Effects of a 12-Week Strength- and Endurance-Based Exercise Program on Fundamental Movement Skills of Preschool Children: A Randomized Controlled Trial

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A B S T R A C T

The aim of this study was to examine the effects of a 12-week strength- and endurance-based exercise program on the fundamental motor skills (FMS) of preschool children. A total of 47 children were randomly assigned to either an experimental group (EG; n = 25, mean age 6.3 ± 0.3 years) or a control group (CG; n = 22, mean age 5.9 ± 0.3 years). The EG participated in strength and endurance exercises three times per week for 30 minutes, while the CG took part in regular kindergarten activities. FMS were assessed before and after the intervention using the Test of Gross Motor Development, Second Edition. Raw and standardized scores were calculated for locomotor skills, object control skills, and overall gross motor skills. Based on a two-way ANOVA, significant group × time interactions were found in three locomotor tasks (running, hopping, and sliding) and three object control tasks (overhand throwing, underhand rolling, and striking a ball). Post hoc analysis revealed significant improvements from pre- to post-test in the EG, but not in the CG. Positive effects of the program were observed in both raw and standardized scores for locomotor skills ($p \leq .01$), object control skills ($p \leq .02$), and overall gross motor skills ($p \leq .01$), with moderate to large effect sizes ($\eta p^2 = .12 – .42$). These findings highlight the importance of integrating structured physical exercise programs into early childhood education.

Keywords: *locomotor skills, object control skills, physical exercise program, gross motor development, experimental study.*

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Introduction

At present, many children spend long periods in sedentary activities, such as using mobile phones or computers for games (Colley et al., 2013). This is concerning because physical inactivity is linked to a higher likelihood of developing cardiovascular and metabolic disorders in childhood (Andersen et al., 2011; Ekelund et al., 2012; Veijalainen et al., 2016).

Physical activity (PA) plays a key role in psychophysical development, with positive effects on physical growth, motor development, aerobic capacity, blood pressure, blood lipid levels, glucose metabolism, and mental health (Butcher, 1983; King et al., 2003; Roth et al., 2010).

Therefore, children need to engage in PA to prevent obesity and achieve numerous health benefits (Cragg & Cameron, 2006; Warburton et al., 2006). Recent evidence also highlights that preschool children who meet activity guidelines are more likely to achieve adequate fundamental movement skills (FMS) proficiency and long-term health outcomes (Jones et al., 2020; Webster et al., 2019). Accordingly, leading world health institutions promote PA and provide guidelines that recommend that preschool children engage in at least 60 minutes of moderate to high-intensity PA (Guan et al., 2020).

Low levels of PA can negatively affect motor development, as children who do not engage in sufficient PA have reduced ability to develop motor skills needed for sports and other physical activities (Lubans et al., 2010). FMS are widely recognized as the foundation of motor competence and later physical activity (Hulteen et al., 2018; Newell, 2020), being particularly crucial in early childhood, when a child encounters new situations and challenges. Through physical exercise, children acquire basic motor skills, improve coordination, balance, and develop object control abilities. Systematic reviews confirm strong associations between motor skill competence, physical activity, and broader aspects of preschool development (Figueroa & An, 2017; Malambo et al., 2022). These skills not only support children in their daily lives but also prepare them for participation in sports and other physical activities later in life (Stodden et al., 2008; Venetsanou et al., 2015).

Although many studies have examined the impact of structured exercise on children’s motor abilities, relatively few have specifically addressed FMS in preschool-aged populations. Recent studies examining the impact of PE on the movement skills of preschool children have shown positive effects of PE in most locomotor and object control tasks compared to the control group (Brian et al., 2017; Duncan et al., 2019; Radanović, 2018; Roach & Keats, 2018). In contrast, the study of Alhassan et al. (2012) showed no difference between the groups. Other recent intervention in preschoolers, such as aerobic exercises, yoga, or general exercise programs, consistently showed benefits for motor and cognitive abilities (Aleksić Veljković et al., 2021; Katanić et al., 2022, 2024). Similar results were observed when comparing motor proficiency between healthy-weight and overweight preschoolers (Banjević et al., 2022) and when exploring associations between motor and cognitive abilities (Katanić et al., 2025). However, none of these studies specifically targeted a structured strength- and endurance-based program. A recent meta-analysis confirmed that structured interventions have a stronger impact on locomotor skills in preschool children than unstructured ones, especially when implemented over a longer duration (Chen et al., 2024). More recently, structured approaches such as functional and neuromuscular exercises have also shown improvements in FMS and fitness in preschool and early school-age children (Wang et al., 2025; Zhang et al., 2024). However, these interventions did not specifically target a combined strength and endurance approach.

