Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 10), Art 309, pp. 2699 - 2709, October 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Unveiling the impact of after-school physical activity on fundamental motor skills in primary school children: Insights from the Slovak 'PAD' project

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Published online: October 31, 2023
(Accepted for publication : October 15, 2023)
DOI:10.7752/jpes.2023.10309

Abstract
Background: Primary school plays a pivotal role in shaping children's motor skill competence. Recognising this critical developmental phase, our study aimed to assess the impact of a two-year after-school physical activity intervention on fundamental motor skills among young primary school children. **Methods:** A cohort of twenty healthy children (10 boys, 10 girls) aged 6–7 years formed a baseline engaged in IAAF Kids' Athletics training, comprising two weekly one-hour sessions. Concurrently, a control group of twenty peers (10 boys, 10 girls) adhered to conventional practices. The assessment involved measuring jumping with max-effort rotation, sit and reach test, standing long jump, ball throwing, 4 × 10 m shuttle run, and 20 m endurance running tasks at half-year intervals throughout the two-year intervention period. Data analysis employed two-way ANOVA with repeated measurements. **Results:** At baseline, intervention students demonstrated superior performance ($p <$ 0.01–0.001) in the standing long jump, ball throwing, and shuttle and endurance runs compared to control subjects. After the two-year intervention, girls in the physical activity group exhibited a positive impact ($p <$ 0.05–0.001) on three out of six motor skills – specifically, the standing long jump, ball throwing, and endurance run – compared to their counterparts in the control group. Conversely, no statistically significant improvements were observed in any motor skills for boys in the intervention group. **Conclusions:** Our findings suggest that a sustained, long-term physical activity intervention can significantly enhance fundamental motor skills in girls, while no such conclusive improvements were observed in boys. Potential factors contributing to these gender-related differences are discussed.
Key words: athletics training, movement development, gender-related differences, physical education

Introduction

During the human lifespan, motor-skill performance changes, depending on physical and psychological characteristics, environmental influences, and opportunities to learn or practise movement tasks (Newel, 1986). Motor skills and motor coordination begin to develop early in life and progress as children grow. For instance, a US study conducted many years ago on the motor achievements of 6-year-old children found that 90% of them were classified as proficient jumpers, 84% as adept throwers, and 63% as capable catchers (Gutteridge, 1939). Fundamental motor skills involve the capacity to utilise major muscle groups to perform coordinated joint movements. They can be categorised into locomotion (i.e. running, jumping, and hopping), object control (manipulative skills, i.e. throwing, kicking, and catching), and stability skills, such as balancing (Gallahue et al., 2012). Clearly, these motor-skill competencies provide a basis for children's development with later, more complex, physical and sporting activities (Thomas, 1997).

Existing literature provides causal evidence of a positive relationship between physical activity and motor-skill proficiency in young children (Lubans et al., 2010; Holfelder & Schott, 2014). The World Health Organization (WHO) recommends that children and young people aged 5–17 years spend an average of at least 60 minutes per day on moderate to vigorous physical activity (WHO, 2020). In the last decade in particular, levels of physical activity have declined among young people (aged 11–15) in roughly a third of European countries, including Slovakia (Inchley et al., 2020). There has been a significant decrease in the time children spend on spontaneous play, interacting with friends, and supervised physical activity (Lee et al., 2021). Structured school-based physical-activity interventions are known to be able to increase how much and how intensely children engage in physical activity (Kriemler et al., 2011). The provision of a good physical education programme in primary school years is crucial to ensure that students in this stage develop and demonstrate proficiency in fundamental motor skills. Physical education should focus on teaching new skills, with children receiving high-quality instruction, pedagogical feedback, and ample opportunities to practise in order to develop their motor-skill proficiency (Hands, 2012).

Recently, McDonough et al. (2020) reviewed the findings from 25 studies assessing the effects of traditional and exergaming-based (i.e. playing interactive video games) physical-activity interventions in promoting motor skills in children 6–12 years of age. Twenty (80%) studies reported significant improvements

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in children's motor-skill performance. In the remaining studies, findings were mixed, with some not showing any beneficial outcomes. Highly variable sample sizes (n = 34 to 891) and durations of intervention (4 weeks to 12 months) were observed across the studies. Notably, movement skills improved when the interventions were conducted in a school setting and traditional physical-activity strategies were employed and in situations where the participants were middle school students (i.e. 11–12 years of age).

The globally recognised International Association of Athletics Federation (IAAF) Kids' Athletics project is a recently developed form of physical-activity intervention designed to encourage athletic-related movement skills among children aged 5–12 years (Gozzoli et al., 2006). The main goals of this project are to engage as many children as possible, to provide exposure to different basic types of athletic skills, and to promote teamwork in races to ensure that participation is not limited to stronger and faster children. As of today, this intervention programme has been adopted by over a hundred countries and has reached an estimated cumulative audience of more than 13 million children and young people (IAAF, 2023).

The Kids' Athletics programme was also incorporated as a voluntary school-activity intervention aimed at promoting health and fitness among primary school children as part of our "PAD" research project ("PAD" is a Slovak acronym standing for *Pohybová Aktivita Detí*, i.e. "Children's Movement Activity"). This project was initiated in September 2019 as a regional population-based survey (in Banská Bystrica and the surrounding area, Central Slovakia) that encompasses questionnaire data, physical examinations, and a long-term physical-activity programme. In a previous study, we demonstrated that, among primary school boys (but not girls), a two-year Kids' Athletics programme is linked to a significantly smaller increase in body mass index and improvement in body fat composition over time (Alberty & Čillík, 2023).

