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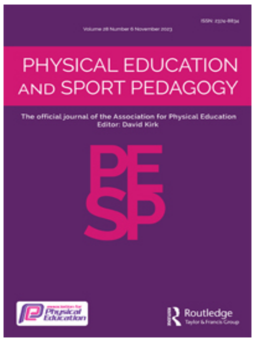
Published in:
Physical Education and Sport Pedagogy

DOI:
10.1080/17408989.2021.2006621



Physical Education and Sport Pedagogy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cpes20

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PHYSICAL EDUCATION AND SPORT PEDAGOGY
2023, VOL. 28, NO. 6, 583–600
https://doi.org/10.1080/17408989.2021.2006621

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R. Mombarg [a,b], A. G. M. de Bruijn [c], I. A. M. Smits[d], B. T. Hemker[d], E. Hartman[e], R. J. Bosker[f] and A. C. Timmermans[f]

[a]School of Sportstudies, Hanze University of Applied Science, Groningen, The Netherlands; [b]Behavior and Society Sciences, University of Groningen, Groningen, The Netherlands; [c]Behavioural and Movement Sciences, VU Amsterdam, Amsterdam, The Netherlands; [d]Cito, Arnhem, The Netherlands; [e]Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [f]Educational Sciences, University of Groningen, Groningen, The Netherlands

ABSTRACT

Background: Fundamental Motor Skills (FMS) are important building blocks for children's sport-participation and lifelong physical activity. In the last decade, several international studies have reported delays in the development of FMS. To get better insight into the Dutch situation and to provide future directions, this study examined the development of FMS in Dutch primary school children.
Method: The main goal of this study is to compare FMS of 11–12-year-old Dutch children in 2016 with scores of similarly-aged-children in 2006. In addition, gender, age, BMI were taken into account, to see whether changes in motor performance are related to these child characteristics. FMS-test scores on seven motor competence tests (balance, swing, jump, roll, shoot, throwing and catching, and tennis) from 1939 children in 2016 were set side by side with those of 1648 children in 2006. Temporal changes in motor competence scores were analyzed using regression-analysis.
Results: This cross-sectional study shows better results for the children in 2006 compared to similarly-aged-children in 2016. Lower scores were found on six out of seven tested FMS, with the largest declines on the object control skills tennis and throwing and catching. Only vaulting jump skills remained on the same level. Overall, children with a higher BMI scored lower on all tests, except for throwing and catching via the wall. On the balancing, jumping and tennis test, the gap with children with a lower BMI widened over the last decade. Girls showed a lower competence level on rolling, shooting and throwing and catching compared to boys. During the last decade, their performance on the tennis test decreased more than for boys.
Conclusions: Results of this study are alarming as diminishing motor skills are related to lower sport participation and poorer health outcomes. For the future generation, new interventions are needed to help children reach a sufficient proficiency level in FMS, to prevent or overcome the negative effects of lowered motor skills. Targeting FMS components during physical education and outside of school hours may potentially be a valuable strategy in reverting the lowering FMS levels amongst children.

ARTICLE HISTORY
Received 26 May 2021
Accepted 7 November 2021

KEYWORDS
Fundamental motor skills; motor competence; proficiency barrier; children

CONTACT R. Mombarg r.mombarg@rug.nl, r.mombarg@pl.hanze.nl School of Sportstudies, Zernikeplein 17, 9747 AS, Groningen, The Netherlands

Introduction

Fundamental Motor Skills (FMS) are essential prerequisites for (lifelong) sport participation and engagement in physical activity (Barnett et al. 2009; De Meester et al. 2016). To participate in sports, children must reach a certain level of motor competences: the so-called *proficiency barrier* (Brian et al. 2020). Compared with their skilled peers, children with lower motor competence levels are less likely to participate in sports, be physically active in daily life, and grow up as healthy adults (Stodden et al. 2008, 2016). In addition, lower motor competence levels are negatively associated with development in a broad range of areas, such as self-esteem, cognitive functioning, and peer relationships (Bailey et al. 2016). Good motor proficiency on the other hand has long-term positive consequences for physical activity and sports participation in child- and adulthood (Engel et al. 2018; Holfelder and Schott 2014; Lloyd et al. 2014). Therefore, it is essential to support all children in developing a sufficient level of FMS.

Fundamental movement skill proficiency of school-aged children

Based on the theoretical groundwork of Barnett and colleagues (2016) we define FMS as: 'Basic learnt movement patterns that do not occur naturally and are suggested to be foundational for more complex physical and sporting activities'. Considerable research has been carried out examining children's FMS (e.g. Barnett, Ridgers, and Salmon 2015; Veldman et al. 2018). The majority of these studies have used checklists to measure specific aspects of FMS, namely locomotor skills (running, galloping, hopping, and horizontal jumping), object control skills (striking a stationary ball, catching, kicking, and overhand throwing) and/or balancing skills (standing on one leg, and walking on a line).

Normally, children's motor competences gradually develop through a common sequence of movements ('Mountain of Motor development'; Clark and Metcalfe 2002) which results in mastery of every FMS. However, several studies have reported developmental delays in FMS (e.g. Brian et al. 2019; Fisher et al. 2005; Veldman et al. 2018). Mitchell et al. (2013) concluded that 70% of the 8-to-10-year-old children in New Zealand did not fully master FMS like kicking and throwing. Comparable delays in motor skill development were found in Australia (Van Beurden et al. 2003) and in the United States (De Meester et al. 2018). Astonishingly, even at later ages, mastery of these essential skills is not evident. O' Brien, Belton, and Issartel (2016) found that only 11% of the 13-year-old children in Ireland reached the proficiency barrier for every FMS.

Whether or when the proficiency barrier is reached also depends on children's background characteristics, such as gender and BMI (Barnett et al. 2016). Compared with the desired development, girls are more likely to lag behind in their development of object control skills, whereas boys show a lower competency in locomotor skills (Hardy et al. 2012). Comparably, children with a higher BMI seem to fall behind on most locomotor skills compared to children with a healthy weight (D'Hondt et al. 2013), confirming the intertwined relationship of BMI with motor competence (e.g. Rodrigues, Stodden, and Lopes 2016; Stodden et al. 2014). Overall, these results confirm the global impression concerning the lack of proficiency in FMS at the end of primary school.

