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The Relationship Between Movement, Mathematics, and Logical Thinking

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ABSTRACT. **Introduction:** Sedentary lifestyles among teenagers persist despite initiatives like daily physical education. While schools are primary arenas for promoting activity, many Hungarian students remain hypoactive and overweight, increasing risks of circulatory diseases. Previous research indicates positive associations between physical activity and cognitive functions. **Objective:** This study investigated the direct and indirect effects of movement on mathematical skills and logical thinking. **Methods:** The first part compared physical performance indicators (agility, speed, endurance via 505 tests, sprint, Yo-Yo test) with mathematics test scores and Raven test for logical thinking in 161 grade 6 and 8 students from sports-focused versus general curriculum schools. The second part assessed a 6-week locomotor intervention using the VSL3D ladder in mathematics lessons (2 lessons/week) with 10 lower secondary students with special educational needs (SEN), measuring changes in math performance and subject attitudes. **Results:** Sports school students demonstrated significantly better physical performance and mathematics scores. The VSL3D intervention yielded significant improvements in specific geometry skills (spatial orientation, mirroring) for SEN students, and mathematics became a more frequently preferred subject, though general liking scores did not change significantly. **Conclusions:** These findings support the complex positive effects of movement on cognitive and academic aspects, suggesting distinct benefits from general physical fitness and targeted, coordinative movement interventions.

Keywords: *physical activity, cognitive function, mathematics performance, coordination skills, VSL3D*

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INTRODUCTION

Movement, as a fundamental human activity, is increasingly recognized for its relationship with cognitive functions (Chaddock-Heyman et al., 2018) and academic performance (Yangüez, Bediou, Hillman, Bavelier, & Chanal, 2021). Many studies highlight the concerning prevalence of sedentary lifestyles among adolescents, with daily physical education often insufficient to counteract this trend (Szakály, Bognár, Lengvári, & Koller, 2018). In Hungary, a significant percentage of students are overweight or obese, contributing to circulatory system diseases and impacting national health statistics (Csányi, Kaj, Kälbli, Hernádi, & Király, 2018; Csányi, Kaj, Kälbli, Hernádi, & Király, 2020). Conversely, higher physical literacy, developed through diverse multi-sport activities, is linked to healthier lifestyles (Thür, Fügedi, 2020).

The neurobiological benefits of physical activity are substantial, including structural brain changes (Chaddock-Heyman et al., 2018) and enhanced cognitive processes (Sibley & Etnier, 2003). Specifically, moderate to high-intensity exercise, meeting WHO recommendations of 60 minutes daily for children (WHO, 2020), acts as a catalyst for physiological mechanisms supporting brain health (Stillmann, Cohen, Lehman, & Erickson, 2016). Research suggests a positive correlation between cardiorespiratory fitness and cognitive domains like executive functions, working memory, attention, and processing speed, which are integral to academic subjects such as mathematics and reading comprehension (Donnelly et al., 2016; Geertsen et al., 2016; Hillman, Erickson, & Hatfield, 2017).

Despite a general consensus on the positive link between physical activity and cognition (Burns, Bai, Fu, Pfledderer, & Brusseau, 2019a; Kirk, Hillman, & Kramer, 2015), the translation of these benefits into direct academic achievement, particularly in subjects like mathematics, remains an area of ongoing investigation with varied methodologies and findings. Some studies show a positive association between fitness levels (especially endurance) and mathematics scores (Yangüez et al., 2021), while others indicate that classroom-based physical activity can improve concentration and classroom behaviour but may not directly enhance cognitive function or subsequent activity levels (Watson, Timperio, Brown, Best, & Hesketh, 2017). Motor skills, particularly fine motor skills, speed, and agility, have also been positively associated with mathematics and reading achievement, especially in early school years (Macdonald, Milne, Orr, & Pope, 2018). Moreover, movement interventions may alleviate subject-specific anxiety, a significant barrier to learning, particularly in mathematics (Eysenck, Derakshan, Santos, & Calvo, 2007; Nótin, Páskuné Kiss, & Kurucz, 2012).

