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ARTICLE

A Physical Education Program Based Upon an Obstacle Course Positively Affects Motor Competence in 6- to 7-Year-Old Children: A Pilot Study

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Purpose: To investigate the effect of an obstacle course based physical education program, designed according to contemporary insights on motor learning, on motor competence (MC) of 6- to 7-year-old Flemish children. ***Method:*** Pupils from 16 primary schools were randomly allocated to either control ($n = 173$, 50.3% boys) or intervention group ($n = 182$, 54.9% boys). MC, assessed with the Körperkoordinationtest für Kinder (KTK), was analyzed with a 2 (Gender, girls vs. boys) × 2 (Group: INT vs. CON) × 3 (Time: pre vs. inter vs. post) Repeated Measures ANOVA. ***Results:*** The MC in the intervention group improved more compared with the control group (Time × Group interaction, $p < .001$). Moreover, a shift to a more favorable MC classification is seen for all children in intervention group. ***Conclusion:*** The results underline the potential value of an obstacle course based PE program based and provide a gateway for optimization of the current PE programs.

Keywords*:* primary school, intervention, PE lessons, fundamental movement skills, motor learning

Motor competence (MC) denotes an individual's degree of proficient performance in a broad range of motor skills as well as their underlying mechanisms (e.g., motor coordination and motor control; Ahnert et al., 2010). The ability to perform a wide range of fine and gross motor skills is crucial to manage everyday tasks (Bardid, 2016; Henderson, 1992; Robinson et al., 2015). Between 3 and 8 years of age, a child's level of MC is reflected by their proficiency in the domains of locomotion, stability, and object control (Burton & Miller, 1998; Stodden et al., 2008). At this age, children need to be equipped with the basic patterns of coordination as these patterns are further elaborated into the building blocks of more complex and specific motor skills (Clark & Metcalfe, 2002). Acquisition of a sufficient level of MC in childhood is essential for developing sports-specific skills, participating in physical activity (PA), and maintaining a healthy lifestyle in adulthood (Goodway et al., 2019). As the ideal age for the development of MC is situated before the age of 12 years (Goodway et al., 2019), opportunities to practice should be omnipresent from an early age in development.

Development of MC during childhood has been recognized as an important predictor of engagement in regular PA in youth and later life (Behan et al., 2020; Engel et al., 2018; Giannakidou et al., 2014; Lopes et al., 2011; Lubans et al., 2010; Robinson et al., 2015; Wrotniak et al., 2006). The developmental model proposed by Stodden et al. (2008) describes the relationship between PA and MC across childhood and into adolescence. This relationship is supposed to become more reciprocal as a child gets older. Over the years, the child develops a greater ability to perceive and understand their competence in various movement contexts, which promotes success and enjoyment in a variety of activities. Thus, higher levels of MC foster more PA and reciprocally, more PA fosters greater MC, which creates a positive spiral of engagement in PA across childhood and into adolescence. At the same time, low MC may result in unsuccessful participation in movement activities, leading to a negative spiral of disengagement from an active lifestyle (Robinson et al., 2015). Therefore, it is important that the development of MC starts at an early age (Stodden et al., 2008) and PA is encouraged through a variety of exercise experiences in early childhood to promote MC.

Yet, over the past several decades, children's MC levels have been declining worldwide (Bolger et al., 2018; Bryant et al., 2014; Eberhardt et al., 2020; Hardy et al., 2013; Prätorius & Milani, 2004; Spessato et al., 2013). Multiple studies indicate a decline in movement skills and movement patterns in school children. For example, Prätorius and Milani (2004) have shown that in the last 25 years, the percentage of German children with low MC has increased from 16% in the original Körperkoordinationtest für Kinder (KTK) validation study to a level of 38%. This decline in MC levels was also observed in Belgian children between 3 and 12 years old (Bardid et al., 2016; Vandorpe et al., 2011). Bardid et al. (2016) reported that the Belgian sample shifted toward the lower end of the motor continuum whereas Vandorpe et al. (2011) reported that 21% of the children is placed in the problematic range of gross motor coordination level.

Schools, and in particular the physical education (PE) lessons, can play a central role in getting children more active and developing (optimizing) their motor skill competence (Dudley et al., 2011; Van Sluijs et al., 2007) because school PE is the primary context where children learn to be active and learn motor skills. The development of a broad range of motor skills should be standard in child interventions (Barnett et al., 2009; Hulteen et al., 2018). These skills need to be instructed, practiced, and reinforced as they do not simply develop as a result of age (Barnett et al., 2016). In Flanders, children are offered PE lessons, consisting of two sessions per week within the normal schedule, organized by PE teachers or by nursery school teachers who earned a college degree.

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This pedagogical context provides an excellent opportunity to systematically improve children's MC. Lorås (2020) suggests that PE classes should operationalize a specific curriculum, including, for example, specific sets of motor skills to be achieved to enhance MC, as they appeared to be more effective compared with teacher-led nonspecific PE. Research on different intervention methods demonstrated that scheduled programs that are age and developmentally appropriate, activity-based, and task-specific, and that contain a certain level of autonomy, are efficient interventional methods to improve various aspects of MC (Jiménez-Díaz et al., 2019; Logan et al., 2012; Morgan et al., 2013; Riethmuller et al., 2009). Research shows that significant improvements were achieved in interventions that were teacher-led for three or more sessions per week (Engel et al., 2018). Furthermore, motor skill interventions based upon a theoretical model or framework for teaching and instructing PE classes in which key concepts for supporting and fostering motor skills are conducted, have been reported to be effective (Barnett et al., 2009; Lai et al., 2014; Renshaw & Chow, 2019). Importantly, schools, and particularly PE classes, should be considered as a key setting, as most children can be reached there (Lai et al., 2014). Consequently, in Flanders, implementing a PE program focusing on the achievement of children's full motor potential provides us with strong motives to increase the MC of young children and to counter the decline therein (Bardid et al., 2016, 2017; Logan et al., 2012; Valentini & Rudisill, 2004; Vandorpe et al., 2011).