This study forms part of a long-term intervention programme under the "PAD" project. Its objective was to examine the impact that a two-year school-based physical-activity intervention using the concept of the Kids' Athletics programme has on the fundamental motor skills of typically developing 6- and 7-year-old children. We hypothesise that, compared with students engaging in standard practices, long-term structured physical training would improve fundamental motor skills in primary school children.

Material and methods

Participants

A cohort of 40 primary school children (20 boys, 20 girls) from the prospective arm of the "PAD" project was selected to participate in a two-year physical-activity intervention programme. The inclusion criteria were: (a) the participants had to be first-grade students (approximately 6–7 years old) at baseline; (b) they were apparently healthy (free from motor and mental impairments) volunteers regularly attending physical-education lessons at school; (c) they did not participate in other organised sports in their leisure time; and (d) parents had to give written informed consent for their children to participate in the study, with the children agreeing orally to participate. Twenty children (10 boys, 10 girls), based on a request from their parents, were placed in the intervention group and engaged in structured physical activity. The other 20 children were assigned to a no-intervention control group and continued their routine physical practice. The study protocol was approved by the local ethics committee at Matej Bel University and adhered to the ethical principles outlined in the latest revision of the Declaration of Helsinki from 2000.

Intervention under the IAAF Kids′ Athletics programme

The intervention group exercised twice a week over a two-year period. The training sessions, each lasting for 60 minutes, were led by enthusiastic, trained educators. Participants kept to the same small group throughout the after-school intervention programme. The general exercise programme consisted of a mix of movement-based games, competitions, and exercises designed to enhance fundamental movement skills (55% of the training volume). Gymnastics was another component, involving gymnastic exercises, strength training, coordination exercises, warm-up routines, and stretching exercises (25% of the training volume). Finally, there was a component of special training that focused on athletics exercises: running ABC exercises, starts, relay running, preparatory jumping exercises, throws, and exercises to prepare for throwing (20% of the training volume). Athletics exercises accounted for 20% of the total training volume at the beginning of the exercise programme, rising to 25% at the end. Given the age of the children, both males and females performed exercises of the same volume and intensity. Throughout the programme, the subjects were asked to maintain a healthy diet, although no standard dietary modifications were introduced. The exercise programme was conducted in a school setting after lessons had ended.

Anthropometric and movement-skill measurements

All measurements were taken in exactly the same way at baseline and then at half-year intervals over the two-year intervention period.

Anthropometric measurements

Standing height was measured using a Soehnle electronic scale. Body weight, body fat percentage, and muscle mass were determined with the bioelectric impedance method using a Biospace Inbody 120 analyser. Body mass index was calculated as kg/m^2. We have reported on the procedure used to generate body composition data in detail elsewhere (Alberty & Čillík, 2023).

Motor skill tests

Fundamental movement skills were assessed using six tests previously adapted for primary school children: jump with max-effort rotation, sit-and-reach test, standing long jump, overhead ball throwing, 4 × 10 m shuttle run, and 20 m endurance shuttle run. These tests are identical or similar to tests under the Eurofit test battery for children (Eurofit, 1993), apart from the vertical jump with max-effort rotation test method, which was adopted from Nagano et al. (2007). The fitness-test components, the dimensions tested, and the units of measurement are described in Table 1. Ahead of the test session, all participating children enrolled in the study practised the skill-test procedures in physical education lessons under the guidance of trained educators. Subsequently, the actual movement-skill testing was conducted in a single session in a school setting, with the stipulation that no unusual physical activity was to be carried out the day before the test. Participants had two attempts for each skill, except for the endurance run, which was completed only once. The best result from the two attempts was used in the final analysis.

Table 1: Description of the fitness test components, dimensions tested and units of measurement

Test component	Dimension	Description	Units of measurement
Jump with max-effort rotation	Coordination	Vertical jumping from standing position with maximum-effort turns	Degrees
Sit-and-reach test	Flexibility	Bending the trunk in a seated position on the floor with straight legs with the feet placed against a test box and outstretched arms move a horizontally positioned scale	Difference between feet soles and the tip of the largest fingers measured in cm
Standing long jump	Power	Jumping from standing position	Distance in cm
Ball throwing	Strength and power	Volleyball throwing over the head from the knee position	Distance in m
4 × 10 m shuttle run	Speed and agility	Running as fast as possible 4 times between 2 lines, 10 m apart	Time in sec
20 m endurance shuttle run	Endurance	Running 20 m forth and back with an initial running pace of 8.5 km/h and a progressive 0.5 km/min raise of the running speed given by a sound	*n* of last completed 20 m laps

Statistical analysis

Mean and standard deviation (SD) or mean difference and 95% confidence interval (95% CI) were reported. The Shapiro-Wilk test was conducted to assess Gaussian distribution for the physical- and movement-skill measurements. Independent samples were *t*-tested to examine differences between groups at baseline with respect to anthropometric and motor-skill characteristics. A two-way ANOVA with repeat measurements was used to assess the impact of treatment (intervention or control), time (categorised as baseline, 0.5 years, 1 year, 1.5 years, and 2 years), and the group–time interaction. In cases where overall significant differences were found, a *post-hoc* Bonferroni test was conducted to identify significant differences in the pairwise comparison. Cohen's d effect size was calculated to express the standardised difference between the means of the intervention and control groups.

