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Investigating levels and determinants of primary school children's basic motor competencies in nine European countries

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Abstract Basic motor competencies (BMC) belong to the key learning goals of Physical Education (PE) in primary school curricula in Europe. These competencies are necessary to participate in sports inside and outside of school. Children should therefore achieve age-adequate BMC in PE and any need for educational motor support should be identified at an early stage. Studies in German-speaking countries showed that various endogenous and exogenous factors are related to children's BMC, but international studies are missing. In the present cross-sectional study, the

Data The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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two BMC areas *object movement* (OM) and *self-movement* (SM) as well as the associations with endogenous (age, sex, body mass index) and exogenous (participation in extracurricular sports) factors were investigated in 1721 8- to 10-year-old primary school children from nine European countries. Over 25% of the children showed need for educational motor support in OM and over 20% in SM. BMC levels differed significantly between the country-specific subsamples. In all subsamples, boys showed better performances in OM, while girls scored better in SM. Older children performed better in OM and SM than younger children. Higher body mass index predicted lower BMC scores in both competence areas. Participation in ball sports was positively associated with OM and SM, and individual sports participation was a significant predictor of SM. As exogenous and endogenous variables consistently predicted BMC in all subsamples, there must be other reasons for variation in BMC levels. Future studies should address country- and school-specific characteristics like content and amount of PE.

Keywords Motor competence · Physical education · Learning objectives · Curriculum · Physical activity

Untersuchung des Niveaus und Determinanten der motorischen Basiskompetenzen von Grundschulkindern in neun europäischen Ländern

Zusammenfassung Motorische Basiskompetenzen (basic motor competencies; BMC) gehören zu den wichtigsten Lernzielen des Sportunterrichts in den Lehrplänen der europäischen Grundschulen. Diese Kompetenzen sind notwendig, um

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innerhalb und außerhalb der Schule Sport treiben zu können. Kinder sollten daher im Sportunterricht altersgemäße BMC erwerben und etwaiger Förderbedarf sollte frühzeitig erkannt werden. Studien im deutschsprachigen Raum zeigten, dass verschiedene endogene und exogene Faktoren mit den BMC der Kinder zusammenhängen, jedoch fehlt es bisher an internationalen Studien. In der vorliegenden Querschnittsstudie wurden die beiden BMC-Bereiche *Etwas-bewegen* (object movement; OM) und *Sich-bewegen* (self-movement; SM) sowie deren Zusammenhänge mit endogenen (Alter, Geschlecht, Body-Mass-Index) und exogenen (Teilnahme an außerschulischem Sport) Faktoren bei 1721 8–10-jährigen Grundschulkindern aus neun europäischen Ländern untersucht. Über 25 % der Kinder wiesen Förderbedarf im Bereich OM auf und über 20 % im Bereich SM. Die BMC-Werte unterschieden sich signifikant zwischen den länderspezifischen Stichproben. In allen Teilstichproben zeigten die Jungen bessere Leistungen im OM, während die Mädchen im SM besser abschnitten. Ältere Kinder erbrachten bessere Leistungen als jüngere Kinder. Ein höherer Body-Mass-Index prognostizierte niedrigere BMC-Werte in beiden Kompetenzbereichen. Die Teilnahme an Ballsportarten stand in einem positiven Zusammenhang mit OM und SM, und die Teilnahme an Individualsportarten war ein signifikanter Prädiktor für SM. Da die exogenen und endogenen Variablen die BMC in allen Stichproben übereinstimmend vorhersagten, muss es andere Gründe für die Unterschiede im BMC-Niveau geben. Künftige Studien sollten länder- und schulspezifische Merkmale wie Inhalt und Umfang des Sportunterrichts untersuchen.

Schlüsselwörter Motorische Kompetenzen · Sportunterricht · Lernziele · Lehrplan · Körperliche Aktivität

1 Background

During primary school, Physical Education (PE) provides an excellent opportunity for children to learn and practice basic competencies which enhance a healthy motor development and enable them to actively engage in sports and physical activities (PA) with their peers (Lopes et al. 2021). These objectives are specified in both European (in overview: European Commission/EACEA/Eurydice 2013) and non-European (e.g. SHAPE America 2014) PE curricula, as PE is a mandatory subject in primary schools in most countries. The curricula include different subject-specific competencies and interdisciplinary competencies like social and self-competence. This broad range of competencies in PE aims at improving physical health, psychosocial health and life skills (Opstoel et al. 2020), as healthy children are more likely to succeed in school (Ickovics et al. 2014). Basic motor competencies (BMC), as a subset of the subject-specific competencies, are minimal but fundamental movement dispositions for a wide range of activities. They are a prerequisite for further movement learning and higher motor competence standards. BMC are distinct from specific motor skills (e.g. Fosbury flop in athletics) or context-independent motor abilities (e.g. strength and endurance), which are also part of the PE curricula. BMC have a control function over these different motor performance dispositions and complement them accordingly. Assessments of BMC are aligned with PE curricula (Herrmann et al. 2017; Herrmann and Seelig 2017a; Scheuer et al. 2019b).

Children with sufficient BMC are able to actively participate in PE and the sports culture outside of school (Schierz and Thiele 2013). However, children's motor competence has decreased in the past years (Bardid et al. 2015; Breuer et al. 2020). Although BMCs are articulated in curricula as minimum requirements that children should meet at a given grade level, many children fail basic movement tasks. Valentini et al. (2016) found low motor proficiency in several fundamental movement skills in children at age 10. Of almost 2500 Belgian primary school children, 21% had problematically low levels of gross motor coordination (Vandorpe et al. 2011). In 9-year-old children in the U.S., actual motor competence predicted if children met the PA guidelines of 60 min of moderate-to-vigorous PA per day. Almost 90% of the children in the lower third of motor competence did not meet the PA guidelines and were at risk for delays in motor development, while more children from the upper third met the guidelines than their less competent peers (De Meester et al. 2018).