In the Netherlands, efforts are already being made to respond to the decline in MC by implementing free running tracks, more specifically soft obstacle courses during PE lessons (van Gelder et al., 2015). However, it has not been investigated if and how much these obstacle courses contribute to the development of children's MC. The concept of these obstacle courses is built on the constraints-led approach (CLA) of motor skill development. In this view, motor skill development is based on the interaction between three primary groups of constraints which are related to the motor task, the individual (i.e., the pupil), and the learning environment. All three can be taken into account to design a more efficient learning environment, to create a more effective approach, and to ensure that pupils have more positive experiences in acquiring their motor skills (Keith et al., 2007; Renshaw et al., 2010). According to Newell (1986), the child's development level can be accommodated by the teacher by manipulating the environment and equipment and by modifying the task. In this manner, effective instruction can be provided to facilitate the learning process. In addition, the CLA provides a framework to create autonomy-supportive learning environments that can effectively support the intrinsic motivation and self-determination of students in PE (Moy, Renshaw, & Davids, 2016; Renshaw et al., 2010). Promising improvements in motor skills among children have been observed when the instructional climate was changed in a motivational learning environment (Hastie et al., 2013; Valentini & Rudisill, 2004). This concept is also in line with the principles of implicit motor learning (i.e., teaching a skill without focusing on the knowledge of the movement execution), in particular error-free learning (i.e., learning new skills at one's own difficulty level with positive experiences to increase the challenge without resorting to trial and error; Maxwell et al., 2001), learning with external focus (i.e., the focus is on factors outside the body during learning; Wulf et al., 1998), and differential learning (i.e., movement variations are considered to be more important for learning than movement repetitions; Beckmann & Schöllhorn, 2006). There is a shortage of school-based intervention studies designed according to those contemporary insights on motor learning. Therefore, this study aims to clarify whether the focus on implicit motor learning in PE lessons may help children to increase their MC level.

Recently the Flemish Education Inspectorate for primary education PE proposed incorporating the current insights of these recent theoretical frameworks into PE practice at school (Overheid, 2018). With these recommendations and the existing Dutch method, a change in PE lessons in Flanders was made, with a focus on implicit motor learning. Therefore, the aim of this study was to investigate whether a PE program consisting of a series of lessons including an obstacle course, covering a broad range of motor skills, and designed according to current insights on motor learning, has a positive effect on the MC of 6- to 7-year-old Flemish children.

Materials and Methods

Setting and Participants

A list of all primary schools in East Flanders (Belgium) was subdivided by[1] educational system and categorized in urban or nonurban school in order to obtain a representative sample of participating schools. The selected sample consisted of six urban and 10 nonurban schools, representing the entire educational system (four community schools, four municipal and provincial schools, and eight free schools). Random assignments were done via the function ASELECT in Microsoft Excel. Forty-nine primary schools were selected and contacted by phone to receive a verbal explanation of the study. In a second contact, a follow-up email was sent to the classroom and PE teachers of the first year. It was deliberately chosen to include only one class of the first grade (6–7 years old) per selected primary school. Sixteen schools showed their interest after receiving the information and were randomly allocated to either control (CON) or intervention (INT) group (CON, $n = 173$, mean age $= 7.08 \pm 0.48$ years, 50.3% boys and INT, $n = 182$, mean age $= 7.04 \pm 0.45$ years, 54.9% boys). There was an average of 22 children per class. Throughout the study, one school (urban and free subsidized education) dropped out of the study because they did not possess sufficient equipment to implement the intervention including an obstacle course. The project was approved by the ethical committee of the University Ghent Faculty of Psychology and Educational Sciences (EC/2020/78).

Intervention

In Flanders, curriculum goals (learning outcomes) for PE lessons are defined by the government and need to be incorporated in curricula, work plans, and textbooks used by schools. To comply with this policy, the structure of the PE program was based on these curriculum goals. In addition, sports equipment in Flemish schools is rather limited, so an inventory was made of equipment needed to implement the current intervention program. Subsequently, the lessons from the handbook of van Gelder et al. (2015) were used as starting point, but were adapted to the Flemish standard (curriculum goals and available equipment and rules) as well as feedback of teachers in the field, and were based on the CLA.

This resulted in a ready-made PE program of 10 lessons which was given to the teachers of the INT group to implement at least once a week. The lessons were provided with a general introduction, a floor plan (see Figure 1), an indication of the goals from the three Flemish education networks, a description of the sports

