



Vertical Jump Performance, Arm Swing Benefit, and Body Size in Grades 3–5: A Cross-Sectional Study

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Abstract

Objectives. The study aimed to compare vertical jump performance across Grades 3–5, examine associations with body size, and secondarily evaluate arm swing benefits.

Materials and Methods. This cross-sectional school study included 129 pupils from eastern Slovakia (3rd grade, n = 46; 4th grade, n = 50; 5th grade, n = 33). Data on sex, biological maturation, organized sport participation, and habitual physical activity were unavailable. The best of three valid Chronojump attempts was analyzed for countermovement jump without arm swing (CMJ), countermovement jump with free arm swing (CMJ FA), and squat jump (SJ). One-way ANOVA tested grade differences in these primary outcomes. Absolute and relative arm swing benefits were secondary exploratory outcomes. ANCOVA, joint models including height and mass, correlations, nonparametric sensitivity analyses, and grade × mass interactions were also examined.

Results. Primary outcomes did not differ by grade ($p = 0.19–0.59$; eta squared = $0.008–0.026$). Secondary exploratory analyses identified differences in absolute and relative arm swing benefit (both $p = 0.002$; eta squared is approximately 0.09), with higher values in the 5th grade than in the 3rd and 4th grades; nonparametric analyses supported these contrasts. Mass-adjusted ANCOVA revealed that mass was significant for all tests, and a grade effect emerged for CMJ FA ($p = 0.013$). In joint models, height was positively and mass negatively associated with each primary outcome, whereas grade effects and grade × mass interactions were nonsignificant.

Conclusions. The findings indicate that primary jump outcomes showed no statistically detectable differences across adjacent grades. The larger secondary exploratory arm swing benefit in the 5th grade group does not demonstrate developmental change within pupils and may partly reflect unmeasured sex, maturation, or activity characteristics. Body size interpretation depended on model specification. School testing should emphasize standardized procedures and individual feedback rather than diagnostic labeling or ranking by grade.

Keywords: countermovement jump, squat jump, arm swing, body mass, physical education, children.

Introduction

Primary school physical education provides a structured setting for developing motor competence and fundamental movement skills. Physical education delivered through the curriculum and school interventions can improve these outcomes (Lorås, 2020; Yin et al., 2025). Varied movement opportunities may help offset prolonged sitting, while appropriately supervised strength activities may support motor development (Mikuláková & Andraščíková, 2008; León-Reyes et al., 2025).

Jumping is a fundamental locomotor skill requiring lower limb force, postural control, and coordinated

segmental action. Jump height and movement patterns vary substantially among children (Liu et al., 2022; Koren et al., 2016; Gieysztor et al., 2024), and vertical jump performance has also been examined in pupils with different sport specializations (Leütterová et al., 2019). A school jump score therefore reflects performance under defined test conditions rather than overall motor development.

Vertical jump tests are noninvasive, quick, and suitable for field assessment. Different protocols provide distinct information on explosive power, strength endurance, and stretch-shortening cycle performance (Zemková & Hamar, 2005). Reliability has also been examined in volleyball (Zapletalová, 2018), and diagnostic sensitivity varies by protocol (Hespanhol et al., 2013). Bogataj et al. (2020) reported reliable assessment of SJ, CMJ, and CMJ with free arms in primary school children. Pueo et al. (2020) reported

high concurrent validity and reliability of the Chronojump system in physically active adults.

The SJ, CMJ, and CMJ FA provide related but distinct information. Muscle morphology and the capacity to generate force can influence modeled vertical jump performance (Wong et al., 2016), while empirical work identifies lower limb strength and rate of force development as major determinants, with a smaller contribution from technique (Vanezis & Lees, 2005). Free arm movement can increase jump height by altering force–time characteristics and impulse (Vaverka et al., 2016), including in preschool children despite variable movement efficiency (Petrić et al., 2025). The difference between CMJ FA and CMJ within each pupil may therefore provide a functional index of arm contribution, but it is not a direct measure of coordination.

Body size also matters. Body mass is the load accelerated during takeoff, and it affects interpretation of CMJ kinetics in children (Jones et al., 2020). Associations of body mass status and BMI with running and jumping vary across samples and subgroups (Nikolaidis et al., 2015; Ayan, 2018; Branet et al., 2018). Body mass does not distinguish lean from fat tissue. Stenevi Lundgren et al. (2011) reported DXA measures alongside neuromuscular outcomes, whereas Ljubičić et al. (2025) linked higher adiposity with poorer jumping outcomes.