Longitudinal findings related to FMS proficiency

Aside from these alarming cross-sectional findings on levels of FMS competence of school-aged children, there are only a few studies that specifically monitored secular/longitudinal trends of FMS proficiency. In the last decade, there have been – to our knowledge – only five studies on this subject (Bös 2004, 1976–1999; Hardy et al. 2013, 1997–2010; Huotari et al. 2018, 2003–2010; Roth et al. 2010, 1985–2007; Runhaar et al. 2010, 1980–2006). Although these studies represent different time periods in different countries (Germany, Australia, Finland, and the Netherlands), in general they all report declines in children's levels of motor skills competence.

A closer look at these studies, however, reveals several contradictions in the direction of the results and type of skills measured. Bös (2004) and Runhaar et al. (2010) reported declines on all measured skills in samples of 9-to-12-year-olds. Most of these declines were found in fitness-oriented skills like running (Bös 2004, 60-minutes run: from 11 km to 9 km) and arm-pull (Runhaar et al. 2010; from 70 kg to 60 kg). The study of Huotari et al. (2018), however, showed a secular decline in obstacle track test scores (from 9.5 to 10 sec.), but no differences in scores on the lateral jump and figure eight test in samples of 15–16-year-old children. Comparably, Roth et al. (2010) reported a decline in balancing backwards (from 73% of the 3–to-6-year-old children being successful in 1989–31% in 2007) and target throwing (from 51% to 46%), but increased scores for the standing long-jump (+ 10 cm). Contrasting, Hardy et al. (2013) found progress in the mastery of motor skills of 9–to-15-year-old Australian children, although different for boys (who improved their locomotor skills – sprint run: from 40% to 60%) and girls (who improved their object control skills – catch: from 18% to 58%). The positive results in the study of Hardy et al. (2013) may be explained by the extra attention that has been given to FMS in Australian physical education lessons in the last decade (1997–2004). The Australian government hired more specialist teachers and implemented a special FMS-program in their schools, which seems to have been effective in increasing children's FMS.

The changes in levels of FMS over time seem to be different for boys and girls. In earlier studies, primary school girls constantly performed worse than boys, whereas girls are now slowly narrowing the gap with boys in high school, especially regarding their object control skills (Huotari et al. 2018; Hardy et al. 2013). This narrowing gap between girls' and boys' FMS may be due to the growing investment in team sports for girls (e.g. growing numbers of girl soccer teams in Europe (Romijn and Elling 2017)).

The present study

Summarizing, previous studies on children's motor skill performance have reported a lack of proficiency in FMS at the end of primary school, especially for girls and overweight children. Previous studies have reported an overall decline in some, but not all motor skills during the last decades. In the Netherlands, it remains unclear how children's FMS proficiency levels have developed over time. Therefore, the aim of the current study is to assess changes in motor skill level of Dutch children at the end of primary school between 2006 and 2016. In addition, age, gender, and BMI were taken into account, to identify critical factors inducing the risk of lowered motor skill competence. Results of this study are important, because internationally, there seems to be a decline in children's motor skill levels. Regarding the critical role that motor skills play in children's engagement in physical activity and sports, it is of vital importance to identify possible delays in children's motor skill development. Early intervention for specific groups (e.g. girls and overweight children) or specific skills might be needed to prevent delays in children's motor development.

The following research questions will be addressed in this study:

(1) What are the differences in FMS proficiency levels of 11–to-12-year-old Dutch children between 2006 and 2016?
(2) What are the differences in FMS proficiency levels of 11–to-12-year-old Dutch children between 2006 and 2016 in different age, gender, and BMI-groups?

Method

Data source

The results of two most recent national assessments in Dutch physical education (Timmermans et al. 2017; Van Weerden, Schoot, and Hemker 2008) were used to investigate changes in motor skill competences of primary school children between 2006 and 2016.

Participants

For both national assessments, two-stage stratified samples were drawn. Strata were based on the composition of socioeconomic status of the child population in the schools. The indicator for socioeconomic status changed between 2006 and 2016 (three categories in 2006 and four categories in 2016); in 2006 both the level of parental education and the country of birth of the parents was considered, whereas in 2016 socioeconomic status was solely based on the level of parental education. In both assessments, a main sample of schools was drawn that was contacted for participation, and two samples were drawn as backup. In case a school from the main sample declined to participate, a similar school from the backup sample(s) was contacted. If schools agreed to participate, all grade six children were included in the sample. The measurement for the 2006 assessment was taken in spring (end of the school year) and the 2016 assessment in fall (beginning of the school year), which implies that students were on average somewhat older in the 2006 sample ($M = 12.4$, $SD = 0.54$) compared to the 2016 sample ($M = 11.7$, $SD = 0.51$).

The 2006 sample included 1246 children from 70 Dutch primary schools. In this sample, 49.3% of the children was male and most children (45.3%) were at the age of 11, with the youngest being 10 years old (0.3%) and the oldest being 14 year old (0.7%). The sample of the 2016 assessment included 1939 children from 69 Dutch regular primary schools.[1] In this sample, 48.1% of the children was male and most children (75.8%) were at the age of 11, with the youngest being 9 years old (0.2%) and the oldest being 13 year old (0.5%). The 2016 sample is considered representative for the Dutch population at school and child level (Timmermans et al. 2017).

Instruments and variables: fundamental motor skills

The FMS tests, criteria and norms used in this study are all based on skill-goals of the Dutch PE-curriculum. The skill tests are a representative selection of the twelve fundamental motor skills that are the central goal of the Dutch PE-curriculum (SLO 2011). The seven representative motor skills tests used in this study were selected by external specialists, because these skills are seen as important prerequisites for future sport participation and are expected to give a good overview of the object-, locomotor- and balance skills that make up FMS (Logan et al. 2016). For each FMS element we included at least two tasks to increase the reliability of the measurements and to keep the assessment feasible: object control (e.g. tennis and ball-throw) skills, locomotor (e.g. vaulting jump and rolling) skills and balancing skills (e.g. balancing on a bench and rope swing). To measure mastery level of these skills, a combination of process- and product-oriented measures was used, depending on the prerequisite of the specific skill involved. This means that in tennis and throwing the criteria are more product-oriented (e.g. amount of successful hits), while for gymnastics a more process-oriented approach was used (e.g. landing on both feet). Based on recommendations in the study of Hands (2012) to adequately discriminate skill-levels of older children, we placed the tasks in a more complex and more ecological valid setting (e.g. tennis against the wall instead of bouncing a tennis ball on the ground).