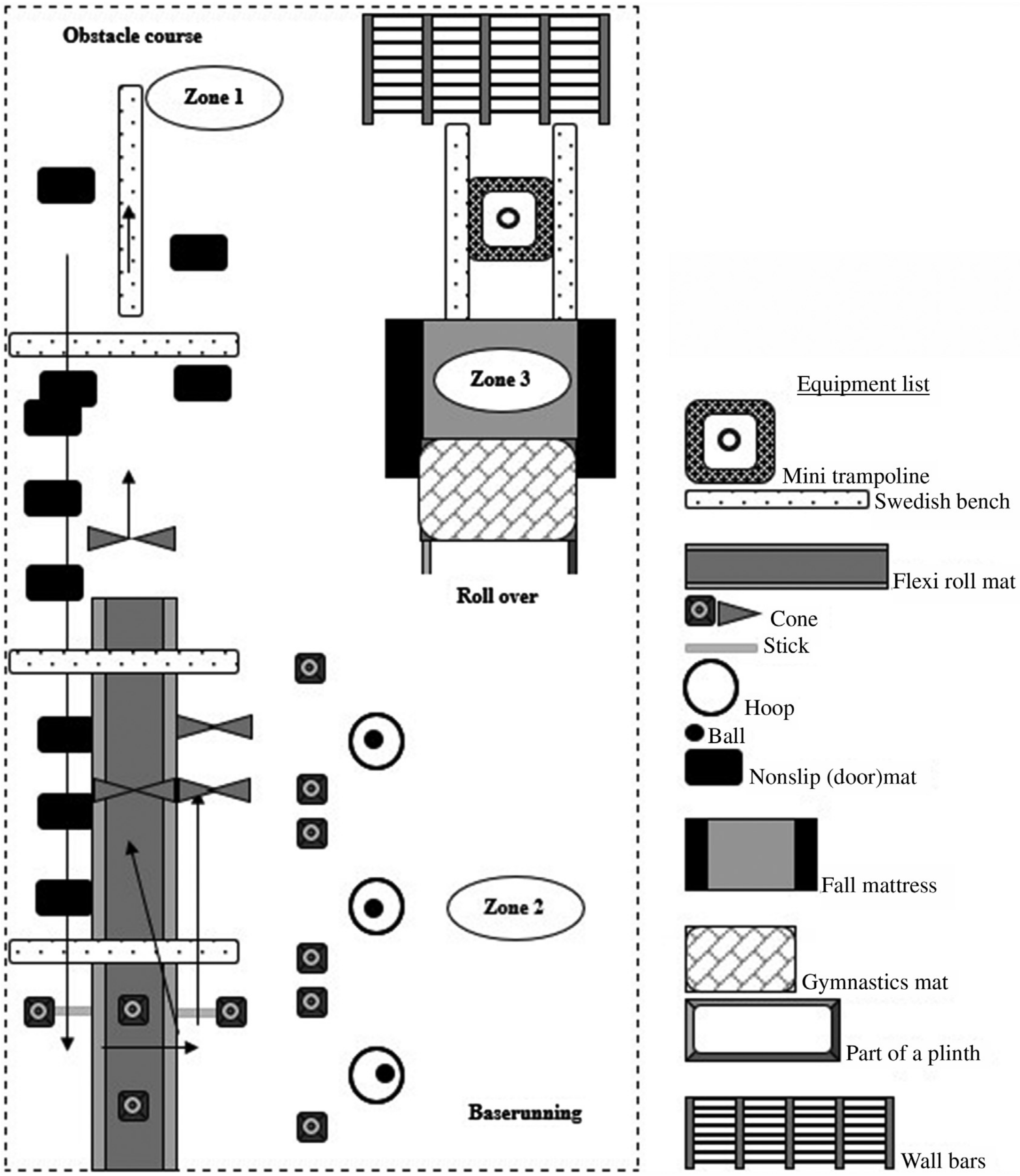

Figure 1 — An example of the floor plan of Lesson 6 from the physical education program implemented in INT group.

equipment needed for that lesson, the instructions to be given by the teacher, and the variations and rules for each component of the lesson. Each lesson started with a cardiovascular warm-up and ended with a relaxing cooldown. For the core of the PE lesson the gym was divided into three different zones: an obstacle course (Zone 1), a (sports play) game (Zone 2), and another movement skill (Zone 3) selected from the 10 different learning lines[2] established in Flemish schools. So, in each lesson, a different learning line was linked to each zone. The lesson content with specific indication of the FMS can be found in Table 1. The purpose was to allow pupils to develop a variety of movement skills by working in three different zones.

To stimulate the pupils' enjoyment, the obstacle course was given a prominent place in the PE program next to the two other zones. The obstacle course was set up each lesson in such a way that the children had to overcome six obstacles and two turning points whereby the full length or width of the gym (room) was used. The turning points are points where the speed drops and forces the children to reach the end in a safe way (no danger of bumping or falling against a wall). If the full length of the gym is used, six to eight children can move at the same time in the obstacle course without a queue forming.

The gym was arranged in such a way that there were no open spaces (maximal use of the space) and the equipment was positioned so that adjustments could easily be made to accommodate variations, in both equipment and movement performance. For example, an obstacle course plotted at knee height provokes jumping. Changing the equipment in the obstacle course (e.g., replace plinth by hurdles, placing more mats as landing place) can provoke a jump with accent on height or distance. Everyone was able to move at their own level in small groups with pleasure and autonomy within the wide variety of learning lines. To allow the

Table 1 Lesson Content for the PE Program With Specific Indication of the FMS

Lesson	Zone 1: Obstacle course, Zone 2: sports play, Zone 3: another movement skill	FMS		
		Balance skills[a]	Locomotor skills[b]	Object control skills[c]
1	Running and jumping, islandball, climbing	Climbing	Running and jumping	Throwing and catching
2	Climbing and landing, goalkeeper game, climbing	Climbing and landing	Running and jumping	Dribbling and kicking
3	Running and jumping, lion cage, rhythmic and expressive movement	Twisting and turning	Running and hopping and galloping and jumping	Bouncing and throwing
4	Rolling and landing, cop and crooks, push and pull	Rolling and landing and balancing	Running	/
5	Combination Lessons 1–4, get clean feet, aiming	Combination skills above	Running	Throwing
6	Running and jumping, baserunning, roll over	Turning	Running and jumping	Striking
7	Climbing and landing, hit and fetch, swing and hang	Climbing and landing, swinging	Running	Throwing and catching
8	Running and jumping, twintap, push and pull	Balancing	Running and jumping	/
9	Rolling and landing, hunter ball, rhythmic and expressive movement	Rolling and landing	Skipping	Throwing
10	Combination Lessons 6–9, get the treasure, balancing	Combination skills above and balancing	Running	Throwing

Note. FMS = fundamental movement skills; PE = physical education.
[a]Balance skills: balancing, rolling, landing, bending and stretching, twisting and turning, swinging and climbing. [b]Locomotor skills: walking, running, jumping, hopping, galloping, crawling, and skipping. [c]Object control skills: catching, throwing, kicking, striking, bouncing, and dribbling.

pupils to move at their own level and speed, they were allowed to cross when moving in the obstacle course, but the children were instructed to not touch or bother other children in their movement. The movement activities were chosen in such a way that the task challenged the pupils and that they could make choices in different situations without too much instruction on the movement execution. Systematically increasing the contextual interference is beneficial for learning motor skills as demonstrated by Porter and Magill (2010).

The teachers were given the space to be more autonomy supportive (Reeve & Cheon, 2016), resulting in their role shifting from instructor toward coach. While designing the PE program, extra attention was also given to the instruction and the instruction time. In favor of the active learning time, the instruction time was kept as short as possible. Therefore, the instructions were written on the lesson sheets, so every teacher used the same language and offered the instruction with a demonstration by a pupil at the start of the lesson. In the first zone, the purpose of the obstacle course was explained along with a few safety suggestions. The games offered in Zone 2 were previously taught by the teacher or were variations of known games, so the children could keep the game going independently. Zone 3 required a little more instruction time as the assignment was often new to the pupils, but instruction time was kept short. Transferring from one zone to another was on the teacher's signal, without additional instructions. Pupils moved at least 12 min in each zone. Throughout the series of lessons, the obstacle course with the same skill theme was offered twice, so that the second time, the instruction time was limited.

