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Acquired characteristics of physical education teachers and students' motor development: a multilevel analysis

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Introduction: Despite extensive research on teachers' acquired characteristics, their effects on student outcomes remain inconsistent, and evidence in physical education (PE) is particularly limited. Existing studies have focused predominantly on mathematics, science, or language subjects, have often relied on cross-sectional designs, and have rarely accounted for the hierarchical structure of educational data. Consequently, the role of teachers' acquired characteristics in students' motor development remains insufficiently understood.

Methods: This longitudinal multilevel study examines whether teachers' general acquired characteristics, including teaching qualification, PE professional development, general teaching experience, and PE teaching experience, as well as teachers' level of physical activity as an additional PE-specific movement-related characteristic, are associated with students' development of basic motor competencies (BMCs). Data from the EMOKK project were used, including 720 students nested within 91 classes. BMCs were assessed at two time points over two school years using standardized MOBAK instruments and analyzed with multilevel regression models.

Results: Results revealed strong temporal stability in students' BMCs, with prior motor competence emerging as the strongest predictor of later performance. General teaching experience was positively associated with BMC development when examined separately; however, in the full model including teaching qualification, PE professional development, general teaching experience, PE teaching experience, and teachers' level of physical activity, only teachers' level of physical activity remained significant.

Discussion: The findings suggest that teachers' acquired characteristics show limited and partly inconsistent longitudinal associations with students' motor development in PE. The significant association with teachers' physical activity may indicate the relevance of PE-specific movement-related teacher characteristics, but this interpretation remains tentative because instructional processes, motivational orientations, and embodied competence were not directly assessed.

KEYWORDS

acquired character, basic motor competencies, motor development, physical education, primary school, teacher characteristics

1 Introduction

Teachers are widely regarded as one of the most influential school-based factors for students' learning and development (e.g., Hattie, 2009). Although teacher characteristics are consistently identified as a key determinant of student learning, there is no clear consensus on which specific teacher characteristics are most critical for student learning outcomes, suggesting that multiple characteristics may contribute to differences in teacher effectiveness (Darling-Hammond, 2006; Scheerens and Blömeke, 2016; Toropova et al., 2019). While psychological characteristics of teachers have been shown to exert a meaningful impact on effective teaching (Bardach and Klassen, 2021; Klassen and Tze, 2014), meta-analytic evidence indicates that teachers' acquired characteristics, defined as education- and experience-related attributes (Coenen et al., 2018), such as formal qualifications, professional experience, or college quality, explain only a limited proportion of the variance in student outcomes, with findings remaining partly inconsistent across studies, educational levels and subject domains (Coenen et al., 2018; Danişman et al., 2019; López-Martín et al., 2023; Wayne and Youngs, 2003). These heterogeneous findings suggest that a more differentiated, subject-specific perspective is needed, particularly as prior research has focused predominantly on subjects such as mathematics, science and language, whereas other domains have received comparatively little attention (Danişman et al., 2019; Wayne and Youngs, 2003).

Empirical evidence on teachers' acquired characteristics in physical education (PE) is still emerging. Some studies suggest that PE delivered by specialist or professionally trained teachers may be associated with greater improvements in children's motor and health-related abilities than PE delivered by generalist teachers (e.g., Lucertini et al., 2013). Moreover, using a randomized controlled design, Sum et al. (2022) found that PE teachers' participation in an eight-month continuing professional development program, as reflected in attendance, was associated with improvements in students' physical literacy and motivation. Preliminary evidence also indicates that teachers' own level of physical activity may represent an important factor related to more activity-promoting practices and stronger role modeling toward their PE students (Kuhn et al., 2021). With regard to teaching experience, the evidence remains inconsistent, although some studies point to a possible association between teaching experience and teachers' implementation of classroom-based physical activity integration (e.g., Vazou and Skrade, 2014). In summary, these initial findings point to the relevance of better understanding the associations between teachers' characteristics in PE and student learning. At the same time, the distinctive nature of the subject PE and motor development as a student outcome suggests the role of teacher characteristics may deviate from patterns observed in more academically structured domains: PE differs substantially from other school subjects and places distinct professional demands on teachers, as the subject is content-wise broad, less sequentially structured, and less cumulatively organized than subjects such as mathematics (Büchel et al., 2022). Moreover, PE represents an instructional context in which learning processes often include embodied and action-oriented elements (Kirk, 2010). Accordingly, learning in PE often involves representation, demonstration, and practice of movement tasks, making teachers' movement-related practices potentially relevant for students' learning (Rink, 2013; Siedentop, 2002).

Despite these considerations, the existing evidence remains inconclusive. Evidence across educational levels appears uneven, with primary education remaining comparatively underexplored. Moreover, teacher-characteristics research has primarily examined cognitively oriented outcomes, whereas substantially less is known about how teachers' characteristics relate to students' motor development as a distinct domain of learning. Accordingly, longitudinal multilevel evidence on how teachers' acquired characteristics relate to students' motor development in primary school PE remains scarce. Consequently, it remains unclear whether and to what extent teachers' acquired characteristics are associated with students' motor development in primary school PE, warranting further investigation using longitudinal multilevel data. Addressing this gap, the present Swiss study examines whether teachers' acquired characteristics, namely teaching qualifications, PE professional development, teaching experience (general and subject-specific) and the level of physical activity are associated with students' basic motor competencies (BMCs) in primary school PE. BMCs refer to foundational movement capacities that provide an essential basis for subsequent motor learning processes and contribute to students' participation in movement culture (Herrmann et al., 2019). The study draws on longitudinal data collected over two school years within the EMOKK project (Development of Motor Basic Competencies in Childhood), supported by the Swiss National Science Foundation, enabling multilevel analyses at both the student and class levels.