Moreover, while numerous physical exercise programs exist, leading organizations such as the WHO and the US Department of Health and Human Services recommend that children aged 5-6 perform at least 60 minutes of PA daily, including both aerobic and strength components (USDHHS, 2008; World Health Organization, 2010).

Although the effects of combined strength and endurance exercise are well-documented in adults (Huiberts et al., 2024; Pito et al., 2022), but remain largely unexplored in preschool children. This gap in knowledge justifies the present study.

This longitudinal research aimed to evaluate the effects of a 12-week strength- and endurance-based exercise program on FMS in preschool children. Based on previous evidence, we hypothesized that the intervention group would achieve significantly greater improvements in FMS compared with peers in regular kindergarten activities.

Method

Participants

This randomized controlled longitudinal study included 47 preschool children aged 5-6 years. Participants were randomly allocated into an intervention group (IG; n = 25; 6.35 ± 0.32 years), and a control group (CG; n = 22; 5.90 ± 0.27). The sample included both boys and girls, all recruited from the same preschool institution to ensure environmental homogeneity (Table 1).

Eligibility required children to be free from any medical condition that could limit safe participation in physical activity. Exclusion criteria included chronic illness, recent injuries, or lack of parental consent. Written informed consent was obtained from all parents/legal guardians, who also provided demographic information and medical assessment forms.

The research was approved by the Ethics Committee of the University of Nis (Ref. No. 04-1186/2) and conducted in accordance with the Declaration of Helsinki.

Table 1
Descriptive indicators of the sample of respondents

Variable	EG	CG
Number of children	25	22
Sex	Boys: 14 Girls: 11	Boys: 9 Girls: 13
Age	6.35 ± 0.32	5.90 ± 0.27
BM (kg)	25.08 ± 4.28	22.60 ± 3.60
BH (m)	1.22 ± 0.05	1.17 ± 0.05
BMI (kg/m^2)	16.90 ± 1.95	16.42 ± 1.65

Note. EG = Experimental group; CG = Control group

Research Design

This study used a mixed longitudinal experimental design with pre- and post-test measurements. Testing of all participants was conducted immediately before (initial measurement) and after the 12-week intervention program (final measurement).

The measurements were conducted in the physical activity hall of the preschool institution at the same time of the day (11:00 a.m.) to minimize circadian influences, with ambient temperature between 22-26 °C. The intervention lasted 12 weeks, with measurements at baseline (week 0) and after completion (week 12).

Instruments

Anthropometric characteristics were measured using standardized anthropometric instruments (GPM, Switzerland) and an international procedure (Eston & Reilly, 2013). Body mass index (BMI) was calculated as weight (kg) / height (m^2). BMI is strongly correlated with body fat and serves as an indicator of nutritional status in children (Wilmore et al., 2022).

Fundamental Movement Skills (FMS) were evaluated using the Test of Gross Motor Development, Second Edition (TGMD-2). This instrument consists of 12 movement tasks divided into two subtests: locomotor skills (LS) and object control (OC). LS includes six locomotor tasks: LS1 – running, LS2 – galloping, LS3 – hopping, LS4 – leaping, LS5 – horizontal jumping, LS6 – sliding. OC includes six object manipulation tasks: OC1 – striking a stationary ball, OC2 – dribbling, OC3 – catching, OC4 – kicking, OC5 – overhead throwing, OC6 – rolling.

Using the standardized TGMD tables, results were converted into age-adjusted values, producing locomotor skills (LSS), object control (OCS), and a total FMS score (FMSS) (Ulrich, 2000).

The Experimental Program

The intervention consisted of a strength- and endurance-based exercise program created in accordance with the National Association for Sport and Physical Education (USA) guidelines, which recommend both aerobic- and strength-based activities for preschool children (USDHHS, 2008).

The program lasted 12 weeks, with three sessions per week, each lasting 30 minutes. The structure of each session comprised a warm-up phase (5 min), a primary exercise phase (20 min), and a cool-down phase (5 min). The program was implemented during the children's regular preschool activities, while the control group (CG) engaged in free-play activities during the same period.