Interrater reliability of the skill tests was assessed in a small-scale pilot study conducted at two primary schools and one special primary school. Each skill test was piloted at one of the schools. During this pilot, each skill test was observed and scored by multiple observers (i.e. multiple ratings of the same attempts). The results regarding inter-rater reliability of the seven skill tests are presented in Appendix 1. The relation of the tests used in the current study to standardized instruments such as the BOT-2 (Bruininks and Bruininks 2005) and KTK (Kiphard and Schilling 1974, 2007) is presented in Appendix 2.

Balancing on an instable bench. The child walked on a bench which was standing on the ground on one side and hanging upside-down in the rings on the other side. The side of the bench that was standing on the ground was the starting point of the test, from which the child had to walk towards the other end within 4 seconds (0–1 point), turn around making a half-turn (0–3 points), walk back down within 4 seconds (0–1 point), and step off in a controlled way (0–1 point). Children got three attempts, of which only the last two were assessed. Scores on both attempts were added up, making a maximum total score of 12 points.

Rope swing. In this test, children stood on a vaulting box, from which they had to make a rope swing, ending with a half-turn before landing on a mat. Four aspects were evaluated: take-off (0–3 points), making a half-turn (0–1 point), landing on the mat (0–1 point), and landing stably (0–2 points). Children got three attempts, of which only the last two were evaluated. The number of points on both attempts was summed, making a maximum total score of 14 points.

Vaulting jump. Children made a jump over a vaulting box, which was evaluated on four aspects: walking towards the trampoline over two benches and making a two-feet take-off in the middle of the trampoline (0–1 point), placing both hands on the vaulting box and making an agile leap with both legs stretched out above the hips (0–3 points), making a two-feet landing (0–1 point) while facing towards the vaulting box (0–1 point). Four attempts were given, of which only the last two were evaluated. For each attempt, six points could be awarded, making a maximum total score of 12 summed over the two attempts.

Rolling on an elevated mat. In this test, children made a forward roll on a heightened mat, which was evaluated on three aspects: starting off the roll (0–2 points), rolling in a straight line (0–2 points), and ending in a squat or standing position (0–2 points). Three attempts were given, of which only the last two were evaluated. Scores on both attempts were summed, making a maximum total score of 12 points.

Aiming with a ball at a heightened target. In this test, children had to aim at a basket from four different positions: at two (position 1) or three (position 2) meters distance right in front of the basket, and at two meters distance on the right side (position 3) or the left side (position 4) of the basket. Five attempts were given for each position, resulting in 20 attempts in total, for which it was rated whether a child scored (2 points), hit the board (1 point), or missed (0 points), making a maximum total score of 40 points.

Throwing and catching via the wall. Children had to throw a tennis ball against the wall, while standing on a mat, trying to catch the ball when it bounced back. They did this from three different positions: the first mat being placed at three meters from the wall, the second at five meters, and the third at seven meters. Three attempts were given for each mat. The total number of caught balls for the three mats together was used as a final score, with a maximum score of nine points.

Tennis via the wall. This test consisted of two parts. In the first part, children tried to hit the ball against the wall above a marked line (at 1.5 meters high) 10 times, using a tennis racket, while also returning it within the field they were standing. In the second part they were given the same assignment, but this time they had to make as many correct hits and returns as possible within a timeframe of 30 seconds. In both parts of the test, a point was awarded for every correctly hit ball (above the line), and every correctly returned ball (within the field). The number of points on both parts was summed to get a final score.

Background characteristics

Gender, age and BMI were considered as covariates.

Gender and age. Information on age and gender of the children was derived from the school administration system. In the 2006 sample, children were on average 12.4 years old ($SD = 0.54$), of which $N = 614$ boys (49.4%). In the 2016 sample, the mean age of the children was 11.7, ($SD = 0.51$), of which $N = 847$ boys (47.8%).

BMI. BMI was computed by dividing children's weight (in kilograms) by their height (in centimeters) squared. BMI ranged from 11.90–29.58 in the 2006 sample ($M = 17.9$, $SD = 2.79$) and from 12.95–33.24 in the 2016 sample ($M = 18.3$, $SD = 3.10$).

Table 1 gives a more in-depth description of the background variables BMI, gender and age in both samples. In Table 1, to ease the comparability of the two samples, a three-category division was

Table 1. Descriptive Statistics of the Samples of 2006 and 2016 with Respect to Gender, Age, and BMI.

	9–10 years		11 years		12 years		13–14 years		Total	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
2006										
N	2	2	223	298	281	228	61	45	567	573
BMI[a] (kg/m^2)	16.98 (0.20)	17.10 (3.23)	17.48 (2.61)	18.06 (2.67)	17.59 (2.64)	18.53 (3.03)	18.02 (3.02)	18.88 (3.33)	17.59 (2.67)	18.31 (2.88)
%Overweight and obesity[b]			15.7	17.8	14.6	16.2	13.1	8.9	14.8	16.4
%Normal	100.0	100.0	81.2	79.5	78.3	78.5	72.1	80.0	78.8	79.2
% (Severe) Thinness			3.1	2.7	7.1	5.3	14.8	11.1	6.3	4.4
2016										
N	29	42	533	611	183	164	5	10	750	827
BMI (kg/m^2)	18.14 (3.85)	17.41 (2.07)	17.81 (2.65)	18.34 (2.99)	18.38 (3.14)	19.32 (3.19)	19.32 (3.72)	21.15 (4.59)	17.97 (2.99)	18.51 (3.06)
%Overweight and obesity	24.1	14.3	21.6	21.9	24.6	25.6	20.0	50.0	22.2	22.6
%Normal	69.0	85.7	75.8	76.8	68.9	73.8	60.0	50.0	73.7	76.3
% (Severe) Thinness	6.9	0.0	2.6	1.3	6.6	0.6	20.0	0.0	3.9	1.1

[a]BMI = Body Mass Index.
[b]Categories are based on the international normscores of the World Health Organization 2007 retrieved from https://www.who.int/growthref/who2007_bmi_for_age/en/; (De Onis and Lobstein 2010): Thinness (including severe thinness, coded as 1), Normal (coded as 2), and Overweight and Obese (coded as 3).

made for BMI based on international age and gender specific norm scores as specified by the World Health Organization (WHO) in 2007 (De Onis and Lobstein 2010); for the exact reference values per age group and gender (WHO, 2021). The following three BMI groups are presented in Table 1: Thinness (including severe thinness, coded as 1), Normal weight (coded as 2), and Overweight and Obese (coded as 3).

