently associated with 4 × 10 m time ($\beta = -0.663$), CMJ performance ($\beta = 0.410$), and SLJ performance ($\beta = 0.290$). The full models explained 61.9%, 22.7%, and 19.0% of the variance in these outcomes, respectively. Children in the highest sample-relative coordination group performed better on all three tests. In this sample, motor coordination was consistently associated with change-of-direction and jumping performance, particularly 4 × 10 m performance. The cross-sectional design precludes causal inference, but the findings support the joint assessment of motor competence and physical performance in physical education.

Keywords: Agility, motor competence, muscular strength, Physical Education, physical fitness.

Introduction

The development of motor skills and physical fitness provides an important foundation for active participation during childhood. Both have been associated with health indicators, physical self-concept, academic achievement, and sustained physical activity over time (Chen et al., 2023; Fernández-Álvarez et al., 2020; Moon et al., 2024; Robinson et al., 2015; Stodden et al., 2008). Associations among motor competence, physical fitness, physical activity, and weight status have also been reported in children, with age-related variation (den Ul et al., 2023). A recent systematic review identified motor competence, physical activity, and physical fitness as interrelated components of childhood development, while noting that the strength of the reported associations may be influenced by methodological heterogeneity, participants' age range, and the assessment instruments used (Rosa et al., 2026). In this context, school physical education provides an appropriate setting in which to assess motor competence and offer systematic opportunities for practice.

Motor competence encompasses the proficient execution of locomotor, stability, and object-control skills. Its development may facilitate participation in games and sports and, in turn, may benefit from greater exposure to varied movement experiences and organized sport. Longitudinal studies have shown that sustained participation in club sports is associated with higher levels of motor coordination during childhood (Vandorpe et al., 2012). This bidirectional framework may help explain why children with broader motor repertoires often exhibit more favorable physical fitness profiles (Fort-Vanmeerhaeghe et al., 2017; Luz et al., 2017; Watanabe et al., 2024).

Jumping and change-of-direction tasks are particularly relevant indicators of physical performance. The standing long jump and countermovement jump provide information about lower-limb neuromuscular performance, whereas the 4 × 10 m shuttle run combines acceleration, deceleration, changes of direction, and postural control. These tests are feasible in school settings, although they should not be interpreted as direct measures of maximal strength or reactive agility.

Previous research has identified associations between motor coordination and physical fitness in school-aged children, but some studies have used small samples, restricted age ranges, or exclusively bivariate analyses (Carballo-Fazanes et al., 2022; Gomes et al., 2019; Mazzardo et al., 2024; Ružbarská, 2016; Sortwell et al., 2024). These relationships therefore warrant comprehensive examination across the primary school years, with

adjustment for age and sex and separate consideration of the different components of motor competence: global coordination, locomotion, and object control.

The primary aim was to examine the association between global motor coordination and performance on the 4×10 m shuttle run, standing long jump, and countermovement jump. Secondary aims were to examine associations with the locomotor and object-control dimensions and to describe differences by sex, age, and relative coordination level. We hypothesized that greater motor coordination would be associated with faster 4×10 m times and better jumping performance.

Materials & Methods

Study Design

This was an observational, cross-sectional analytic study. Global motor coordination was the primary predictor; 4×10 m time, standing long jump distance, and countermovement jump height were the dependent variables. Age and sex were included as covariates in the multivariable models. Locomotor and object-control scores were analyzed as secondary variables.

Participants

The sample comprised 636 children aged 6–11 years (mean age = 8.86 ± 1.59 years) from two public primary schools in the province of Seville, Spain. The age and sex distribution is presented in Table 1. Participants were selected through purposive nonprobability sampling. Mean body mass and height were 36.44 ± 10.23 kg and 136.72 ± 10.41 cm, respectively. Children were eligible if their health status was compatible with completing the tests; those with functional limitations, disabilities, or pharmacological treatment that could interfere with performance were excluded.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki (World Medical Association, 2013). Legal guardians received verbal and written information about the study aims and procedures and provided written informed consent. The children received age-appropriate information and participated voluntarily. The study was approved by the Research Ethics Committee of Pablo de Olavide University, Seville, Spain (approval code 25/7-75; approved December 1, 2025).