All analyses were conducted using IBM SPSS Statistics for Windows version 28.0 (IBM Corp., Chicago). A statistical significance level of $p < 0.05$ was applied.

Results

Main effects in ANOVA analysis

The two-way ANOVA with repeated measurements analysed the impact of the intervention period (factor: time) and physical intervention (factor: intervention) on the motor-skill performance of young primary school children (Supplementary Tables S I–S III). The main effect analysis indicated a moderate (Cohen's d = 0.6–0.8) effect of "time" on several motor-skill characteristics, i.e. jump with max-effort rotation ($F_{(4,\ 144)}$= 60.746, $p < 0.001$), standing long jump ($F_{(4,\ 144)}$ = 102.867, $p < 0.001$), ball throwing ($F_{(4,\ 144)}$= 94.018, $p < 0.001$), and 20 m endurance shuttle run ($F_{(4,\ 144)}$ = 84.188, $p < 0.001$). It also revealed that there was a second moderate effect of "intervention" only in relation to the 4 × 10 m shuttle run test ($F_{(3,\ 36)}$ = 21.442, $p < 0.001$). For other motor-skill analyses, even where statistically significant differences (p < 0.05–0.01) occurred over time or across study groups, the impact of these main effects was low (d = 0.2–0.4). In addition, no significant interaction effect (time × intervention) could be demonstrated for any of the motor-skill characteristics monitored except the endurance shuttle run test ($F_{(12,\ 144)}$ = 5.213, $p < 0.001$, d = 0.303).

Baseline anthropometric and skill measurements

Differences between the intervention and control subjects (Δ Int/Con %) in terms of anthropometric and motor-skill measurements are expressed as a percentage of the control-subject values.

Table 2 shows the baseline anthropometric and movement-skill characteristics by treatment group. Intervention subjects exhibited a significant 17.6% lower body fat percentage than control subjects, with a body fat percentage of 14.8 ± 4.6% for the intervention group and 17.4 ± 4.2% for the control group ($p < 0.05$). There were no statistical differences between the intervention and control body weight (23.6 ± 2.8 kg vs. 24.0 ± 2.7 kg), the intervention and control height (1.25 ± 0.05 m vs. 1.24 ± 0.03 m), and the intervention and control BMI (15.2 ± 1.3 kg/m^2 vs. 15.7 ± 1.8 kg/m^2) (all $p > 0.3$). The statistical analysis revealed a trend of 5% higher muscle mass in the intervention group, i.e. 10.1 ± 1.3 kg, compared with the control group, i.e. 9.6 ± 0.7 kg ($p > 0.08$).

Table 2: Baseline anthropometric and motor skill characteristics for intervention and control groups of young primary school children

Outcomes	Intervention group (n = 20)	Control group (n = 20)	Δ Int/Con (in %)
Body weight, kg	23.6 ± 2.8	24.0 ± 2.7	–1.7 $p = 0.609^*$
Height, m	1.25 ± 0.05	1.24 ± 0.03	0.8 $p = 0.743$
Body mass index, kg/m^2	15.2 ± 1.3	15.7 ± 1.8	–3.3 $p = 0.347$
Body fat, %	14.8 ± 4.6	17.4 ± 4.2	–17.6 $p = 0.038$
Muscle mass, kg	10.1 ± 1.3	9.6 ± 0.7	5.0 $p = 0.083$
Motor skills			
Jump with max-effort rotation, °	226 ± 29	209 ± 39	7.5 $p = 0.121$
Sit-and-reach test, cm	20.6 ± 5.2	21.9 ± 7.2	–6.3 $p = 0.515$
Standing long jump, cm	131 ± 15	114 ± 9	13.0 $p < 0.001$
Ball throwing, m	4.7 ± 0.8	3.9 ± 0.6	15.7 $p = 0.004$
4 × 10 m shuttle run, sec	13.3 ± 0.8	14.7 ± 0.6	–10.5 $p < 0.001$
Endurance running, *n* of 20 m distance	25.4 ± 9.8	14.0 ± 6.2	44.9 $p < 0.001$

Data are presented as mean ± SD.
* *t*-test for independent samples.

Differences between intervention and control subjects are expressed in % of the values of control subjects.

Performance in the standing long jump at baseline was a significant 13% ($p < 0.001$) higher in the intervention subjects (131 ± 15 cm) compared to the control subjects (114 ± 9 cm). The performance in ball throwing was a significant 15.7% ($p < 0.01$) higher in the intervention group (4.7 ± 0.8 m) than in the control group (3.9 ± 0.6 m). The 4 × 10 m shuttle run results showed that the intervention subjects (13.3 ± 0.8 sec) were 10.5% faster ($p < 0.001$) than the control subjects (14.7 ± 0.6 sec). The intervention subjects also performed a significant 44.9% better ($p < 0.001$) in the number times they covered the 20 m distance (25.4 ± 9.8) than the control peers (14 ± 6.2). However, there were no statistically significant differences between the intervention and control groups in the jump with max-effort rotation (226 ± 29° versus 209 ± 39°, $p > 0.1$) or in the sit-and-reach test (20.6 ± 5.2 versus 21.9 ± 7.2 cm, $p > 0.05$).

Follow-up skill measurements

Performance changes in movement-skill tests over the study period for intervention and control subjects have been presented separately for boys and girls in Tables 3 and 4, and Figures 1–6.