2 Theoretical framework and state of research

The concept of teacher characteristics has been used in diverse ways in educational research. While it generally refers to attributes relevant for teachers' professional practice, its scope and categorization vary considerably across studies. The Organization for Economic Co-operation and Development (OECD, 2009, 2020), for example, defines teacher characteristics broadly as the attributes and qualities of teachers that shape teachers' beliefs, attitudes, and instructional practices, thereby highlighting their role in influencing classroom processes. Earlier research on teacher characteristics, particularly during the 1990s, often focused on formally measurable indicators such as teaching experience, teacher education level, certification status, and teachers' content and pedagogical knowledge. Similar indicators have also been examined in more recent empirical work (Çakır and Bichelmeyer, 2016). In this research tradition, teacher characteristics were largely operationalized through observable qualifications, credentials, and experience-related indicators. More recent approaches, however, propose more differentiated frameworks. Building on prior research on teacher characteristics, including work by Klassen and Tze (2014), Coenen et al. (2018) distinguish between three main categories of teacher characteristics. In addition to the acquired characteristics outlined above, they differentiate between

sociodemographic and psychological characteristics. Sociodemographic characteristics refer to relatively stable background variables such as race, gender, and ethnicity. Psychological characteristics, in contrast, refer to individual attributes such as personality, self-efficacy, and motivation (e.g., Klassen and Tze, 2014). Similarly, Danişman et al. (2019), in their meta-analysis, organize teacher characteristics within a conceptual framework comprising five dimensions: professional knowledge, instructional management, social factors, personal quality, and background characteristics. Compared to the threefold distinction proposed by Coenen et al. (2018), this framework differentiates more explicitly between instructional competencies and broader personal and contextual attributes. Taken together, both approaches reveal substantial conceptual overlap but differ in their level of differentiation and emphasis. One framework places greater emphasis on formally measurable qualifications, whereas the other more explicitly incorporates psychological dispositions and instructional competencies.

Given the conceptual diversity outlined above, the present study focuses predominantly on acquired teacher characteristics as conceptualized by Coenen et al. (2018). In this framework, acquired characteristics refer to education- and experience-related attributes that are empirically measurable and potentially amenable to educational policy interventions. Studying these characteristics is therefore important because they represent observable, policy-relevant teacher characteristics that may be shaped through education and professional development (Coenen et al., 2018). This focus should be distinguished from competence-oriented approaches to teacher quality. Models of teachers' professional competence conceptualize cognitive, motivational, and affective dispositions, situation-specific skills, and teaching performance as more proximal determinants of teaching and learning (Baumert and Kunter, 2011; Blömeke et al., 2015). In the present study, teaching qualification, PE professional development, and teaching experience (general and specific) are therefore treated as distal education- and experience-related indicators rather than as direct measures of professional competence. Previous research has already examined associations between selected facets of PE teachers' professional competence, such as motivational orientations and beliefs, and students' BMC development (Büchel et al., 2026). The present study adopts a complementary perspective by focusing on more distal acquired and movement-related teacher characteristics rather than on direct measures of professional competence.

Teachers' level of physical activity is included as an additional PE-specific movement-related characteristic because it is directly related to the subject domain of physical education. Conceptually, this variable is linked to teachers' movement- and sport-related experiences, but it is not equivalent to formal qualification, professional development, or teaching experience. In the present study, it is therefore understood as a lifestyle-related proxy for teachers' movement-related orientation and potentially embodied PE-specific resources. This inclusion is theoretically motivated by the embodied and action-oriented nature of PE, where motor learning often involves demonstration, practice, task modification, and feedback rather than verbal instruction alone (Metzler, 2017; Rink, 2013). At the same time, teachers' physical activity may be viewed as an experience-related characteristic that is potentially modifiable and therefore of possible relevance to educational policy and professional development, although it does not constitute an acquired characteristic in the narrower sense proposed by Coenen et al. (2018). For reasons of terminological consistency, the term *acquired teacher characteristics* is used throughout the paper as an overarching label that also includes teachers' level of physical activity in this broader sense. Based on this conceptualization, the following sections outline the current state of research on the selected teacher characteristics.

2.1 Teaching qualification

Teacher qualification is frequently discussed as an important determinant of student outcomes, yet empirical findings remain inconsistent. While some studies report positive associations between teachers' qualifications and student achievement (e.g., Goe, 2007; Goldhaber and Brewer, 2000), others find no significant effects (e.g., Hanushek, 1986; Wenglinsky, 2002). These mixed findings partly reflect substantial variation in teacher education programs across countries as well as inconsistent definitions of qualifications in the literature (Blömeke et al., 2016; Wayne and Youngs, 2003). Terms such as *teacher qualification*, *teacher education level*, or *teacher degree* are often used interchangeably, sometimes referring to the academic level of education and sometimes to formal certification or licensure. In the present study, teaching qualification refers to teachers' academic educational level, irrespective of the specific school level for which the qualification was obtained. In the Swiss education system, this qualification is partly subject-specific. At the primary and lower secondary levels, teachers are typically trained as generalists and teach multiple subjects, whereas at the upper secondary level teacher education is usually subject-specific, typically focusing on one or two subjects. Despite mixed overall evidence, research increasingly suggests that subject-specific qualifications are particularly relevant for student achievement (e.g., Clotfelter et al., 2010; Coenen et al., 2018; Dee and Cohodes, 2008). One possible explanation is that subject specialists differ from generalist teachers in their professional knowledge and orientations. They tend to engage more frequently with subject-related literature, report stronger subject-specific and instructional beliefs, and demonstrate higher levels of subject-specific professional knowledge (Oesterreich and Heim, 2006; Wittwer et al., 2024). This may be particularly relevant in PE, where teaching requires specific sport-pedagogical knowledge. Classroom teachers with limited PE-specific training may initially feel uncertain or lack confidence when teaching PE, although supportive professional development can strengthen their confidence and instructional capacity over time (Faucette et al., 2002). However, most empirical evidence on teacher qualification stems from academic subjects such as mathematics, whereas much less is known about its role in PE. This research gap is particularly relevant with regard to primary schools because international data suggest that PE in primary schools is frequently taught by non-specialist teachers (Hardman, 2008). Although empirical studies on qualification effects in PE remain scarce, existing findings provide some initial indications. Teachers with more specialized PE qualification have been shown to provide higher levels of physical activity during lessons, although this did

not translate into increased overall weekly activity levels among students (Sallis et al., 1997; Telford et al., 2016). Other studies suggest that PE taught by specialist PE teachers, as well as teacher training within school-based PE interventions, may contribute to improvements in students' motor skills, health-related fitness, and fundamental movement skills (Lander et al., 2017; Lucertini et al., 2013). In addition, students taught by subject-specialist teachers may show greater improvements in motor performance than those taught by non-specialists (Wirszing, 2015). With specific regard to BMCs, Schole et al. (2022) found that students taught by subject-qualified teachers achieved higher scores in "object-movement," whereas no effect emerged for "self-movement." Building on this work, the present study extends the analysis by examining multiple indicators of acquired teacher characteristics and a different operationalization of teacher qualification within a longitudinal design. Overall, these findings suggest that teacher qualification may be relevant for selected PE outcomes, but its role in students' motor development remains insufficiently understood.