Procedure

In 2006, the tests were administered at sporting facilities at five locations in the Netherlands. In 2016 the tests were administered at the location where children followed their regular physical education lessons. Both assessments included more tasks than individual children could participate in. Therefore, block designs were used, meaning that children only participated in a selection of tasks (six tasks in 2006 and four tasks in 2016). Tasks were randomly allocated to children, in 2006 at the child level; in 2016 at the school level. The random allocation ensured that the children who completed a particular task were representative for the entire sample.

A comprehensive protocol was developed for each task, including instructions for the materials and observations. Trained teams of research assistants administered the tests and recorded the results. Instructions on how the tasks had to be executed were given to the children through videos (the exact same videos were used in both assessments). Organizational instructions such as 'wait on my signal to begin' were also standardized and provided to children by trained research assistants. Children were not provided with feedback in-between attempts.

Analytic strategy

The data had a hierarchical structure, that is: children (level 1) were nested within schools (level 2), therefore the statistical modeling needed to adequately account for dependencies in the data by using a multilevel model (e.g. Goldstein 2010; Snijders and Bosker 2012). The data were analyzed in a two-level regression model, using the MLwiN 3.0 software (Rasbash et al. 2009). For each of the FMS, a separate multilevel regression model was estimated. First, empty models were estimated to assess the intraclass correlation for each of the FMS. Thereafter, main effect models were estimated by using a dummy variable to assess the differences in FMS between the two national assessments, with the assessment of 2006 being the reference category. In this model, gender, age, and BMI were included to take potential differences between the samples in these covariates into account. For the continuous variables age and BMI, grand mean centering was applied (Enders and Tofighi 2007). For gender, boys were used as the reference group. From these main effect models, the regression coefficients for the assessments were converted to Cohen's *d* by dividing the regression coefficient of assessment by the pooled total standard deviation, see Hedges (2007).

Finally, a series of models were estimated in which interactions between the dummy variable for the national assessments and the covariates (BMI, gender and age) were added to assess potential moderator effects (i.e. whether changes between 2006 and 2016 were equally large for different groups of children). Level of significance was set at $p < .05$ for all analyses.

Results

Descriptive statistics of the two samples

When comparing the samples of the two national assessments, no significant differences were found with respect to gender ($\chi^2(1) = 0.721$, $p = .396$). The samples differed in the age of the children at the time of data collection (t (2431.5) = 23.30, $p < .001$), with the children in the 2006 national assessment being older on average ($M = 12.13$, $SD = 0.54$) than the children in the 2016 national assessment ($M = 11.67$, $SD = 0.51$). This age difference can be fully explained by a difference in the timing of the data collection (spring vs. fall).

A comparison of the two samples in terms of BMI is presented in Table 1. BMI of children in the two national assessments significantly differed: $t(2699.0) = -3.36$, $p = .001$, $d = 0.13$. Children in the national assessment of 2016 had a higher BMI on average ($M = 18.32$, $SD = 3.09$) than children in 2006 ($M = 17.95$, $SD = 2.78$). The fraction of children categorized as overweight or obese by international standards also increased between 2006 and 2016, holding for both boys ($\chi^2(2) = 14.85$, $p = .001$) and girls ($\chi^2(2) = 21.82$, $p < .001$). The fraction of children categorized as overweight or obese also increased for all age groups (11-years-olds $\chi^2(2) = 6.39$, $p = .041$; 12-year-olds $\chi^2(2) = 14.13$, $p = .001$; 13 and 14-year-olds $\chi^2(2) = 8.60$, $p = .014$), except for the small group of 9- and 10-year-olds; $\chi^2(2) = 1.06$, $p = .590$.

Main effects of the 2006 and 2016 cohort comparison on fundamental motor skills

The raw means and standard deviations as well as the intraclass correlations (proportion of variance at the school level) for all FMS variables are presented in Table 2. The ICCs of the FMS vary between .13 (Rolling on an elevated mat) and .35 (Tennis via the wall), indicating that for each of the FMS a significant part of the variance is located at the school level.

The results of the multilevel regression models for the comparison of the two national assessments are presented in Table 3. After controlling for gender, age, and BMI, significant differences between the 2006 and 2016 assessments were found for all FMS variables except for Vaulting Jump; $b = -0.006$, $t(1185) = -0.022$, $p = .982$. The differences between the two assessments are all negative, thus implying a decline in FMS between 2006 and 2016. Furthermore, we found no significant associations between the FMS and age. BMI was related to all FMS except for Catching and throwing via the wall. The negative associations indicate that children with higher BMI values on average performed lower on the FMS tasks. Gender was significantly related to Vaulting jump, Aiming with a ball at a heightened target, Catching and throwing via the wall, and Tennis via the wall. On these skills boys outperformed girls.

In terms of standardized effect sizes (Cohen's d), the decline between 2006 and 2016 can be considered substantial but also rather dependent on the particular FMS under study, see Table 4. The strongest relative decline was found for Catching and throwing via the wall ($d = -0.84$) and Tennis via the wall ($d = -1.41$).

Moderation effects of the 2006 and 2016 cohort comparison on fundamental motor skills

Table 5 presents the results of the multilevel regression models that were used to test the potential moderation effects of gender, age and BMI in the comparison of the two national assessments. Likelihood ratio tests comparing the fit of the models from Table 3 with the models from Table 5 revealed that the added moderation effects for gender, age, and BMI did not significantly improve

Table 2. Descriptive Statistics of the Test Results of the 2006 and 2016 Samples.