The warm-up included aerobic dynamic exercises such as marching or light skipping, along with shaping movements. The main phase consisted of intervals of high-intensity activity (30 seconds) alternated with low-intensity bodyweight exercises (30 seconds).

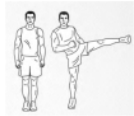
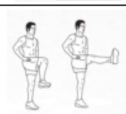
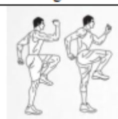
The program consisted of bodyweight exercises commonly used in group fitness, with an emphasis on strengthening the muscles of the upper limbs, chest, and shoulder girdle (push-up variations and other weight-bearing support exercises); the trunk (sit-ups and planks); and the lower limbs (squats, lunges, jumps, and running in place).

Each complex (1 high + 1 low intensity exercise) was repeated twice, with 8-10 complexes per session. In the cool-down phase, stretching and relaxation exercises were performed (Table 2; Figure 1).

Table 2
An overview of the physical exercise program

Training session	Activity	Duration
Warm-up	Low intensity aerobic and shaping exercises	5 min
Main activity	Complex: 1 exercise of high 30'' - 1 exercise of low intensity 30'' x 2 (8-10 complexes)	20 min
Cool down	Stretching and breathing exercises	5 min

Figure 1
Example of the main part of the training session for the experimental group (Rey, 2017)

No.	Exercise description	Exercise I – higher intensity (30 sec)	Exercise II – lower intensity (30 sec)	Sets
1.	I – Two-footed forward–backward jumps; II – Alternating leg abduction (one leg, then the other).			X2
2.	I – From a wide stance, lower into a squat and jump upward (not continuous/jumps); II – Marching with knee raises and hand-to-knee contact, alternating legs.			X2
3.	I – From running in place, drop into a high plank position and extend one arm forward, then the other, and return to running in place; II – "Grape picking" exercise.			X2
1 minute of light marching with deep breathing (inhale–exhale).				
4.	I – Jumping jacks (from a feet-together stance to a wide stance with arms raised overhead); II – In a single-leg stance, perform arm movements from lateral abduction to forward raise, alternating positions.			X2
5.	I – From running, on every third step perform one lunge step, then three ground contacts, then other leg; II – Marching twice with forward trunk flexion.			X2
6.	I – Skipping, and on every 5th contact drop into a lunge and perform a vertical jump, then skipping and switch legs; II – Marching with lower-leg extension (and knee extension).			X2
1 minute of light marching with deep breathing (inhale–exhale).				
7.	I – High skipping (high knees), on every 3rd step hold the position for 1 second; II – From a forward bend into an arch position, diagonal movement (other side).			X2
8.	I – In a high plank position, perform alternating trunk rotations to both sides; II – Marching with arms abducted (side raises).			X2
9.	I – Two jumps + two arm raises with a clap overhead; II – Back extension (prone trunk extension).			X2

Statistical Analysis

Descriptive statistics, expressed as means and standard deviations, were computed for all variables. In the course of preliminary analyses, the distributional characteristics of the data were assessed based on the coefficients of skewness and kurtosis as measures describing deviations from symmetry and normal distribution. In addition to these indices, a visual inspection of Q-Q plots was performed, along with the analysis of skewness and kurtosis values (Tables 3 and 4). The results indicated that the distributions of the examined variables did not show substantial deviations from normality.

To evaluate the effects of the intervention, a mixed-design repeated measures ANOVA 2 × 2 was applied. This statistical model allows for the analysis of three effects: the main effect of group (differences between the experimental and control groups), the main effect of time (changes between baseline and post-intervention measurements), and the interaction effect of group and time (differential patterns of change between groups).

The level of statistical significance was set at $p < .05$ (two-tailed).Effect sizes were calculated to assess the practical significance of the results. Partial eta-squared values obtained from the ANOVA were converted into Cohen's *d*, and additional group-specific pre–post effect sizes were calculated using the formula:

$$d = \frac{M_{post} - M_{pre}}{SD_{pooled}} \quad (1)$$

Interpretation of Cohen's *d* followed conventional thresholds: trivial (< .20), small (.20-.50), moderate (.50-.80), large (.80-1.30), and very large (> 1.30) (Cohen, 1988). All statistical analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp.).