The PE program is consistent with implicit motor learning, as the children were given the opportunity to try out which way of movement was successful to get over the obstacles. The obstacle course was arranged is such a way that the performances were adapted to the capabilities of the children. To obtain implicit learning, focus was directed toward the aim of the movement (getting over the obstacle) instead of aspects of movement execution (i.e., how to jump over it). The children were given a lot of space to experiment what kind of support jump they could perform (support with one or two hands, turn left or right when jumping, etc.). The obstacle course was designed in such a way that each child could participate at his/her level and was given choices from multiple situations. For example, bypasses with lower obstacles were created, allowing the children to choose a route that suited their skills. Or, for example, the children could reduce the distance between the obstacles to cross by placing extra mats or equipment in the obstacle course. This way, the pupils could all experience success by minimizing the number of errors entirely, according to the concept of error-free learning.

It was also suggested in the instructions to give directions aimed at the effect of the movement; in other words, focus was put externally. An example of an instruction is "try to touch the ceiling" when a teacher noticed that a child was not reaching high enough to overcome the obstacle, or "imagine yourself pushing off lava" when a teacher wanted to stimulate a child to push off as quickly as possible when taking the support jump. Teachers gave only limited explanation about the implementation of the movement and used metaphors as described above (analogy learning) because this fits in the children's world and is much easier to remember than all the separate steps of which a movement consists.

Finally, a lot of attention was given to "variation" as each activity was performed with different types of equipment or in different ways. For example, the obstacles could be crossed in multiple different ways each time around; there was not one correct execution. Children could figure out for themselves what variety of movement they tried, ensuring that implicit learning was stimulated, within the differential learning view. One time they took a support jump over a hard box and the next time over a soft cube, with better control of the skill as a result of this variation. Offering this variation ensured that implicit learning was stimulated.

The background of the motor learning principles, the approach, tips, and so on were described in a manual. None of the teachers received training prior to the implementation but they all were asked to read the manual carefully. They could contact the researchers for clarification at any time during the intervention.

The teachers of the CON group were informed about the aim of this study. The pupils of the control schools also participated in a standard PE curriculum twice a week but were not offered the intervention PE program. Those schools followed the regular (traditional) curriculum in their PE classes, in which one curriculum goal was addressed in each lesson. In such a standard PE curriculum, the actual content, the skills to be practiced, is similar to the content that was offered in the intervention program. In the standard PE curriculum, however, the approach is typically top-down, with the teacher providing detailed movement instructions to the students, thereby limiting the active involvement of the students. The lesson content is introduced by the teacher and children practice the task for a set period of time until the next task is presented. Utilizing direct teaching methods, instructions are very detailed, and feedback is often given after the task to the whole group with the focus on a particular facet of the body. The setup in which the children of the CON group were taught was in large group activities (the total group performing the same exercises and skills), preceded by a warm-up and ending with a cooldown.

Procedure and Instrumentation

Measurements

The KTK3 (Novak et al., 2017), a short and validated version of the original KTK (Kiphard & Schilling, 2007), was used to evaluate MC, more particularly motor coordination of the children. The original KTK is a standardized test, a norm-referenced measure that is considered highly reliable in estimating the gross motor coordination of children between 5 and 15 years, with limited influence of physical or anthropometric characteristics, and appropriate for children with both typical and atypical developmental patterns. The test is widely used in Europe in both educational and sports settings (Iivonen et al., 2016). It was decided to use the KTK3 instead of the original KTK version with four subtests to reduce the risk of injuries related to the fourth subtest and to save time during testing. The validity of the KTK3 is evident from high correlations between overall MC scores based on the KTK3 and the KTK4 version ($r = .97$, $p < .001$; Novak et al., 2017).

The KTK3 consists of the following three subtests: (a) balancing backward over three bars of different width (walking backward along a balance beam), (b) jumping back and forth over a bar as often as possible in 15 s (two attempts; jumping sideways), and (c) move sideways as often as possible using two boards in 20 s (two attempts; moving sideways on boxes). Administration of the KTK3 battery takes approximately 20 min per child. Scores attained in these three subtests can be converted into motor quotients (MQ), allowing for a comparison with age- and gender-specific norms. In addition, the raw performance scores of each subtest were transformed into age- and gender-specific MQs using the manual's normative tables (Lenoir et al., 2013). The MQ scores of the three subtests were summed and then divided by 3 to compute an overall motor quotient (overall MQ), which allowed the use of the original cut-points as established by Kiphard and Schilling (2007) (see De Meester 2017 for a similar procedure). The total MQ allows classification of a child's performance into five categories. Children with an MQ value between 56 and 70 (0 to 2nd percentile) are considered as having a severe gross motor coordination disorder (disturbed or severe motor disorder). Children scoring between 71 and 85 (third to 16th percentile) are considered as having a moderate gross motor coordination disorder (insufficiently or moderate motor disorder). Children with an MQ value between 86 and 115 (17th–84th percentile) are considered as having normal gross motor coordination (normal MC). Children scoring between 116 and 130 (85th–98th percentile) are considered as having good motor coordination (good MC), and children scoring between 131 and 145 (99th–100th percentile) are considered as having a high gross motor coordination (very good MC).

Children's MC was evaluated before the start of the intervention, after five lessons, and at the end of the experiment (10 lessons spread over 16 weeks). Age and gender data were collected via existing class lists obtained from the school management. Participants were personally interviewed to gather information regarding leisure-time PA. They were asked whether they engaged in non-organized or organized sport activities outside school and if they participated in youth movements.

All data were collected by trained researchers. Training consisted of (a) providing detailed instructions on the KTK3 test protocol, (b) practicing completing quoting forms of children during a practice session, and (c) discussing potential ambiguities in instructions and scoring. The same researchers performed all assessments across all time points.

Data Analysis

Comparison of pupils' demographic variables at intake for intervention and CON group were made by applying Pearson χ^2 tests for the dichotomous variables (gender and the presence or absence of leisure-time PA) and a two-tailed t test for age. To evaluate the effects on global MC, overall MQ was submitted to a 2 (Gender, boys vs. girls) × 2 (Group, intervention vs. CON) × 3 (Time, pre, inter, and post measurements) analysis of variance with repeated measures on the last factor. To obtain insight in the evolution of the different subtests, MQ scores of each subtest were submitted to a 2 (Gender, boys vs. girls) × 2 (Group, intervention vs. CON) × 3 (Time, pre, inter, and post measurements) multivariate analysis of variance with repeated measures on the last factor. For all quantitative analyses, SPSS Statistics was used (version 25.0; IBM Corp., Armonk, NY). Significance level was set at $p < .05$ and effect size was provided as partial eta squared (η_p^2).