2.2 Physical education professional development

Professional development is commonly understood as an important resource for teachers' ongoing professional learning and adaptation to changing educational demands (Dadds, 2014). In educational research, it is often discussed as a lever for improving teaching quality, particularly when it connects professional learning with instructional practice (Darling-Hammond, 2006; Kennedy, 2016; Timperley et al., 2007). From this perspective, professional development may influence student outcomes indirectly by strengthening teachers' professional competence and their ability to create effective learning opportunities. At the same time, its effects are likely to depend on the content, quality, and practical relevance of the learning opportunities provided.

In PE, professional development is considered an important means of supporting teachers' professional growth across their careers (Armour et al., 2017; Sum et al., 2018). PE teachers themselves recognize the potential benefits of professional development for improving their competence in facilitating student learning (Sum et al., 2018). Empirical evidence further suggests that participation in professional development may be associated with improvements in student outcomes. For example, professional development interventions have been linked to improvements in students' physical literacy, motivation, and enjoyment of physical activity, with effects still evident after 14 months (Sum et al., 2022). However, it remains unclear to what extent teachers' engagement in professional development is associated with students' development of motor competence in school-based PE.

2.3 Teaching experience

Research on the relationship between teaching experience and student achievement has produced mixed findings across school subjects (Blömeke et al., 2016; Rice, 2010). While some studies report positive associations between teaching experience and student achievement (e.g., Coenen et al., 2018; Darling-Hammond, 2000), others find weak or non-significant effects (Çakir and Bichelmeyer, 2016; Hanushek and Rivkin, 2012). In addition, there is ongoing debate about whether the effects of teaching experience follow a linear trajectory across teachers' careers. Some studies suggest that teaching experience is particularly influential during the early years of teaching, whereas its impact may level off later in teachers' careers (Darling-Hammond, 2000; Rice, 2010). Notably, increases in teaching experience do not necessarily coincide with continued growth in professional knowledge, which appears to occur primarily during initial teacher education (Kleickmann et al., 2017). At the same time, more recent evidence suggests that teaching experience may contribute to student achievement throughout teachers' careers (Coenen et al., 2018). One possible explanation is that its effects operate through instructional practice: with repeated teaching, teachers may increasingly learn to apply and refine their professional knowledge in authentic classroom situations, thereby developing more effective instructional routines (Toropova et al., 2019). However, empirical research directly examining these mechanisms remains limited, particularly with regard to specific instructional processes.

In PE, research on the role of teaching experience for student outcomes has received comparatively little attention. Nevertheless, some studies suggest that teaching experience may influence how PE lessons are conducted. For example, qualitative evidence suggests that years of teaching experience may support teachers' successful integration of movement activities into classroom-based instructional contexts (Vazou and Skrade, 2014). At the same time, classroom teachers may face substantial challenges in delivering quality PE when they lack PE-specific training and knowledge (DeCorby et al., 2005). Teaching experience may therefore be relevant for how teachers structure learning opportunities in PE. Such instructional design decisions include the allocation of time for motor skill practice, the selection of appropriate exercises, and the adaptation of tasks to students' skill levels, all of which are relevant for students' motor skill learning (Silverman and Mercier, 2015). These aspects may be particularly relevant in PE because teaching movement-related content involves specific instructional demands. PE lessons require the organization of equipment, the management of transitions between activities, and the assurance of student safety (Wolters and Kemna, 2011). In addition, effective learning opportunities in PE are closely linked to students' opportunities for active motor engagement (Steinegger, 2013). In this context, more experienced teachers may be better able to organize PE lessons in ways that provide structured practice opportunities, appropriate task progression, and feedback during movement activities. Although these mechanisms have rarely been examined empirically in school-based PE research, they provide a plausible explanation for why teaching experience could be associated with students' motor development.

2.4 Level of physical activity

In contrast to more academically oriented subjects, learning in PE is inherently embodied and action-oriented, as motor

competencies can also be supported through demonstration, imitation, repeated practice, and corrective feedback rather than through verbal explanation alone (Metzler, 2017; Rink, 2013). From the perspective of embodied cognition, teaching and learning in PE can be understood as closely linked to bodily action, movement experience, and situated interaction (Shapiro, 2011). Because PE learning also involves demonstration, practice, task adaptation, and feedback, teachers' movement-related practices may be considered theoretically relevant for students' learning opportunities (Metzler, 2017; Rink, 2013; Silverman and Mercier, 2015). Against this background, teachers' own physical activity levels, motor competence, and movement-related habits may also be relevant, although this pathway has rarely been examined directly. Accordingly, PE research has raised the question of whether PE teachers should possess and demonstrate sport-related skills and movement competencies (e.g., Siedentop, 2002). Building on this perspective, it can be argued that teachers who are more physically active may attach greater personal value to movement and physical activity. In turn, this may be associated with higher motivation to engage students in physical activity and to create movement-rich learning environments. While this assumption has not been directly tested, research suggests that teachers' motivational orientations and subject-related interest are important predictors of their instructional behavior (Büchel, 2019). Empirical studies directly examining the relationship between PE teachers' own sport-related abilities or physical activity levels and student outcomes remain scarce. For example, studies have shown that teachers' active participation in PE lessons and the demonstration of movements can increase students' motivation and physical activity during lessons (Senne et al., 2009; Vidourek et al., 2011). Furthermore, research suggests that teachers who are themselves more physically active may be more likely to promote physical activity during lessons and to function as positive role models for students (Kuhn et al., 2021). Supporting this perspective, Cheung (2020) found that children were significantly more physically active during PE classes taught by more active teachers than during classes taught by less active teachers (Cheung, 2020). However, most existing studies have focused on teachers' in-lesson behavior rather than on their own physical activity levels as an individual characteristic. Consequently, it remains unclear whether teachers who perceive themselves as physically active also contribute to students' motor competence development in PE.

2.5 Basic motor competencies (BMCs)

To examine whether teachers' acquired characteristics are associated with student learning outcomes in PE, basic motor competencies (BMCs) provide a particularly relevant outcome perspective. According to Herrmann (2018), BMCs are context-specific and functional performance dispositions that emerge from the demands of concrete movement situations and form a foundational prerequisite for the acquisition of sport-specific skills. They enable children to participate successfully in sport and physical activity contexts and are considered an important basis for an active lifestyle across the lifespan (Hulteen et al., 2018). BMCs are also highly relevant from an educational perspective, as they reflect central learning goals of PE in early childhood and primary school. Empirical research shows that differences in BMCs already emerge during childhood and are associated with factors such as age, gender, body mass index, and characteristics of children's movement environments (Wälti et al., 2023). These findings highlight the importance of providing children with appropriate opportunities for movement and learning at a young age. Educational settings such as kindergartens and primary schools therefore play a crucial role, as they offer structured contexts in which BMCs can be systematically supported and developed (Bildungsdirektion des Kantons Zürich, 2017).

