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Self and proxy (parents and teachers') reports of child motor competence: A three-year longitudinal study

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ABSTRACT

Objective: The aims of this study were to: 1) analyse the longitudinal trends in the evolution of the association between children's actual and perceived motor competence (AMC and PMC, respectively) according to the source of information: children, parents, and Physical Education (PE) teachers; 2) assess whether children, parents, and PE teachers can report on children's AMC longitudinally (considering the children's age, sex, and the type of motor competence).

Design and method: A sample of 108 typically developing Spanish children (47.12% girls) from five schools participated in this study. AMC and PMC (locomotion, object control and overall MC) data was collected at three time points one year apart. Longitudinal mixed effects models with repeated measures were conducted.

Results: Regardless of the domain of MC, no longitudinal association between children's AMC and PMC was found. Parents also exhibited limited capability to proxy report their children's AMC longitudinally. PE teachers' proxy reports of children' AMC were associated over time with object control and overall level.

Conclusion: This study confirms the necessity of specific training in AMC to effectively report on children's motor competence. PE teachers can be seen as a potential source to empower children's AMC and PMC development over time.

1. Introduction

Promoting movement behaviour in childhood is important for physical, mental, and social health (Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019). One important contributor to children's movement behaviour is actual motor skill competence (AMC) (Barnett, Lai, et al., 2016; Robinson et al., 2015) which enables children to move and actively engage in their environment. AMC refers to the degree of proficiency in performing a wide range of fundamental motor skills (FMS) as well as the underlying mechanisms (e.g., control and coordination) required in daily life activities (Robinson et al., 2015). FMS can be broken down into, locomotor (e.g., running, jumping, sliding …) and object control skills (e.g., throwing, bouncing, kicking …) (Barnett, Lai, et al., 2016).

Despite the efforts of public polices and school physical education (PE), wherein the value of movement behaviour and motor development are priorities (Usher, Edwards, & Meyrick, 2015), some countries have reported secular decreases in AMC (Hardy, Barnett, Espinel, & Okely, 2013; Huotari, Heikinaro-Johansson, Watt, & Jaakkola, 2018). A recent study in the United Kingdom (Duncan et al., 2020) revealed that a low percentage of children (depending on the skill, between 1.2% and 11.4%) mastered the expected levels of AMC according to the PE curriculum. Low levels of AMC are a concern as they have been associated with negative implications for children's health such as an unhealthy weight status and poor physical fitness (Barnett et al., 2022; Barnett, Stodden, et al., 2016).

Children's perceived competence (in the broad sense) is also key for children's well-being, social acceptance, general movement behaviour, and willingness to participate in PE (Ntoumanis, 2001; Stodden et al., 2008). From a motor development perspective, not only AMC but also

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perceived motor competence (PMC) influences children's health (Barnett et al., 2022; Robinson et al., 2015; Stodden et al., 2008). Indeed, evidence in youth exhibited that those who overestimated their AMC tend to be more motivated for PE and participate in sports than their peers with similar levels of AMC who accurately perceived their competence (De Meester et al., 2016). PMC is a specific domain of physical competence which refers to a child's perception of his/her AMC (Estevan & Barnett, 2018). During early childhood, PMC tends to be unrealistically high (Harter, 1999). It seems that (around 8 years-old and younger) children may first perceive effort as mastery of FMS and later (around 8-11 years-old) they tend to incorporate a more abstract perspective in their descriptions as they age (Goswami, 2010). As a result, being around 7-13 years-old is an important period for development of regions of the brain which are involved in self-evaluation (Dreiskämper, Tietjens, & Schott, 2022). The construction of self-perception in terms of an individual's ability to make their own real judgements of AMC starts in childhood (Estevan & Barnett, 2018), but is dynamic. During primary school, due to individual peer comparisons and/or personal experiences (with or without success), a decline in PMC is said to occur (Harter, 1999), as an example, a study in early childhood involving five years-old children by Crane, Naylor, Cook, and Temple (2015) reported this. Another longitudinal study reported that this decline in PMC may be accelerated at late childhood and early adolescence (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), although a study in middle childhood over one year did not report a decline in PMC (van Veen et al., 2020). So, even though the decline in PMC is evidenced, the period when this decline starts might vary (Noordstar, Net, Jak, Helders, & Jongmans, 2016).

Hence, with both AMC and PMC being related to children's psychosocial health and well-being (Horn, 2018), its association has also a potential consequential link to their long-term health, such as movement behaviour or PE active participation (Scrabis-Fletcher, Rasmussen, & Silverman, 2016). For instance, those children with low levels of AMC and PMC would be less likely to engage in physical activity and sport participation (Stodden et al., 2008) as confirmed by person-oriented approaches (De Meester et al., 2016; Estevan, García-Massó, Molina-García, & Barnett, 2019).