Results

At baseline the pupils in the intervention group showed no significant differences compared to control group for age (INT, 7.04 ± 0.45 years; CON, 7.08 ± 0.48 years; $p = .336$), gender (INT, 54.95% boys; CON, 50.29% boys; $\chi^2 = 0.867$; $p = .352$), and the presence or absence of leisure-time PA (INT, 72.94% is practicing a leisure-time PA; CON, 79.61%; $\chi^2 = 2.618$; $p = .270$; see Table 2).

The 2 (Gender) × 2 (Groups) × 3 (Time) repeated-measures analysis of variance with overall MQ scores showed a main effect of group, $F(1, 281) = 12.00$, $p = .001$, $\eta_p^2 = .041$ and time, $F(2, 562) = 460.23$, $p < .001$, $\eta_p^2 = .621$. No significant main effect of gender was found, $F(1, 281) = 3.13$, $p = .078$, $\eta_p^2 = .011$. More pertinent to the aim of this study, a significant Time × Group interaction indicated that the MQ scores of the INT group improved

Table 2 Descriptive Statistics of Age at Baseline, Distribution of the Classes (Students Per Class, Educational Network, and Urban or Nonurban Schools), and Participation in Leisure-Time PA in Both Intervention and Control Group, as Well as in the Total Sample

	Intervention group (*n* = 182; 100 boys)	Control group (*n* = 173; 87 boys)	Total sample (*N* = 355; 187 boys)
Age (years) at baseline	7.04 ± 0.45	7.08 ± 0.48	7.06 ± 0.46
Students per class (*n* ± *SD*)	22.63 ± 2.92	21.50 ± 5.04	22.06 ± 4.02
Community schools (*n*)	Urban (1)—nonurban (1)	Urban (1)—nonurban (1)	Urban (2)—nonurban (2)
Municipal and provincial schools (*n*)	Urban (0)—nonurban (2)	Urban (0)—nonurban (2)	Urban (0)—nonurban (4)
Free schools (*n*)	Urban (2)—nonurban (2)	Urban (2)—nonurban (2)	Urban (4)—nonurban (4)
Active in leisure-time PA (%)	72.94%	79.61%	76.09%

Note. PA = physical activity.

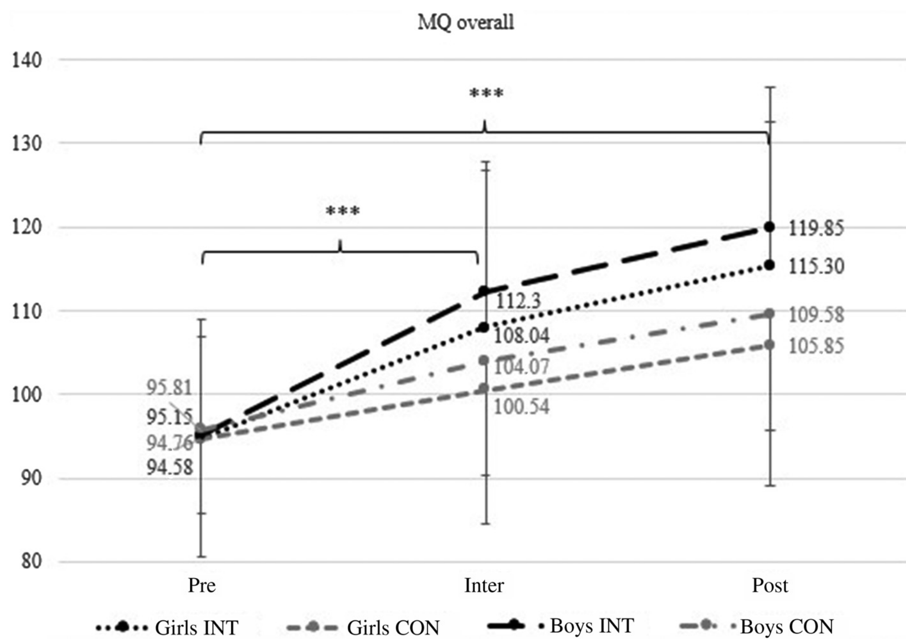

Figure 2 — Evolution of pupil's overall MQ (MQ scores of the 3 subsets were summed and then divided by 3) (±*SD*), measured at 3 moments (pre, inter, and post) in INT and CON groups subdivided by gender. CON = control; INT = intervention; MQ = motor quotients. ****p* < .001.

more than those of the CON group, $F(2, 562) = 43.19$, $p < .001$, $\eta_p^2 = .133$. A significant Time × Gender interaction was found, $F(2, 562) = 5.02$, $p = .007$, $\eta_p^2 = .018$, with no differences between girls and boys at premeasurement ($p = .591$), but a difference at inter ($p = .043$) and postmeasurement ($p = .034$). This interaction was not due to the intervention as no Time × Group × Gender interaction was found, $F(2, 562) = 0.187$, $p = .830$, $\eta_p^2 = .001$. The evolution of pupils' overall MQ, measured at pre, inter, and post, in both groups, as well as subdivided by gender, can be viewed in Figure 2.

The 2 (Gender) × 2 (Group) × 3 (Time) multivariate analysis of variance on the MQ scores of each subtest showed a multivariate main effect of time, $F(6, 1{,}116) = 125.38$, $p < .001$, $\eta_p^2 = .403$, a multivariate Time × Group interaction, $F(6, 1{,}116) = 15.80$, $p < .001$, $\eta_p^2 = .078$, and a multivariate Time × Gender interaction, $F(6, 1{,}116) = 2.17$, $p = .043$, $\eta_p^2 = .012$. No Time × Group × Gender interaction, $F(6, 1{,}116) = 0.250$, $p = .959$, $\eta_p^2 = .001$ was found. Between-subjects effects revealed only a main effect for gender in the subtest jumping sideways, gender—$F(1, 280) = 8.106$, $p = .005$, $\eta_p^2 = .028$, and a main effect of group in the subtests walking backward, group—$F(1, 280) = 23.10$, $p < .001$, $\eta_p^2 = .076$, and jumping sideways, group—$F(1, 280) = 8.44$, $p = .004$, $\eta_p^2 = .029$. No Group × Gender interactions for any of the subtests were found. Means and *SD*s of the performance on the KTK3, both raw and MQ scores, are shown in Table 3.