Results

Table 3 presents descriptive values for all motor skills in the experimental group (IG). Standard deviations indicate moderate variability in results among participants, while the range of observed values shows that participants utilized nearly the full scale range for most variables, suggesting satisfactory measurement discriminativeness. It is important to highlight the mean values for the total standardized variables LVS (6.68 ± 1.63), KOS (7.08 ± 1.42), and FMVS (13.76 ± 2.71).

Measures of distribution shape indicate that skewness coefficients ranged from -0.81 to 0.94, while kurtosis coefficients ranged from -1.17 to 0.81. The obtained skewness values fall within acceptable limits, and kurtosis values are also within the reference range, indicating no substantial deviations from normality. Negative skewness values for most variables suggest a slight left-sided asymmetry, whereas positive values for some variables (e.g., KO1) indicate a slight right-sided asymmetry.

Table 3
Descriptive data at baseline measurement for the experimental group (IG)

	M	*SD*	Minimum	Maximum	Range	Skewness	Kurtosis
LS1	4.52	1.39	1.00	7.00	6.00	-0.66	0.52
LS2	4.92	1.55	2.00	7.00	5.00	-0.58	-0.39
LS3	6.32	1.41	3.00	9.00	6.00	-0.33	0.02
LS4	3.64	1.11	1.00	5.00	4.00	-0.78	-0.10
LS5	4.04	1.02	2.00	6.00	4.00	-0.09	0.20
LS6	5.48	1.08	3.00	7.00	4.00	-0.69	0.56
LST	28.92	5.02	16.00	37.00	21.00	-0.81	0.81
LSS	6.68	1.63	3.00	9.00	6.00	-0.57	-0.25
OC1	5.04	1.97	2.00	10.00	8.00	0.94	0.59
OC2	4.08	1.55	1.00	7.00	6.00	-0.07	-0.78
OC3	4.36	0.70	3.00	5.00	2.00	-0.64	-0.64
OC4	4.60	1.61	2.00	7.00	5.00	0.07	-1.17
OC5	4.76	1.20	3.00	7.00	4.00	0.19	-0.76
OC6	4.36	1.04	2.00	6.00	4.00	-0.33	-0.25
OCT	27.20	4.77	18.00	37.00	19.00	0.17	-0.14
OCS	7.08	1.42	4.00	10.00	6.00	0.14	-0.08
GMST	56.12	8.68	37.00	72.00	35.00	-0.25	0.08
GMSS	13.76	2.71	7.00	19.00	12.00	-0.35	0.42

Note. *M* – arithmetic mean; *SD* – standard deviation; Minimum – minimum value; Maximum – maximum value; Skewness – coefficient of asymmetry; Kurtosis – coefficient of distribution peakedness; LS1-6 – locomotor skill tasks from task 1 to 6; LST – total raw scores of locomotor skills; LSS – total standardized values of locomotor skills; OC1-6 – object control (manipulative skill) tasks from task 1 to 6; OCT – total raw scores of manipulative skills; OCS – total standardized values of manipulative skills; GMST – total gross motor skill scores; GMSS – total standardized values of gross motor skills.

Table 4 presents descriptive values of motor skills in the control group (CG). Standard deviations indicate moderate variability in results among participants, while the range of observed values also shows that participants utilized nearly the full scale range for most variables, suggesting satisfactory measurement discriminativeness. It is important to highlight that the mean values for the total standardized variables LVS (7.09 ± 1.60), KOS (6.86 ± 1.73), and FMVS (13.95 ± 2.97) are relatively similar to those observed in the experimental group (IG).

Measures of distribution shape indicate that skewness coefficients ranged from -0.71 to 0.99, while kurtosis coefficients ranged from -0.98 to 1.85. The obtained skewness values fall within acceptable limits, and kurtosis values are also within the reference range, indicating no substantial deviations from normality. Negative skewness values for a larger number of variables suggest a slight left-sided asymmetry, whereas positive values for certain variables (e.g., KO5 and KO6) indicate a slight right-sided asymmetry; however, no consistent pattern of skewness dominance was observed, as it varied depending on the variable.