Donnelly and Lambourne (2011) proposed a model where physical activity supports learning through conditioning-related factors. However, the specific impact of coordinative movement-based interventions, distinct from general fitness or endurance activities, on mathematical abilities and logical

thinking warrants further exploration. There is a need to differentiate the effects of general physical preparedness (e.g., speed, agility, endurance) from those of targeted movement programs integrated into academic lessons.

OBJECTIVES AND HYPOTHESES

This study, therefore, aimed to investigate the relationship between movement and mathematics and logical thinking from two perspectives:

1. To compare physical performance indicators (speed, agility, endurance) and logical thinking (Raven test scores) with mathematics test scores between students in sports-focused versus general curriculum schools.
2. To evaluate the impact of a classroom-based locomotor intervention using the VSL3D ladder on mathematics performance and subject-related attitudes among students with special educational needs (SEN).

We hypothesized that students with higher physical fitness would exhibit better mathematics and logical thinking scores, and that the VSL3D intervention would positively affect mathematics skills and attitudes in SEN students, potentially offering an alternative pathway for learning support based on coordination skills.

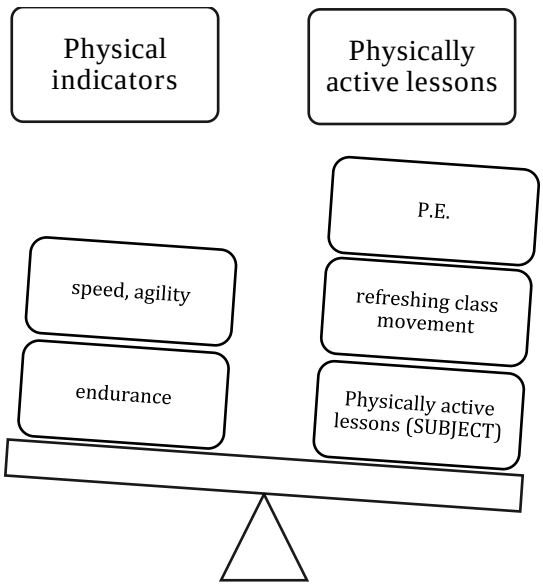

Fig. 1. Conceptual framework of the relationship between physical activity, physical indicators, and subject performance
Source: Authors

MATERIALS AND METHODS

This research comprised two distinct studies investigating the relationship between movement and mathematical/logical thinking. Informed consent was obtained from parents and assent from students where appropriate.

Study 1: Physical Indicators, Logical Thinking, and Mathematics Performance

- *Participants*
  A total of 161 students from grade 6 (n=80) and grade 8 (n=81) in a county town in Hungary participated. Participants were recruited from schools with a standard physical education curriculum (general curriculum group: grade 6, n=39; grade 8, n=38) and schools with a specialized sports-focused public education program (Special type sports class group; sports group: grade 6, n=41; grade 8, n=43). This grouping allowed for comparison based on differences in the pedagogical program and intensity of physical education.
- *Measures*
  - Physical Performance:
    - Speed and Acceleration: Measured using light gates for 5m, 10m, 20m, and 30m sprints from a standing start. The better of two trials was recorded.
    - Agility: Assessed using the validated 505 Agility Test (Draper & Lancaster, 1985). Students performed the test in both left and right directions; the better of two trials was recorded.
    - Endurance: Evaluated using the Yo-Yo Intermittent Recovery Test Level 1 (Bangsbo, Iaia, & Krustrup, 2008). This test was performed once.
  - Mathematics Performance: Scores were obtained from a validated, paper-based mathematics test selected from previous national competency assessments in Hungary. Mathematical literacy tests examine how well students are able to apply mathematical knowledge learned in school to real-world situations and contexts. While the assessment considers mathematics curricula, it doesn't expect students only to use the knowledge required for their specific grade level.
  - **Logical Thinking:** Assessed using a mobile application version of Raven's Progressive Matrices for logical thinking and problem solving. Scores were recorded.

- *Procedures*
  Physical performance tests and the Raven test were administered to all participants. Mathematics test scores were obtained from school records or administered concurrently.
- *Analysis*
  Descriptive statistics (means, standard deviations) were calculated for all measures. Independent samples t-tests were used to compare the mean scores of physical indicators, Raven test results, and mathematics test scores between the sports school groups and general curriculum groups for each grade level. The significance level was set at $p < 0.05$.