Further analysis of the Time × Group interactions in overall MQ, as well as MQ scores on each subtest, showed significances from pre to inter and from pre- to postmeasurements. However, in the subtest moving sideways, significant Time × Group interaction was found from inter to post as well (see Table 4).

Based on Kiphard and Schilling's classification (2007), both pupils in INT and CON group started with an overall MQ indicating that the vast majority (INT, 69.2%; CON, 74.1%) had a normal MC before the intervention, some had insufficiency or moderate motor disorder (INT, 19.6%; CON, 21.5%) and very few had good MC (INT, 4.4%; CON, 6.4%; Figure 3). Almost none had disturbed or severe motor disorder (INT, 1.9%; CON, 2.3%) or very good MC (INT, 0.0%; CON, 0.6%). After the 16-

Table 3 Mean and *SD* of Performance on the KTK3 (Raw and Standardized Scores)

	Intervention group						Control group					
	Pre		Inter		Post		Pre		Inter		Post	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Raw scores												
Walking backward	20.29	12.83	29.16	13.92	32.01	13.69	18.48	9.92	21.78	11.35	24.76	11.69
Moving sideways	30.27	6.10	37.09	7.44	40.46	8.82	32.06	5.35	35.60	6.77	37.13	6.48
Jumping sideways	37.63	10.50	48.62	14.20	53.84	14.24	37.75	9.35	42.23	13.17	47.58	13.46
MQs												
Walking backward	89.48	15.90	100.30	17.26	104.07	17.12	86.35	12.29	90.45	14.43	94.13	14.67
Moving sideways	97.80	17.26	116.98	21.13	126.59	24.51	102.29	16.56	112.15	19.79	116.46	19.13
Jumping sideways	97.37	16.30	114.87	23.31	123.14	23.63	97.21	16.38	104.32	22.45	112.55	23.09
Overall	94.90	12.93	110.41	17.07	117.83	17.17	95.28	12.19	102.31	14.99	107.72	15.50

Note. KTK3 = Körperkoordinationtest für Kinder; MQ= motor quotients.

Table 4 The Time × Group Interactions for Both Raw Scores and MQs of the KTK3 Performance for Each Subtest and for Overall MQ

	Pre–inter–post		Pre–inter		Inter–post		Pre–post	
	$F_{\text{Time} \times \text{Group}}$	η_p^2	$F_{\text{Time} \times \text{Group}}$	η_p^2	$F_{\text{Time} \times \text{Group}}$	η_p^2	$F_{\text{Time} \times \text{Group}}$	η_p^2
MQs								
Walking backward	12.34***	.042	3.89*	.012	0.00	.000	16.35***	.054
Moving sideways	21.58***	.072	5.82*	.018	4.19*	.014	38.67***	.119
Jumping sideways	21.73***	.072	6.89**	.021	0.15	.001	27.88***	.089
Overall	43.19***	.133	41.69***	.116	1.24	.004	73.11***	.203

Note. KTK3 = Körperkoordinationtest für Kinder; MQ= motor quotients.
**p* ≤ .05. ***p* < .01. ****p* < .001.

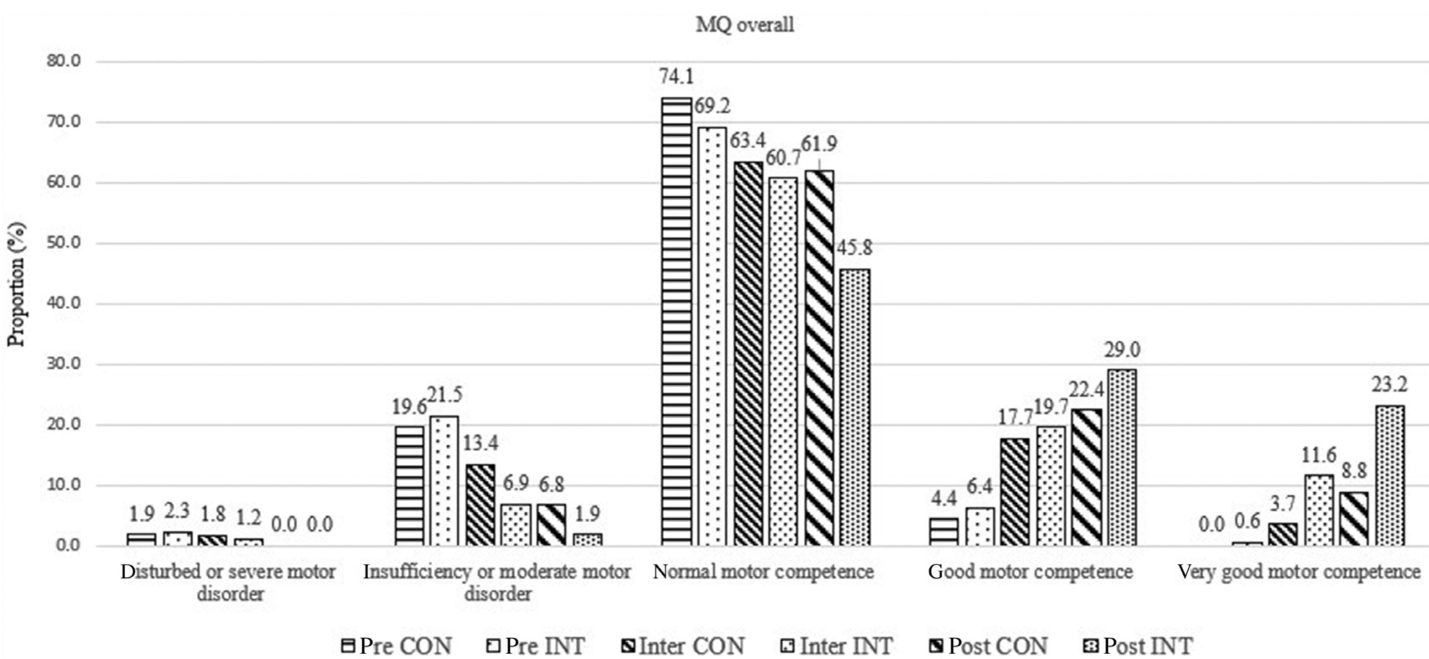

Figure 3 — Distribution, expressed in % and based on Kiphard and Schilling's classification (2007), of the overall MQ in INT and CON groups at 3 moments (pre, inter and post). CON = control; INT = intervention; MQ = motor quotients.

week intervention, 23.2% of the pupils in INT group showed an MQ indicating a very good MC, while this was only 8.8% in the CON group. A good MC was seen in INT group (29.0%) and in CON group (22.4%) at postmeasurement and a normal MC was present for 45.8% in intervention and 61.9% in CON group. The number of pupils having an insufficiency or moderate motor disorder declined to 1.9% in INT group and 6.8% in CON group. No one was assigned to the category of disturbed or severe motor disorder at postmeasurement.