Evidence specific to adjacent primary school grades is limited. Normative data are available for children aged 10–15 years, whereas some comparisons use sport samples spanning wider age ranges (Taylor et al., 2010; Nikolaidis, 2014). Specific muscular strength characteristics are associated with vertical jump performance in adolescent athletes (Harčarik & Falat Leütterová, 2024). Sex and biological maturation may contribute to variation in jump performance (Ayan, 2018; Hespanhol et al., 2013). Habitual physical activity, organized sport, and training exposure may also influence performance (Rajkovic Vuletic et al., 2024; Wu et al., 2025). These factors complicate interpretation of cross-sectional differences between grades.

The primary aim was to compare CMJ, CMJ FA, and SJ performance among pupils in the 3rd, 4th, and 5th grades and to examine associations between body size and jump outcomes. We expected only modest differences between grades in absolute jump height and a negative association between body mass and performance. A secondary exploratory aim was to compare absolute and relative arm swing benefit across grades; no directional confirmatory hypothesis was specified for this exploratory analysis.

Materials and Methods

Participants

The analytical sample comprised 129 pupils (3rd grade, $n = 46$; 4th grade, $n = 50$; 5th grade, $n = 33$). Body height and body mass increased descriptively across grades (Table 1). Participants received compulsory physical and sports education at least twice weekly. Inclusion required enrolment in a target grade and complete data for body height, body mass, and jump tests. Archived age summaries for each group were 9.10 ± 0.44 years for the 3rd grade, 10.32 ± 0.53 years for the 4th grade, and 11.10 ± 0.59 years for the 5th grade. Sex was not recorded in the archived analytical dataset and therefore could not be included in descriptive or inferential

analyses. Information on organized sport participation and habitual physical activity outside compulsory physical education was unavailable. Biological maturation was not assessed.

Table 1. Participant characteristics by school grade

Grade	n	Age, years M $\pm$ SD	Body mass, kg M $\pm$ SD	Body height, cm M $\pm$ SD
3 rd grade	46	9.10 $\pm$ 0.44	32.40 $\pm$ 7.35	138.59 $\pm$ 6.49
4 th grade	50	10.32 $\pm$ 0.53	37.29 $\pm$ 7.79	145.15 $\pm$ 6.30
5 th grade	33	11.10 $\pm$ 0.59	37.42 $\pm$ 8.22	146.84 $\pm$ 8.84
Total	129	NA	35.58 $\pm$ 8.05	143.24 $\pm$ 7.88

Note. Age values are archived summaries for each group. M = mean; SD = standard deviation.

Study design

This cross-sectional observational study conducted in schools examined vertical jump performance and somatic characteristics among pupils in the 3rd, 4th, and 5th grades. School grade was the grouping variable, and reporting was guided by the STROBE recommendations (von Elm et al., 2007). No intervention was administered; the measurements represented a single assessment point under ordinary school conditions.

School grade was the grouping variable. The primary outcomes were CMJ, CMJ FA, and SJ height. Body height and body mass were prespecified somatic covariates. In the exploratory analysis, absolute arm swing benefit was calculated as CMJ FA – CMJ (cm), and relative benefit as [(CMJ FA – CMJ) / CMJ] $\times$ 100 (%).

Procedures and Instruments

Testing was conducted individually under regular school conditions. Body height (cm) and body mass (kg) were recorded before jump testing and were used for sample description and covariate analyses.

Vertical jump height was measured in centimeters using the Chronojump system (Chronojump Boscossystems, Barcelona, Spain), whose concurrent validity and reliability have been demonstrated in physically active adults (Pueo et al., 2020). After verbal instruction, pupils performed CMJ without arm swing, CMJ FA, and SJ in this fixed order. CMJ involved a rapid countermovement without arm swing; CMJ FA permitted free arm movement; SJ began from a static squat without a preceding countermovement.

Each test included one practice trial followed by three measured attempts. The best valid jump height from the three measured attempts was retained for analysis. An SJ attempt was repeated when a countermovement was observed. At least one minute of rest separated the three jump variations. Values from individual trials were not retained in the analytical file, so reliability within the testing session could not be estimated.

Statistical analysis

Means, standard deviations, 95% confidence intervals (CIs), and minima and maxima were calculated.

Distributional assumptions were assessed with Shapiro–Wilk tests and homogeneity of variance with Levene tests centered on the median. One-way ANOVA was used to compare grades across the three primary outcomes and the two exploratory benefit outcomes. Significant omnibus tests were followed by Tukey comparisons. Eta squared quantified omnibus effects. Cohen's *d* was used to quantify pairwise standardized differences (Cohen, 1988). The 95% confidence intervals were calculated for each Cohen's *d* estimate.