Multiple individual factors are associated with BMC. Endogenous factors such as age, sex and body mass index (BMI) have been assessed consistently in BMC research. Higher age is known to be positively related with object movement (OM) and self-movement (SM). Boys consistently perform better in OM tasks than girls, but girls tend to show slightly better results in SM tasks (Herrmann 2018; Strotmeyer et al. 2020). According to the conceptual model about the role of motor competence in various health-related aspects of child development by Stodden et al. (2008), weight status is directly negatively related to motor competence. Systematic reviews and meta-analyses on different aspects of motor competence support this pathway in both directions (Barnett et al. 2016, 2022; Robinson et al. 2015). Studies assessing BMC in third and fourth graders also found a negative relationship between motor competence and weight status, especially between SM and BMI (Carcamo and Herrmann 2020; Strotmeyer et al. 2020). However, these are only cross-sectional results and do not imply causality.

Besides these biological factors, the exogenous factor extracurricular PA is an important associate of motor competence (Stodden et al. 2008). Participation in sports clubs or organized PA belongs to the main leisure time activities of children in primary school. Participating in extracurricular PA is a facilitator of a healthy motor development in third grade children (Augste and Jaitner 2010). In line with data from early primary school, third and fourth grade children participating in ball sports perform better on OM and SM tasks and children participating in individual sports are better in SM tasks (Herrmann and Seelig 2017b; Strotmeyer et al. 2020). Extracurricular PA participation is therefore an important determinant of motor competence, especially because of its modifiability.

BMC development is strongly related to socialization processes outside of school, and as a result, children's BMC levels can differ widely (Wirszing 2015). For some children, PE classes are the only context for experiencing PA and movement challenges (Lorås 2020). Because of these different internal and external preconditions for children, it is the responsibility of PE to teach BMC, provide a basic level of motor competence and support children in their motor development (Herrmann 2018). Appropriate monitoring of children's BMC verifies whether children meet this subset of the age-specific learning objectives of the PE curriculum or demonstrate need for educational motor support in BMC. Early detection of movement difficulties is essential in providing appropriate measures. BMC assessment in PE further enables scientists and educators to develop adequate teaching material to support teachers in fostering these competencies in children.

According to the International Motor Competence Network, understanding the correlates and determinants of motor competence across different countries as well as differences in social, individual and cultural backgrounds is of great relevance (Lopes et al. 2021). Few studies compared motor competence levels and associates over several countries or regions. They found better fine and gross motor skills in northern European countries than in southern (Haga et al. 2018) and strong differences in SM tasks across European countries in first and second grade children (Wälti et al. 2022). Differences in motor competence levels between Brazilians and Portuguese children were dependent on the sex (Flôres et al. 2021) or on extracurricular PA when comparing Portuguese and U.S. children (Luz et al. 2019). Because many test instruments used for monitoring PE are limited to measuring specific motor abilities or performance in certain skills (Scheuer et al. 2019b), children with deficits in motor competence are often not identified or do not receive appropriate support. Therefore, test instruments that are strongly aligned with the core competencies of the curricula should be used. BMC assessments capture important areas of motor competence based on PE curricula and are capable of identifying need for educational motor support in these areas (Herrmann 2018). Some German-speaking countries have established regional BMC assessments in PE to evaluate components of children's motor competence levels systematically (Sportkreis Hessen, Germany; Luxembourg). Unfortunately, such assessments are still the exception, and many countries have never tested motor competence levels of their students.

To tackle this problem, we investigated BMC in children from the third and fourth grade of primary school in nine European countries. Our goals were a) a screening of BMC with the same assessment tool across Europe, b) to detect the amount of children with need for educational motor support in BMC, and c) to analyze if endogenous and exogenous factors were significant predictors of BMC across Europe.

2 Methods

2.1 Study design

In the Erasmus+-project "Basic Motor Competencies in Europe (BMC-EU)—Assessment and Promotion" (590777-EPP-1-2017-1-DE-SPO-SCP), BMC of children from first to fourth grade were investigated in twelve countries. The project was led by a team from the Universities of Potsdam (Germany), Luxembourg and Basel (Switzerland). The cross-sectional study presented here used only data from the third and fourth graders from this project.

Nine partner institutions assessed data in their countries in fall 2018 after obtaining ethical clearance. Parents gave written and children oral informed consent to participate in the study. This study fully conforms to the Declaration of Helsinki. All subsamples were representative of their specific assessment region.

2.2 Participants

The data of $N = 1721$ children from third and fourth grade were included in the analyses. The total sample consists of nine subsamples. These are named after the main city in their specific assessment region: Salzburg (Austria), Brno (Czech Republic), Athens (Greece), Foggia (Italy), Kaunas (Lithuania), Groningen (Netherlands), Lisbon (Portugal), Trnava (Slovakia), Zurich (Switzerland).

2.3 Instruments

2.3.1 Basic motor competencies

Assessment of BMC was done using the MOBAK-3-4 (Herrmann 2018; Herrmann and Seelig 2017b) for 8- to 10-year-old children and standardized equipment. The eight test items cover the two motor competence areas object movement (OM; test items: throwing, catching, bouncing and dribbling) and self-movement (SM; test items: balancing, rolling, jumping and running), which are part of several national PE curricula in Europe (in overview: Gerlach et al. 2018). In addition, local PE experts reviewed and agreed on the curricular validity of the assessment tool for their specific country. The children had two attempts (no trial run) for the six items bouncing, dribbling, balancing, rolling, jumping and running. The test leader recorded whether it was a failed or a passed attempt for each turn (failed attempt = 0 points; passed attempt = 1 point). Later, the points from both attempts were summed up per test item. The children performed six consecutive attempts for the test items throwing and catching. The test leader marked the number of successful attempts on the protocol, later on they were transformed into points (0–2 successful attempts = 0 points; 3–4 successful attempts = 1 point; 5–6 successful attempts = 2 points). Per item, a total of two points can be reached, therefore a maximum of 8 points per competence area is possible. A total of less than three points per motor competence area is defined as need for educational motor support in this area (Herrmann 2018).

2.3.2 Endogenous factors

Age (by month and year of birth) and sex of each child were recorded by the test leader. Measurement of body height and weight for BMI calculation (mass(kg)/height^2(m^2)) was performed using measuring tape (in cm, rounded up/off to whole numbers and later converted into m) and a scale (in kg, rounded up/off to whole numbers).