	2006			2016			
	N	*M*	*SD*	*N*	*M*	*SD*	ICC
Balancing	694	7.79	2.88	594	6.45	2.66	0.16
Rope swing	698	10.58	2.40	612	8.63	2.63	0.25
Vaulting jump	690	7.82	2.68	577	7.75	2.43	0.15
Rolling on an elevated mat	707	7.55	2.82	570	6.82	2.67	0.13
Aiming with a ball at a heightened target	695	26.85	3.80	527	25.22	5.13	0.33
Catching and throwing via the wall	520	4.85	2.39	455	2.87	2.29	0.25
Tennis via the wall	683	17.45	3.08	504	12.41	4.59	0.35

Table 3. Results of the Multilevel Models for Testing the Difference in Performance Between the 2006 and 2016 Samples.

	Balancing			Rope swing			Vaulting jump			Rolling on an elevated mat		
	B	SEb	*p*	b	SEb	*p*	b	SEb	*p*	B	SEb	*p*
Fixed Part												
Intercept	7.485	0.182	<.001	10.555	0.178	<.001	7.945	0.176	<.001	7.305	0.175	<.001
Gender (girl)	0.273	0.153	.074	−0.042	0.135	.756	−0.326	0.139	.019	0.199	0.154	.195
BMI	−0.312	0.026	<.001	−0.186	0.024	<.001	−0.216	0.025	<.001	−0.290	0.027	<.001
Age	0.264	0.152	.082	−0.160	0.137	.242	−0.039	0.134	.772	0.076	0.152	.618
Assessment (2016)	−0.823	0.293	.005	−1.719	0.291	<.001	−0.006	0.276	.982	−0.579	0.276	.036
Random Part												
Schools	0.827	0.214		0.975	0.220		0.847	0.202		0.715	0.194	
Children	6.234	0.271		5.002	0.214		5.331	0.226		6.295	0.274	
#schools	82			84			84			84		
#children	1135			1172			1191			1133		
−2*loglikelihood:	5376.693			5314.474			5464.544			5372.371		

	Aiming with a ball at a heightened target			Catching and throwing via the wall			Tennis via the wall		
	b	SEb	*p*	b	SEb	*p*	b	SEb	*p*
Fixed Part									
Intercept	27.449	0.369	<.001	5.763	0.171	<.001	18.001	0.255	<.001
Gender (girl)	−1.438	0.219	<.001	−1.787	0.140	<.001	−1.088	0.222	<.001
BMI	−0.128	0.039	.001	−0.024	0.024	.311	−0.103	0.039	.007
Age	0.367	0.218	.092	0.142	0.136	.297	−0.009	0.214	.967
Assessment (2016)	−1.653	0.658	.012	−1.804	0.262	<.001	−5.282	0.404	<.001
Random Part									
Schools	5.939	1.113		0.618	0.167		1.493	0.404	
Children	12.541	0.544		4.037	0.197		12.529	0.553	
#schools	85			71			83		
#children	1147			909			1103		
−2*loglikelihood:	6312.851			3919.558			5991.665		

Table 4. Effect Sizes of the 2006–2016 Difference in Performance Derived from the Multilevel Model Presented in Table 3.

FMS	Cohen's d
Balancing	−0,31
Rope swing	−0,70
Vaulting jump	−0,00
Rolling on an elevated mat	−0,22
Aiming with a ball at a heightened target	−0,38
Catching and throwing via the wall	−0,84
Tennis via the wall	−1,41

the model fit for rope swing ($\chi^2(3) = 1.99$, $p = 0.575$), aiming with the ball at a heightened target ($\chi^2(3) = 3.00$, $p = 0.392$), and catching and throwing via the wall ($\chi^2(3) = 1.03$, $p = 0.794$). This implies that the changes between 2006 and 2016 on these FMS were approximately equally large for children with different gender, age or BMI.

Comparing the fit of the models from Table 3 with the models from Table 5 revealed that the added moderation effects for gender, age, and BMI did significantly improve the model fit for balancing on an instable plane ($\chi^2(3) = 13.08$, $p = 0.005$), vaulting jump ($\chi^2(3) = 11.90$, $p = 0.008$), rolling on an elevated plane ($\chi^2(3) = 8.27$, $p = 0.041$), and tennis against the wall ($\chi^2(3) = 13.18$, $p = 0.004$). For balancing, the difference between 2006 and 2016 was dependent on the children' BMI, indicating a larger decline in performance for low BMI children and an increasingly smaller decline for children with a higher BMI; $b = 0.16$, $t(1124) = 3.2$, $p = .001$ (see Figure 1, Panel A). For vaulting jump, a positive moderation effect of BMI was found; $b = 0.14$, $t(1182) = 2.8$, $p = .005$ (see Figure 1, Panel B). Again, a stronger decrease in performance was observed for children with lower BMI values. For the FMS test 'Rolling on an elevated plane', after adding the moderator variables to the model, the differences in motor performance between 2006 and 2016 was no longer significant ($b = -0.18$, $t(1127) = 0.56$, $p = .575$). The difference in performance on rolling on an elevated plane between 2006 and 2016 was moderated by Gender ($b = -0.76$, $t(1127) = 2.45$, $p = .014$). As can be seen from Figure 1 panel C, performance in rolling on an elevated plane slightly increased for the boys whereas it decreased for girls. For Tennis via the wall, the gap between 2006 and 2016 was dependent on both gender and BMI (See Figure 1, Panel D and E), with a larger decline for girls than for boys ($b = -1.45$, $t(1094) = 3.22$, $p = .001$), and a slightly larger decline on Tennis via the wall for children with a lower BMI than for children with a higher BMI ($b = 0.15$, $t(1094) = 2.00$, $p = .046$).

Discussion

The aim of this study was to compare levels of FMS of 11–to-12-year-old Dutch children between 2006 and 2016. Even when controlling for age, BMI and gender, the balancing, rope swinging, rolling, aiming, catching and tennis skills all were lower in the 2016 compared to the 2006 sample. Only children's performance on the vaulting jump remained stable within this decade. Although our results are cross-sectional, they suggest that, in general, there is a decline in children's FMS, which cannot be explained by other factors like BMI and gender. This result is worrisome, as a lack of motor skill proficiency may eventually result in lowered rates of sport participation and unhealthy lifestyles (Clark and Metcalfe 2002). Our results are in line with the negative development of motor skills reported in other studies (Huotari et al. 2018; Roth et al. 2010). In the Netherlands, the amount of time spent in PE-lessons (90 minutes per week) and the percentage of children participating in sports clubs (64%) remained quite stable from 2003 to 2017 (Van den Dool and Van den Breul 2018; Slot-Heijs and Lucassen 2017). However, in the same period, a decline occurred in time spent in free-outdoor play (from 17% to 10% children who played outside more than three hours per week; Dellas, Dool, and Collard 2018) and an increase was found in time spent sedentary

Table 5. Results of the Multilevel Models for Testing the Moderation Effects of Age, Gender, and BMI.