Measures

- 4×10 m shuttle run. The ALPHA-Fitness battery protocol was followed (Ruiz et al., 2011). Performance was recorded in seconds; a shorter time indicates better performance in running movements with preplanned changes of direction.
- Standing long jump. This test was used as an indicator of horizontal jumping ability and lower-limb neuromuscular performance, following the ALPHA-Fitness protocol (Ruiz et al., 2011). Distance was recorded in centimeters.
- Countermovement jump. A portable infrared optical-bar system was used (Optojump; Microgate, Bolzano, Italy). Participants performed a rapid knee flexion to approximately 90 degrees followed by maximal extension while keeping their hands on their hips. Jump height was estimated from flight time and expressed in centimeters.
- Motor coordination. The 3JS test was administered. The test has been validated for primary schoolchildren and has demonstrated adequate internal consistency, temporal stability, and interrater agreement (Cenizo-Benjumea et al., 2016, 2017). It comprises seven consecutive tasks: vertical jumps over a bar, a longitudinal-axis turn, a one-handed throw, a ball kick, change-of-direction running, hand dribbling while moving, and foot dribbling. It provides a global score and separate locomotor and object-control scores.

Procedure

Measurements were collected in January during scheduled physical education lessons, under comparable conditions and by the same assessors. Testing was conducted on two nonconsecutive days. On the first day, the standing long jump, countermovement jump, and 4×10 m shuttle run were assessed in an indoor gymnasium with polyurethane flooring. On the second day, the 3JS test was administered on a 40×20 m court.

Before testing, participants completed a standardized warm-up consisting of two minutes of joint mobility, two minutes of multidirectional running, and two sets of five bodyweight squats. Tests were performed in the following order: standing long jump, countermovement jump, and 4×10 m shuttle run, with two minutes of recovery between tests.

For the standing long jump, participants completed two trials and the better result was retained. For the countermovement jump, five trials were completed at 20-second intervals; the highest and lowest values were discarded, and the mean of the three middle values was calculated. For the 4×10 m shuttle run, participants completed two trials with full recovery, and the faster time was retained. The intraclass correlation coefficients calculated from the repeated trials were 0.976, 0.981, and 0.977, respectively.

Statistical Analysis

Means and standard deviations were calculated. Overall sex differences were analyzed using independent-samples Student's *t* tests and accompanied by Cohen's *d*. Age-stratified comparisons were considered exploratory and are presented in the supplementary material.

For the bivariate analysis, Pearson correlations were prespecified between each of the three coordination scores—global, locomotor, and object control—and each of the three physical performance indicators. *P* values were adjusted using Holm's procedure. Additional sex- and age-specific correlations were interpreted as exploratory.

Three multiple linear regression models were fitted using the simultaneous entry method.

Each physical performance indicator was entered as the dependent variable in a separate model; global motor coordination was the primary predictor, and age and sex were included as covariates. Sex was coded as 0 = boys and 1 = girls. Unstandardized coefficients (*B*), standardized coefficients (β), 95% confidence intervals, and adjusted *R*² values were estimated. Adjusted *R*² was interpreted as the variance explained by the full model, not as the unique contribution of motor coordination. Multicollinearity was assessed using tolerance and the variance inflation factor.

As a secondary analysis, global motor coordination was classified into three groups relative to the sample distribution: below -0.5 standard deviations, between -0.5 and $+0.5$ standard deviations, and above $+0.5$ standard deviations. Classification was performed independently within each age-by-sex stratum. The sample was first stratified by age (6, 7, 8, 9, 10, and 11 years) and then by sex within each age, yielding 12 strata. These categories are descriptive and do not represent normative cutoffs.

Between-group differences were analyzed using one-way analysis of variance; when variances were heterogeneous, Welch's analysis of variance and Games–Howell pairwise comparisons were used. Bonferroni adjustment was applied to the remaining post hoc analyses. Effect sizes were expressed as eta squared (η^2) and interpreted according to conventional criteria (Cohen, 1988). The alpha level was set at 0.05. Analyses were conducted using IBM SPSS Statistics 29.

Results

Descriptive statistics by age and sex are presented in Table 1. Overall, boys showed higher values for jumping performance and motor coordination and faster 4×10 m times.

Overall sex differences were significant for all four variables; the largest effect size was observed for motor coordination ($d = 1.116$). Age-stratified comparisons are provided in Supplementary Table S1.