Table 4

Descriptive data at baseline measurement for the control group (CG)

	M	*SD*	Minimum	Maximum	Range	Skewness	Kurtosis
LS1	5.00	1.27	3.00	7.00	4.00	0.31	-0.92
LS2	4.86	1.39	2.00	7.00	5.00	-0.09	-0.66
LS3	6.09	1.19	4.00	8.00	4.00	-0.01	-0.70
LS4	2.91	1.27	1.00	6.00	5.00	0.65	0.17
LS5	4.18	1.05	3.00	6.00	3.00	0.41	-0.97
LS6	5.50	1.30	3.00	8.00	5.00	-0.07	-0.72
LST	28.55	4.75	21.00	39.00	18.00	0.39	-0.51
LSS	7.09	1.60	5.00	11.00	6.00	0.68	0.42
OC1	4.32	1.70	2.00	8.00	6.00	0.79	0.45
OC2	3.55	1.47	1.00	7.00	6.00	0.59	0.07
OC3	3.77	1.07	2.00	6.00	4.00	0.24	-0.61
OC4	2.95	1.05	1.00	5.00	4.00	0.10	-0.98
OC5	4.64	1.18	3.00	8.00	5.00	0.99	1.85
OC6	4.77	0.81	3.00	6.00	3.00	-0.71	0.60
OCT	24.00	4.51	15.00	33.00	18.00	0.13	-0.10
OCS	6.86	1.73	4.00	11.00	7.00	0.54	0.64
GMST	52.55	8.03	40.00	70.00	30.00	0.34	-0.67
GMSS	13.95	2.97	10.00	22.00	12.00	0.75	1.20

Note. *M* – arithmetic mean; *SD* – standard deviation; Minimum – minimum value; Maximum – maximum value; Skewness – coefficient of asymmetry; Kurtosis – coefficient of distribution peakedness; LS1-6 – locomotor skill tasks from task 1 to 6; LST – total raw scores of locomotor skills; LSS – total standardized values of locomotor skills; OC1-6 – object control (manipulative skill) tasks from task 1 to 6; OCT – total raw scores of manipulative skills; OCS – total standardized values of manipulative skills; GMST – total gross motor skill scores; GMSS – total standardized values of gross motor skills.

Table 5 presents baseline and post-intervention values of motor variables in the experimental (IG) and control (CG) groups. In the experimental group, improvements are observed in all examined variables, both in individual tests and composite scores.

The most pronounced improvement is evident in the overall indicators, where LVT increased from 28.92 ± 5.02 to 35.12 ± 4.63, KOT from 27.20 ± 4.77 to 33.04 ± 5.22, and FMV from 56.12 ± 8.68 to 68.16 ± 8.51.

Additionally, all individual locomotor variables (LV1-LV6) show a consistent increase in the experimental group, with the most notable improvements observed in LV1 (from 4.52 ± 1.39 to 6.12 ± 1.13) and LV4 (from 3.64 ± 1.11 to 4.84 ± 0.99). A similar trend is evident for LVS (from 6.68 ± 1.63 to 8.60 ± 1.53) and FMVS (from 13.76 ± 2.71 to 17.48 ± 3.10).

In the control group, changes are considerably smaller and inconsistent. While slight improvements are observed in some variables (e.g., KO3 and KO4), stagnation or even decreases are present in others (e.g., KO1 and KO6). Overall results also indicate minimal changes, with KOT increasing from 24.00 ± 4.51 to 25.14 ± 5.09 and FMV from 52.55 ± 8.03 to 54.68 ± 8.70.

Table 5

Descriptive indicators of the examined variables at baseline and post-intervention measurements in the experimental and control groups