Because arm swing benefit distributions departed from normality in some groups, Kruskal–Wallis tests followed by Mann–Whitney comparisons adjusted using the Holm method were used as sensitivity analyses. Separate ANCOVA models adjusted each primary outcome for body height and body mass; adjusted means with 95% CI, comparisons adjusted using the Bonferroni method, and partial eta squared were reported. Because height and mass were correlated, models including both covariates were included in sensitivity analyses, and variance inflation factors were used to assess collinearity. Interactions between grade and body mass tested whether the slope of the association between body mass and performance differed across grades.

Pearson correlations with 95% CI described associations between body mass and jump outcomes within each grade and in the total sample. These correlations were treated as exploratory; Spearman correlations and the Benjamini–Hochberg adjustment for the false discovery rate were used as sensitivity checks. Statistical significance was set at $p < 0.05$. The available eligible sample determined the study size; no a priori calculation was performed. With $n = 129$ and $\alpha = 0.05$, the design had 80% power to detect approximately Cohen $f = 0.277$ (eta squared = 0.071). Statistical analyses were performed in IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, USA).

Results

Primary Vertical Jump Outcomes

For the three primary outcomes, unadjusted grade effects were not statistically significant for CMJ, $F_{(2,126)} = 0.69$, $p = 0.506$, eta squared = 0.011; CMJ FA, $F_{(2,126)} = 1.69$, $p = 0.189$, eta squared = 0.026; or SJ, $F_{(2,126)} = 0.52$, $p = 0.594$, eta squared = 0.008 (Table 2). Estimated grade effects were small. Mean CMJ FA and SJ values were descriptively highest in the 5th grade, whereas CMJ remained broadly stable; no Tukey comparison was significant.

Secondary exploratory arm swing benefit

In the secondary exploratory analyses, absolute arm swing benefit differed by grade, $F_{(2,126)} = 6.53$, $p = 0.002$, eta squared = 0.094, as did relative benefit, $F_{(2,126)} = 6.44$, $p = 0.002$, eta squared = 0.093 (Table 3). Both outcomes were higher in the 5th grade than in the 3rd and 4th grades, while the two younger grades did not differ. For absolute benefit, standardized differences were $d = 0.90$ (95% CI 0.43 to 1.37) for the 3rd versus 5th grade and $d = 0.63$ (0.18 to 1.08) for the 4th versus 5th grade. Corresponding effects for relative benefit were $d = 0.81$ (0.35 to 1.28) and $d = 0.67$ (0.21 to 1.12). Kruskal–Wallis sensitivity analyses confirmed grade differences for absolute benefit ($H(2) = 13.57$, $p = 0.001$) and relative benefit ($H(2) = 12.16$, $p = 0.002$);

Table 2. Vertical jump performance by grade and one-way ANOVA

Test	3 rd grade (n = 46)	4 th grade (n = 50)	5 th grade (n = 33)	ANOVA result F; p; η^2
CMJ	20.02 ± 4.10 [18.81, 21.24]	20.71 ± 4.35 [19.47, 21.94]	19.68 ± 3.71 [18.37, 21.00]	F = 0.69 p = 0.506 $\eta^2 = 0.011$
CMJ FA	22.76 ± 4.01 [21.57, 23.95]	23.74 ± 5.28 [22.24, 25.24]	24.70 ± 4.55 [23.09, 26.32]	F = 1.69 p = 0.189 $\eta^2 = 0.026$
SJ	19.08 ± 3.99 [17.89, 20.26]	19.82 ± 4.34 [18.58, 21.05]	19.92 ± 4.15 [18.44, 21.39]	F = 0.52 p = 0.594 $\eta^2 = 0.008$

Note. Values are mean ± standard deviation with 95% confidence interval in brackets. CMJ = countermovement jump without arm swing; CMJ FA = countermovement jump with free arm swing; SJ = squat jump; η^2 = eta squared.

pairwise results adjusted using the Holm method confirmed both contrasts involving the 5th grade. Individual distributions are shown in Figure 1.