Study 2: VSL3D Locomotor Intervention in Mathematics for SEN Students

- *Participants*
  Ten students (N=10) with Special Educational Needs (SEN) from a lower secondary school institution in the South Hungary region participated.
- *Measures*
  - Mathematics Performance: Assessed using pre- and post-intervention mathematics worksheets designed by the researchers. These worksheets included algebraic tasks, geometric tasks (e.g., spatial orientation, mirroring), and problem-solving items. Scores were based on the number of correctly solved items. The worksheet likely consisting of 10 distinct items, identified by "M/" prefixes and point-value suffixes (e.g., "M/1-2p" indicates 2 possible points for that item). For each of these items, performance data (mean scores and standard deviations) was collected from two separate measurement occasions, consistently involving all participants for each. A comparative statistical analysis, specifically a t-test, was then conducted to compare the mean scores between these two measurements for every individual item / subscale. These individual item scores contribute to an overall assessment score, indicated to have a maximum total of 100 points.
  - Attitude towards Mathematics:
    - Liking of Mathematics: Assessed pre- and post-intervention using a 5-point Likert-type scale, modified with smiley faces for easier comprehension by SEN students (1 =very much dislike; 2 =dislike; 3= neutral; 4 =like; 5 =very much like).

§ Subject Preference: Assessed pre- and post-intervention by asking students: "Which are your three favourite subjects?" The frequency of "mathematics" appearing in their top three choices was recorded.

o Intervention Tool: The VSL3D (Variable Sport Ladder 3D) (Kertész, 2021) was used.

· *Procedures*

The intervention lasted for 6 weeks. Participating teachers received three webinars on the use of the VSL3D system and were provided with the tool, a methodological guide (Kertész, Cseresznyés, 2015), and VSL3D-based lesson plans for mathematics. Students used the VSL3D ladder during mathematics lessons for two sessions per week, engaging in movement-based learning activities as part of the intervention. Pre-intervention (input) measures (mathematics worksheets, attitude/ preference) were collected before the intervention began, and post-intervention (output) measures were collected upon its completion.

· *Analysis*

Descriptive statistics were calculated for pre- and post-intervention scores. Paired samples t-tests were used to compare pre- and post-intervention means for mathematics worksheet scores (total and sub-scores) and liking of mathematics scores. Changes in the frequency of mathematics as a preferred subject were descriptively analysed. The significance level was set at $p < 0.05$.

RESULTS

Study 1: Physical Indicators, Logical Thinking, and Mathematics Performance

Students in the sports-focused groups consistently demonstrated better mean scores on physical performance measures compared to students in the general curriculum groups in both grade 6 and grade 8 (see Table 1 and Table 2).

Table 1. Mean Physical Performance Indicators for Grade 6 Students by Curriculum Type (N=80)

Physical indicators (mean)	**Speed (s)**				**Agility**	**Endurance**
	5m	**10m**	**20m**	**30m**	**(s)**	**(m)**
6. general curriculum (n=39)	1.37	2.35	4.17	5.91	3.42	680
6. sport curriculum (n=41)	1.31	2.33	3.89	5.61	3.29	780

Table 2. Mean Physical Performance Indicators for Grade 8 Students by Curriculum Type (N=81)

Physical indicators (mean)	**Speed (s)**				**Agility**	**Endurance**
	5m	**10m**	**20m**	**30m**	**(s)**	**(m)**
General curriculum 8 (n=38)	1.28	2.2	3.9	5.52	3.55	880
Sport curriculum 8 (n=43)	1.21	2.04	3.67	5.36	3.39	1080

Statistically significant differences were found between the sports and general curriculum groups for agility and endurance measures in both grades (independent samples t-test, $p < 0.001$). Significant differences were also observed for speed measures across various distances ($p < 0.001$).

Regarding mathematics performance and logical thinking, students in the sports groups also achieved higher mean scores on the mathematics competency tests and Raven test compared to the general curriculum groups (see Table 3).