While previous research has increasingly examined individual and extracurricular determinants of BMC development, such as family background or leisure-time sport participation (e.g., Gramespacher et al., 2020), school-related factors have received considerably less attention. In particular, the role of PE teachers, who shape learning opportunities, instructional practices, and the overall learning environment in PE, remains largely underexplored. Against this background, examining whether teachers' acquired characteristics are associated with students' BMC development may provide important insights into school-related conditions that support motor learning in PE.

3 Research questions and hypotheses

Previous research suggests that the effects of teachers' acquired characteristics on student outcomes may vary across subject domains (e.g., Wayne and Youngs, 2003). This appears particularly relevant in PE, which differs from other school subjects in its embodied, movement-based nature and in the instructional demands it places on teachers (Herrmann and Gerlach, 2020; Richartz and Kohake, 2021). A central outcome in PE is the development of basic motor competencies (BMCs), which represent an important prerequisite for children's participation in movement-related activities. Given the central role of PE teachers in shaping PE development, teaching processes, and students' learning opportunities (Schnitzius et al., 2021), it is important to examine whether characteristics of PE teachers are associated with students' BMC development. Against this background, the present longitudinal multilevel study investigates whether PE teachers' acquired characteristics, including both general professional characteristics and a domain-specific characteristic, are associated with students' gains in BMCs. The following research questions and hypotheses specify this overarching aim.

3.1 Research question 1 (RQ1)

To what extent are PE teachers' general acquired characteristics (teaching qualification and general teaching experience) associated with students' gains in BMCs over two school years?

It is hypothesized that teaching qualification (H1) and teaching experience (H2) are each positively associated with students' gains in BMCs.

3.2 Research question 2 (RQ2)

To what extent are PE-related teacher characteristics, namely PE professional development, PE teaching experience, and teachers' level of physical activity, associated with students' gains in BMCs over two school years?

It is hypothesized that professional development in PE (H3), PE teaching experience (H4) and teachers' level of physical activity (H5) are each positively associated with students' gains in BMCs.

3.3 Research question 3 (RQ3)

To what extent do PE-specific teacher characteristics differ from general acquired teacher characteristics in their associations with students' gains in BMCs over two school years?

It is hypothesized that PE-related teacher characteristics show stronger positive associations with students' gains in BMCs than general acquired teacher characteristics (H6).

4 Method

4.1 Study design

The analyses are based on data from the EMOKK study, which follows a multi-cohort sequential design. Several age cohorts were assessed at two measurement points (T1: spring 2023; T2: spring 2024). At both time points, motor competence tests were administered during regular PE lessons in schools across Switzerland. Information on teachers' teaching qualifications, PE professional development, teaching experience (general and specific), and level of physical activity was collected at T1 using a standardized online questionnaire (EvaSys). The resulting dataset has a hierarchical structure, with teachers' acquired characteristics measured at the teacher level and BMCs assessed at the student level.

4.2 Sample

A total of 720 students ($M = 7.83$ years, $SD = 1.25$; 48% female, 0% diverse) from 91 classes in the first and second years of kindergarten as well as grades 1 to 4 of primary school took part in the study. These classes were taught in PE by 77 teachers ($M = 40.74$ years, $SD = 9.80$; 75% female, 0% diverse) at the time of data collection. In some instances, teachers were responsible for more than one class. To be included in the longitudinal analyses, students had to complete the same MOBAK assessment instrument at both measurement points (i.e., no transition between different age-specific test versions) and be taught by the same teacher. Due to these inclusion criteria, the average number of students participating per class was 7.91. Accordingly, the teacher sample used in the multilevel analyses included only those teachers linked to the longitudinal student sample. By contrast, the bivariate correlations among the acquired teacher characteristics were calculated using the full teacher dataset from the EMOKK study ($N = 224$, $M = 40.54$ years, $SD = 11.10$; 84% female, 0% diverse). Participants were recruited through a multi-stage information process involving school principals, teachers, and parents. Children participated only after written informed consent had been obtained from their legal guardians. The study was approved by the responsible cantonal ethics committee (Project No. 200840).

4.3 Instruments

BMCs were assessed using the MOBAK test instruments, which are available in age-specific versions (MOBAK-KG for kindergarten, MOBAK 1–2 for grades 1–2, and MOBAK 3–4 for grades 3–4 of primary school; Herrmann, 2018; Herrmann et al., 2020). Each version comprises eight standardized tasks reflecting central learning objectives of PE in Switzerland (Deutschschweizer Erziehungsdirektoren-Konferenz, 2016) and is largely aligned with PE curricula in other European countries (Wälti et al., 2023). The tasks assess two competence domains: self-movement (balancing, rolling, jumping, running) and object-movement (throwing, catching, bouncing, dribbling). In all tasks except throwing and catching, children performed two attempts without prior practice. Performance was scored dichotomously based on predefined criteria ("pass" vs. "fail"), with each successful attempt awarded one point, resulting in a maximum of two points per task. In the throwing and catching tasks, children completed six consecutive attempts. Scores were assigned based on the number of successful trials (0–2 = 0 points, 3–4 = 1 point, 5–6 = 2 points). Scores were summed within each competence domain (maximum of 8 points per domain), resulting in a total BMC score ranging from 0 to 16 points across both domains.

Teachers' acquired characteristics were assessed using single items adapted from Büchel (2019) and translated into three languages. General teaching experience and teaching experience in PE were assessed as open-ended responses reported in years (How many years of experience do you have as a physical education teacher?). Teaching qualification was assessed as an ordinal indicator of formal qualification level and subsequently categorized into two groups. Teachers qualified for *kindergarten* or *primary school* were classified as *generalists*, whereas teachers qualified for *upper secondary school* or holding a *corresponding master's degree* were classified as *specialists*. Professional development was assessed using a six-point scale indicating the number of subject-specific professional development courses attended within the past four years, ranging from 1 ("none") to 6 ("more than four courses"). Teachers' level of physical activity was measured using a four-point self-report scale ranging from 1 ("I hardly engage in any sports or physical activity") to 4 ("I am physically active and engage in sports for more than two hours per week"). A detailed overview of all items and scales used in the EMOKK project is provided in Herrmann et al. (2023).

4.4 Data collection procedure

Data collection in each class was carried out by externally trained test administrators. Motor assessments were conducted

in small groups of four to five children using standardized BMC test stations and predefined assessment procedures. Prior to data collection, all test administrators completed a training program covering the theoretical background of the BMC concept, the standardized administration of the tasks, and the documentation and coding of test outcomes. A testing period of approximately 45 min per class was allocated for the motor assessments. On the day of the motor assessment, teachers received an email containing a link to the online questionnaire. If the questionnaire was not completed, a written reminder was sent seven days later. For the analyses, all datasets were anonymized, and student and teacher data were linked using pseudonymized matching codes.