Table 3. Exploratory absolute and relative arm swing benefit

Outcome	3 rd grade (n = 46)	4 th grade (n = 50)	5 th grade (n = 33)	ANOVA result F; p; η^2
Absolute benefit, cm	2.73 ± 2.55 [1.98, 3.49]	3.03 ± 3.49 [2.04, 4.03]	5.02 ± 2.53 [4.12, 5.92]	F = 6.53 p = 0.002 $\eta^2 = 0.094$
Relative benefit, %	14.98 ± 13.85 [10.86, 19.09]	15.69 ± 17.25 [10.78, 20.59]	26.49 ± 14.52 [21.34, 31.63]	F = 6.44 p = 0.002 $\eta^2 = 0.093$

Note. Values are mean ± standard deviation with 95% confidence interval in brackets. Comparisons adjusted using the Tukey method were significant for the 3rd versus 5th grade (absolute $p = 0.003$; relative $p = 0.004$) and the 4th versus 5th grade (absolute $p = 0.009$; relative $p = 0.006$); the 3rd and 4th grades did not differ. Kruskal–Wallis sensitivity analyses were also significant (absolute $H(2) = 13.57$, $p = 0.001$; relative $H(2) = 12.16$, $p = 0.002$).

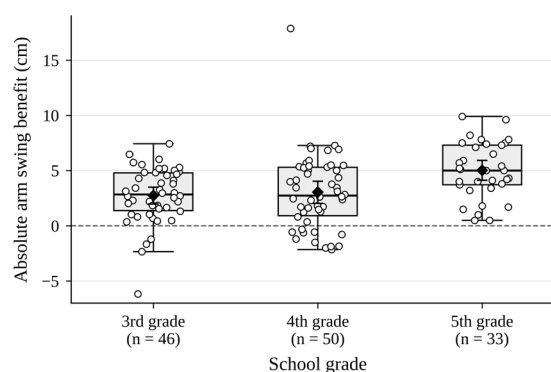


Fig. 1. Distribution of absolute arm swing benefit by grade. Open circles represent pupils; boxes show the interquartile range and median; whiskers extend to $1.5 \times$ IQR; diamonds and error bars show the mean and approximate 95% confidence interval. The dashed line indicates no benefit.

ANCOVA and joint sensitivity models for body size

In ANCOVA containing body height only, neither body height nor grade was significant for any jump outcome (Table 4, Panel A). In models containing body mass only, body mass was significant for CMJ, $F_{(1,125)} = 12.45$, $p < 0.001$; CMJ FA, $F_{(1,125)} = 16.70$, $p < 0.001$; and SJ, $F_{(1,125)} = 11.07$, $p = 0.001$. A grade effect emerged for CMJ FA adjusted for body mass, $F_{(2,125)} = 4.48$, $p = 0.013$, with a difference between the 3rd and 5th grades after adjustment using the Bonferroni method ($p = 0.014$).

Interpretation changed in sensitivity models that simultaneously included height and mass. Variance inflation factors were below 1.8. Body height was positively associated with CMJ ($B = 0.174$ cm per cm, $p = 0.004$), CMJ FA ($B = 0.208$, $p = 0.002$), and SJ ($B = 0.204$, $p < 0.001$), whereas body mass was negatively associated with CMJ ($B = -0.254$ cm per kg), CMJ FA ($B = -0.320$), and SJ ($B = -0.264$; all $p < 0.001$). Grade effects were not significant in these joint models ($p = 0.213$ – 0.713 ; Supplementary Table S2).

Associations between body mass and jump outcomes

Pearson correlations between body mass and the three primary outcomes were negative in the total sample and were numerically strongest in the 3rd grade (Table 5). Neither absolute nor relative arm swing benefit was significantly correlated with body mass. After adjustment for the false discovery rate, the three correlations in the 3rd grade, the CMJ FA correlation in the 4th grade, and all three correlations in the total sample remained significant; however, the CMJ FA association in the 4th grade was not significant in the Spearman sensitivity analysis. Interactions between grade and body mass were not significant for CMJ ($p = 0.302$), CMJ FA ($p = 0.396$), or SJ ($p = 0.345$), providing no statistical evidence that the slope of the association between body mass and performance differed by grade.