Variables	EG		CG	
	Initial	Final	Initial	Final
LS1	4.52 ± 1.39	6.12 ± 1.13	5.00 ± 1.27	5.18 ± 1.05
LS2	4.92 ± 1.55	5.80 ± 1.53	4.86 ± 1.39	4.95 ± 1.17
LS3	6.32 ± 1.41	7.04 ± 1.34	6.09 ± 1.19	5.45 ± 0.91
LS4	3.64 ± 1.11	4.84 ± 0.99	2.91 ± 1.27	4.18 ± 1.05
LS5	4.04 ± 1.02	4.92 ± 0.86	4.18 ± 1.05	4.55 ± 0.86
LS6	5.48 ± 1.08	6.40 ± 1.00	5.50 ± 1.30	5.23 ± 1.11
LST	28.92 ± 5.02	35.12 ± 4.63	28.55 ± 4.75	29.55 ± 4.49
LSS	6.68 ± 1.63	8.60 ± 1.53	7.09 ± 1.60	7.18 ± 1.62
OC1	5.04 ± 1.97	6.16 ± 1.25	4.32 ± 1.70	3.82 ± 1.10
OC2	4.08 ± 1.55	5.00 ± 1.68	3.55 ± 1.47	3.91 ± 1.54
OC3	4.36 ± 0.70	5.00 ± 0.87	3.77 ± 1.07	4.55 ± 0.74
OC4	4.60 ± 1.61	5.16 ± 1.52	2.95 ± 1.05	3.95 ± 1.53
OC5	4.76 ± 1.20	6.48 ± 1.00	4.64 ± 1.18	5.09 ± 1.02
OC6	4.36 ± 1.04	5.24 ± 1.01	4.77 ± 0.81	3.82 ± 1.05
OCT	27.20 ± 4.77	33.04 ± 5.22	24.00 ± 4.51	25.14 ± 5.09
OCS	7.08 ± 1.41	8.88 ± 1.90	6.86 ± 1.73	7.23 ± 1.69
GMST	56.12 ± 8.68	68.16 ± 8.51	52.55 ± 8.03	54.68 ± 8.70
GMSS	13.76 ± 2.71	17.48 ± 3.10	13.95 ± 2.97	14.41 ± 3.11

Note. LV1-6 – locomotor skill tasks from task 1 to 6; LVT – total raw scores of locomotor skills; LVS – total standardized values of locomotor skills; KO1-6 – object control (manipulative skill) tasks from task 1 to 6; KOT – total raw scores of manipulative skills; KOS – total standardized values of manipulative skills; FMV – total gross motor skill scores; FMVS – total standardized values of gross motor skills; IG – experimental group; CG – control group.

The results of the mixed-design repeated measures ANOVA (2 × 2) (Table 6) indicate significant effects of the group factor, time factor, and their interaction across a large number of examined variables.

The effect of the group factor was statistically significant for most variables, particularly for LV3 (p = .004; ηp^2 = .169), LV4 (p = .011; ηp^2 = .136), LVT (p = .019; ηp^2 = .117), KO1 (p < .001; ηp^2 = .349), KO4 (p < .001; ηp^2 = .260), KO5 (p = .002; ηp^2 = .186), KOT (p < .001; ηp^2 = .308), KOS (p = .023; ηp^2 = .110), and FMV (p < .001; ηp^2 = .255), indicating baseline differences between the experimental and control groups at the level of main effects.

The effect of time was statistically significant for most variables, with particularly notable effects observed for LV1 (p < .001; ηp^2 = .314), LV4 (p < .001; ηp^2 = .484), LV5 (p < .001; ηp^2 = .227), LVT (p < .001; ηp^2 = .404), LVS (p < .001; ηp^2 = .336), KO3 (p < .001; ηp^2 = .339), KO4 (p = .001; ηp^2 = .208), KO5 (p < .001; ηp^2 = .351), KOT (p < .001; ηp^2 = .342), KOS (p = .001; ηp^2 = .230), FMV (p < .001; ηp^2 = .434), and FMVS (p < .001; ηp^2 = .332), indicating significant changes between baseline and post-intervention measurements in the overall sample.

Most importantly, the group × time interaction was statistically significant for a large number of variables, including LV1 (p = .001; ηp^2 = .225), LV3 (p = .002; ηp^2 = .200), LV6 (p = .001; ηp^2 = .235), LVT (p < .001; ηp^2 = .261), LVS (p < .001; ηp^2 = .336), KO1 (p = .018; ηp^2 = .119), KO5 (p = .006; ηp^2 = .155), KO6 (p < .001; ηp^2 = 0.415), KOT (p = .002; ηp^2 = .191), KOS (p = .019; ηp^2 = .117), FMV (p < .001; ηp^2 = .272), and FMVS (p = .001; ηp^2 = .233), indicating that changes over time differed between the experimental and control groups.

It is particularly important to emphasize that the significant interaction effects were accompanied by moderate to large effect sizes (ηp^2), suggesting that the intervention had a meaningful and practically significant impact on the improvement of motor performance compared to the control group.