There are multiple factors such as age and sex which could influence the association between AMC and PMC across childhood. In relation to age, several studies report no association between AMC and PMC in 4–5 years-old children, with this association starting to be evident in children 6-11 years-old (Spessato, Gabbard, Robinson, & Valentini, 2013; True, Brian, Goodway, & Stodden, 2017). Yet a recent systematic review and meta-analyses reported that age was not a moderating factor of the relationship between AMC and PMC (De Meester et al., 2020). Authors reported this might have been because there were not as many studies in the older age groups compared to childhood studies and as such, a potential relationship might have been missed. As such, a gap in the literature is longitudinal analyses to be able to understand how self-report accuracy might change over time as children mature.

With regard to the sex, there is a tendency of girls to underestimate and boys to overestimate AMC (Masci, Schmidt, Marchetti, Vannozzi, & Pesce, 2018). As an example, Carcamo-Oyarzun, Estevan, and Herrmann (2020) showed that girls report a stronger association between AMC and PMC in locomotion than boys but similar moderate levels in object control skills. The review and meta-analyses by De Meester et al. (2020) did not find that sex moderated the relationship, although this could also be because there were not many single sex studies included in the analysis in order to compare associations. Nevertheless, it is important to adjust models according to the age and sex of the child as both factors influence at least one variable (Barnett, Lai, et al., 2016).

Another potential factor to consider when attempting to understand how AMC and PMC are associated, is whether aligned instruments are used, as it may be expected that when the actual and perceived skill measure is aligned there could be a stronger association (Estevan & Barnett, 2018). Although, studies using aligned assessments in the motor competence specific domain have reported children have large to moderate (Carcamo-Oyarzun et al., 2020; Duncan, Jones, O'Brien, Barnett, & Eyre, 2018; Jaakkola et al., 2019) and also, weak or no ability to self-report their MC (Hall, Eyre, Oxford, & Duncan, 2019). The aforementioned meta-analysis (De Meester et al., 2020) did not find alignment to be a moderating factor, although authors note that the comparison group for aligned studies (i.e., studies with non-aligned measures) included a range of instrument types and measures and as such, more research in this area is needed. Also, the type of motor competence (i.e., how it is operationalised, e.g., locomotion and object control) is another important factor to consider (Niemistö et al., 2019). For field-based tests (Duncan et al., 2018; Jaakkola et al., 2019), it is important to study not only overall motor competence, but also its components (Masci et al., 2018; Niemistö et al., 2019). The meta-analysis by De Meester et al. (2020) regarding associations between actual and perceived skills report different pooled effects for overall motor competence (N = 54; r = 0.25), object control (N = 50; r = 0.22) and locomotor (N = 45; r = 0.19).

A dearth in the evidence is the relative lack of longitudinal studies (Barnett et al., 2022). Few longitudinal studies examining the association between AMC and PMC consider the children's sex and type of motor competence and focus on the transition between kindergarten and primary school (between 4 and 8 years-old). One longitudinal cohort study in the Netherlands involving 5-7 years-old children at baseline, reported no association between actual and perceived competence for boys or girls in ball and athletic competence, and whilst AMC remained stable across time, PMC declined in boys and girls (Noordstar et al., 2016). In 5-7 years-old children from Canada, the longitudinal association between AMC and PMC strengthened for boys (from weak to moderate association in object control and locomotion) but weakened for girls (even disappears in locomotion across time) (Crane, Foley, Naylor, & Temple, 2017). In Spanish 4-9 years-old children at baseline, when AMC and PMC are high across time the probability of maintaining active movement behaviours and healthy weight status after two years is higher than in children with low or medium values AMC and PMC (Estevan, Menescardi, García-Massó, Barnett, & Molina-García, 2021).

Proxy report of child AMC by caregivers can be an additional or alternative sources of information for children's motor competence. In this line, parents and teachers were purported as social agents capable enough to proxy-report their children's motor competence (Estevan, Molina-García, Bowe, et al., 2018; Lalor, Brown, & Murdolo, 2016; Liong, Ridgers, & Barnett, 2015; O'Neill et al., 2014). These social agents (i.e., parents and PE teachers) might be integral in cultivating children's motor competence by verbal and nonverbal judgements and/or by encouraging (or not) children to engage in activities promoting motor competence (Estevan, Molina-García, Bowe, et al., 2018). However, the majority of studies analysing the association between AMC and PMC are cross-sectional, whereas we need to understand how individuals' AMC and PMC evolves across time (Horn, 2018). Actually, to the authors' knowledge, the longitudinal association of children's, parents' and PE teachers' perception of children's motor competence and children's AMC has not been examined yet. Thus, the purposes of this study were twofold: 1) to analyse the trends in the evolution of the association between children's AMC and PMC according to the source of information (children, parents, and PE teachers) longitudinally; 2) to assess whether children, parents, and PE teachers can report on children's AMC longitudinally (considering the children's age, sex, and type of FMS).