2.3.3 Exogenous factors

Extracurricular PA was self-reported by each child. After interviewing the child (Do you participate in any kind of regular weekly sport activities outside of school? What kind of sports do you participate in?), the test leader classified the child's answer into one of four types of sport (ball sports, racket sports, endurance-oriented activities, coordination-oriented activities) and recorded it in a standardized protocol (for each type of sport: 0 = no participation, 1 = participation). Later on, extracurricular PA was divided into the variables ball sports (including ball sports) and individual sports (summarizing racket sports, endurance-oriented activities and coordination-oriented activities) according to the BMC areas OM and SM.

2.4 Procedures

Assessments took place during regular PE classes in groups of 4–5 students and one specially certified test leader. The test leaders led their groups through all eight test stations and assessed the performance of each child. Each item of the MOBAK-3-4 was explained and demonstrated once by the test leader. Each test leader chose the order of the items randomly. Before or after the measurement of the BMC, the test leader interviewed the children and assessed their body height and weight.

Table 1 Descriptive statistics of sex, age and body mass index, stratified by subsample site

			Age (years)			Body mass index (kg/m^2)[a]					
Subsample site	*N*	Girls [%]	*M*	*SE*	95% *CI*	Boys	*SE*	95% *CI*	Girls	*SE*	95% *CI*
Salzburg (Austria)	210	50	9.35	0.04	[9.28, 9.43]	17.54	0.27	[17.02, 18.07]	17.15	0.27	[16.63, 17.68]
Brno (Czech Republic)	277	54	9.08	0.03	[9.02, 9.14]	16.53	0.22	[16.09, 16.96]	16.62	0.20	[16.22, 17.02]
Athens (Greece)	179	53	8.83	0.04	[8.74, 8.91]	18.02	0.35	[17.33, 18.72]	18.27	0.33	[17.61, 18.92]
Foggia (Italy)	282	53	9.08	0.03	[9.02, 9.13]	19.49	0.30	[18.91, 20.07]	18.17	0.28	[17.62, 18.72]
Kaunas (Lithuania)	162	43	9.72	0.04	[9.65, 9.79]	18.27	0.33	[17.61, 18.93]	16.92	0.38	[16.16, 17.68]
Groningen (Netherlands)	99	48	9.34	0.06	[9.22, 9.45]	17.22	0.34	[16.54, 17.91]	17.01	0.36	[16.29, 17.73]
Lisbon (Portugal)	128	48	9.57	0.03	[9.51, 9.63]	18.52	0.36	[17.80, 19.25]	18.11	0.38	[17.36, 18.85]
Trnava (Slovakia)	186	48	9.11	0.04	[9.04, 9.18]	16.51	0.24	[16.04, 16.97]	15.97	0.24	[15.49, 16.45]
Zurich (Switzerland)	198	52	9.49	0.04	[9.40, 9.57]	16.33	0.24	[15.86, 16.79]	16.52	0.23	[16.08, 16.97]
Total sample	1721	51	9.25	0.01	[9.22, 9.28]	17.62	0.10	[17.42, 17.82]	17.21	0.10	[17.01, 17.40]

CI confidence interval; *M* mean; *N* sample size; *SE* standard error

Note: 95% confidence intervals are added to test for differences between subsamples and total sample

[a] Body mass index is adjusted for age by conducting univariate analyses of covariance with sex and body mass index with age as a covariate

2.5 Data analyses

Listwise deletion resulted in a total sample with complete data in BMC values, sex, age, BMI and extracurricular PA variables of $N = 1721$ ($N = 2138$ before data cleaning). Dropouts were due to incomplete BMC or anthropometric data assessments caused by lack of time or incorrectly completed protocols. Descriptive statistics (mean, standard error and 95% confidence interval (*CI*)) were calculated for all variables (Tables 1 and 2). BMI values were adjusted for age by univariate analyses of covariance and reported separately for boys and girls. We conducted univariate analyses of covariance with calculation of partial η^2 to compare endogenous and exogenous variables among all subsamples and to estimate effect sizes of these differences (0.01: small effect; 0.06: medium effect; 0.14 or higher: large effect; Cohen 2013). We considered 95% *CI* in order to compare the subsamples with the total sample in these variables.

To examine differences in BMC levels between boys and girls, Table 3 contains OM and SM values and the effect size per subsample (Cohen's *d*: 0.2: small effect; 0.5: medium effect; 0.8: large effect; Cohen 2013). Table 3 further shows BMC values adjusted for age and sex (marginal estimates) and the rate of children with need for educational motor support per competence area, for each subsample and the total sample.

We analyzed associations between endogenous factors and BMC areas (Table 4) and between exogenous factors and BMC areas (Table 5) for each subsample using multiple linear regression models. For the total sample, intraclass correlations (0.13 in OM, 0.26 in SM) indicated effects of our multilevel structure on portions of explained variances which we accounted for using multilevel analyses (Tables 3 and 4). Before conducting the analyses, data were tested for suitability for the applied methods. Balancing uneven subsample sizes and accounting for potential violations of the prerequisites of the applied methods, we calculated bias-corrected and accelerated bootstrap 95% *CI* with 1000 bootstrap replicates in all analyses. We used IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) for all statistical analyses. The following were considered as statistically significant: $p < 0.05$, 95% *CI* with no overlap and 95% *CI* that did not contain zero.

3 Results

3.1 Sample characteristics

The sex distribution was well-balanced in the total sample and the subsamples (Table 1). We found differences between the subsamples in BMI for the boys ($F(8, 841) = 14.74$, $p < 0.001$, range: 16.33 (Zurich)–19.49 (Foggia), $\eta^2 = 0.123$) as well as for the girls ($F(8, 860) = 10.80$, $p < 0.001$, range: 16.52 (Zurich)–18.27 (Athens), $\eta^2 = 0.091$). Overall, girls had a significant lower BMI than boys. There were moderate to large differences between the subsamples in participation in extracurricular ball sports ($F(8, 1710) = 25.01$, $p < 0.001$, range: 25.9% (Foggia)–80.9% (Kaunas), $\eta^2 = 0.105$) and individual sports ($F(8, 1710) = 36.87$, $p < 0.001$, range: 39.4%

Table 2 Participation rates in extracurricular physical activity, stratified by subsample site