Table 6
Effects of the physical exercise program on motor skills

	Group			Time			Group x Time		
	F	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2
LS1	0.59	.44	.013	20.57	.00**	.31	13.03	.00**	.22
LS2	1.60	.21	.035	4.94	.03*	.09	3.26	.07	.06
LS3	9.16	.00**	.16	0.04	.83	.00	11.24	.00**	.20
LS4	7.05	.01*	.13	42.16	.00**	.48	0.03	.84	.00
LS5	0.28	.59	.00	13.19	.00**	.22	2.27	.13	.04
LS6	4.04	.05	.08	4.07	.05	.08	13.82	.00**	.23
LST	5.94	.01*	.11	30.53	.00**	.40	15.92	.00**	.26
LSS	1.47	.23	.03	22.73	.00**	.33	22.73	.00**	.33
OC1	24.15	.00**	.34	0.88	.35	.01	6.05	.01*	.11
OC2	4.30	.04*	.08	7.29	.01*	.14	1.37	.24	.03
OC3	6.76	.01*	.13	23.03	.00**	.33	0.20	.65	.00

	Group			Time			Group x Time		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
OC4	15.83	.00**	.26	11.84	.00**	.20	0.94	.33	.02
OC5	10.30	.002**	.18	24.29	.00**	.35	8.22	.00**	.15
OC6	4.49	.040*	.09	0.05	.82	.00	31.87	.00**	.41
OCT	19.98	.00**	.30	23.34	.00**	.34	10.61	.00**	.19
OCS	5.56	.023*	.11	13.46	.00**	.23	5.93	.01*	.11
GMST	15.43	.00**	.25	34.52	.00**	.43	16.84	.00**	.27
GMSS	3.69	.061	.07	22.35	.00**	.33	13.67	.00**	.23

Note: *F* – F-test coefficient for the significance of Wilks' lambda; *p* – level of statistical significance; ηp² – partial eta squared; LV1-6 – locomotor skill tasks from task 1 to 6; LVT – total raw scores of locomotor skills; LVS – total standardized values of locomotor skills; KO1-6 – object control (manipulative skill) tasks from task 1 to 6; KOT – total raw scores of manipulative skills; KOS – total standardized values of manipulative skills; FMV – total gross motor skill scores; FMVS – total standardized values of gross motor skills; * $p < .05$; ** $p < .01$.

Discussion

The obtained results indicate clear differences between the experimental and control groups, as well as significant changes over time in most examined motor variables. The statistically significant effect of the group factor, particularly in variables with larger effect sizes (e.g., KO1, KO4, KOT and FMV), suggests that participants in the experimental group achieved overall better outcomes compared to the control group already at the level of baseline differences. At the same time, a significant time effect across a large number of variables, accompanied by moderate to large ηp² values, indicates an overall training or developmental effect in the entire sample, with the most pronounced improvements observed in LV4, FMV, and LVT.

However, the most relevant finding is the statistically significant group × time interaction for the majority of variables, which clearly indicates that changes differed between groups, i.e., that the experimental intervention led to significantly greater improvements compared to the control group. These results, together with moderate and large effect sizes, further confirm the practical relevance of the applied program in enhancing participants' motor performance.

Based on the descriptive analysis of the initial measurements, it is noticeable that the average values of motor parameters were similar between the experimental and control groups in most variables. The achieved results of preschool-aged children in both groups in locomotor skills were consistent with the results of other studies (Duncan et al., 2019; Johnstone et al., 2017; Logan et al., 2014). Thus, the motor skill levels of participants in this study correspond to those reported in the literature for children of similar age. However, in certain studies, children achieved slightly higher average values in locomotor skills (Cliff et al., 2009; Grant-Beuttler et al., 2017; Roach & Keats, 2018).

Regarding manipulative skills, the results obtained are in line with previous findings (Newell, 2020; Katanić et al., 2022), while some studies have reported slightly higher average values (Cliff et al., 2009; Grant-Beuttler et al., 2017; Roach & Keats, 2018). Similarly, gross motor skill outcomes correspond to results from other studies (Katanić et al., 2022; 2024), although higher values have been reported elsewhere (Cliff et al., 2009; Grant-Beuttler et al., 2017; Roach & Keats, 2018), while in contrast, lower values were found in another investigation (Duncan et al., 2019).