4.5 Data analysis

Statistical analyses were conducted using Mplus (Version 8.11; Muthén and Muthén, 2017). As preliminary analyses, descriptive statistics were calculated for teacher-, student-, and class-level variables to characterize the study sample. In addition, bivariate correlations among the teacher-level variables were examined to assess potential multicollinearity. These correlations were based on listwise complete cases. Of the 243 teachers available for this analysis, 19 were excluded because of missing data on at least one variable included in the correlation matrix. Thus, all correlations were based on the same analytic sample of 224 teachers, and no missing values were imputed. Because the multilevel models were estimated using a smaller final analytic sample, additional multicollinearity diagnostics were conducted specifically for the teacher-level predictors included simultaneously in Model 7. Variance inflation factors, tolerance statistics, and condition indices were calculated using the Level-2 predictor matrix of the final analytic sample of 91 classes. These diagnostics were therefore based on the same predictor values and class-level units used in the final multilevel model.

To address RQ1–RQ3, multilevel regression models were estimated to examine factors associated with gains in BMCs. To ensure comparability across models, all multilevel analyses were estimated using the same complete-case sample. The initial longitudinal sample comprised 904 students nested within 113 classes. Students with missing data on at least one variable required for Models 1–7 were excluded. Classes without any remaining eligible students or with missing class-level predictor data were also excluded. This resulted in a final analytic sample of 720 students nested within 91 classes taught by 77 teachers. Given the hierarchical structure of the data, students (Level 1) were nested within classes (Level 2). Classes were used as the Level 2 clustering unit. Given the limited replication of classes within teachers (91 classes taught by 77 teachers), a separate teacher level was not modeled. The teacher-related predictors (teaching qualification, PE professional development, (general and subject-specific) teaching experience, and level of physical activity at T1) were assigned to the respective classes and specified at Level 2, whereas students' BMC score at the second measurement point (MOBAK T2) served as the outcome variable at the individual level. The intraclass correlation coefficient (ICC1) for BMC at T2 was .139, indicating that about 14% of the variance in students' BMC scores was attributable to differences between classes. The models were estimated stepwise. Model 1 (M1) served as the baseline model and included students' BMC score at T1 as a predictor at both the individual (within) and class levels (between). In addition, age and gender were included as control variables at the student level. In Models 2 to 6 (M2–M6), each of the teachers' acquired characteristics was introduced separately at the class level to examine its individual association with students' BMC development (RQ1–RQ2). Finally, Model 7 (M7) included all teacher characteristics simultaneously in order to assess their unique contributions to explaining students' BMC development. All models were estimated using maximum likelihood estimation with robust standard errors (MLR).

5 Results

5.1 Descriptive statistics

Descriptive statistics for the teacher- and student-level variables are presented in Table 1. Slightly more than half of the teachers were classified as PE generalists (51.6%), whereas 48.4% were classified as PE specialists. Teachers reported an average PE professional development participation score of 3.57 (SD = 1.98). Participating teachers had an average of 15.33 years of general teaching experience (SD = 10.15), while their PE-specific teaching experience averaged 14.22 years (SD = 9.90). The mean physical activity level was 3.34 (SD = 0.71). Students' BMC scores averaged 9.63 points (SD = 3.35) at the first measurement point (T1) and 10.99 points (SD = 3.12) at the second measurement point (T2).

TABLE 1 Descriptive characteristics of the study sample.

Variable	M	SD
Teachers ($N = 77$)		
[1]Qualification		
PE generalist (%)	51.6	
PE specialist (%)	48.4	
[2]PE professional development participation	3.57	1.98
Teaching experience (years)	15.33	10.15
PE teaching experience (years)	14.22	9.90
[3]Physical activity level	3.34	0.71
Student ($N = 720$)		
BMC score T1	9.63	3.35
BMC score T2	10.99	3.12

M, mean; SD, standard deviation; BMC, basic motor competencies. Percentages are reported for categorical variables. [1]Qualification scale: 1 = multiple-subject qualification for kindergarten/primary school, 2 = multiple-subject qualification for lower secondary school, 3 = subject-specific qualification in PE/sport for upper secondary school, 4 = no PE qualification. Only category 3 was classified as PE specialist; all other categories were classified as PE generalist. [2]Professional development participation scale: 1 = no courses, 2 = one course, 3 = two courses, 4 = three courses, 5 = four courses, 6 = more than four courses. [3]Physical activity level scale: 1 = practically no sport or physical activity, 2 = occasional and irregular sport or physical activity, 3 = regular sport or physical activity up to approximately two hours per week, 4 = more than two hours of sport or physical activity per week.

The bivariate correlations among the teacher-level variables are presented in Table 2. These analyses are based on the full teacher dataset from the EMOKK cohort 2022–2024 ($N = 224$), including all teachers who completed the survey. Accordingly, a strong positive correlation was found between general teaching experience and teaching experience in PE ($r = .80$, $p < .001$), indicating substantial overlap between the two variables. Teaching experience in PE was moderately positively associated with PE professional development ($r = .34$, $p < .001$), and PE professional development was positively related to teachers' level of physical activity ($r = .30$, $p < .001$). Smaller associations were observed between general teaching experience and PE professional development ($r = .12$, $p < .10$) and between general teaching experience and physical activity level ($r = -.11$, $p < .10$). No statistically significant relationship was observed between teaching experience in PE and physical activity level ($r = .09$, $p > .05$). Because the correlation reported in Table 2 was based on the full teacher sample, additional multicollinearity diagnostics were conducted using the Level-2 predictor matrix of the final analytic sample of 91 classes. The variance inflation factors were 4.14 for general teaching experience and 4.25 for PE teaching experience, with corresponding tolerance values of .241 and .235. VIF values for the remaining teacher-level predictors ranged from 1.21 to 1.79, and the maximum condition index was 16.96. Taken together, the diagnostics indicated substantial and potentially problematic multicollinearity, particularly between the two experience variables.