Table 3. Mean Mathematics Competency and Raven Test Scores by Curriculum Type and Grade Level

Competence	**Mathematics (points)**	**Raven (scores)**
6 General curriculum (n=39)	1445	85
6 sport curriculum (n=41)	1540	96
General curriculum 8 (n=38)	1510	86
Sport curriculum 8 (n=43)	1634	99

Study 2: VSL3D Locomotor Intervention in Mathematics for SEN Students

Changes in mathematics performance for students with SEN following the 6-week VSL3D intervention are presented in Table 4. Significant improvements ($p < 0.05$) were observed for geometry tasks related to spatial orientation (M/2: $t(9) = -2.52$, $p = 0.021$) and a trend towards improvement was noted for mirroring tasks (M/4: $t(9) = -1.77$, $p = 0.094$). No statistically significant changes were detected in the algebra task scores or the total mathematics worksheet score (Total_100p: $t(9) = 0.15$, $p = 0.885$).

Table 4. Changes in Mathematics Worksheet Scores for Students with SEN (N=10) Pre- and Post-VSL3D Intervention.

Item	Pre-intervention Score	Post-intervention Score	t-value	p	Valid N 1st	Valid N 2nd	Std.Dev. 1st	Std.Dev. 2nd
M/1-2p	0.90	1.00	-0.25	0.809	10	10	0.88	0.94
M/2-6p	2.30	4.40	-2.52	0.021	10	10	1.77	1.96
M/3-8p	7.10	7.00	0.10	0.923	10	10	2.51	2.00
M/4-7p	0.90	2.00	-1.77	0.094	10	10	1.10	1.63
M/5-4p	2.70	2.90	-0.28	0.781	10	10	1.77	1.37
M/6-2p	0.40	1.00	-1.50	0.151	10	10	0.84	0.94
M/7-42p	22.70	19.20	0.56	0.581	10	10	14.80	12.98
M/8-8p	3.40	2.60	0.67	0.509	10	10	2.63	2.67
M/9-9p	1.00	1.20	-0.26	0.795	10	10	1.49	1.87
M/10-12p	2.00	0.60	1.63	0.120	10	10	2.49	1.07
Total_10(	4.40	41.90	0.15	0.885	10	10	24.03	21.58

Regarding affective changes, there was no statistically significant change in the mean liking of mathematics scores pre- and post-intervention (see Table 5).

Table 5. Change in Liking of Mathematics Scores for Students with SEN (N=10) Pre- and Post-VSL3D Intervention.

	Pre-intervention	Post-intervention	t-value	p	Valid N 1st	Valid N 2nd	Std.Dev. 1st	Std.Dev. 2nd
The love of Mathematics	4.20	3.90	0.57	0.572	10	10	1.23	1.10

However, an analysis of the subject preference list indicated a positive shift. Before the intervention, 5 out of 10 students (50%) did not list mathematics among their three favourite subjects. After the VSL3D program, this proportion decreased to 1 out of 10 students (10%), meaning 90% of students included mathematics in their top three favourite subjects (seeFigure2).

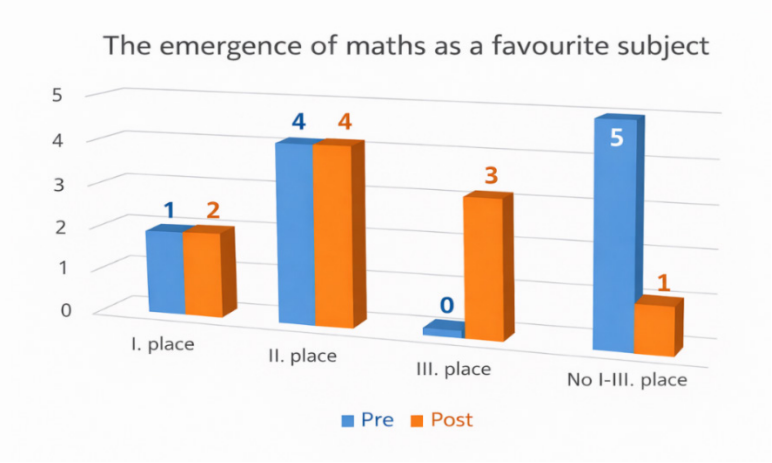

Fig. 2. Frequency of Mathematics Listed Among Top Three Favourite Subjects by Students with SEN (N=10) Pre- and Post-VSL3D Intervention
Source: Authors