	Ball sports participation[a]		Individual sports participation[a]		Overall extracurricular PA participation[a]	
Subsample site	*M* [%]	95% *CI*	*M* [%]	95% *CI*	*M* [%]	95% *CI*
Salzburg	63.8	[57.1, 70.3]	93.3	[89.9, 96.4]	97.6	[95.3, 99.5]
Brno	49.1	[43.3, 55.3]	83.8	[79.6, 88.0]	93.5	[90.6, 96.4]
Athens	37.4	[30.5, 44.7]	57.0	[49.7, 64.2]	73.3	[67.0, 80.6]
Foggia	25.9	[20.9, 31.0]	39.4	[33.6, 45.3]	61.0	[54.9, 67.3]
Kaunas	80.9	[74.7, 86.8]	85.8	[79.9, 91.2]	97.5	[94.8, 99.9]
Groningen	33.3	[23.5, 43.8]	83.8	[76.3, 90.5]	89.9	[82.8, 95.8]
Lisbon	49.2	[40.6, 57.6]	58.6	[50.4, 67.2]	79.7	[72.5, 86.1]
Trnava	41.9	[34.6, 48.7]	69.4	[62.6, 76.1]	79.0	[73.5, 84.7]
Zurich	27.8	[21.3, 34.3]	69.2	[62.4, 75.6]	85.4	[79.8, 90.5]
Total sample	44.7	[42.3, 47.2]	70.0	[67.7, 72.1]	83.3	[81.5, 84.8]

CI confidence interval, *M* mean, *PA* physical activity

Note: 95% confidence intervals are added to test for differences between subsamples and total sample

[a] No participation = 0, participation = 1

(Foggia)–93.3% (Salzburg), $\eta^2 = 0.147$). Overall participation in extracurricular PA ranged from 61.0% in Foggia to 97.6% in Salzburg (Table 2). In total, 83.3% of all children participated in extracurricular PA, and 31.4% of these were active in ball sports as well as in individual sports.

3.2 Levels of basic motor competencies

There were differences between the subsamples in BMC levels controlled for sex and age: OM: $F(8, 1710) = 37.97$, $p < 0.001$, range: 2.27 (Foggia)–4.59 (Zurich), $\eta^2 = 0.151$; SM: $F(8, 1710) = 84.52$, $p < 0.001$, range: 1.76 (Foggia)–5.06 (Brno), $\eta^2 = 0.283$. Four of nine subsamples scored significantly higher in OM than the total sample with 3.92 points. Only the sample of Foggia had significant lower values in OM than the total sample. In SM, four of nine subsamples were significantly above the total sample, while two samples scored below the total mean of 4.12 points (Table 3).

In OM, boys performed significantly better than girls in the total sample ($t(1719) = 14.96$, $p < 0.001$, $d = 0.72$) as well as in all subsamples. This effect was large in six subsamples. In SM, girls were significantly better than boys in the total sample ($t(1719) = –3.82$, $p < 0.001$, $d = –0.18$) and in two subsamples showing

Table 3 Levels of basic motor competencies per competence area in the total subsamples (marginal estimates, adjusted for age and sex), stratified by subsample site and sex including Cohen's *d* for effect size of differences between boys and girls, and share of need for educational motor support

	Boys			Girls			Cohen's *d*	Total subsample[a]			Need for educational motor support[b]	
Subsample site	*M*	*SE*	95% *CI*	*M*	*SE*	95% *CI*		*M*	*SE*	95% *CI*	*M* [%]	95% *CI*
Object movement												
Salzburg	5.18	0.18	[4.84, 5.53]	3.35	0.18	[3.01, 3.70]	1.02	4.21	0.13	[3.96, 4.47]	19.5	[14.2, 25.0]
Brno	4.88	0.17	[4.54, 5.21]	3.85	0.16	[3.55, 4.16]	0.54	4.45	0.11	[4.22, 4.67]	19.5	[14.9, 24.2]
Athens	4.55	0.21	[4.14, 4.96]	2.71	0.20	[2.32, 3.09]	0.97	3.80	0.15	[3.52, 4.09]	31.8	[26.1, 37.4]
Foggia	2.80	0.16	[2.50, 3.11]	1.57	0.15	[1.28, 1.86]	0.69	2.27	0.11	[2.04, 2.49]	62.1	[56.1, 67.9]
Kaunas	5.49	0.21	[5.08, 5.90]	3.87	0.24	[3.40, 4.34]	0.82	4.46	0.15	[4.16, 4.76]	17.3	[11.2, 23.6]
Groningen	4.62	0.26	[4.09, 5.14]	2.98	0.28	[2.43, 3.53]	0.86	3.75	0.19	[3.38, 4.12]	27.3	[18.8, 35.7]
Lisbon	4.68	0.24	[4.21, 5.15]	2.92	0.24	[2.43, 3.40]	0.91	3.65	0.17	[3.32, 3.98]	30.5	[22.8, 39.2]
Trnava	4.92	0.20	[4.52, 5.31]	4.10	0.21	[3.69, 4.51]	0.42	4.56	0.14	[4.28, 4.83]	17.7	[12.3, 23.3]
Zurich	5.60	0.20	[5.21, 5.99]	3.83	0.19	[3.45, 4.20]	0.93	4.59	0.14	[4.32, 4.85]	18.2	[13.2, 23.9]
Total sample	4.68	0.07	[4.54, 4.82]	3.19	0.07	[3.05, 3.32]	0.72	3.92	0.05	[3.83, 4.02]	28.5	[26.5, 30.4]
Self-movement												
Salzburg	4.78	0.16	[4.46, 5.10]	5.19	0.16	[4.87, 5.54]	–0.25	4.95	0.12	[4.71, 5.18]	6.2	[3.4, 9.4]
Brno	4.73	0.17	[4.39, 5.06]	5.25	0.16	[4.94, 5.56]	–0.27	5.06	0.11	[4.85, 5.27]	10.1	[6.8, 13.6]
Athens	3.46	0.19	[3.10, 3.83]	3.59	0.18	[3.24, 3.94]	–0.07	3.70	0.14	[3.43, 3.96]	25.7	[20.1, 31.7]
Foggia	1.76	0.14	[1.48, 2.04]	1.64	0.14	[1.37, 1.91]	0.07	1.76	0.11	[1.55, 1.96]	70.2	[65.0, 75.8]
Kaunas	4.52	0.17	[4.19, 4.85]	5.47	0.19	[5.09, 5.85]	–0.59	4.76	0.14	[4.48, 5.05]	7.4	[3.6, 11.4]
Groningen	3.88	0.25	[3.38, 4.39]	5.09	0.27	[4.56, 5.61]	–0.66	4.43	0.18	[4.08, 4.78]	18.2	[11.2, 25.8]
Lisbon	4.17	0.23	[3.72, 4.62]	4.47	0.23	[4.00, 4.93]	–0.16	4.19	0.16	[3.88, 4.50]	15.6	[9.7, 22.4]
Trnava	4.00	0.18	[3.72, 4.62]	4.47	0.18	[4.11, 4.83]	–0.27	4.30	0.13	[4.04, 4.55]	19.4	[14.0, 25.9]
Zurich	4.51	0.19	[4.12, 4.89]	5.22	0.19	[4.85, 5.59]	–0.38	4.77	0.13	[4.52, 5.02]	13.1	[8.5, 18.0]
Total sample	3.92	0.07	[3.78, 4.06]	4.31	0.07	[4.17, 4.45]	–0.18	4.12	0.05	[4.02, 4.22]	23.1	[21.2, 24.9]