Jump with max-effort rotation

Among boys, physical performance in the jump with max-effort rotation increased significantly ($p < 0.001$) over time. At two years, it was only slightly better ($p > 0.2$) in the intervention group, at 81° (95% CI: 48; 114), than among the control subjects, at 72° (95% CI: 40; 105) (Table 3, Fig. 1).

Among girls, at two years the jump with max-effort rotation performance was 52.4% higher in the intervention group, at 96° (95% CI: 61; 131), than among control subjects, at 63° (95% CI: 19; 107), though there was no significant statistical ($p > 0.06$) difference between them (Table 4, Fig. 1).

Sit-and-reach test

Among boys, skill in the sit-and-reach test increased only very slightly over time, i.e. at two years, intervention subjects had improved by 5% ($p > 0.2$) and the control subjects by 7% ($p < 0.01$). Therefore, there is no statistically significant ($p > 0.4$) difference between the intervention and control groups (Table 3, Fig. 2).

Among girls, the analysis of the sit-and-reach test revealed statistically significant enhanced performance of 0.7 cm (95% CI: –5.3; 6.7, $p < 0.05$) in the control group, but no significant improvement, at 2.5 cm (95% CI: –4.1; 9.1, $p > 0.7$), in the intervention group. The intervention-based positive effect ($p < 0.02$) observed across the groups at one year had not continued significantly ($p > 0.1$) at two years (Table 4, Fig. 2).

Standing long jump

In the standing long jump, among boys a high-performance gain ($p < 0.001$) of 24.1 cm (95% CI: 17.2; 31.0) was observed in the intervention group, but no significant difference ($p > 0.09$) was reported among control subjects, at 22.9 cm (95% CI: 10.3; 35.2). The 1.2 cm end-point rise in performance (95% CI: –6.3; 8.7) between groups was not statistically significant ($p > 0.3$) (Table 3, Fig. 3).

The results for girls exhibited a trend similar to that for boys. Physical performance increased significantly ($p < 0.01$) over time in intervention subjects, at 28.6 cm (95% CI: 2.7; 54.5), while the rise among control subjects, at 18.1 cm (8.0; 28.2), was not statistically significant ($p > 0.4$). Unlike the boys, at two years the difference between groups of girls, at 10.5 cm (95% CI: 0.4; 20.1), was statistically significant ($p < 0.05$) (Table 4, Fig. 3).

Table 3: Mean differences in fundamental motor skills between boys′ intervention and control groups of young primary school children

Outcomes		Baseline	0.5 years– baseline	1 year– baseline	1.5 years– baseline	2 years– baseline
Jump with max-effort rotation, °	I C	221 ± 26 198 ± 31	23 (-5; 50) $p = 0.052$	6 (-25; 37) $p = 0.344$	4 (-27; 34) $p = 0.405$	9 (-26; 44) $p = 0.295$
Sit-and-reach, cm	I C	19.9 ± 4.5 17.3 ± 5.9	0.2 (-0.8;1.2) $p = 0.334$	1.2 (-0.3; 2.6) $p = 0.095$	0.8 (-1.4; 3.0) $p = 0.223$	-0.2 (-2.9; 2.5) $p = 0.440$
Standing long jump, cm	I C	130 ± 6 117 ± 10	-1.3 (-4.7; 2.1) $p = 0.217$	-2.4 (-8.4; 3.6) $p = 0.205$	4.7 (-1.9; 11.3) $p = 0.076$	1.2 (-6.3; 8.7) $p = 0.371$
Ball throwing, m	I C	4.6 ± 0.5 3.9 ± 0.6	-0.1 (-0.5; 0.3) $p = 0.263$	-0.2 (-0.9; 0.5) $p = 0.266$	-0.3 (-0.9; 0.4) $p = 0.204$	-0.6 (-1.1; 0.3) $p = 0.081$
4 × 10 m shuttle run, sec	I C	13.6 ± 1.0 14.7 ± 0.8	0.1 (-0.2; 0.4) $p = 0.228$	-0.1 (-0.6; 0.4) $p = 0.332$	-1.4 (-4.2; 1.5) $p = 0.161$	-0.4 (-1.1; 0.3) $p = 0.139$
Endurance running, n laps	I C	26.8 ± 8.3 11.9 ± 4.0	0.7 (-3.2;4.6) $p = 0.354$	2.5 (-4.1; 9.1) $p = 0.219$	4.1 (-2.8; 11.0) $p = 0.115$	6.4 (-1.8; 14.6) $p = 0.059$

Data are presented as mean ± SD or mean difference (95% confidence interval).
I, intervention group; C, control group.
p-value, ANOVA with repeated measurements between-groups difference.