	Balancing			Rope swing			Vaulting jump			Rolling on an elevated mat		
	B	SE	*p*	B	SE	*p*	b	SE	*p*	B	SE	*P*
Fixed Part												
Intercept	7.53	0.20	<.001	10.66	0.19	<.001	7.86	0.19	<.001	7.11	0.19	<.001
Assessment(2016)	−0.90	0.34	.007	−1.91	0.32	<.001	0.23	0.31	.456	−0.18	0.32	.567
Gender(girls)	0.24	0.20	.237	−0.22	0.18	.242	−0.09	0.19	.640	0.54	0.20	.008
BMI	−0.40	0.04	<.001	−0.19	0.03	<.001	−0.29	0.03	<.001	−0.34	0.04	<.001
Age	0.09	0.19	.644	−0.21	0.18	.234	−0.15	0.18	.408	0.12	0.19	.536
Assessment(2016)*Gender(girls)	0.10	0.31	.738	0.37	0.27	.167	−0.50	0.29	.068	−0.76	0.31	.014
Assessment(2016)*BMI	0.16	0.05	.002	−0.002	0.05	.966	0.14	0.05	.004	0.09	0.05	.091
Assessment(2016)*Age	0.44	0.31	.158	0.11	0.28	.698	0.22	0.27	.411	−0.09	0.31	.786
Random Part												
Variance school	0.85	0.22		0.98	0.22		0.82	0.20		0.714	0.19	
Variance student	6.15	0.27		4.99	0.21		5.28	0.22		6.248	0.27	
Units: School	82			84			84			84		
Units: Student	1135			1172			1191			1133		
−2*loglikelihood:	5363.61			5312.48			5452.64			5364.10		

	Aiming with a ball at a heightened target			Catching and throwing via the wall			Tennis via the wall		
	B	SE	*p*	B	SE	*p*	B	SE	*p*
Fixed Part									
Intercept	27.62	0.39	<.001	5.68	0.19	<.001	17.64	0.28	<.001
Assessment(2016)	−1.99	0.70	.004	−1.68	0.30	<.001	−4.51	0.47	<.001
Gender(girls)	−1.71	0.29	<.001	−1.68	0.19	<.001	−0.45	0.29	.123
BMI	−0.15	0.05	.003	−0.03	0.03	.423	−0.17	0.05	.001
Age	0.26	0.28	.368	0.22	0.18	.218	0.10	0.28	.705
Assessment (2016)*Gender (girls)	0.62	0.44	.160	−0.22	0.28	.424	−1.45	0.45	.001
Assessment (2016)*BMI	0.05	0.08	.513	0.01	0.05	.912	0.15	0.08	.049
Assessment (2016)*Age	0.25	0.44	.567	−0.19	0.27	.490	−0.33	0.44	.455
Random Part									
Variance school	5.89	1.11		0.61	0.17		1.54	0.41	
Variance student	12.51	0.54		4.03	0.20		12.36	0.55	
Units: School	85			71			83		
Units: Student	1147			909			1103		
−2*loglikelihood:	6309.85			3918.53			5978.49		

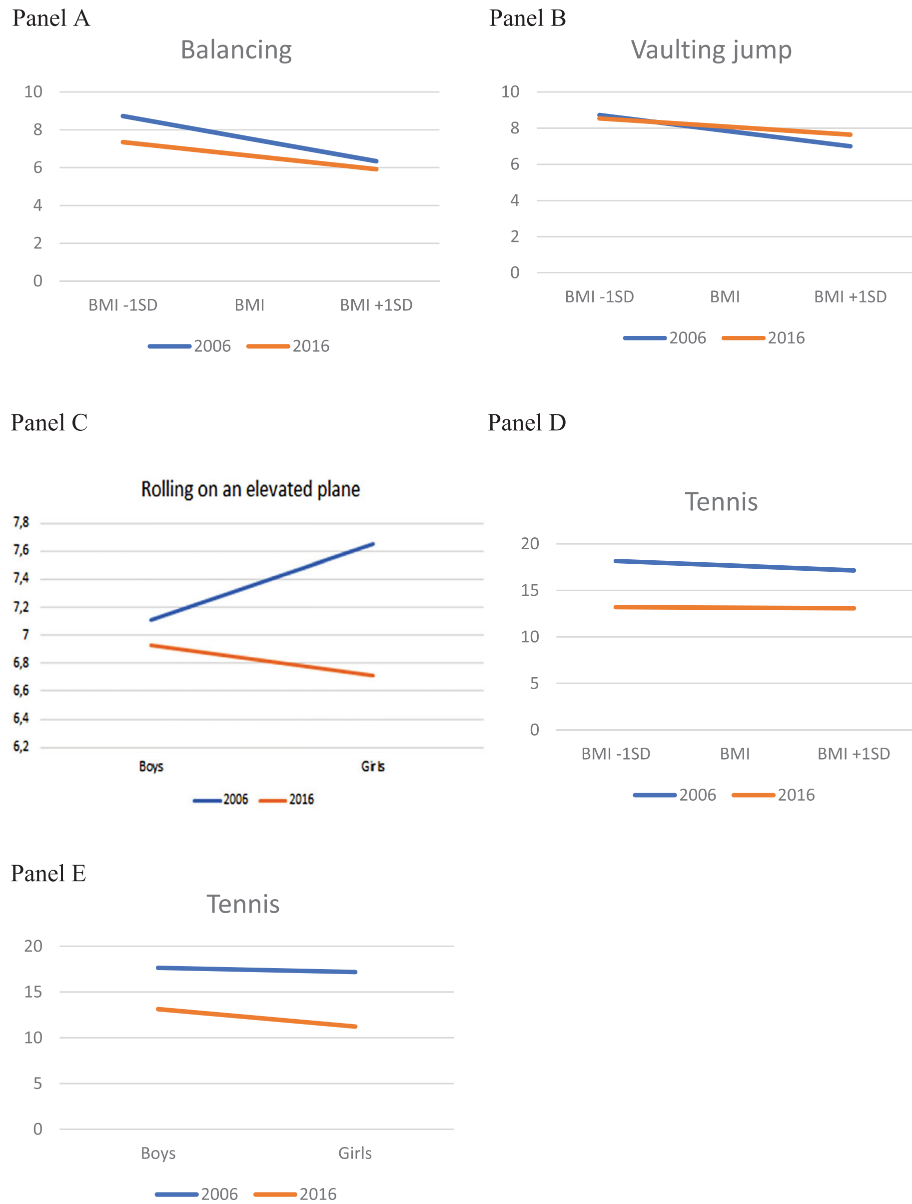

Figure 1. Graphical representation of moderation effects.