CI confidence interval, *M* mean, *SE* standard error

Notes: Range for object movement and self-movement is 0–8 points per competence area

[a] Adjusted for age and sex

[b] Need for educational motor support is defined as achieving <3 points per competence area

Table 4 Multiple linear regression (subsamples) and multilevel analyses (total sample) of endogenous factors on basic motor competencies

Subsample site	Predictor	Object movement B^a [95% *CI*]	SE_B^a	β	*t*	*p*	Self-movement B^a [95% *CI*]	SE_B^a	β	*t*	*p*
Salzburg	Age	0.80 [0.35, 1.25]	0.22	**0.23**	3.79	<0.001	0.91 [0.47, 1.34]	0.21	**0.31**	4.96	<0.001
	Sex	−1.80 [−2.26, −1.29]	0.24	**−0.45**	−7.50	<0.001	0.42 [0.02, 0.84]	0.21	**0.12**	1.98	0.049
	BMI	−0.12 [−0.20, −0.04]	0.04	**−0.16**	−2.65	0.009	−0.20 [−0.26, −0.14]	0.03	**−0.33**	−5.17	<0.001
Brno	Age	−0.10 [−0.49, 0.30]	0.20	−0.03	−0.43	0.671	0.06 [−0.36, 0.53]	0.22	0.02	0.28	0.782
	Sex	−1.01 [−1.47, −0.56]	0.23	**−0.26**	−4.40	<0.001	0.53 [0.11, 1.00]	0.23	**0.14**	2.29	0.023
	BMI	−0.03 [−0.11, 0.05]	0.04	−0.04	−0.71	0.477	−0.10 [−0.19, 0.00]	0.05	**−0.13**	−2.17	0.031
Athens	Age	0.93 [0.42, 1.42]	0.25	**0.25**	3.78	<0.001	0.59 [0.17, 1.01]	0.22	**0.20**	2.69	0.008
	Sex	−1.82 [−2.35, −1.29]	0.27	**−0.43**	−6.61	<0.001	0.16 [−0.33, 0.65]	0.24	0.05	0.66	0.513
	BMI	−0.07 [−0.15, 0.00]	0.04	−0.10	−1.57	0.118	−0.14 [−0.22, −0.07]	0.04	**−0.28**	−3.81	<0.001
Foggia	Age	0.55 [0.15, 0.97]	0.21	**0.15**	2.60	0.010	0.53 [0.16, 0.91]	0.19	**0.16**	2.75	**0.006**
	Sex	−1.36 [−1.78, −0.92]	0.22	**−0.36**	−6.29	<0.001	−0.30 [−0.70, 0.14]	0.21	−0.09	−1.54	0.125
	BMI	−0.06 [−0.12, 0.01]	0.03	−0.11	−1.86	0.064	−0.10 [−0.15, −0.06]	0.02	**−0.21**	−3.63	**<0.001**
Kaunas	Age	0.43 [−0.28, 1.04]	0.31	0.09	1.28	0.204	0.88 [0.38, 1.39]	0.24	**0.24**	3.28	0.001
	Sex	−1.82 [−2.41, −1.25]	0.32	**−0.42**	−5.64	<0.001	0.70 [0.21, 1.23]	0.25	**0.21**	2.75	0.007
	BMI	−0.10 [−0.22, −0.01]	0.05	**−0.15**	−2.07	0.040	−0.08 [−0.18, 0.00]	0.05	**−0.15**	−2.01	0.046

Table 4 (Continued)