Table 4: Mean differences in fundamental motor skills between girls′ intervention and control groups of young primary school children

Outcomes		Baseline	0.5 years– baseline	1 year– baseline	1.5 years– baseline	2 years– baseline
Jump with max-effort rotation, °	I C	231 ± 33 221 ± 45	29 (-2; 60) $p = 0.031$	39 (7; 69) $p = 0.010$	42 (-5; 89) $p = 0.037$	33 (-10; 76) $p = 0.061$
Sit-and-reach, cm	I C	21.3 ± 5.9 26.5 ± 5.3	1.7 (1.0; 2.4) $p < 0.001$	1.4 (0.3; 2.5) $p = 0.008$	1.9 (0.1; 3.7) $p = 0.018$	1.8 (-1.0; 4.6) $p = 0.100$
Standing long jump, cm	I C	133 ± 21 112 ± 8	3.4 (-1.9; 8.7) $p = 0.097$	3.9 (-4.6; 12.4) $p = 0.174$	10.7 (1.7; 19.7) $p = 0.011$	10.5 (0.4; 20.1) $p = 0.021$
Ball throwing, m	I C	4.7 ± 1.0 3.9 ± 0.6	0.2 (-0.2; 0.6) $p = 0.172$	0.3 (-0.4; 0.9) $p = 0.212$	0.7 (-0.8; 1.4) $p = 0.039$	0.6 (-0.1; 1.3) $p = 0.024$
4 × 10 m shuttle run, sec	I C	12.9 ± 0.6 14.8 ± 0.5	-0.2 (-0.5; 0.0) $p = 0.038$	-0.4 (-1.0; 0.2) $p = 0.082$	-0.3 (-0.8; 0.2) $p = 0.084$	-0.3 (-0.8; 0.2) $p = 0.088$
Endurance running, n laps	I C	24.0 ± 11.3 16.0 ± 7.5	2.3 (-1.9; 6.5) $p = 0.134$	5.4 (0.1; 10.7) $p = 0.022$	5.9 (-0.2; 12.0) $p = 0.029$	14.2 (7.6; 20.8) $p < 0.001$

Data are presented as mean ± SD or mean difference (95% confidence interval).
I, intervention group; C, control group.
p-value, ANOVA with repeated measurements between-groups difference.

Ball throwing

Among boys, physical performance in ball throwing improved significantly in both the intervention and control groups ($p < 0.001$ vs. $p < 0.05$). Ball-throwing results showed that intervention subjects improved by 34.7%, i.e. 1.6 m (95% CI: 1.0; 2.3), while performance among control subjects increased by 56.4%, i.e. 2.2 m (95% CI: 1.1; 3.2). At the end of the study, the outcome was not significantly different ($p > 0.08$) between the two groups: – 0.6 m (95% CI: – 1.1; 0.3) (Table 3, Fig. 4). Girls in the intervention group improved at throwing a ball by 40.4% ($p > 0.06$) and those in control groups by 30.7% ($p > 0.1$). Unlike the boys, the difference in ball throwing between the groups, at 0.6 m (95% CI: –0.1; 1.3), was statistically significant ($p < 0.05$) (Table 4, Fig. 4).

4 × 10 m shuttle run

The time it took for intervention-group boys to complete the 4 × 10 m shuttle run improved by a significant 11% ($p < 0.01$), while among the control subjects there was a 8.2% improvement ($p < 0.001$). The improvement in physical performance was not significantly different ($p > 0.1$) between the two groups –0.4 sec (95% CI: –1.1; 0.3) (Table 3, Fig. 5). The girls in the intervention group also significantly ($p < 0.01$) reduced their running time, improving by 7.8%. Control subjects improved by 5.4% ($p < 0.05$). The difference ($p > 0.08$) between the intervention and control groups was not significant, standing at –0.3 sec (95% CI: –0.8; 0.2) (Table 4, Fig. 5).

20 m endurance shuttle run

At two years, boys' performance in the endurance shuttle run increased by 78.7% ($p < 0.01$) in the intervention group and more than two-fold from baseline in the control group. However, the difference between groups was not significant ($p > 0.05$), corresponding to an additional 6.4 lengths (95% CI: –1.8; 14.6) in favour of the intervention group (Table 3, Fig. 6). In this movement skill, girls in the intervention group also achieved a statistically significant ($p < 0.01$) 77.9% increase, while there was a much smaller rise (28.1%, $p < 0.001$) among the control subjects. At two years, intervention-group girls exhibited significantly better endurance performance ($p < 0.001$) than control-group girls, corresponding to a difference of 14.2 additional lengths (95% CI: 7.6; 20.8) (Table 4, Fig. 6).

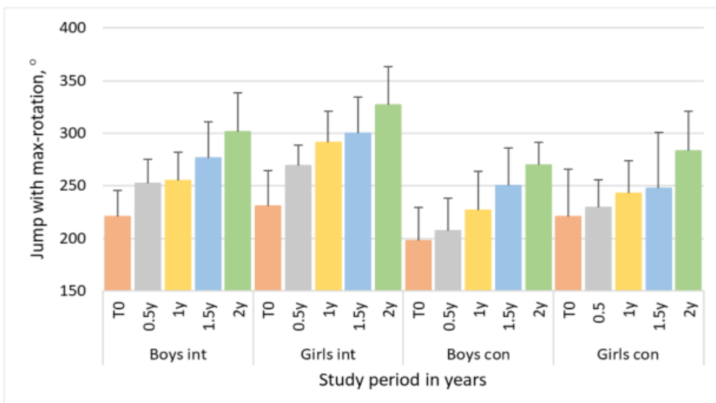

Fig. 1: The impact of a physical intervention on jump with max-effort rotation task in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int, intervention group. Within-group differences: Boys int and Boys con (both $p < 0.001$), Girls con ($p < 0.05$). Between-groups differences: Girls int *vs.* Girls con and Girls int *vs.* Boys con ($p < 0.05$ and $p < 0.001$, respectively).