DISCUSSION

This study investigated the multifaceted relationship between movement, mathematics, and logical thinking, employing two distinct approaches: comparing physically active students with their peers, and implementing a targeted movement intervention. The findings largely support the hypothesized positive impact of physical activity and specific movement programs on cognitive and academic outcomes.

In Study 1, students enrolled in sports-focused school programs consistently outperformed their peers from general curriculum schools in physical fitness indicators (speed, agility, endurance), mathematics competency, and Raven test scores for logical thinking. This aligns with a substantial body of literature suggesting that higher physical fitness correlates with enhanced cognitive functions and academic achievement (Donnelly et al., 2016; Yangüez et al., 2021). The observed superiority in mathematics might be linked to the general cognitive benefits of regular, structured physical activity, such as improved executive functions and attention (Geertsen et al., 2016). While direct statistical correlations between specific physical indicators and math scores within groups were not performed and assessed in the results presented here, the group differences suggest an overall advantage. The authors' previous work also supports these school-type differences (Thür, Fügedi 2020; 2021). It is plausible that agility, as a skill often requiring rapid decision-making and spatial awareness (Matlák, Rácz, & Tihanyi,

2014), may have a more direct cognitive link to mathematical problem-solving components than pure endurance or speed, though all contribute to overall physical literacy.

Study 2 demonstrated the potential of a targeted, coordination-based locomotor intervention (VSL3D ladder) to enhance specific mathematical skills in students with SEN. Significant improvements were noted in geometry tasks involving spatial orientation and mirroring. This suggests that movement activities emphasizing coordination, spatial awareness, and sequential processing—inherent in VSL3D ladder exercises—can directly benefit mathematical sub-skills that rely on similar cognitive processes. This finding resonates with research highlighting the link between motor skills (especially involving coordination) and academic performance (Macdonald et al., 2018). The lack of significant change in algebra tasks or overall math scores may be due to the relatively short intervention duration (6 weeks), the specific nature of the VSL3D tasks being more aligned with visuospatial and geometric concepts, or the inherent challenges in remediating broad mathematical difficulties in SEN students within a short timeframe.

Affectively, while the general "liking" of mathematics (measured by a Likert scale) did not significantly change for SEN students, there was a notable positive shift in mathematics being listed as a "favourite subject." This suggests the VSL3D intervention may have enhanced engagement or reduced negative perceptions associated with mathematics lessons, even if explicit "liking" scores remained stable. Increased engagement and preference can be crucial precursors to improved learning and sustained effort, especially for students who often experience academic frustration. This experiential aspect, enhancing motivation through movement games, aligns with practical observations (as noted by the authors).

The current findings contribute to the understanding that both general physical fitness and specific, cognitively engaging movement interventions can support mathematical learning. The results from Study 1 support models linking overall fitness and potentially higher cognitive engagement in sports school environments to better academic outcomes, consistent with Donnelly and Lambourne's (2011) model emphasizing conditioning factors (see Figure 3). Study 2, however, suggests an alternative or complementary pathway (see Figure 4, conceptualized by the authors) where learning is supported primarily through coordination-based movement activities, potentially improving specific cognitive skills directly relevant to academic tasks and enhancing student motivation.

Limitations of this research include the non-randomized nature of Study 1 group comparisons; pre-existing differences beyond physical activity levels could have influenced outcomes. The Raven test mobile application used in Study 1 was not formally validated, which should be considered when interpreting logical thinking scores. In Study 2, the sample size was small (N=10), limiting generalizability, and the intervention was short. Future research should explore

longer interventions with larger, diverse samples, potentially incorporating more varied mathematical content and validated cognitive measures. The precise mechanisms—whether improved brain function, enhanced specific cognitive skills like working memory or inhibition, or motivational factors—warrant further investigation using neuroimaging or detailed cognitive testing. As noted by Donnelly et al. (2016), understanding the biological basis, as well as optimal type, extent, intensity, and frequency of physical activity, remains key.