Discussion

The purpose of this study was to examine the effects of a PE program, including an obstacle course, on the MC of 6- to 7-year-old children. In agreement with our hypothesis, the PE program resulted in a positive evolution of the children in the INT group, superior to the increase in MC in the CON group. The absence of a Time × Group × Gender interaction revealed that boys and girls equally benefitted from the program.

The superiority of the intervention parallels findings from other intervention studies in a similar context. Karabourniotis et al. (2002) reported that students in their 12-week movement skill curriculum intervention scored significantly higher than the CON group following a regular PE program. Offering a skills-oriented program to the children in the first grade increased their motor skill proficiency, similar to the results in this study. Costello and Warne (2020) reported that their 4-week intervention was successful, as children benefited and already showed higher scores on the posttest program. A review of Riethmuller et al. (2009) summarized the efficacy of interventions in young children and recommended interventions on average 12 weeks in duration to improve motor development. Our results add to this body of knowledge, underlining that structured PE programs are effective in influencing the development of MC in children (Morgan et al., 2013).

At first sight, this study duplicates the results of previous intervention studies in the PE context. However, it is difficult to compare effect sizes between different studies because of the differences in test instruments to evaluate MC. Several characteristics of the current intervention content do however align well with contemporary principles of motor learning of which the efficacy has been established in numerous motor learning experiments, however only rarely in the context of PE.

A first explanation for the positive evolution in MC in the INT group may be the fact that the children had the chance to practice all of the domains of motor development (locomotor tasks, manipulative tasks, stabilizing tasks, or combinations of the three) more often throughout those 16 intervention weeks. The intervention was designed in such a way that a wide variety of movement skills were practiced and this is also represented in the positive outcome on the three subtests of the KTK, which in turn indicates a general improvement in MC. It has extensively been reported in motor learning literature that variation is key to the mastery of new and more complex skills (Magill & Hall, 1990; Travlos, 2010; Wulf & Schmidt, 1997). The obstacle course allows the repetition of different skills in a mixed order, and within a given motor skill, different movement solutions are presented to achieve a goal (e.g., an obstacle can be negotiated by using one or two hands for support).

Second, the multiple and varied tasks in the obstacle course gave the children the opportunity to complete the course according to their own abilities. The learning environment challenged each child to attempt a movement task appropriate to their developmental level. As such, they were stimulated to address the level just beyond the reach of what a child can do on its own, based on Vygotsky's concept of zone of proximal development (Berk & Winsler, 1995). Vygotsky argues that the educational offer should be adapted to what the child is already able to do. Teachers need to bring the child from its "zone of current development" (what it can do) to its "zone of proximal development" (what it cannot yet do independently, but with feedback of the teacher). This ensures that children are challenged and stimulated in their development (Orey, 2010). The children were also given the autonomy to choose their own challenges, to make choices, and to take initiative. Consequently, the environment was more child- and learner-centered compared with a standard PE program where the learning context prescribes specific movement templates for children to rehearse and reproduce. The child could change the environmental condition to his own ability and capacity, for example, by placing an extra landing spot or by taking a bypass in the obstacle course. The child had to explore how to adapt his action to a different performance condition. Those individualized experiences facilitated learning. This approach, based on the CLA, is an effective approach to cater to individual differences during the learning process, which is in line with Lee et al. (2014), Moy, Renshaw, Davids and Brymer (2016), and Chow et al. (2013; 2021). The results of this study suggest that a developmentally, age, and task-specific appropriate program is effective for the development of MC, as seen in previous interventional methods (Logan et al., 2012; Morgan et al., 2013; Riethmuller et al., 2009).

Third, the improvements in the MC can also be attributed to the fact that the program was designed to elicit implicit motor learning by (a) limiting the number of errors made and (b) promoting an external focus of attention. The PE program reduced errors by adapting the task difficulty and by assuming that to achieve implicit learning, children can learn without too many instructions (Masters & Maxwell, 2004; Maxwell et al., 2001). Procedural knowledge of the movement execution was acquired with only limited cognitive involvement as it was not orally provided by the teacher. Previous research already showed that reduced performance errors in motor skill training results in greater motor learning (Capio et al., 2013). Implicit motor learning also covers the theory of learning with external focus. According to this principle, motor learning can be improved by focusing attention on the effects of the movements ("external focus") rather than the body movements producing the effect ("internal focus"; Wulf et al., 1998). In this intervention program, the instruction or feedback that was given to the children while practicing the motor skill was targeted on the effects of the intended movement. For example, while throwing a ball, the children were asked to focus on the landing spot of the ball (bucket). In fact, there was no coaching instruction to correct technique. Sometimes imaginary language was used based on implicit motor learning by learning with analogy (Liao & Masters, 2001); e.g., in a height jump children were asked to touch the ceiling and not to put the focus on the power of the legs.

From a classification point of view, participants in the current study had a pretest MC level comparable with the age-related reference values of the KTK (Kiphard et al., 2014; Vandorpe et al., 2011). The initial MC classification of the pupils at pretesting was similar in both groups. After the 16-week intervention, a shift to a more favorable classification is seen for all children in the INT group, which means that even with an already "good" MC a shift to "very good" was made (INT: 23.2% very good, 29.0% good, and 45.8% normal MC, 1.9% insufficiency or moderate disorder; CON:

8.8%, 22.4%, 61.9%, 6.8%). More specifically, the number of children from the INT group that has been categorized in "disturbed or severe motor disorder," "insufficiency or moderate motor disorder," and "normal," has decreased for the benefit of the number of children that has been categorized in "good" and "very good" MC. This evolution was attributable to the intervention, getting 21.9% of the children out of the "below average" zone (this is the "lower" end of the motor continuum).