Discussion

The primary analyses found no statistically detectable grade differences in CMJ, CMJ FA, or SJ, and estimated

Table 4. ANCOVA of jump performance adjusted separately for body height and body mass

Test	3 rd grade	4 th grade	5 th grade	Grade effect F (p); η^2	Covariate effect F (p); η^2
Panel A. Body height as a covariate					
CMJ	20.06 [18.77, 21.36]	20.69 [19.52, 21.86]	19.65 [18.19, 21.12]	0.67 (0.513) $\eta^2 = 0.011$	0.03 (0.868) $\eta^2 = 0.000$
CMJ FA	22.75 [21.28, 24.23]	23.74 [22.41, 25.07]	24.70 [23.03, 26.37]	1.38 (0.256) $\eta^2 = 0.022$	0.00 (0.997) $\eta^2 = 0.000$
SJ	19.22 [17.91, 20.54]	19.76 [18.57, 20.94]	19.80 [18.31, 21.29]	0.21 (0.814) $\eta^2 = 0.003$	0.37 (0.545) $\eta^2 = 0.003$
Panel B. Body mass as covariate					
CMJ	19.52 [18.33, 20.70]	20.98 [19.87, 22.09]	19.98 [18.61, 21.34]	1.64 (0.198) $\eta^2 = 0.026$	12.45 (<0.001) $\eta^2 = 0.091$
CMJ FA	22.10 [20.77, 23.42]	24.10 [22.85, 25.34]	25.08 [23.56, 26.61]	4.48 (0.013) $\eta^2 = 0.067$	16.70 (<0.001) $\eta^2 = 0.118$
SJ	18.59 [17.38, 19.79]	20.08 [18.94, 21.21]	20.20 [18.81, 21.59]	1.99 (0.140) $\eta^2 = 0.031$	11.07 (0.001) $\eta^2 = 0.081$

Note. Adjusted means are estimated marginal means in centimeters with 95% confidence intervals in brackets. η^2 = partial eta squared. Pairwise comparisons adjusted using the Bonferroni method were not significant except for CMJ FA adjusted for body mass, where the 3rd and 5th grades differed ($p = 0.014$). Joint models including height and mass are reported in Supplementary Table S2.

Table 5. Pearson correlations between body mass and primary jump outcomes

Group	n	Body mass with CMJ r [95% CI]; p	Body mass with CMJ FA r [95% CI]; p	Body mass with SJ r [95% CI]; p
3 rd grade	46	-0.442 [-0.649, -0.174]; p = 0.002	-0.486 [-0.680, -0.228]; p < 0.001	-0.463 [-0.664, -0.199]; p = 0.001
4 th grade	50	-0.280 [-0.518, -0.002]; p = 0.049	-0.351 [-0.573, -0.081]; p = 0.012	-0.199 [-0.452, 0.084]; p = 0.166
5 th grade	33	-0.146 [-0.466, 0.208]; p = 0.417	-0.179 [-0.492, 0.175]; p = 0.319	-0.202 [-0.510, 0.152]; p = 0.260
Total	129	-0.277 [-0.429, -0.109]; p = 0.001	-0.282 [-0.434, -0.114]; p = 0.001	-0.245 [-0.401, -0.075]; p = 0.005

Note. BM = body mass; CMJ = countermovement jump without arm swing; CMJ FA = countermovement jump with free arm swing; SJ = squat jump. Raw p values are shown; adjustment for the false discovery rate and Spearman sensitivity results are provided in Supplementary Table S3.

effects were small. The secondary exploratory analysis identified a larger CMJ FA – CMJ difference in the 5th grade, also supported by nonparametric analyses. Body mass was negatively associated with jump height, while conclusions about height and adjusted grade effects depended on model specification.

Cross-sectional groups combine pupils with different body size, strength, movement experience, and task familiarity. Nonsignificant findings do not establish equivalence; effects below about eta squared = 0.071 were not detectable with 80% power. Grade should therefore be treated as context, not evidence of change within pupils or motor maturity.

Sex, biological maturation, and physical activity

Sex was not recorded. Sex differences in vertical jump performance have been reported in this age range (Ayan, 2018; Taylor et al., 2010), so unknown group composition may have increased variability or confounded grade comparisons. Biological maturation was also unmeasured. Differences in body proportions, fat-free mass, and neuromuscular function may be relevant particularly to the arm swing contrast in the 5th grade (Hespanhol et al., 2013; Nikolaidis, 2014). Organized sport participation and habitual physical activity were unavailable; variation in training exposure and jump familiarity may therefore have affected performance (Rajkovic Vuletic et al., 2024; Wu et al., 2025). These unmeasured characteristics prevent attribution to grade alone.

Arm swing benefit

The largest grade contrast arose in the secondary exploratory analysis of arm swing benefit. Although CMJ and CMJ FA considered separately did not differ significantly by grade, their difference within each pupil was larger in the 5th grade. This pattern occurred for both indices and in nonparametric analyses. The result is therefore hypothesis-generating rather than confirmatory evidence.