2. Method

2.1. Study design and participants

An observational longitudinal design was used to study 108 typically developing children (47.12% girls) from 4 to 9 years old (M = 6.4 years; SD = 1.3) at baseline: 20 (18.5%) children were aged between 4 and 5 years-old; 14 (13.0%) were aged between 5 and 6 years-old; 40 (37.0%) were between 6 and 7 years-old; 21 (19.4%) were between 7 and 8 years-old; and 13 (12.0%) were between 8 and 9 years-old). Participants were recruited (consent rate of 79.6%) by convenience from one preschool and four (two public and two private; two from coastal cities and two from inland) primary schools. The data were collected at three time points (around 12 months apart) between January 2016 and May 2018. Data from the current project were used in previous studies which focused on the validation of the scales, significant others' reports feasibility and/or understanding profiles of child behaviour longitudinally (Estevan et al., 2017, 2021; Estevan, Molina-García, Abbott, et al., 2018; Estevan, Molina-García, Bowe, et al., 2018). In the previous longitudinal study (Estevan et al., 2021) we adopted a person-centered approach whereas in the current study we maintain a variable-centered approach involving children's, parents' and PE teachers' perception of children's MC which has not been published previously. Written consent from a parent or guardian was obtained for all participants prior to participation. The study was approved by the Institutional Review Board of the University (H1446557620395).

2.2. Measures

Actual motor competence. The Spanish version of the Test of Gross Motor Development (TGMD) 3rd version (Estevan et al., 2017; Webster & Ulrich, 2017) was used to assess AMC (overall, locomotion, and object control). In this process-oriented test children perform 13 skills (6 for locomotion and 7 for object control skills). For each skill, one point is awarded for each task performance criterion that is correctly executed. The sum of each skill informs the total skill score. The total score range for the scale was 0–100, with scores in locomotion and object control ranging from 0 to 46 and 0–54, respectively. Raw scores of locomotion and ball skills were converted to age equivalents for boys and girls. Normative-based scale scores were summed to establish a motor quotient and percentile values (Ulrich, 2019). This test has excellent internal consistency in children. (Estevan et al., 2017). Two raters coded 108 participant's AMC. Good intra-rater reliability was found in locomotion ($\alpha = 0.73$), object control ($\alpha = 0.78$) and overall MC ($\alpha = 0.84$), and excellent inter-rater reliability was found in locomotion ($\alpha = 0.94$), object control ($\alpha = 0.94$) and overall MC ($\alpha = 0.96$). Test-retest analysis (by using intra-class correlation coefficient [ICC] of 21 videos) exhibited good to excellent reliability in locomotion (ICC = 0.88), object control (ICC = 0.95) and overall AMC (ICC = 0.87) (Estevan et al., 2021).

Children's perceived motor competence. The Spanish version of the pictorial scale of Perceived Movement Skill Competence (PMSC) (Barnett, Ridgers, Zask, & Salmon, 2015; Estevan, Molina-García, Abbott, et al., 2018) was used to assess PMC (overall, locomotion, and object control) by means of twelve pictographic tasks rated on a 4-point scale (with a higher score indicating high perceived competence). The range of scores for the total scale was 12–48, with subscales ranging from 6–24 (i.e., locomotion & object control). The PMSC is aligned with the TGMD 2nd version. The internal consistency and test-retest reliability of this scale (α & ICC >0.70, respectively) for Spanish children was acceptable (Estevan, Molina-García, Abbott, et al., 2018). The ordinal alpha according to the type of FMS and the total score at each time point is reported in Table 1.

Proxy-reports. Parents and PE teachers' perception of children's motor competence was obtained by using an adapted scale of the PMSC to be self-reported by adults (Estevan, Molina-García, Abbott, et al., 2018). It consists of the same twelve pictographic tasks aligned with the TGMD 2nd version. Every task is also rated on a 4-point scale with a range of total scores between 12 and 48, and subscales ranging from 6 to 24 for locomotion and object control skills. Confirmatory factor analysis with data from parents by using EQS software (BMDP Statistical Software Inc) with robust methods confirmed a two-factor (locomotion and object control skills) model: χ^2 (53) = 104.65; $p < .001$; Comparative Fit Index (CFI) = 0.957; Standardized Root Mean-Square Residual (SRMR) = 0.056; Root Mean Square Error of Approximation (RMSEA) = 0.058 (90% CI = 0.042–0.093). Model-fit satisfactory indexes were confirmed in two ways. On the first hand, through the χ^2/df ratio and values of CFI, SRMR, and RMSEA. In this sense, Carmines and McIver (1981) suggested that values of χ^2/df lower than 3 suggest a well-fitting model. In the current model, the χ^2/df ratio is 1.97, supporting the well fit of the model. Moreover, according to Hu and Bentler (Hu & Bentler, 1999), values of CFI equal or higher than 0.90 and values of RMSEA between 0.05 and 0.10 can be interpreted as acceptable (Hu & Bentler, 1999). The Cronbach's and ordinal alphas are reported in Table 1.