(Bernaards, Hildebrandt, and Hendriksen 2016) for children in the Netherlands. This could be an explanation for the decline in FMS proficiency during the last decade.

Object control and locomotor skills

Our results suggest that there are especially differences in object control skills (catching and throwing and tennis via de wall). In the last decade, these skills showed the biggest cross-sectional decline in comparison with locomotor skills. There are several potential explanations for this difference in decline between object control and locomotor skills, one being building blocks of which the two sets of skills are composed, and the time needed to acquire sufficient levels of locomotor and object control skills. Previous studies have shown that locomotor skills are less complex to acquire than object control skills in primary school children (Westendorp et al. 2014). Locomotor skills mostly consist of a succession of qualitative, fixed movement patterns, for example when jumping (preparatory movement: bending the knees, movement: taking off by extending legs, ending movement: landing on both feet and bending the knees). Object control skills on the other hand are dependent on a reaction to the movement of an external object (i.e. to catch a ball a child has to adjust the position of his feet and hands based on the ball-trajectory). Therefore, instead of a fixed movement pattern, object control skills mostly consist of a complex, adaptive combination of movements that is executed within a short timeframe, resulting in a quantitative result (i.e. catching the ball or not). To master object control skills, prolonged exposure to motor experiences is necessary, which is more likely to result in delays than the fixed movement patterns needed for locomotor skills. Following, object control skills are the most likely to be affected when children are not provided with enough opportunities to practice, which is the case in education, as there is reduced time available for (outdoor) play (Dellas, Dool, and Collard 2018; Van der Woud and Grinsven 2018).

Role of gender, age and BMI

The present study shows that gender was related to FMS. Boys outperformed girls on all object control skills and on one locomotor skill: the vaulting jump. This result is in line with former studies (Behan et al. 2019; Valentini et al. 2016), except for the results on the vaulting jump. Although highly hypothetical, the need to take risks with a vaulting jump might put boys more in favor, as they are overall more prone to take risks (Castanier, Scanff, and Woodman 2010).

We found no significant associations between age and FMS, possibly because the majority of the children were in the same grade, causing a restriction in the range of the age variable. As a result, in general children followed similar PE classes, thereby being exposed to the same frequency and comparable content of PE-lessons. This idea is in line with other research (Lester et al. 2017) in which children of the same school-year-group were found to obtain closely related FMS-scores.

BMI was negatively related to all FMS, except for catching and throwing via the wall. The theory of Stodden (2016), suggests that overweight children will engage less in (sport) activities and are therefore less likely to have enough practice to enhance their FMS. Our results support this theory and are also in line with the effect of BMI on FMS that was found in several other studies (Barnett et al. 2021;Cattuzzo et al. 2016; De Meester et al. 2016; D'Hondt et al. 2013; Duncan, Bryant, and Stodden 2017; Lopes et al. 2012). Overweight children generally perform worse on tests in which they have to move against gravity or in which their enlarged body limits their movement opportunities (Cattuzzo et al. 2016). Comparing the two samples, there was a smaller difference in scores on balancing, tennis and the vaulting jump for overweight children compared to children with a healthy weight. This result can possibly be explained by the compensating effect of BMI on muscle-growth, as children with a higher BMI generally have more muscle strength than children with a normal BMI (D'Hondt et al. 2013). Despite the smaller decline in FMS for overweight children, overall a higher BMI went hand in hand with lowered FMS in both samples and is therefore an important risk factor to consider in the development of interventions.

Strengths and limitations

Strengths of this study include the large cross-sectional comparison of 3182 children between 2006 and 2016, using the same motor skill assessment: and the use of multi-level analyses, taking into account moderation effects of age, gender and BMI on FMS. As the data is derived from a national assessment, the study encompasses children from different regions in the Netherlands, thereby being quite robust against regional and situational influences.

The tests that were used were chosen based on their representativeness for the skills that are typically taught within the Dutch PE-curriculum. This makes the study highly ecologically valid. However, a disadvantage of this procedure is that it makes it more difficult to compare results with those acquired using more widely-used FMS tests like the TGMD-2, which is an obstacle for international comparison of study results. Yet, the skills that were assessed are important skills for Dutch children, as they are representative of the skills needed for the sports and games that children participate in. For future studies we recommend including more culturally specific and ecologically valid assessments like the ones we used. As for the Netherlands, it would make sense to include measures of cycling skills, as this is one of the fastest-growing physical activities among adults, and a healthy means of transportation.

Related to the previous limitation, the tests used were developed specifically for the national assessments in the Netherlands. Therefore, only limited information is available regarding the validity and reliability of these tests. Nevertheless, small scale pilot data indicate that the scoring of the skills by two or three different raters can be done in a consistent and reliable manner. Moreover, children's scores on these skill tests correlated positively with (subtests of) standardized instruments.

Further, the school's socio-economic background of the child population was not included in the multilevel models, meaning that we could not test whether differences in FMS performance between the samples were associated with differences between the populations in terms of socio-economic status. Yet, we believe that the differences in performance between the two samples are not attributable to changes in socio-economic status, as the share of low SES people in the Dutch adult population has been declining during the time frame we examined (Scheerens, Timmermans, and van der Werf 2019). Moreover, this holds specifically for parents of Grade 6 students, as the percentage of Dutch students with highly educated parents increased from 28.1% in 2008 to 35.5% in 2014 (Scheerens, Timmermans, and van der Werf 2019).