Arm swing can increase jump height by altering impulse and takeoff strategy (Vaverka et al., 2016). The contrast in the 5th grade may reflect group differences in arm use, strength, familiarity, sex, maturation, sport participation, or activity. It cannot indicate developmental improvement or directly measure coordination because the design was cross-sectional and technique was not recorded. The fixed CMJ then CMJ FA order also leaves possible familiarization effects. Prospective studies should randomize order and assess technique and participant characteristics.

Body size and performance

Body size results depended on model specification. In separate ANCOVA models, height was not associated with performance, while mass was significant for all tests. In joint models, height was positively and mass negatively associated with performance, and the grade effect for CMJ FA adjusted for mass was no longer significant. Collinearity was modest. These findings may reflect body proportions and load, but body composition was not measured.

The negative mass associations agree with studies linking body size, higher BMI, or overweight status to poorer

jumping in some child and youth samples (Jones et al., 2020; Nikolaidis et al., 2015; Ayan, 2018; Ljubičić et al., 2025). Because body mass combines muscle and adipose tissue, a plausible mechanical explanation is that force-producing tissue and nonpropulsive load contribute differently. This remains inferential.

Correlations were numerically strongest in the 3rd grade, but interactions between grade and body mass were nonsignificant. The data therefore do not show that older pupils compensate for mass more effectively; weaker estimates in the 5th grade may reflect sampling variation, limited power, or unmeasured group differences.

Practical implications

For school use, CMJ, CMJ FA, and SJ should be administered with consistent equipment, instructions, order, and scoring. Absolute jump height should be interpreted with body size in mind and preferably compared within pupils over time. The CMJ FA – CMJ difference may prompt observation of arm use but is not a diagnostic measure of coordination. The data do not support ranking or performance thresholds based on grade.

Strengths and limitations

Strengths include three complementary tests, electronic measurement, arm swing indices within each pupil, effect size reporting, and sensitivity analyses. Limitations include the regional three-grade sample and unavailable sex, maturation, sport participation, and habitual activity data, leaving potential confounding of grade contrasts. Individual age, body composition, and jump kinematics were also unavailable. The cross-sectional design cannot establish development or causality. Test order was fixed, only one practice trial was given, and values from individual trials were unavailable. Selecting the best of three attempts may increase variability. The arm swing analysis was exploratory, the relative index was sensitive to extreme ratios, multiple correlations increased multiplicity, and small grade effects could not be reliably detected.

Future studies should record these participant characteristics, retain all attempts, randomize test order, and assess technique directly. Longitudinal designs are needed to examine change within pupils, and instructional studies to test whether practice modifies arm swing benefit.

Conclusions

The primary analyses showed no statistically detectable grade differences in CMJ, CMJ FA, or SJ across Grades 3–5, and estimated effects were small. The secondary exploratory analysis observed greater absolute and relative arm swing benefit in the 5th grade than in the 3rd and 4th grades, but this cross-sectional contrast does not demonstrate developmental change within pupils. Body mass was negatively associated with jump height, whereas the independent contributions of body height and the adjusted grade effect depended on model specification. Use in schools should emphasize standardized testing, interpretation that accounts for body size, and feedback for each pupil rather than diagnostic labeling or ranking by grade.

Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Commission of the University of Presov (approval number ECUP 092024PO, 2024).

Informed Consent

Written informed consent was obtained from the parents or legal guardians of all participating pupils before data collection.

Data Availability Statement

The data may be obtained from the corresponding author upon reasonable request, subject to applicable institutional and ethical requirements.

AI Transparency Statement

AI tools were used to assist with language editing, manuscript organization, and independent numerical verification. The authors critically reviewed all analyses, interpretations, and wording and take full responsibility for the final manuscript.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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Supplementary material

Vertical Jump Performance, Arm Swing Benefit, and Body Size in Grades 3–5: A Cross-Sectional Study

Table S1. Distributional diagnostics and robust analyses of arm swing benefit

Outcome	Grade	n	Median [IQR]	Min to max	Shapiro–Wilk W (p)
Absolute benefit, cm	3rd	46	2.83 [1.38, 4.78]	–6.18 to 7.43	0.947 (0.036)
	4th	50	2.72 [0.92, 5.29]	–2.15 to 17.87	0.890 (<0.001)
	5th	33	5.00 [3.70, 7.30]	0.50 to 9.90	0.969 (0.464)
Relative benefit, %	3rd	46	12.84 [7.66, 23.63]	–21.59 to 42.34	0.978 (0.513)
	4th	50	15.04 [3.76, 24.20]	–10.07 to 83.90	0.920 (0.002)
	5th	33	24.00 [17.70, 38.27]	2.66 to 55.62	0.967 (0.410)

Absolute benefit: Kruskal–Wallis $H(2) = 13.57$, $p = 0.001$. Mann–Whitney p values adjusted using the Holm method: 3rd vs 4th = 0.869, 3rd vs 5th = 0.002, 4th vs 5th = 0.004.