5.2 Associations between teachers' acquired characteristics and students' BMCs (RQ1–RQ3)

To address Research Questions 1–3, a series of multilevel regression models were estimated (see Table 3), with students' BMCs at the second measurement point (T2) as the outcome variable. At the student level, prior BMCs at T1 consistently showed the strongest association with BMCs at T2 across all models ($\beta = .56$–$.58$, $p < .001$). In addition, age was negatively related to students' BMC development in all models ($\beta = -.14$ to $-.17$, $p < .001$), indicating that younger students tended to show stronger gains over the two-year period. No statistically significant associations were observed for gender. Regarding RQ1, Models 2 and 4 examined the role of teachers' general acquired characteristics, namely teaching qualification and general teaching experience. Teaching qualification was not significantly associated with students' BMC gains (M2: $\beta = -.17$, *95% CI* [−.45, .11], $p = .23$). In contrast, general teaching experience showed a positive association with students' BMC gains when entered separately in Model 4 ($\beta = .29$, *95% CI* [.01, .58], $p = .04$). Thus, the findings did not support H1, whereas H2 was supported in the separate model. Turning to RQ2, Models 3, 5, and 6 examined PE-specific teacher characteristics, namely PE professional development, PE teaching experience, and teachers' level of physical activity. Professional development in PE was not significantly associated with students' BMC gains (M3: $\beta = -.02$, *95% CI* [−.26, .23], $p = .91$). PE teaching experience showed a positive but statistically non-significant association when entered separately in Model 5 ($\beta = .24$, *95% CI* [−.05, .52], $p = .10$). Similarly, teachers' level of physical activity was positively but not significantly associated with students' BMC gains when included as the only teacher-level predictor in Model 6 ($\beta = .15$, *95% CI* [−.07, .37], $p > .05$). Overall, the separate models provided no statistical support for H3, H4, or H5. To examine RQ3, the full model (M7) included all general acquired and PE-specific teacher characteristics simultaneously. In this model, teachers' level of physical activity emerged as the only teacher characteristic significantly associated with students' BMC gains ($\beta = .33$, *95% CI* [.04, .62], $p < .05$). The effects of teaching qualification ($\beta = -.20$, *95% CI* [−.63, .23], $p > .05$), PE professional development ($\beta = -.06$, *95% CI* [−.43, .31], $p > .05$), general teaching experience ($\beta = .18$, *95% CI* [−.20, .56], $p > .05$), and PE teaching experience ($\beta = .15$, *95% CI* [−.30, .61], $p > .05$) were not statistically significant when all predictors were considered simultaneously. Thus, the pattern of findings offered limited, but not conclusive, support for H6: one PE-specific characteristic, teachers' level of physical activity, showed a significant positive association with students' BMC gains in the full model, whereas the other PE-specific and general acquired characteristics were not significant.

Across all models, the proportion of explained variance at the student level remained relatively stable (R^2 within = .37–.38). At the class level, the explained variance ranged from R^2 between = .59 to .74, with the highest value observed in the final model.

TABLE 2 Bivariate correlations among teacher-level variables.

Variables	1	2	3	4	M	SD
1) General teaching experience (years)	–	**.80*** **	.12(*)	−.11 (*)	13.96	10.38
2) Teaching experience in physical education (years)		–	**.34*** **	.09	13.67	10.29
3) Professional development			–	**.30*** **	3.00	1.98
4) Level of physical activity				–	3.05	.87

Cohort 22/23/24; $N = 224$; Significance levels: (*)$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$; significant values are printed in bold.

6 Discussion

6.1 Discussion of findings

This study examined the extent to which teachers' acquired characteristics are longitudinally associated with the development of students' BMCs. Overall, the multilevel regression analyses revealed a high degree of temporal stability, with prior BMCs emerging as the strongest predictor of subsequent performance. In other words, students with higher BMC scores at T1 also tended to achieve higher BMC scores at T2. This finding underscores the central role of baseline competence in shaping students' developmental trajectories. Beyond this general pattern, student-level characteristics included as control variables provided only limited additional explanatory power. No consistent longitudinal gender differences in motor development were observed, which is only

TABLE 3 Multilevel regression models examining associations of teachers' characteristics with students' BMC development.

Predictor	MOBAK students t2						
	M1	M2	M3	M4	M5	M6	M7
	β (95% CI)	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)
Within level							
BMC students (t1)	**.57 [.53, .62]*****	**.57 [.51, .62]*****	**.58 [.53, .62]*****	**.57 [.52, .62]*****	**.56 [.53, .62]*****	**.56 [.53, .62]*****	**.56 [.51, .62]*****
Gender	.03 [−.02, .09]	.05 [−.01, .10]	.03 [−.02, .09]	.04 [−.02, .09]	.03 [−.02, .09]	−.03 [−.02, .09]	.05 [−.01, .11]
Age	**−.14 [−.20, −.07]*****	**−.16 [−.23, −.09]*****	**−.14 [−.20, −.07]*****	**−.14** [−.21, −.07]***	**−.14** [−.20, −.07]***	**−.13** [−.20, −.07]***	**−.17** [−.24, −.09]***
Between level							
BMC students (t1)	**.79** [.56, .99]***	**.75** [.47, .99]***	**.77** [.53, .99]***	**.71** [.41, .99]***	**.73** [.47, .99]***	**.77** [.53, .99]***	**.65** [.31, .99]***
Teacher qualification (t1)		−.17 [−.45, .11]					−.20 [−.63, .23]
Professional development (t1)			−.02 [−.26, .23]				−.06 [−.43, .31]
General teaching experience (t1)				**.29** [.01, .58]*			.18 [−.20, .56]
PE teaching experience (t1)					.24 [−.05, .52]		.15 [−.30, .61]
Level of physical activity (t1)						.15 [−.07, .37]	**.33** [.04, .62]*
Explained variance (R^2) within	**.38 [.32, .43]*****	**.38 [.31, .44]*****	**.37 [.32, .43]*****	**.37 [.31, .43]*****	**.37 [.32, .43]*****	**.37 [.32, .43]*****	**.37 [.31, .44]*****
Explained variance (R^2) between	**.63 [.26, .96]*****	**.66 [.32, .99]*****	**.59 [.23, .96]*****	**.65 [.28, .96]*****	**.64 [.32, .96]*****	**.61 [.24, .97]*****	**.74 [.42, .98]*****

M = model; *β* = standardized regression coefficient; *95% CI* = 95% confidence interval; MOBAK = basic motor competencies. Bold values indicate statistically significant effects. Significance level: (*)$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

partially in line with previous findings. Several cross-sectional studies (e.g., Herrmann et al., 2019) report gender-specific differences, with boys achieving higher scores in the competence domain "object-movement" and girls outperforming boys in "self-movement." These patterns have been interpreted as reflecting gender-specific opportunities for motor experiences and social expectations, which may shape children's development in different movement domains. However, when both domains are aggregated, as in the present study, these differences appear to balance out, resulting in no overall significant gender differences. In contrast, age was negatively associated with developmental gains, with older students showing smaller improvements than their younger peers. To date, comparable longitudinal evidence on this relationship remains scarce. Cross-sectional findings (Herrmann et al., 2019) indicate that older children achieve higher competence levels within age-specific MOBAK instruments. However, these findings do not contradict the present results, as the current study focuses on developmental change rather than absolute performance levels. The observed pattern may be explained by methodological and theoretical factors. Ceiling effects may limit measurable progress at higher performance levels, while negatively accelerated learning curves (Schmidt et al., 2018) imply diminishing gains with increasing competence.