Subsample site	Predictor	Object movement B^a [95% *CI*]	$SE_B{}^a$	β	*t*	*p*	Self-movement B^a [95% *CI*]	$SE_B{}^a$	β	*t*	*p*
Groningen	Age	0.70 [0.02, 1.35]	0.37	**0.20**	2.01	0.047	–0.23 [–0.92, 0.40]	0.34	–0.07	–0.68	0.499
	Sex	–1.63 [–2.36, –0.88]	0.37	**–0.40**	–4.33	<0.001	1.12 [0.36, 1.84]	0.37	**0.29**	3.11	0.002
	BMI	–0.17 [–0.32, 0.00]	0.08	**–0.22**	–2.18	0.032	–0.16 [–0.27, –0.03]	0.06	**–0.23**	–2.21	0.030
Lisbon	Age	1.16 [–0.05, 2.34]	0.56	**0.18**	2.26	0.025	0.85 [–0.13, 1.94]	0.51	0.16	1.75	0.083
	Sex	–1.83 [–2.47, –1.18]	0.32	**–0.43**	–5.47	<0.001	0.23 [–0.37, 0.82]	0.32	0.06	0.71	0.479
	BMI	–0.12 [–0.24, –0.02]	0.06	**–0.18**	–2.15	0.033	–0.16 [–0.25, –0.07]	0.05	**–0.26**	–2.97	0.004
Trnava	Age	–0.02 [–0.63, 0.59]	0.29	0.00	–0.06	0.953	1.12 [0.65, 1.60]	0.24	**0.31**	4.26	<0.001
	Sex	–0.86 [–1.49, –0.21]	0.29	**–0.22**	–2.98	0.003	0.45 [0.03, 0.94]	0.24	0.13	1.85	0.065
	BMI	–0.08 [–0.21, 0.05]	0.06	–0.10	–1.32	0.187	–0.04 [–0.13, 0.07]	0.05	–0.05	–0.67	0.503
Zurich	Age	0.70 [0.26, 1.16]	0.21	**0.21**	3.23	0.001	0.40 [–0.02, 0.80]	0.22	0.13	1.83	0.068
	Sex	–1.60 [–2.11, –1.05]	0.27	**–0.38**	–5.95	<0.001	0.84 [0.35, 1.33]	0.26	**0.22**	3.14	0.002
	BMI	–0.12 [–0.22, 0.00]	0.06	**–0.13**	–2.07	0.040	–0.20 [–0.31, –0.06]	0.06	**–0.24**	–3.52	<0.001
Total sample[b]	Age	0.53 [0.37, 0.71]	0.08	**0.14**	6.17	<0.001	0.52 [0.37, 0.67]	0.08	**0.14**	6.49	<0.001
	Sex	–1.49 [–1.68, –1.30]	0.09	**–0.34**	–16.48	<0.001	0.39 [0.22, 0.57]	0.08	**0.09**	4.65	<0.001
	BMI	–0.09 [–0.12, –0.06]	0.01	**–0.12**	–5.50	<0.001	–0.12 [–0.15, –0.10]	0.01	**–0.18**	–8.49	<0.001

B unstandardized beta, *CI* confidence interval, *M* mean, SE_B standard error for the unstandardized beta, β standardized beta

[a] Bias-corrected and accelerated bootstrap 95% CI and standard errors (1000 samples)

[b] Total sample calculated using multilevel analyses

Significant coefficients are bold

a medium effect, and four other subsamples showing at least a small effect in the same direction.

In the total sample, 28.5% of the children showed need for educational motor support in OM and 23.1% in SM. Compared to the total sample, five subsamples in OM and four subsamples in SM had a lower need for educational motor support. In both competence areas, only the subsample from Foggia had a significantly higher need for educational motor support than the total sample (Table 3).

3.3 Predictors of basic motor competencies

Overall, all tested endogenous factors were substantial predictors of OM (Table 4). In the total sample, age, sex and BMI were significant determinants of OM (age: $\beta = 0.14, p < 0.001$; sex: $\beta = -0.34, p < 0.001$; BMI: $\beta = -0.12, p < 0.001$) and SM (age: $\beta = 0.14$, $p < 0.001$; sex: $\beta = 0.09$, $p < 0.001$; BMI: $\beta = -0.18$, $p < 0.001$). In all nine subsamples, sex significantly predicted OM with boys scoring higher than girls. This effect was small to moderate. Meanwhile, girl performed better in SM in five subsamples. Age showed significant positive associations in six subsamples with OM and in five subsamples with SM. BMI was a negative determinant of OM in five subsamples and of SM in eight subsamples. Multiple regression analyses for each subsample confirmed this model.

Multilevel analyses with exogenous factors (Table 5) revealed that extracurricular ball sports activities were significant positive determinants of BMC and individual sports activities were significant predictors of SM (Total sample, OM: ball sports: $\beta = 0.24$, $p < 0.001$; individual sports: $\beta = -0.03$, $p = 0.277$; SM: ball sports: $\beta = 0.08$, $p < 0.001$, individual sports: $\beta = 0.13$, $p < 0.001$). Children who participated in any kind of extracurricular PA showed higher levels of BMC in at least one competence area. Ball sports participation was a predictor for OM in six of the subsamples with a small to moderate effect size. Individual sports participation was a significant negative determinant of OM in one subsample. Ball and individual sports participation were positively associated with SM in four subsamples each, with small to moderate effects.

4 Discussion

To date, regular internationally coordinated evaluations of motor learning objectives in PE are scarce, and many countries lack insight into the level of motor competence of their children. In our multinational study, we measured BMC using the curriculum-responding MOBAK-3-4 (Herrmann 2018) and assessed age, sex, BMI and extracurricular PA participation in over 1700 8- to 10-year-old children from nine European countries. The goals of our study were a) to assess BMC in third and fourth grade children across Europe simultaneously with the same assessment tool and procedure, b) to display the rate of need for educational motor support in BMC and c) to analyze possible individual predictors of BMC in those countries.

Table 5 Multiple linear regression (subsamples) and multilevel analyses (total sample) of exogenous factors on basic motor competencies