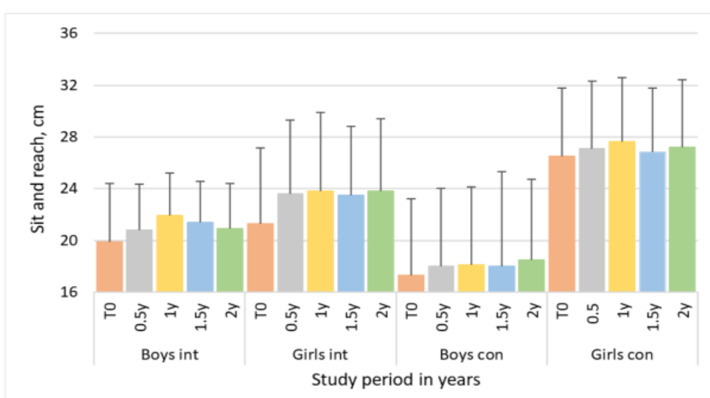

Fig. 2: The impact of a physical intervention on sit-and-reach test in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int,

intervention group. Within-group differences: Boys con and Girls con ($p < 0.01$ and $p < 0.05$, respectively). Between-groups difference: Boys con *vs.* Girls con ($p < 0.01$).

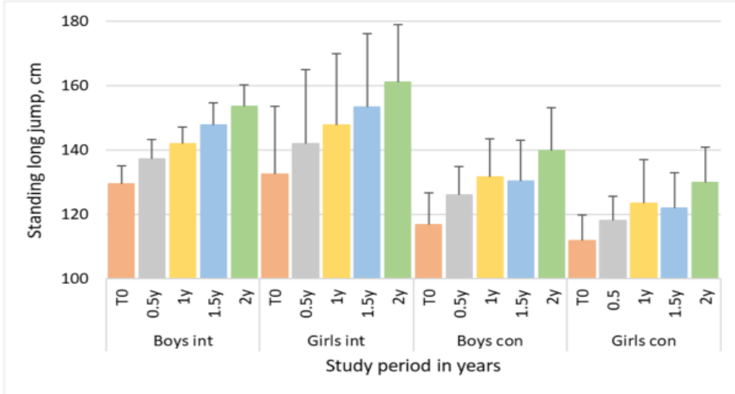

Fig. 3: The impact of a physical intervention on standing long jump task in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int, intervention group. Within-group differences: Boys int and Girls int ($p < 0.001$ and $p < 0.05$, respectively). Between-groups differences: Boys con *vs.* Girls int ($p < 0.05$); Boys int *vs.* Girls con ($p < 0.01$); Girls int *vs.* Girls con ($p < 0.001$).

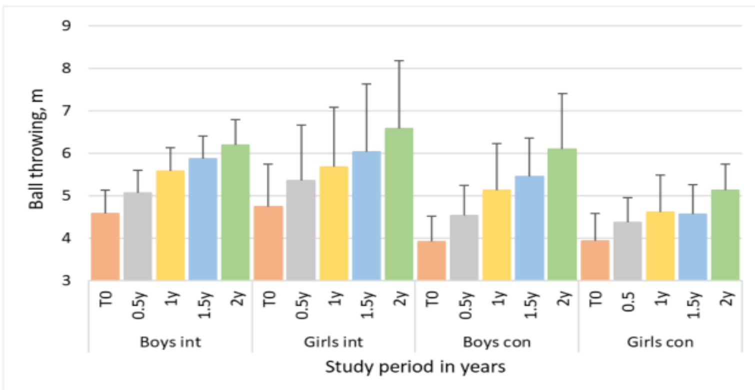

Fig. 4: The impact of a physical intervention on overhead ball throwing task in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int, intervention group. Within-group differences: Boys int and Boys con ($p < 0.001$ and $p < 0.05$, respectively). Between-groups difference: Girls int *vs.* Girls con ($p < 0.05$).

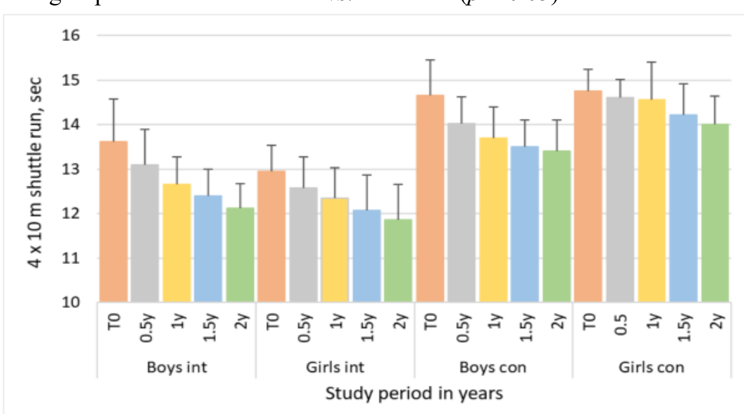

Fig. 5: The impact of a physical intervention on 4 × 10 m shuttle run task in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int, intervention group. Within-group differences: Boys int and Boys con ($p < 0.01$ and $p < 0.001$, respectively); Girls int and Girls con ($p < 0.01$ and $p < 0.05$, respectively). Between-groups differences: Boys int *vs.* Boys con and Boys int *vs.* Girls con (both $p < 0.001$); Girls int *vs.* Boys con and Girls int *vs.* Girls con (both $p < 0.001$).