Not only were significant improvements found for overall MQ, but also for each subtest of the KTK3. Except for the evolution from inter to post in walking backward along a balance beam and jumping sideways, all evolutions (preinter, pre–post, and interpost) were significantly different in the INT group compared with the CON group. The intervention was designed in such a way that a wide variety of movement skills were practiced, and this is also represented in the positive outcome on the three subtests of the KTK, which in turn indicates a general improvement in MC.

It is not clear what interpretation can be given for the Time × Gender interaction which indicated that at premeasurement boys and girls did not differ in MC, but at inter and post measurement a difference was found indicating that boys improved more than girls. Even though no significant association with participating or not in leisure-time PA (this factor was only evaluated as a yes/no answer) was found, this might be the explaining factor. The time spent outdoors, the way in which the sport was presented (school-based or not, competition or recreative) and the type of sport could have played an important role in this evolution, but was not assessed.

It has to be noted that MC of the CON group also improved significantly during the intervention period. This age-related increase is a normal phenomenon in typically developing children across the elementary school years (Ahnert et al., 2010; Vandorpe et al., 2012). The improvement could also be related to a test effect; that is, familiarity with a new assessment tools might lead to a higher score as a result of repeated measurements (Vandorpe et al., 2012). Such a test effect could also explain why the improvement tended to be larger between pretest and intermediate test compared with the intermediate and posttest and level off toward the end of the intervention. However, another plausible explanation is that the increase in MC in the CON group was the result of the standard PE lessons still being delivered by PE specialist teachers. Curriculum-based PE has also the potential to increase the development of MC, as presented in a recent review by Lorås (2020).

A notable finding is that most of the gain in MC was made in the first half of the intervention period, while the improvement from the intermediate measurement to the posttest was limited. The MC levels halfway through the intervention were already well above the age-related expected level, so the scores could not continue to rise so drastically anymore. Such a ceiling effect was also observed in the study of Costello and Warne (2020), which explains the smaller and nonsignificant improvement between inter and post.

This study has highlighted the importance of a specific PE program, based on actual motor learning principles. The content of the PE program under study can give a clear boost to the development of a broad range of motor skills and holds great potential for maintaining and increasing children's MC.

Limitations and Future Directions

The obstacle-based program is effective in improving MC in all 6- to 7-year-old Flemish children, with no gender differences. However, some limitations and future directions need to be considered within the context of this study. First, in the present study, MC was assessed by using the KTK3 (Novak et al., 2017). One may argue that there was no similarity between the PE content and the type of assessment (MC as assessed by subtests of the KTK3). This type of assessment illustrates that there was no interrelatedness between the assessment and the PE content. The authors feel that this was not a limitation but rather a strength given that improvements were observed on tasks that were not included in the intervention, suggesting improvement in MC underlying the execution of specific motor skills. From this point of view, it was an appropriate choice to evaluate the impact of the PE program on the MC of the children (de Niet et al., 2021; Lorås, 2020). Second, the motivation of the children might be a potential contributing mechanism in these positive results. In order to optimally motivate children for PE, the self-determination theory states that it is critical to support the satisfaction of their innate, psychological needs for autonomy, competence, and relatedness by being autonomy-supportive, structuring the environment, and creating a warm and solid relationship (Ryan & Deci, 2000). The intervention was designed according to similar practices that stimulate children's motivation according to self-determination theory. This factor was, however, not formally included, nor assessed in this study. The importance of the self-determination theory has been demonstrated in previous studies (Lonsdale et al., 2009; Ntoumanis & Standage, 2009; Van den Berghe et al., 2014), so the variables (e.g., teacher feedback and teacher style) that are part of a need-supportive environment that can provide various motivational benefits to impact children's MC should be included in further research. Third, after each lesson, the teachers of the INT group were asked to formulate feedback on the lesson sheet to ensure treatment validity. This feedback was used to determine whether they could conduct the lessons as described by the manual. However, the researchers did not video record the PE lessons so there was no systematic collection of process data to document implementation fidelity. Future research should implement a validated direct observation instrument (e.g., SOFIT video recording) to obtain more objective and detailed information on the lesson content.

In young children, PA is suggested to drive the development of MC through a variety of exploratory and structured movement experiences (Stodden et al., 2008). Proficiency in MC is associated with certain levels of PA (Engel et al., 2018; Logan et al., 2012, 2015; Lubans et al., 2010; Morgan et al., 2013). As children transition to middle and late childhood, this relationship is hypothesized to become stronger and more reciprocal, driven by the child's ability to perceive its competence in various movement contexts (Stodden et al., 2008). Consequently, the question arises, what would have been the outcome in this pilot study if PA levels had been assessed and compared between the INT and CON group given the positive increase in MC in the INT group? Assessing PA levels would be a key area to focus on in further research to identify if primary schoolchildren's MC is a contributing factor to their PA level as seen in recent research (Lee et al., 2020). To better understand how PA and MC are related in early childhood, future research should investigate the reciprocal relationship of objectively measured PA and MC.

Finally, as a standard PE curriculum consists of a wide range of gross movement exercises, it is recommended to point out the PE content of such curricula in more detail in future research. Parameters such as lesson time, content type and sequence, instructional methods, and teacher interactions might give substantial information to interpret and explain the increase in children's MC.

Knowing the impact of a teaching program designed to increase MC through practicing a broad range of movement skills on the children's PA levels and motivation is a must to convince the policymakers to make changes. The findings of this study and future research on this topic can further induce optimization of the current PE programs in the field. Future research should include the abovementioned limitations and concerns as they are important contributors to children's MC level.

Conclusion

A PE program consisting of a series of lessons including an obstacle course had a positive impact on the development of MC in 6- to 7-year-old Flemish children. Significant improvements were found for overall MQ scores, as well as for each subtest of the KTK3, in the INT group compared with the CON group, with similar evolutions for boys and girls. Moreover, for all (starting with low, normal, or high MC) children, a shift toward a better level of MC was found after the total implementation of the intervention. Our findings highlight the importance of the implementation of a PE program, focusing on the development of a broad range of movement skills and designed according to the latest insights on implicit motor learning, in order to counter the secular decline in children's MC.

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Notes

1. In Flanders, three school networks are distinguished: community schools, municipal and provincial schools, and free schools.

2. The 10 learning lines are balance, climbing, hanging, rotating, jumping, running, throwing and catching, sports and games, rhythmic and expressive movement, and swimming.

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