		Object movement					Self-movement				
Subsample site	Predictor	B^a [95% *CI*]	SE_B^a	β	*t*	*p*	B^a [95% *CI*]	SE_B^a	β	*t*	*p*
Salzburg	Ball	1.30 [0.74, 1.86]	0.28	**0.31**	4.74	<0.001	0.21 [–0.25, 0.70]	0.24	0.06	0.86	0.391
	Individual	–0.47 [–1.44, 0.38]	0.51	–0.06	–0.89	0.373	0.83 [–0.25, 1.89]	0.54	0.12	1.80	0.074
Brno	Ball	0.94 [0.49, 1.39]	0.23	**0.24**	4.07	<0.001	0.46 [0.01, 0.91]	0.24	**0.12**	1.99	0.047
	Individual	–0.15 [–0.88, 0.61]	0.36	–0.03	–0.49	0.625	0.63 [–0.05, 1.21]	0.33	**0.12**	1.99	0.048
Athens	Ball	1.04 [0.43, 1.70]	0.32	**0.24**	3.27	0.001	–0.12 [–0.63, 0.40]	0.26	–0.03	–0.45	0.651
	Individual	–0.16 [–0.76, 0.49]	0.31	–0.04	–0.50	0.615	0.47 [–0.06, 0.93]	0.25	0.14	1.84	0.068
Foggia	Ball	1.59 [1.05, 2.11]	0.27	**0.37**	6.33	<0.001	0.52 [0.07, 0.97]	0.23	**0.14**	2.28	0.023
	Individual	0.19 [–0.25, 0.67]	0.22	0.05	0.84	0.404	0.72 [0.32, 1.14]	0.21	**0.21**	3.50	<0.001
Kaunas	Ball	0.71 [–0.15, 1.65]	0.43	0.13	1.68	0.096	–0.07 [–0.66, 0.53]	0.31	–0.02	–0.22	0.827
	Individual	0.63 [–0.38, 1.60]	0.55	0.10	1.33	0.187	0.68 [–0.14, 1.56]	0.39	0.14	1.81	0.072
Groningen	Ball	0.73 [–0.15, 1.58]	0.45	0.17	1.66	0.099	–0.20 [–1.07, 0.62]	0.42	–0.05	–0.50	0.618
	Individual	–0.45 [–1.65, 0.82]	0.63	–0.08	–0.81	0.420	0.76 [–0.18, 1.70]	0.45	0.15	1.44	0.152
Lisbon	Ball	0.89 [0.16, 1.55]	0.36	**0.21**	2.43	0.017	0.69 [0.07, 1.30]	0.32	**0.19**	2.14	0.034
	Individual	–0.40 [–1.08, 0.34]	0.37	–0.09	–1.06	0.289	–0.38 [–1.02, 0.32]	0.34	–0.10	–1.17	0.245
Trnava	Ball	0.53 [0.00, 1.02]	0.28	0.13	1.80	0.073	0.58 [0.09, 1.07]	0.24	**0.16**	2.30	0.023
	Individual	–0.64 [–1.27, –0.01]	0.33	**–0.15**	–2.03	0.043	0.90 [0.38, 1.43]	0.27	**0.24**	3.35	<0.001
Zurich	Ball	1.61 [0.89, 2.30]	0.33	**0.34**	4.73	<0.001	0.61 [–0.02, 1.18]	0.30	0.14	1.88	0.061
	Individual	0.34 [–0.36, 1.07]	0.34	0.08	1.04	0.299	0.89 [0.24, 1.53]	0.33	**0.21**	2.85	0.005
Total sample[b]	Ball	1.05 [0.84, 1.25]	0.10	**0.24**	10.34	<0.001	0.34 [0.14, 0.52]	0.09	**0.08**	3.77	<0.001
	Individual	–0.12 [–0.34, 0.10]	0.12	–0.03	–1.09	0.277	0.61 [0.42, 0.78]	0.10	**0.13**	6.02	<0.001

B unstandardized Beta, *Ball* ball sports participation, *CI* confidence interval, *Individual* individual sports participation, *M* mean, SE_B standard error for the unstandardized beta, β standardized beta

[a] Bias-corrected and accelerated bootstrap 95% CI and standard errors (1000 samples)

[b] Total sample calculated using multilevel analyses

Significant coefficients are bold

4.1 Levels of basic motor competencies

BMC levels varied strongly between the subsamples, especially in SM with a difference of over three points between the subsamples. Distribution of BMC levels was skewed, with only one subsample in OM and two in SM scoring significantly lower than the total mean. These differences in BMC between the country subsamples were to be expected, as previous multinational studies showed strong variation in motor competence levels. The authors of those studies suspected that differences may result from varying individual and environmental factors like active play in children, governmental strategies (Laukkanen et al. 2020), country-specific differences in PE objectives and school frameworks (Haga et al. 2018) or the present sports culture and sports participation (Luz et al. 2019). However, a final explanation of the reasons for the variation remains missing. We hypothesize that differences in BMC levels could be associated to country- and region-specific structures and frameworks of PE, as, for example, weekly hours for PE differ across countries (D'Anna et al. 2019). Next to children's PA participation, other individual and environmental factors such as socioeconomic status, parental participation in PA, or migration status could explain the variance in BMC. Longitudinal studies may provide further insight into the direction of the effects.

Over 25% of the children in our study showed need for educational motor support in OM, and over 20% in SM. These numbers are alarming, indicating that these children do not achieve some basic curricula requirements of PE and are at risk of not being able to participate age-adequately in various sports activities and thus develop an active lifestyle. A study found that 40% of children from southern Europe and around 10% of children from northern and central Europe demonstrated impaired or poor performance in locomotion tasks (Laukkanen et al. 2020). Children with low motor coordination are less likely to participate in active free play, organized PA or sports clubs and have a higher BMI (Beutum et al. 2013). Joshi et al. (2015) found that boys with developmental coordination disorder experience a more rapid increase in BMI and waist circumference at the age of eleven than normally developing boys. Therefore, action steps like adequate teaching material or additional PE support lessons for those children are needed (Scheuer and Heck 2020). Establishing a permanent international motor competence observatory would be helpful in identifying children within the population that are most in need of support (Lopes et al. 2021).

Variations in BMC between the subsamples were even higher in this study than in a previous study that examined only first and second graders (Wälti et al. 2022). The transition phase from second to third grade seems to determine whether a child's development is age-appropriate or delayed (Augste and Jaitner 2010). Older children have more movement experiences inside and outside of school than younger children. At the individual level, the influence of endogenous variables on BMC may become more evident during the course of primary school. At the national level, the content and amount of PE may become decisive factors of BMC levels. On the other hand, children in third and fourth grades with need for educational motor support or no extracurricular PA participation already lack several years of appropriate BMC development or have experienced much fewer motor challenges than their active peers. As motor competence levels of 10-year-olds are known to affect future sport club participation (Drenowatz and Greier 2019), systematic assistance in BMC development is important for children with need for educational motor support.

4.2 Predictors of basic motor competencies

The endogenous factors analyzed in our study were consistent predictors of BMC in all subsamples, showing that associations between biological factors and BMC are independent of the region of assessment. Boys achieved substantially better results in OM than girls. Girls, on the other hand, scored slightly better in SM than boys, although this effect was rather small. These differences between boys and girls are in line with previous findings on BMC and other aspects of motor competence (Barnett et al. 2016; Strotmeyer et al. 2020). Our findings also confirm previous results that higher age is positively associated with BMC (Herrmann 2018), as it was a positive predictor of OM and SM in all subsamples. This is mainly due to the still ongoing motor development and linear growth in children at this age as well as the accumulation of motor experiences (Goodway et al. 2019; Lopes et al. 2021). Lastly, BMI was a negative predictor for BMC in both competence areas, but particularly in SM. Longitudinal studies should identify the direction of these effects. Previous research suggests that children's weight status negatively influences future levels of some aspects of motor competence and vice versa (Pereira et al. 2021). Therefore, preventive measures such as education, motivation for PA and observation of children's weight status and motor competence levels are crucial.