Lastly, as our data were cross-sectional, we could only describe differences in FMS between children in 2006 and 2016 FMS. Future studies should also use intervention designs to reinstate sufficient levels of FMS. Building on the hypothesis that not all children may receive equal opportunities to reach proficiency in their FMS due to social-cultural and organizational backgrounds, a change of PE-content, differentiation between children, and re-organization of playground activities are probably needed to equal differences between children. National interventions like 'Move it Groove it' (Morgan et al. 2013) directed towards teaching FMS have provided promising results, but future research in this direction is needed to find country-specific solutions.

Conclusion

This study confirms the world-wide decline in FMS levels of children in the last decade. We conclude that six out of the seven important motor skills show a pronounced negative difference between comparable age-groups within one decade. This presents a potential threat for the health and well-being of the future generation. Furthermore, BMI and gender were found to be associated with the results on the motor assessments. Children with a higher BMI performed at the lower end of the spectrum. Additionally, girls scored lower than boys on all object control skill tests and on the vaulting jump test. These results underline the importance of developing interventions that stimulate the development of more complex FMS like object skills, to guarantee that every child surpasses the proficiency barrier. A solution may be found in providing more practice opportunities at school, as schools reach every child, thereby overcoming unwanted inequalities.

Note

1. The 2016 sample also included 462 children from 20 schools for special primary education. For the sake of a fair comparison between the two cohorts these children were excluded from the analyses.

Acknowledgements

We thank the children, teachers, and schools for participating in this study. Furthermore, we thank the students and teachers from the Institute of Sport Studies and the students from the Center of Human Movement Sciences for their assistance in conducting the study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

R. Mombarg http://orcid.org/0000-0001-8289-990X
A. G. M. de Bruijn http://orcid.org/0000-0001-6609-0967

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Appendices

Appendix 1. Inter-rater reliability of the seven motor skill tests in the national assessment of 2016

Test	Items	Type	#obs.	#students	Attempt 1	Attempt 2
Balancing on an instable plane	Walking up in 4 seconds	Binary	2	16	κ = .62	κ = .57
	Balance while walking up	Ordinal	2	16	κ = .44	κ = .56
	Halve turn	Ordinal	2	16	κ = .70	κ = .43
	Walking down in 4 seconds	Binary	2	16	κ = .60	κ = .81
	Balance while walking down	Ordinal	2	16	κ = .74	κ = .51
	Jumping of the plane	Binary	2	16	κ = 1.0	κ = .1.0
Rope Swing	Jumping of vault	Ordinal	3	16	κ = .38	κ = .26
	Use of knot	Binary	3	16	κ = .82	κ = .67
	Landing on the mat	Binary	3	16	κ = 1.0	κ = 1.0
	Landing with halve turn	Binary	3	16	κ = .84	κ = .87
	Landing on two feet	Ordinal	3	16	κ = .63	κ = .02
Vaulting jump[a]	Position in trampoline	Binary	2	12	κ =−.14	Incongruent for two students
	Position of legs while passing vault	Ordinal	2	12	γ = 1.0	γ = .70
	Landing on two feet	Binary	2	12	κ = .11	κ = .40

(*Continued*)

Continued.

Test	Items	Type	#obs.	#students	Attempt 1	Attempt 2
	Landing facing towards the vault	Binary	2	12	κ = .63	κ = .50
Rolling on an elevated plane	First bodypart to touch the mat after placing the hands	Ordinal	2	15	κ = .84	κ = .75
	Student rolls within the saggital plan	Ordinal	2	15	κ = .71	κ = .45
	Position of learning after rolling	Ordinal	2	15	κ = .82	κ = .1.0
Aiming with a ball at a heightened target[b]	Two meter distance	Ordinal	2	15	κ = .67–1.0	
	Three meter distance	Ordinal	2	15	κ = .83–1.0	
	Right side of the basket	Ordinal	2	15	κ = .77–1.0	
	Left side of the basket	Ordinal	2	15	κ = 1.0–1.0	
Catching and throwing via the wall[c]	Three meters from the wall: throwing overhead	Binary	2	15	κ = .76–.76	
	Three meters from the wall: throwing contralateral	Binary	2	15	κ = .76–1.0	
	Three meters from the wall: catching the ball	Binary	2	15	κ = .72–1.0	
	Five meters from the wall: throwing overhead	Binary	2	15	κ = .58–1.0	
	Five meters from the wall: throwing contralateral	Binary	2	15	κ = .19–.42	
	Five meters from the wall: catching the ball	Binary	2	15	κ = .82–1.0	
	Seven meters from the wall: throwing overhead	Binary	2	15	κ = .76–1.0	
	Seven meters from the wall: throwing contralateral	Binary	2	15	κ = 1.0–1.0	Third attempt incongruent for 2 students
	Seven meters from the wall: catching the ball	Binary	2	15	κ = 1.0–1.0	Second attempt incongruent for 1 student
Tennis via the wall	10 attempts: correct hits	Count	2	14	$r = .88$	
	10 attempts: outside the field	Count	2	14	$r = .70$	
	30 seconds: correct hits	Count	2	14	$r = .88$	
	30 seconds: outside the field	Count	2	14	$r = .53$	

[a]Due to low inter-rater reliability in the pilot study the observation protocol has been adapted. Instead of one rater, each attempt is observed by two raters of which one assesses the first two items, and the second one observes the last two items for better visibility lines.

[b]Five attempts were made from each position. For keeping the overview as clear as possible the ranges of inter-rater reliabilities for the five attempts per position were reported. In all positions the inter-rater reliability varied between excellent and perfect.

[c]From each of the three positions the students had three attempts. For keeping the overview as clear as possible the ranges of inter-rater reliabilities for the three attempts per position were reported. Generally, the inter-rater reliability varied between good and perfect.

Appendix 2. Correlations between the motor skill tests used and (subtests of) standardized instruments for assessing childrens' motor competence from the 2016 national assessment

Motor skill test	BOT-2 subtest Balance	BOT-2 subtest upper limb coordination	KTK
Balance on an unstable plane	.194	.150	.194
Rope Swing	.210		
Vaulting jump			.281
Rolling on an elevated plane	.172		
Aiming with a ball at a heightened target		.246	
Catching and throwing via the wall		.499	
Tennis via the wall		.469	

Note: Because of the block design used in the 2016 national assessment, not all bivariate correlations could be calculated.