Relative benefit: Kruskal–Wallis $H(2) = 12.16$, $p = 0.002$. Mann–Whitney p values adjusted using the Holm method: 3rd vs 4th = 0.985, 3rd vs 5th = 0.005, 4th vs 5th = 0.005.

Table S2. Joint models including body height and body mass

Outcome	Adjusted mean for 3 rd grade [95% CI]	Adjusted mean for 4 th grade [95% CI]	Adjusted mean for 5 th grade [95% CI]	Grade effect $F(2,124)$, p ; η^2	Height B [95% CI], p	Mass B [95% CI], p	R^2
CMJ	20.02 [18.82, 21.22]	20.81 [19.73, 21.90]	19.53 [18.17, 20.89]	1.19 0.306 0.019	0.174 [0.056, 0.292] 0.004	–0.254 [–0.362, –0.146] <0.001	0.158

Table S2. Continued

Outcome	Adjusted mean for 3 rd grade [95% CI]	Adjusted mean for 4 th grade [95% CI]	Adjusted mean for 5 th grade [95% CI]	Grade effect F(2,124), p; η^2	Height B [95% CI], p	Mass B [95% CI], p	R ²
CMJ FA	22.70 [21.37, 24.04]	23.89 [22.68, 25.10]	24.55 [23.03, 26.06]	1.56 0.213 0.025	0.208[0.076, 0.339] 0.002	−0.320 [−0.440, −0.199] <0.001	0.204
SJ	19.18 [17.97, 20.39]	19.88 [18.78, 20.98]	19.67 [18.30, 21.04]	0.34 0.713 0.005	0.204 [0.084, 0.323] <0.001	−0.264 [−0.373, −0.155] <0.001	0.166

Note. Adjusted means are estimated at the total sample mean body height and body mass. B coefficients represent centimeters of jump height per 1 cm of height or 1 kg of mass difference while holding the other covariate and grade constant. Variance inflation factors were 1.78 for height and 1.70 for mass.

Table S3. Pearson and Spearman sensitivity analyses for body mass correlations

Group	Outcome	n	Pearson r [95% CI]	p values raw / FDR / Holm	Spearman ρ (p)
3 rd	CMJ	46	−0.442 [−0.649, −0.174]	0.002 / 0.008 / 0.034	−0.467 (0.001)
3 rd	CMJ FA	46	−0.486 [−0.680, −0.228]	<0.001 / 0.007 / 0.012	−0.400 (0.006)
3 rd	SJ	46	−0.463 [−0.664, −0.199]	0.001 / 0.007 / 0.023	−0.466 (0.001)
3 rd	Absolute benefit	46	−0.054 [−0.339, 0.240]	0.721 / 0.774 / 1.000	−0.013 (0.931)
3 rd	Relative benefit	46	0.059 [−0.235, 0.344]	0.696 / 0.774 / 1.000	0.072 (0.633)
4 th	CMJ	50	−0.280 [−0.518, −0.002]	0.049 / 0.122 / 0.634	−0.177 (0.219)
4 th	CMJ FA	50	−0.351 [−0.573, −0.081]	0.012 / 0.035 / 0.173	−0.272 (0.056)
4 th	SJ	50	−0.199 [−0.452, 0.084]	0.166 / 0.368 / 1.000	−0.158 (0.272)
4 th	Absolute benefit	50	−0.182 [−0.438, 0.101]	0.206 / 0.412 / 1.000	−0.153 (0.288)
4 th	Relative benefit	50	−0.115 [−0.381, 0.169]	0.427 / 0.610 / 1.000	−0.099 (0.494)
5 th	CMJ	33	−0.146 [−0.466, 0.208]	0.417 / 0.610 / 1.000	−0.321 (0.068)
5 th	CMJ FA	33	−0.179 [−0.492, 0.175]	0.319 / 0.532 / 1.000	−0.275 (0.122)
5 th	SJ	33	−0.202 [−0.510, 0.152]	0.260 / 0.472 / 1.000	−0.341 (0.052)
5 th	Absolute benefit	33	−0.107 [−0.434, 0.246]	0.554 / 0.693 / 1.000	−0.101 (0.576)
5 th	Relative benefit	33	−0.061 [−0.396, 0.288]	0.735 / 0.774 / 1.000	−0.022 (0.903)
Total	CMJ	129	−0.277 [−0.429, −0.109]	0.001 / 0.007 / 0.025	−0.279 (0.001)
Total	CMJ FA	129	−0.282 [−0.434, −0.114]	0.001 / 0.007 / 0.023	−0.264 (0.002)
Total	SJ	129	−0.245 [−0.401, −0.075]	0.005 / 0.017 / 0.078	−0.269 (0.002)
Total	Absolute benefit	129	−0.061 [−0.232, 0.113]	0.489 / 0.652 / 1.000	−0.025 (0.780)
Total	Relative benefit	129	0.003 [−0.170, 0.175]	0.977 / 0.977 / 1.000	0.042 (0.640)