With regard to the general acquired teacher characteristics addressed in RQ1, the findings were mixed. Teaching qualification (H1) was not significantly associated with students' gains in BMCs, whereas general teaching experience (H2) showed a positive association. Accordingly, Hypothesis 1 was not supported, while Hypothesis 2 received partial support. The absence of a significant association for teaching qualification contrasts with previous empirical studies suggesting that formal teacher qualification may be related to student outcomes, particularly when qualifications are subject-specific (Clotfelter et al., 2010; Dee and Cohodes, 2008). However, this finding is informative, because formal qualification is commonly used as a policy-relevant indicator of teachers' educational background and professional preparation (Coenen et al., 2018; Wayne and Youngs, 2003). One possible explanation for the non-significant association in the present study lies in the way teaching qualification was operationalized. Teaching qualification was coded dichotomously by distinguishing between generalist and specialist teachers. Although specialist teachers had completed a master's degree in sport or sport science and can therefore be assumed to have had more extensive sport-related academic training, this distinction does not necessarily reflect the pedagogical and didactical competencies required for fostering BMC development in early schooling. Generalist teachers may have received less extensive PE-specific training, but their

education is typically more closely aligned with kindergarten and primary school pedagogy, age-specific didactics, and methodological approaches for teaching younger children. Conversely, specialist teachers' qualifications may reflect stronger subject-specific academic preparation but are often oriented toward upper secondary teaching contexts. Thus, the present results should not be interpreted as evidence that teacher education is irrelevant for PE. Rather, they suggest that formal qualification level alone and particularly a dichotomous generalist–specialist distinction may be insufficient to explain differences in students' motor competence development in kindergarten and primary school PE. In contrast, general teaching experience was positively associated with students' gains in BMCs. However, this association was attenuated and no longer statistically significant in the simultaneous model. Moreover, the strong overlap between general teaching experience and PE teaching experience limits the extent to which their unique contributions can be distinguished. Given the substantial multicollinearity between the two experience variables, as reflected in the elevated VIF values, their coefficients in the simultaneous model should be interpreted with caution. Accordingly, the positive association observed in the separate model should not be understood as evidence of a clearly separable effect of general teaching experience. Its practical significance is therefore uncertain, because the association was confined to the separate model and was attenuated in the simultaneous model. The corresponding confidence interval also indicates limited precision in the estimate. Nevertheless, the pattern is broadly in line with research indicating that teaching experience can be positively related to student outcomes (Coenen et al., 2018) and may suggest that accumulated pedagogical experience is relevant for creating learning environments that support motor competence development. Teaching experience has been linked to student outcomes through its association with instructional quality and classroom processes, which are considered more proximal determinants of learning (Toropova et al., 2019). This appears particularly relevant in PE, where students' motor development is likely to be supported by opportunities for active engagement, repeated practice, and instructionally meaningful movement settings. In PE, such learning opportunities require well-organized tasks, high levels of active learning time (Steinegger, 2013), and classroom management that enables students' simultaneous participation in movement-related activities (Baumgartner et al., 2021). In addition, PE lessons involve specific organizational demands, including the management of movement time, equipment, transitions between activities, and student safety (Wolters and Kemna, 2011). These demands place considerable emphasis on general teaching skills related to organization, structuring, and classroom management, which may be developed across years of teaching in different subjects and contexts.

Turning to the PE-specific acquired characteristics addressed in RQ2, the results provide only limited support for the hypothesized associations with students' BMC development. Neither professional development in PE (H3) nor PE teaching experience (H4) was significantly associated with students' gains in BMCs. Teachers' level of physical activity (H5) showed a more differentiated pattern: it was not significant in the separate model but emerged as significant in the full model. Accordingly, H3 and H4 were not supported, whereas H5 received partial support. These non-significant findings should not be interpreted as evidence of no association, particularly given the limited teacher-level sample size and the simultaneous inclusion of several correlated teacher-level predictors in the full model. The non-significant finding for professional development in PE contrasts with research suggesting that sustained and pedagogically focused PE professional development can support student outcomes (Armour et al., 2017; Sum et al., 2018, 2022). However, PE professional development does not automatically improve teaching or student learning; its effectiveness depends on content focus, duration, active engagement, and connection to instructional practice (Kennedy, 2016). Thus, PE-related professional development may be relevant for BMC development only when it specifically targets competence-oriented motor learning.

The non-significant association for PE teaching experience also requires caution. Research on teaching experience has produced mixed findings, and its effects appear to depend on how experience translates into instructional practice (Coenen et al., 2018; Hanushek and Rivkin, 2012; Toropova et al., 2019). PE-specific experience is therefore not automatically BMC-specific. A further possible explanation concerns teachers' instructional roles, which may also be relevant for interpreting the non-significant finding for teaching qualification. Teachers with more PE teaching experience may more often work in PE-specialist roles, teaching PE across several classes rather than teaching one class across multiple subjects. If so, their contact with a given class may be limited to a few PE lessons per week, whereas generalist teachers may know students' learning needs, developmental levels, and class dynamics more comprehensively. Such familiarity may be particularly relevant in early schooling and could partly explain why general teaching experience, but not PE teaching experience, was associated with students' BMC gains in the separate model. A somewhat different pattern emerged for teachers' level of physical activity. In the single-predictor model, it was not significantly associated with students' gains in BMCs, whereas it emerged as a significant predictor in the full model. Accordingly, Hypothesis 5 received only partial support and should be interpreted cautiously. The standardized association in the full model was of moderate magnitude, but its educational significance remains uncertain because the confidence interval was relatively wide and the effect emerged only in the simultaneous model. This pattern indicates that the association was model-dependent and may reflect shared variance or a suppression effect among the teacher-level predictors. Because teachers' level of physical activity became significant only after the other predictors were included, the robustness of this finding remains uncertain. The non-significant association in the single-predictor model is consistent with previous research, which has primarily linked teachers' physical activity or active involvement in lessons to students' motivation and in-lesson physical activity rather than to competence-related outcomes (e.g., Cheung, 2020; Senne et al., 2009). A physically active teacher is therefore not necessarily more effective in fostering motor competence. BMC development likely depends more strongly on whether teachers create meaningful opportunities for practice, provide appropriate

feedback, and design tasks that support progressive skill development. At the same time, the significant association in the full model may suggest that teachers' physical activity captures a PE-specific characteristic not fully represented by formal indicators such as PE teaching experience or PE professional development. The association may reflect factors such as role modelling, demonstration quality, motivation, or activity-promoting teaching practices. One possible interpretation is that physically active teachers differ in movement-related orientations, confidence, or instructional practices. However, because these mechanisms were not assessed directly, these explanations remain speculative.