Table 1

Descriptive statistics by age and sex. Data are presented as mean $\pm$ standard deviation.

		6 years	7 years	8 years	9 years	10 years	11 years	
n	Boys	39	39	67	60	76	69	
	Girls	26	35	55	58	59	53	
SLJ (cm)	Boys	136.54 $\pm$ 15.8	154.05 $\pm$ 18.9	152.73 $\pm$ 23.2	156.37 $\pm$ 29.2	163.19 $\pm$ 30.1	166.20 $\pm$ 30.1	$\pm$
	Girls	123.42 $\pm$ 13.1	136.54 $\pm$ 16.5	133.76 $\pm$ 30.6	147.76 $\pm$ 27.9	145.40 $\pm$ 29.2	160.51 $\pm$ 29.3	$\pm$
4×10 m (s)	Boys	14.29 $\pm$ 1.05	14.44 $\pm$ 1.35	12.55 $\pm$ 0.74	12.48 $\pm$ 0.92	12.09 $\pm$ 1.15	11.96 $\pm$ 0.94	$\pm$
	Girls	15.46 $\pm$ 1.35	15.28 $\pm$ 1.26	13.38 $\pm$ 1.16	13.02 $\pm$ 1.13	13.01 $\pm$ 1.27	12.70 $\pm$ 0.76	$\pm$
CMJ (cm)	Boys	16.65 $\pm$ 3.33	18.11 $\pm$ 2.88	20.18 $\pm$ 3.77	19.99 $\pm$ 4.73	21.16 $\pm$ 5.17	21.38 $\pm$ 4.91	$\pm$
	Girls	14.78 $\pm$ 3.62	16.48 $\pm$ 3.38	17.66 $\pm$ 3.84	19.30 $\pm$ 4.20	18.89 $\pm$ 4.10	20.89 $\pm$ 4.47	$\pm$
MC (points)	Boys	18.72 $\pm$ 2.53	20.05 $\pm$ 2.61	23.10 $\pm$ 2.65	23.57 $\pm$ 2.64	24.17 $\pm$ 3.12	24.94 $\pm$ 2.80	$\pm$
	Girls	15.35 $\pm$ 2.03	17.31 $\pm$ 1.51	19.55 $\pm$ 2.47	20.59 $\pm$ 1.87	20.03 $\pm$ 2.39	21.06 $\pm$ 2.05	$\pm$

Note. SLJ = standing long jump; CMJ = countermovement jump; MC = motor coordination.

All prespecified correlations remained significant after Holm adjustment (adjusted $p < 0.001$). Global motor coordination was associated with SLJ performance ($r = 0.405$), 4×10 m time ($r = -0.756$), and CMJ performance ($r = 0.438$). Locomotor coordination showed its strongest association with CMJ performance ($r = 0.512$), whereas the strongest association in the study was between global motor coordination and 4×10 m time.