When considering the exogenous factor extracurricular PA, four subsamples showed a very high participation rate of over 80% in individual PA. 70% of all children participated in individual sports. A European-wide analysis of sports club affiliations in children aged 6–9 years showed a membership rate of 44.1% in the total sample, with a range of 14.4–91.2% in the 25 countries (Whiting et al. 2021). Although these numbers do not take other organized and regular PA outside of sports clubs into account, they show that participation rates vary widely across countries, which is congruent with the results of our study. The predictive power of ball sports participation was visible in OM (almost medium effect) and in SM (almost small effect). Children participating in individual sports tended to have higher BMC values only in SM. While there was no association between individual sports participation and OM in the total sample, individual sports participation negatively predicted OM in one subsample. Reasons for that remain unclear, as the subsample does not show any abnormalities compared to the total sample. Therefore, variations in the specific sports culture, the access to extracurricular PA in the countries and the role of PE in encouraging children for PA should be addressed in future research. As continuous extracurricular PA participation, especially team sports activities, predicts later health-related quality of life and levels of motor competence and coordination, it should be promoted throughout primary school (Vandorpe et al. 2012; Vella et al. 2014).

The data from Foggia showed alerting results with over 60% of children in need for educational motor support in OM and over 70% in SM. This subsample had the highest values for BMI in boys, the lowest participation in ball sports and individual sports, and the lowest levels in both OM and SM. Despite efforts to achieve regional representativeness, a cohort effect cannot be ruled out. Nevertheless, with BMI and extracurricular PA participation as significant predictors of BMC, uncovering the underlying causes for these results and tackling these issues with multifaceted approaches is important. Future studies assessing BMC in other regions of Italy could provide a more holistic picture of the urgency for action.

4.3 Strengths and limitations

The main strengths of our study were the synchronized assessment of children's BMC levels in nine European countries using a curriculum-specific test instrument and the identification of the need for educational motor support in these regions. We further analyzed predictors known from previous research in additional countries, expanding our understanding of determinants of BMC. All assessments were standardized and data management and analyses were centralized. With the widespread use of the MOBAK-3-4-instrument as an age- and curriculum-appropriate test, this study has taken another step toward acceptance and confirmation of the potential of this test instrument for educational testing (Scheuer et al. 2019b). The MOBAK test instrument covers two large areas of motor competence, OM and SM, which are the basis for most common sport activities. With the knowledge gained on BMC levels, predictors of BMC and need for educational motor support in children in Europe, targeted interventions, country-specific research and long-term monitoring can be established. Our study allows for deeper analyses between endogenous and exogenous factors, e.g. the mediating effect of extracurricular PA on the association between gender and BMC (Gramespacher et al. 2020). In addition, BMC assessments form the basis for further research on physical and psychological factors related to motor development.

Nevertheless, the generalizability of our results is subject to certain limitations. While we focused exclusively on OM and SM, PE curricula contain further motor competence areas (Scheuer et al. 2019a) and other fields of competence, e.g. tactical competence or cognitive competence (Messmer 2015), that we were unable to cover in our study. Data are representative only for the specific assessment regions and not for countries in general. Direct comparisons between the countries should be avoided, as specific circumstances and particularities of the subsamples are unknown. As subsample sizes were relatively low, anthropometric data were likely influenced by coincidence and site-specific conditions. Therefore, we used adjusted statistics. We recommend future studies with representative data for all countries and higher sample sizes. These studies should also include further determinants of BMC like amount and content of PE or social background, as this would provide additional insights beyond the current endogenous and exogenous predictors. While the cross-sectional nature of this study allows a snapshot, it nevertheless lays the groundwork for longitudinal research.

5 Conclusion

The purpose of this study was to determine BMC and possible endogenous and exogenous predictors thereof in 8- to 10-year-old children in nine European countries. This paper showed that children from these countries differ in achieving basic motor requirements and learning objectives of PE and that many are in need of special educational support in developing BMC. These findings are concerning, as they are linked directly to children's health and motor development. As internationally coordinated PE evaluation studies do not yet exist, our study contributes to an initial overview of the current situation and allows for a deeper understanding and further analyses of motor competence status of children in European countries. Endogenous and exogenous factors like age, sex, BMI and extracurricular PA were consistent predictors of BMC in all subsamples, indicating that these associations are independent of country-specific characteristics. Therefore, deeper research of country-specific PE frameworks including hours per week, content, and teaching methods is needed and suggested in order to discover additional factors which may be responsible for differences in BMC.

Fostering BMC development in PE is crucial in order to provide children with a solid foundation for a healthy motor development and the possibility to engage in various types of PA. As even simple interventions in PE improve BMC (Strotmeyer et al. 2021), materials to support teachers in teaching the motor learning objectives of PE could be of great value. Furthermore, as PE is supposed to support children's physical and psychosocial health, schools and teachers should facilitate preventive measures for modifiable factors, such as promoting healthy nutrition in order to achieve and maintain an age-appropriate weight and motivating children to participate in extracurricular PA.

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Author Contribution Marina Wälti was responsible for study management and analyzed the data and drafted the manuscript. Christian Herrmann was responsible for the overall conception and design of this study and contributed to data analysis and interpretation of results. Harald Seelig contributed to data analysis and interpretation of results. All other authors were responsible for data assessment and management in their regions and country-specific additions to the study. All authors provided critical feedback to the manuscript, have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Declarations

Conflict of interest M. Wälti, H. Seelig, M. Adamakis, D. Colella, A. Emeljanovas, E. Gerlach, I. Kossyva, J. Labudová, D. Masaryková, B. Miežienė, R. Mombarg, D. Monacis, B. Niederkofler, M. Onofre, U. Pühse, A. Quitério, J. Sallen, C. Scheuer, P. Vlček, J. Vrbas and C. Herrmann declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards. Study procedures were approved by the ethics committee of the respective sample regions of the partner institutions. Parents gave written informed consent. Children assented orally.

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