Finally, RQ3 examined whether PE-specific teacher characteristics show stronger associations with students' BMC gains than general acquired teacher characteristics. Based on the subject-specific, embodied, and action-oriented nature of PE, stronger associations were expected for PE-specific characteristics (Kirk, 2010; Metzler, 2017; Rink, 2013). The findings provided only limited support for H6. General teaching experience was positively associated with students' BMC gains in the separate model but not in the full model. Among the PE-specific characteristics, only teachers' level of physical activity was significant in the full model. Thus, the results do not indicate a general advantage of PE-specific over general acquired teacher characteristics. Rather than supporting one category of teacher characteristics over the other, the findings suggest that both general teaching experience, as a general acquired characteristic, and teachers' level of physical activity, as a PE-specific characteristic, may be relevant for students' motor development. This pattern aligns with broader evidence showing that acquired teacher characteristics are often weakly and inconsistently related to student outcomes (Coenen et al., 2018; Danişman et al., 2019; López-Martín et al., 2023; Wayne and Youngs, 2003).

6.2 Limitations

A key strength of the present study lies in its longitudinal design, the large nationwide sample, and the integration of objective motor assessments with teacher-reported data. The combination of multilevel longitudinal data and standardized motor testing remains relatively uncommon in PE research. Nevertheless, several limitations need to be acknowledged.

First, all teacher-level variables were assessed via self-report, which may be subject to social desirability and measurement bias (Paulhus and Vazire, 2007). In addition, key constructs were operationalized in a rather simplified manner. For instance, PE professional development was measured solely in terms of the number of courses attended, without accounting for their content, duration, or practical relevance. Similarly, teaching experience was modeled as a linear predictor, although previous research suggests that its effects may vary across career stages (e.g., Darling-Hammond, 2000). Teachers' level of physical activity was assessed using a single self-report item and may therefore not fully capture the frequency, intensity, type, or context of physical activity represented by the broader movement-related construct discussed in the theoretical framework. These measurement limitations may have attenuated potential associations. Second, substantial conceptual and empirical overlap among the teacher-level variables complicates the interpretation of the regression results. This was particularly evident for general and PE teaching experience. Consequently, single-predictor models reflect both shared and unique variance, whereas the full model isolates only unique effects. Third, the study focused exclusively on distal teacher characteristics and did not account for proximal instructional processes. Moreover, PE lessons were not directly observed, so the study could not examine how the reported teacher characteristics were reflected in actual instructional practice. As teacher effects are likely to operate indirectly through classroom practices (Seidel and Shavelson, 2007), no conclusions can be drawn about the underlying mechanisms. Relatedly, Kennedy (2010) argues that educational research and policy often attribute teaching quality too strongly to teachers' personal characteristics, while underestimating the role of situational conditions. These include resources, planning time, instructional materials, schedules, student composition, and other aspects of school infrastructure, all of which may shape the quality of teaching practice in a given classroom context. Fourth, the MOBAK instruments capture only selected domains of motor competence, and the longitudinal design was limited to two measurement points, which precluded the modeling of longer-term developmental trajectories. For example, causal effects could be traced using cross-lagged panel designs based on three or more measurement points. In addition, some teachers were responsible for more than one participating class. Because the analyses modeled students nested within classes but did not include a separate teacher level, potential dependencies between classes taught by the same teacher were not explicitly accounted for. The limited replication of classes within teachers did not allow a reliable separation of class- and teacher-level variance. Finally, the relatively limited number of Level-2 units may have provided insufficient statistical power to detect small teacher-level associations, particularly in the full model including several correlated predictors simultaneously. Consequently, smaller associations may have remained undetected, and the corresponding coefficient estimates may be less stable. Moreover, potentially relevant teacher-level covariates, such as teachers' age and gender, were not included and may have contributed to unexplained variation in students' motor development. In addition, the findings should be generalized beyond the Swiss educational context with caution, as teacher education, qualification pathways, and the organization of primary school PE differ across educational systems.

6.3 Conclusion and outlook

The present findings showed limited and inconsistent associations between teachers' general acquired characteristics, one additional PE-specific movement-related characteristic, and students' BMC development. The observed association with teachers' physical activity should be regarded as tentative, as the study did not assess the instructional or motivational mechanisms that might underlie this finding. This supports calls to consider teacher characteristics together with facets of professional competence and instructional processes rather than

as isolated background indicators (López-Martín et al., 2023). Future research should therefore examine whether and how acquired teacher characteristics are related to facets of professional competence and, through instructional processes, to students' motor development. In particular, it appears promising to investigate whether acquired characteristics such as teaching qualification or PE professional development are associated with motivational orientations, beliefs, or domain-specific professional knowledge of PE teachers. Such approaches would allow the modeling of indirect pathways and mediation processes, linking more distal teacher characteristics to student outcomes. To address these questions, subsequent studies should include three or more measurement points, use objective measures of teachers' level of physical activity, directly observe instructional quality, and test mediation models linking teacher characteristics, instructional practices, and students' motor development. To date, evidence is inconclusive regarding which specific skills or instructional practices develop through factors such as teaching experience or qualification, and how these, in turn, affect students' learning opportunities in PE. Finally, PE-specific characteristics such as teachers' own level of physical activity warrant further investigation. Given the observational design and the simplified measurement of teacher characteristics, the present findings do not support direct recommendations for teacher education or policy. Practically, the results suggest that formal qualifications and experience indicators alone may be insufficient to identify the teacher characteristics most relevant to students' BMC development.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethics Committee of the University of Zurich (No. 21.2.5, 19 December 2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

FB: Writing – review & editing, Conceptualization, Investigation, Visualization, Methodology, Writing – original draft. SB: Methodology, Data curation, Supervision, Conceptualization, Writing – original draft, Funding acquisition, Writing – review & editing. TH: Conceptualization, Supervision, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. The Gemini model 2.5 Flash and ChatGPT version 4 were employed for the linguistic revision of this manuscript to enhance its clarity, coherence, and overall readability. This AI-assisted editing was focused on refining sentence structure, improving phrasing, and ensuring academic rigor, while maintaining the integrity of the original content.

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