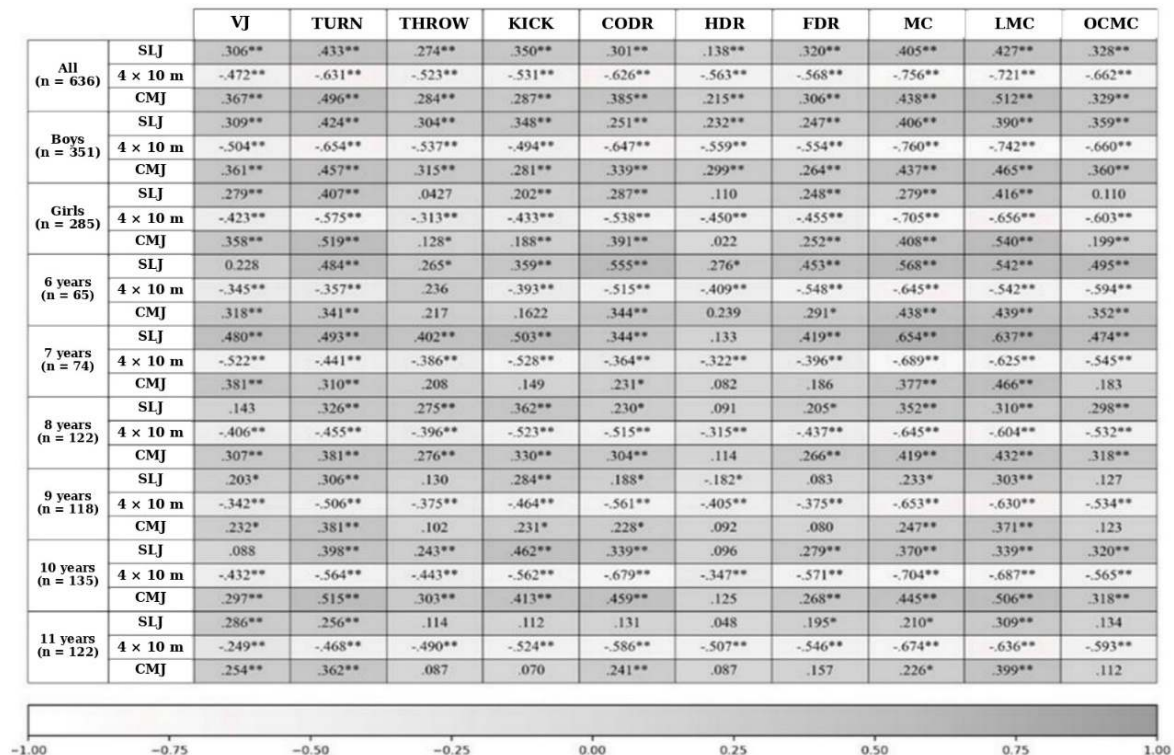


Figure 1. Pearson correlations between motor coordination and physical performance.

Notes. 4 × 10 m = 4 × 10 m shuttle run; CODR = change-of-direction running task; CMJ = countermovement jump; FDR = foot dribbling; HDR = hand dribbling while moving; KICK = ball kick; LMC = locomotor motor coordination; MC = motor coordination; OCMC = object-control motor coordination; SLJ = standing long jump; THROW = one-handed throw; TURN = longitudinal-axis turn; VJ = vertical jumps. ** $p < 0.01$; * $p < 0.05$. For the 4 × 10 m shuttle run, negative values indicate that greater motor coordination is associated with a shorter completion time.

Models adjusted for age and sex are shown in Table 2. Motor coordination remained associated with all three dependent variables after adjustment. The standardized coefficient was largest for 4 × 10 m time ($\beta = -0.663$), followed by CMJ performance ($\beta = 0.410$) and SLJ performance ($\beta = 0.290$). The full models explained 61.9%, 22.7%, and 19.0% of the variance, respectively. No relevant multicollinearity was observed ($VIF \leq 1.92$).

Table 2
Multiple linear regression models adjusted for age and sex.

Dependent variable	Predictor	B	95% CI	β	p	Adjusted R ²
SLJ (cm)	MC	2.40	1.60 to 3.20	0.290	< 0.001	0.190
	Sex	-5.10	-10.00 to -0.20	-0.088	0.043	
	Age	3.10	1.60 to 4.60	0.171	< 0.001	
4 × 10 m (s)	MC	-0.275	-0.303 to -0.248	-0.663	< 0.001	0.619
	Sex	-0.154	-0.326 to 0.018	-0.052	0.079	
	Age	-0.223	-0.277 to -0.170	-0.241	< 0.001	
CMJ (cm)	MC	0.526	0.405 to 0.647	0.410	< 0.001	0.227
	Sex	0.288	-0.468 to 1.043	0.031	0.455	
	Age	0.394	0.158 to 0.630	0.137	0.001	

Note. SLJ = standing long jump; CMJ = countermovement jump; MC = motor coordination; B = unstandardized coefficient; 95% CI = 95% confidence interval. Sex: 0 = boys, 1 = girls. Adjusted R² refers to the full model. For the 4 × 10 m shuttle run, a negative coefficient indicates a shorter completion time.