Despite these limitations, this study provides evidence that diverse approaches to integrating movement can be beneficial. The findings underscore the WHO's (2020) call for daily physical activity and suggest that schools have multiple avenues—enhancing general physical education effectiveness and creatively integrating movement into academic subjects—to not only combat sedentary behaviour and improve health but also to potentially support cognitive development and academic success.

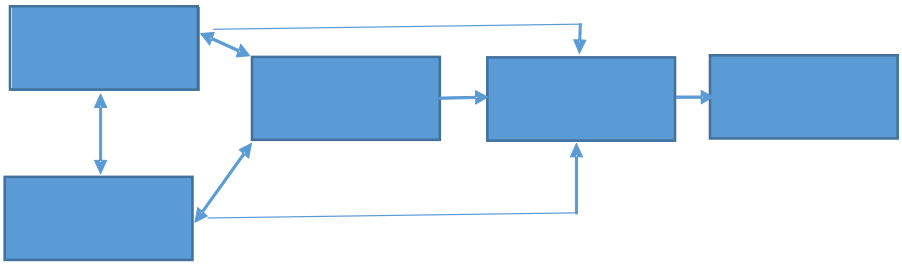

Fig. 3. Model of factors associated with improved learning outcomes
Source: Donnelly, & Lambourne, 2011, p37.

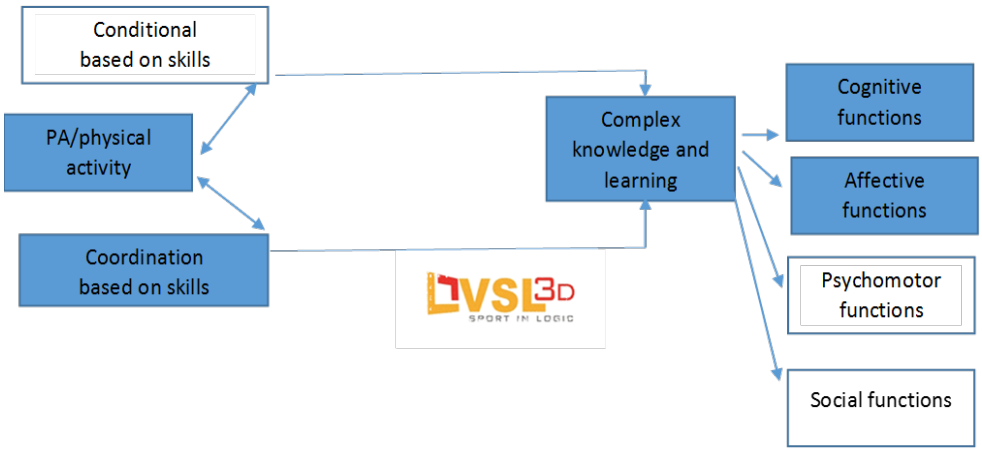

Fig. 4. An alternative way to support learning based on coordination skills
Source: Authors

CONCLUSIONS

This research demonstrated that students in sports-focused school programs exhibited superior physical fitness, mathematical competency, and logical thinking scores compared to peers in general curriculum schools, reaffirming the broad benefits of sustained physical activity. Furthermore, a targeted 6-week locomotor intervention using the VSL3D ladder for students with SEN led to measurable improvements in specific mathematics skills, particularly spatial orientation, and positively influenced their preference for mathematics as a subject.

The findings support a dual role for movement in education: fostering general physical and cognitive advantages through comprehensive physical activity programs, and enhancing specific academic skills and motivation through carefully designed, coordination-based movement activities integrated into classroom learning. While the mechanisms are complex and warrant further study with larger samples and more in-depth methodologies, this study indicates that both pathways contribute positively to student development. Incorporating diverse movement opportunities within the educational framework not only promotes physical health but also appears to be a valuable strategy for supporting cognitive function and academic engagement, aligning with calls for more active learning environments.

Disclosure statement
The authors report no conflicts of interest.

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