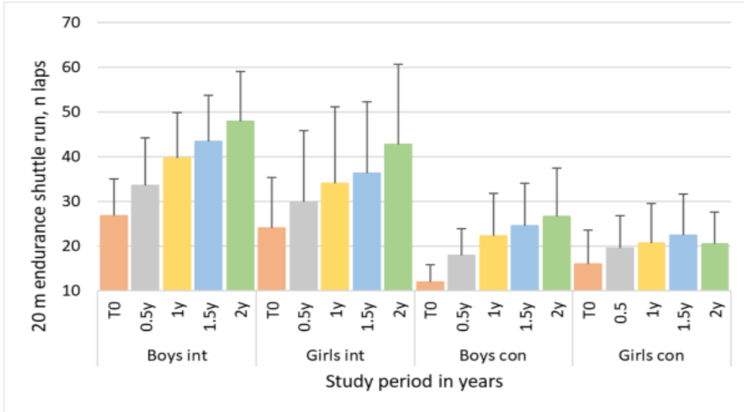

Fig. 6: The impact of a physical intervention on 20 m endurance shuttle run task in young primary school children. Columns and bars represent means and standard deviations, respectively. T0, at baseline; y, year; con, control group; int, intervention group. Within-group differences: Boys int and Girls int (both $p < 0.01$); Boys con and Girls con (both $p < 0.001$). Between-groups differences: Boys int *vs.* Boys con ($p < 0.01$); Boys int *vs.* Girls con ($p < 0.01$); Girls int *vs.* Girls con ($p < 0.05$).

Discussion

Previous studies have shown that primary school years are the optimal time of life to develop fundamental movement skills (Rico-González, 2023). These skills do not occur naturally and are more likely to be acquired through active play and with perceived educator support (Gallahue et al., 2012). The main goal of the current study was to assess, in a controlled setting, how the long-term physical activity intervention affects fundamental movement skills in young primary school children.

Main findings

Our study clearly demonstrates that physical fitness and movement skills, such as strength, coordination, speed, agility, and flexibility, increase parallel with age in both the intervention and control groups. However, improvements were greater in the intervention group and may differ by gender. Intervention-group girls, compared to class peers who engage in standard physical exercise, performed significantly better in three of the six motor skills tested (i.e. the standing long jump, ball throwing, and endurance run). Among boys, on the other hand, intervention was not shown to have any significant effects in any of the motor-skill measurements after the completion of the study. This does not come as a surprise since girls often score better in their performance in certain motor test batteries than boys (Smits-Engelsman et al. 2023).

For both boys and girls, most progress in motor performance was observed in the endurance shuttle run test. This motor skill is indirectly affected by improvements in the other motor components of physical fitness, and, notably, by the extensive changes in the cardiovascular and respiratory systems during infancy and early childhood (Saikia & Mahanta, 2019). Conversely, the lowest degree of stability in motor performance was found in the jump with max-effort rotation. This test is used as an indicator of the muscular power of the legs and the ability to flex and extend the trunk rapidly at the hip joints. Our findings suggest that is difficult for younger schoolchildren to incorporate these different and complex motor coordination movements. Another important reason for unstable performance in the jump with max-effort rotation test over time is the increasing body weight of children, because it has been shown that body weight (size) is negatively associated with performance in this task (Lee et al., 2001). These are two main reasons, in our opinion, why this test is not frequently used in the battery of basic motor skill tests intended for primary-school-aged children (Scheuer et al., 2019).

Comparison with standard motor skill data

The consistent improvement in fundamental motor-skill performance observed in the present study aligns with other findings showing that motor skills improve with age, particularly in response to increased amounts and higher intensities of physical activity (Branta et al., 1984; Hands, 2008). A few studies have established standard data for primary-school-aged children in certain motor skill tasks (De Migel-Etayo et al., 2014; Rodrigues et al., 2019; Emeljanovas et al., 2020; Vaccari et al., 2021). Overall, and with small variations by gender and age, the mean values observed in our children were slightly or considerably higher (≈ 75th percentile) in motor skills such as the standing long jump, sit and reach, and endurance run tests than those of children from eight European countries in an IDEFICS study (De Migel-Etayo et al., 2014). In addition, our children also achieved higher performance scores in the standing long jump than Portuguese and Lithuanian children of the same age (Rodrigues et al., 2019; Emeljanovas et al., 2020). Slovak girls achieved much better results in the flexibility test (i.e. sit-and-reach) than their Italian counterparts (Vaccari et al., 2021), while our boys and girls in the intervention groups, but not in the control groups, sprinted faster (4 × 10 m shuttle run) than the general population of schoolchildren in Portugal (Rodrigues et al., 2019). Consequently, our children's results seem to be satisfactory when we compare them with their peers in other European countries.

Gender-related differences

Several studies have identified gender-related differences in fundamental movement skills throughout middle childhood (Barnett et al., 2010; Rodrigues et al., 2019; Lee et al., 2020; Lisowski et al., 2020). In a recent study, Hohmann *et al.* (2021) examined motor-skill performance among 577 Chinese and German primary school children (8–9 years old). Over one-year period, boys performed better than girls in the 20 m sprint, endurance running, push-up, and sit-up tests, while girls were better at the flexibility tasks. In a cross-sectional study, Larsen et al. (2017) assessed fitness and motor performance in 8-10-year-old Danish schoolchildren, 209 girls and 214 boys, of whom 67% and 74%, respectively, were active in sports clubs. The girls' performance in the balance test was 15% better than the boys, whereas the boys performed 47% better than the girls in endurance running. The boys also performed 5% better in the 20 m sprint test and had 8% better long-jump results than the girls. Furthermore, children who actively involved in sports clubs generally put in better physical and motor performance than children who did not belong to such clubs.