Because some of the seven tasks included in the global motor coordination score could overlap with the physical performance outcomes, specific sensitivity analyses were conducted to assess the robustness of the observed associations. For the 4×10 m shuttle run, the motor coordination score was recalculated after excluding the running task to assess potential overlap between the two measures. The association between motor coordination without the running task and 4×10 m time remained strong ($r = -0.730$; $p < 0.001$). In the model adjusted for age and sex, motor coordination without the running task remained independently associated with 4×10 m performance ($\beta = -0.634$; adjusted $R^2 = 0.588$). For the jumping outcomes, the motor coordination score was recalculated after excluding the jumping task, and its associations with the standing long jump and countermovement jump were examined to determine whether the observed relationships were driven by overlap in task content. Motor coordination without the jumping task remained significantly associated with SLJ performance ($r = 0.401$; $p < 0.001$) and CMJ performance ($r = 0.437$; $p < 0.001$) and remained an independent predictor of both outcomes in models adjusted for age and sex (SLJ: $\beta = 0.265$; adjusted $R^2 = 0.182$; CMJ: $\beta = 0.376$; adjusted $R^2 = 0.210$). Overall, the associations between motor coordination and physical performance remained consistent after excluding tasks potentially related to each performance test, although the standardized coefficients and explained variance decreased moderately.

The analysis by sample-relative coordination group showed differences in all three tests (Table 3). The upper group outperformed the lower group on every indicator. A graded pattern across all three groups was observed for the 4×10 m shuttle run and CMJ; for SLJ, the middle group did not differ from the lower group. The effect size was large for the 4×10 m shuttle run and moderate for the jumping tests.

Table 3
Physical performance by sample-relative motor coordination group.

Variable	Lower group	Middle group	Upper group	Statistic	η^2	p	Post hoc
SLJ (cm)	144.08 ± 28.0	148.90 ± 28.0	165.84 ± 28.0	F(2, 629) = 29.10	0.085	< 0.001	Upper > middle; upper > lower; middle = lower
4×10 m (s)	13.76 ± 1.55	12.93 ± 1.22	12.09 ± 1.02	Welch's F(2, 396.21) = 85.42	0.191	< 0.001	Upper < middle < lower for completion time
CMJ (cm)	17.89 ± 4.18	19.67 ± 4.36	21.32 ± 4.76	F(2, 633) = 29.79	0.086	< 0.001	Upper > middle > lower

Note. Groups were defined relative to the sample distribution: lower < -0.5 SD; middle from -0.5 to $+0.5$ SD; upper > $+0.5$ SD. These are not normative categories. Groups were defined independently within each of the 12 strata formed by combining age (6–11 years) and sex and were then pooled for presentation in Table 3. For SLJ: $n = 266$, 225 , and 145 ; for the 4×10 m shuttle run and CMJ: $n = 268$, 226 , and 142 . Welch's analysis of variance and Games–Howell comparisons were used for the 4×10 m shuttle run; Bonferroni adjustment was used for the remaining analyses.

Discussion

The main finding was a consistent association between motor coordination and change-of-direction and jumping performance. This relationship remained after adjustment for age and sex and was strongest for the 4×10 m shuttle run. This study extends previous work by analyzing a large sample spanning the primary school years, incorporating the dimensions of the 3JS test, and distinguishing bivariate associations from multivariable models.

The association with the 4×10 m shuttle run is functionally plausible. The test requires acceleration, deceleration, turning, and rapid reorganization of movement within a confined space and therefore shares demands for postural control, spatial orientation, and motor sequencing with locomotor coordination. The findings are consistent with research linking motor competence to performance in locomotor tasks (Cenizo et al., 2022; Gomes et al., 2019; Ružbarská, 2016; Mazzardo et al., 2024). In school settings, motor coordination is associated with exposure to varied movement experiences and with tasks requiring body control, movement adaptation, and motor decision-making (Romeu et al., 2023). However, the magnitude of this association should be interpreted cautiously because the 3JS test includes a change-of-direction running task; some covariance may therefore reflect shared motor content between the predictor and outcome. Nevertheless, the sensitivity analysis excluding this task from the global motor coordination score confirmed that the association remained consistent. Taken together, these findings suggest that the association between motor coordination and change-of-direction performance is not explained solely by the locomotor component included in the original coordination score.

Associations with the standing long jump and countermovement jump were weaker but remained present in the adjusted models. Jumping performance depends not only on force production but also on intersegmental coordination, postural control, temporal synchronization, and efficient force transmission. This pattern is consistent with previous research on motor competence and muscular fitness (Carballo-Fazanes et al., 2022; Luz et al., 2017; Sortwell et al., 2024). Both tests should, however, be described as indicators of neuromuscular performance or jumping ability

rather than direct measures of maximal strength. The sensitivity analyses confirmed that the associations remained after the jumping task was excluded from the motor coordination score, although their magnitude decreased moderately.