Note. The Benjamini–Hochberg adjustment for the false discovery rate (FDR) and the Holm correction were applied across the 20 Pearson correlation tests. These analyses were exploratory.

Table S4. Interaction tests between grade and body mass and design sensitivity

Outcome	Interaction F(2,123)	p
CMJ	1.21	0.302
CMJ FA	0.93	0.396
SJ	1.07	0.345

At n = 129, alpha = 0.05, and three groups, 80% power corresponded to Cohen f = 0.277 (eta squared = 0.071). Approximate absolute correlations detectable with 80% power were r = 0.47 at n = 33, 0.40 at n = 46, 0.39 at n = 50, and 0.24 at n = 129.

Результативність вертикальних стрибків, ефективність махових рухів руками та розміри тіла учнів 3–5 класів: поперечне дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 1 рис., 30 джерел.

Мета дослідження. Дослідження мало на меті порівняти результативність вертикальних стрибків учнів 3–5 класів, вивчити зв'язок із розміром тіла, а також додатково оцінити ефективність махових рухів руками.

Матеріали та методи. У цьому поперечному шкільному дослідженні взяли участь 129 учнів зі Східної Словаччини (3-й клас: $n = 46$; 4-й клас: $n = 50$; 5-й клас: $n = 33$). Дані щодо статі, біологічного дозрівання, участі в організованій спортивній діяльності та звичної фізичної активності були відсутні. Проаналізовано оптимальну з трьох валідних спроб у системі Chronojump для таких тестів: стрибок із контррухом без маху руками (СКР), стрибок із контррухом з вільним махом руками (СКР ВР) та вистрибування з присіду (ВП). Міжкласові відмінності за цими первинними показниками перевіряли за допомогою однофакторного дисперсійного аналізу. Абсолютна та відносна ефективність маху руками виступали як додаткові дослідницькі показники. Також застосовано коваріаційний аналіз, досліджено спільні моделі з урахуванням довжини та маси тіла, кореляції, непараметричний аналіз чутливості та взаємодію факторів «клас $\times$ маса тіла».

Результати. Первинні показники не відрізнялися залежно від класу ($p = 0.19$ – 0.59 ; ета-квадрат = 0.008 – 0.026). Додатковий дослідницький аналіз виявив відмінності в абсолютній та відносній ефективності маху руками (для обох показників $p = 0.002$; ета-квадрат становить приблизно 0.09), причому вищі значення спостерігалися в учнів 5-го класу порівняно з 3-м та 4-м класами; непараметричний аналіз підтвердив ці контрасти. Коваріаційний аналіз із поправкою на масу тіла показав, що маса була значущим фактором для всіх тестів, а для СКР ВР виявлено ефект класу ($p = 0.013$). У спільних моделях довжина тіла мала позитивний, а маса тіла — негативний зв'язок із кожним первинним показником, тоді як ефекти класу та взаємодія «клас $\times$ маса тіла» були незначущими.

Висновки. Отримані результати свідчать про відсутність статистично значущих відмінностей між первинними показниками стрибків у суміжних класах. Вища додаткова дослідницька ефективність маху руками у групі 5-го класу не демонструє внутрішньоіндивідуальні розвиткові зміни в учнів і може частково відображати невраховані характеристики статі, дозрівання або рухової активності. Інтерпретація розмірів тіла залежала від специфікації моделі. Шкільне тестування має акцентувати увагу на стандартизованих процедурах та індивідуальному зворотному зв'язку, уникаючи діагностичного ярликування або ранжування учнів за класами.

Ключові слова: стрибок із контррухом, вистрибування з присіду, мах руками, маса тіла, фізичне виховання, діти.

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