Gender differences in fundamental movement skills can be explained by heredity and environmental factors. Earlier studies of twins and recent genome-wide association studies have indicated that well characterised gene polymorphisms account for much of the differences in motor-control and motor-learning capacity, with heritability ranging from 0.56 to 0.86, depending on the motor task (Fox et al., 1996; Missitzi et al., 2013; Mountford et al., 2021). It is believed that girls may exhibit more significant improvements in motor-skill competence than boys due to their greater potential for change, particularly in object-control tasks (Barnett et al., 2010). Environmental factors, notably poor socio-economic conditions in high-risk community groups (i.e. a lack of opportunity to engage in organised sports, poor-quality physical education, low-income parents, and unsafe neighbourhoods), can negatively affect children's physical fitness and development of their motor-skill performances (Cohen et al., 2015).

Physical intervention programmes

Numerous studies have also been conducted as school-based physical programmes with a wide range of interventions and different test durations. However, there is a shortage of studies investigating the impact that intervention under the Kids' Athletics programme has on physical fitness and motor-skill development in young children. To the best of our knowledges, only six studies targeting middle childhood and young teens could be identified in multiple open online databases. All these studies were published between 2015 and 2020, and were conducted in Slovakia (Willwéber, 2016; Čillík & Willwéber, 2016), Greece (Blatsis et al., 2016), Turkey (Çalik et al., 2018), Algeria (Bensikaddour et al., 2015), and India (Abhaydev et al., 2020). These indicate that 285 children between the ages of 6 and 14 years (8% of children were younger than 8 years old) have participated in a school-based Kids' Athletics programme. The duration of the interventions ranged from 6 weeks to 9 months across the studies. The results of these studies have clearly demonstrated the positive effects of Kids' Athletics intervention on most fundamental motor skills in both boys and girls. In this context, we have a rather speculative explanation as to why intervention-group girls in our study outperformed intervention-group boys in motor skill tasks: unlike the boys, they were able to harness their greater gender-related potential for coping with individual changes, as mentioned above (Barnett et al., 2010).

Physical education implications

The role of physical education in the primary school curriculum is to facilitate the development of students' fundamental motor skills. Motor tests serve as valuable tools for monitoring children's level of motor performance and help to identify their strengths and weaknesses either at a specific moment or over time. Our findings that girls outperform boys in fundamental motor skills have important implications for physical education. First, they indicate that distinct differences in motor competence might be present in a group of healthy young children. To mitigate these differences, accurate and early identification (i.e. pedagogical diagnosis) is essential, and employing various pedagogical approaches (i.e. providing opportunities to practise, offering clear instructions, and modelling) to enhance the motor performance and physical fitness of those with lower levels is warranted. Secondly, children's motor skills should be measured and evaluated every year during physical-education lessons. Contemporary motor skill tests are straightforward to conduct, well suited to a school setting (a sports field or gym), and do not require specialised equipment. They are also time-efficient, making them ideal for mass testing. Furthermore, motor-skill testing can foster improved self-esteem, a positive body image, fair play in sports, and cooperation among students. Thirdly, our intervention programme did not have adverse effects on the development of motor skills. Nor did we record any serious injury or illness as a result of the programme. Fourthly, in an educational context, the Kids' Athletics programme and similar training activities can be integrated as routine and structured school-based physical interventions. This support for motor performance plays a pivotal role in enhancing children's overall motor skills, ultimately leading to their increased participation in sports and other leisure-time physical activities.

Strengths and limitations

A notable strength of this study is its systematic long-term monitoring of both the intervention and control groups, utilising objective, valid, and reliable motor-skill tests. Furthermore, studying a less-explored group of very young primary school children can be considered an advantage. Nonetheless, this study is not without its limitations. First, due to practical constraints, the small sample size of children in the intervention group restricts the generalisability of the results to a larger child population. Secondly, there may be a participation bias, as more motivated children and those with better motor skills may have been more inclined to engage in this physical-activity intervention. Lastly, we did not have detailed information on the full spectrum and forms of children's everyday physical activities.

Conclusions

The aim of this study was to investigate the impact of a two-year after-school physical intervention programme on motor-skill performance in young primary school children. Our findings revealed a statistically significant increase in motor-skill performance among girls, but no significant positive changes were observed in boys compared to the control group. In both genders, the most substantial progress was observed in the endurance-run task (i.e. cardiorespiratory fitness). The physical exercise and intervention-programme management were overseen by a trained teacher to ensure that the training sessions included WHO-recommended intensity for physical activity. The programme had the added benefit of positively influencing the children's daily routines. Additionally, parental involvement played a crucial role in the intervention programme's success (social background, motivation, the transportation of the children to the sessions). The Kids´ Athletics program or similar training activity may be taken as a regular and controlled school-based physical intervention. Future research should focus on more rigorously designed experimental studies aimed at establishing a cause-effect relationship between fundamental motor skills and physical activity.

Acknowledgements
We thank all parents, children, and physical education teachers for their exemplary collaboration in this study.
Funding information
The study was supported by Ministry of Education, Science, Research and Sport of the Slovak Republic, Grant/Award Number: VEGA-1-0491-20.
Conflicts of interest: The authors declare no competing interests.

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