The stronger association observed for the 4×10 m shuttle run may reflect the considerable overlap between the neuromuscular demands of this test and the components of locomotor coordination assessed by the 3JS test. The 4×10 m shuttle run requires repeated acceleration, deceleration, changes of direction, and rapid reorganization of movement. The sensitivity analysis indicated that this strong relationship was not attributable solely to direct overlap in task content, because the association remained strong after the running task was removed from the 3JS score. It may instead reflect the close relationship between change-of-direction performance and mechanisms of motor control and perceptual-motor integration. By contrast, standing long jump and CMJ performance depend more heavily on the ability to produce explosive lower-limb force. The weaker associations with the jumping tests may therefore reflect the greater influence of force production and biological maturation on these tasks. Because biological maturation was not assessed, however, this explanation remains hypothetical and cannot be confirmed by the present data. This difference supports the parallel and complementary assessment of motor development from a qualitative perspective, using process-oriented instruments such as the 3JS test, and of quantitative physical fitness, using performance tests such as the 4×10 m shuttle run. Physical fitness tests quantify performance, which is influenced by several factors, including neuromuscular capacity and force production; qualitative assessment identifies the efficiency and quality of the movement pattern and provides complementary information about how movement is organized and executed.

Motor coordination had the largest standardized β coefficient among the predictors in all three models. Nevertheless, adjusted R^2 represents the variance jointly explained by motor coordination, age, and sex; it does not represent the percentage attributable exclusively to motor coordination. This distinction is particularly important for the 4×10 m model, which had a high adjusted R^2 . Quantifying the incremental contribution of motor coordination would require hierarchical models or estimates of partial R^2 , neither of which was available in the present set of results. Sex differences were more pronounced for motor coordination than for jumping performance. Age-stratified comparisons showed a heterogeneous pattern and should be considered exploratory because of the number of comparisons performed. Unmeasured factors, including biological maturation, extracurricular physical activity, sport experience, and differential opportunities for practice, may contribute to these differences (Cenizo-Benjumea et al., 2024; Malina, 2014; Watanabe et al., 2024).

Classification into sample-relative groups provides an applied interpretation but should not be treated as a diagnostic standard. The cutoffs were derived from this sample and describe an internal performance gradient. Their external utility should be examined in independent samples using age- and sex-specific normative values.

From an educational perspective, the findings support the integrated assessment of motor skills and physical performance. Tasks that combine locomotion, jumping, turning, and object control may broaden children's motor repertoires. A cross-sectional study cannot, however, demonstrate that improving coordination alone leads to better physical performance. That hypothesis requires controlled interventions and longitudinal follow-up.

Study strengths include the large sample, broad age range, feasibility of the tests in a school setting, and adjustment for age and sex. Several limitations constrain the conclusions. First, the cross-sectional design precludes establishing temporality or causality. Second, purposive sampling from two schools limits generalizability, and the possible dependence of observations within schools or classes was not modeled. Third, biological maturation, body composition, physical activity, and sport experience were not controlled. Fourth, some 3JS tasks overlap in content with the physical performance tests. Fifth, although sensitivity analyses excluded the change-of-direction running and jumping tasks from the global coordination score, future studies should confirm these findings using longitudinal or experimental designs, multilevel models, and independent samples.

Conclusions

In this sample of schoolchildren, greater motor coordination was associated with faster 4×10 m shuttle-run times and better standing long jump and countermovement jump performance, even after adjustment for age and sex. The association was particularly strong for the 4×10 m shuttle run and may be partly influenced by motor content shared with the 3JS test; however, sensitivity analyses showed that the associations remained after potentially overlapping tasks were excluded. The findings support the joint assessment of motor coordination and physical performance in physical education but do not establish that either variable causes changes in the other.

Practical Applications

The 3JS test, standing long jump, countermovement jump, and 4×10 m shuttle run can be combined to describe motor profiles in school settings. Their use should support educational planning and monitoring rather than isolated individual diagnosis. Teaching programs may integrate progressive tasks involving locomotion, deceleration, changes of direction, jumping, turning, and object control while maintaining specific and balanced physical fitness development. The effectiveness of such interventions should be evaluated in longitudinal or experimental studies.

Conflicts of interest: The authors declare no conflicts of interest.

Declaration of generative AI and AI-assisted technologies in the writing process During the preparation of this work the authors did not use generative AI or AI-assisted technologies.

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