The combined analysis of variance revealed positive effects of strength- and endurance-based exercise program on locomotor, manipulative, and overall gross motor skills. These findings are consistent with earlier research that has confirmed the beneficial influence of structured physical activity on motor development in preschool children, particularly in locomotor (Deli et al., 2006; Duncan et al., 2019; Radanovic, 2018; Roach & Keats, 2018), manipulative (Bellows et al., 2013; Brian et al., 2017; Duncan et al., 2019; Radanovic, 2018; Roach & Keats, 2018) and overall gross motor skills (Duncan et al., 2019; Radanovic, 2018; Roach & Keats, 2018).

One expected outcome was the greater improvement in locomotor skills, given that the program was primarily composed of bodyweight exercises such as running in place, hopping, and jumping. A particularly interesting finding was the transfer of these locomotor activities to object control skills, even though the program did not directly target object manipulation.

When locomotor tasks were analyzed individually, improvements were observed in LV1 (running), LV3 (hopping), LV6 (lateral movement), LVT (total raw values of locomotor skills), and LVS (total standardized values of locomotor skills), while no significant differences were found in LV2 (galloping), LV4 (jumping over), and LV5 (standing long jump).

In the case of object control tasks, significant improvements were recorded in KO1 (striking a stationary ball), KO5 (overhand throwing), and KO6 (rolling the ball), as well as in KOT (total raw values of manipulative skills) and KOS (total standardized values of manipulative skills), whereas no differences were found in KO2 (dribbling), KO3 (catching), and KO4 (kicking).

Furthermore, significant improvements were achieved in the overall motor skill variables FMV (total gross motor skill scores) and FMVS (total standardized gross motor skill scores). These results indicate that, although the program was effective in improving locomotor and object control skills overall, a more detailed analysis shows that significant improvements were achieved in only half of the tasks, suggesting that the effects cannot be generalized across all motor domains.

Overall, the findings reinforce the importance of structured exercise interventions in preschool education. They also highlight the potential for transfer effects from locomotor-focused activities to object control performance, even in the absence of direct training. All of this underlines the need for a holistic approach in designing physical education programs for young children and sets the stage for the conclusions presented below.

The primary limitation of the present study concerns the relatively small sample size and the duration of the intervention program. These factors may restrict the generalizability of the results. In addition, the study was limited to a single preschool institution, which further constrains the external validity of the findings.

Despite these limitations, the main strength of this study lies in the fact that it is the first to examine a strength- and endurance-based exercise program in preschool children. Also, strengths of the study include the fact that a randomized trial was conducted, an experimental treatment was carried out for 12 weeks, and motor skills were thoroughly examined using the entire TGMD-2 test scale. Furthermore, valuable data were obtained on the impact of concurrent physical exercise intervention on preschool children's motor skills. These data support the fact that children cannot develop motor skills without physical exercise programs (Goodway & Branta, 2003) because the maturation process alone is insufficient for adequate development of motor skills in children (Malina et al., 2004).

Future investigations should include larger and more diverse samples, as well as interventions of varying duration, to provide deeper insights into the dose-response effects of physical activity on motor development in preschoolers. It would also be valuable to explore the effects of programs that combine locomotor and object control exercises, to determine whether integrated training yields broader or more balanced improvements across all fundamental movement skills. Longitudinal studies are further recommended to assess the sustainability of the observed improvements over time.

Conclusion

This study demonstrated that a 12-week strength- and endurance-based exercise program produced significant improvements in locomotor, object control, and overall motor skills in preschool children. These findings confirm the effectiveness of structured exercise interventions in early childhood and align with the study’s objective of enhancing fundamental movement skills through targeted training.

The practical implications are clear: integrating concurrent training into preschool curricula may not only foster motor competence but also encourage long-term engagement in physical activity, thereby supporting children’s health and development in an increasingly sedentary environment.

Despite the positive outcomes observed, interpretation of the results should account for certain limitations, including a limited sample size and data collection at a single site. Further research involving larger and more heterogeneous samples is warranted, as well as exploring combined or longer interventions to assess the sustainability and breadth of motor skill gains.

In conclusion strength- and endurance-based exercise emerges as a valuable and practical strategy for promoting motor development in preschoolers. By embedding such programs into daily routines, educators and policymakers can contribute to healthier childhood trajectories and lay the foundation for lifelong physical activity.

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