2.3. Procedure

Proxy-reports from significant others on children's AMC were obtained each year within the next two weeks after the meeting for gaining child consent.

AMC assessment was conducted in a large sports hall by two trained research assistants: one research assistant was responsible for guiding participants in performing the TGMD and another operated the video camera to record each task. For each skill, each child was allowed to perform one practice attempt and two assessment trials. Two independent research assistants coded videos in a counterbalanced order.

PMC was assessed after AMC by conducting individual interviews according to the protocol of the original scale (Barnett et al., 2015). For each pictorial skill a dichotomy two-staged process was used to rate perception in an individual item. That is, each child was instructed to choose which picture he/she felt looked like them; then for his/her chosen picture he/she was asked to rate his/her PMC.

Table 1
Cronbach's and ordinal alphas for perceived motor competence from children, parents, and PE teachers.

Variable	*n*	Year 1			Year 2			Year 3	
		Cronbach's α	*Ordinal* α	*n*	Cronbach's α	*Ordinal* α	*n*	Cronbach's α	*Ordinal* α
Children									
Locomotion	108	.58	.65	107	.46	.49	106	.60	.68
Obj Control	108	.65	.70	107	.67	.72	106	.69	.73
Overall MC	108	.69	.76	107	.68	.76	106	.75	.79
Parents									
Locomotion	98	.86	.87	96	.84	.85	92	.84	.85
Obj Control	98	.83	.82	96	.83	.83	92	.85	.84
Overall MC	98	.87	.87	96	.88	.88	92	.87	.87
PE Teachers									
Locomotion	102	.94	.94	106	.94	.91	106	.95	.96
Obj Control	102	.90	.89	106	.91	.90	106	.92	.93
Overall MC	102	.95	.95	106	.94	.92	106	.96	.97

Note. Obj Control refers to object control skills. MC refers to motor competence. PE refers to physical education. Standardised Cronbach's and Ordinal alphas are shown in Table from R studio.

2.4. Statistical analyses

To examine the association of AMC (raw score) and PMC over time, longitudinal mixed effects models with repeated measures were conducted where score outcomes (i.e., locomotor, object control, and overall AMC) were confirmed to be normally distributed, and error terms to be approximately normal. Mixed effects models were considered for all data and modelled separately for children, parents, and PE teachers' data. This method allows for participants missing data to remain in the model. Each model included a random effect (i.e., random intercept) for the teachers to account for the clustering of classes in the study. All models used an unstructured correlation matrix with robust standard errors (SE). Models included an interaction term between the PMC and time (PMC x Time) to determine whether there was a significant association between AMC and PMC over time. A three-way interaction term (PMC x Sex x Time) was also conducted for children's, parents' and PE teachers' perception of children's MC in locomotion, object control and overall AMC. Following Lorah (2018), the effect size for each independent variable was reported as a standardized effect size in the correspondent model. The results were also adjusted for covariates such as sex, baseline age and its interaction term (sex x age).

To compare models for the best fitting based on the perception from children, parents, and PE teachers, complete case mixed effects models using the same sample size were conducted to calculate Akaike's information criterion (AIC) and Bayesian information criterion (BIC). The best fit was determined based on the lowest AIC and BIC values. Since multiple outcomes were tested during modelling, a more conservative level of significance was considered (i.e., an alpha level of 1%) (Shaffer, 1995). All analyses were conducted using Stata 16 SE (StataCorp., 2019).

In addition, a sensitivity analysis was performed for all models using multiple imputation and complete case analysis (see supplementary materials for more details). For participants with missing data at either time-point, multiple imputation with 50 resamples were used, and were based on baseline variables age and sex (specific patterns of missingness in the data were considered - not reported). Missing data were imputed using chained equations in Stata 16 SE.

3. Results

Table 2 shows the descriptive statistics (mean and standard deviation) of children's AMC (i.e., locomotion, object control) and children's, parents' and PE teachers' perception of children's AMC. At each time point the mean percentile of AMC in our sample based on normative values is below 50 (i.e., 46, 44, 49) indicating children were below the mean on normative scoring. The mean PMC was around 38 out of 48. Children's perceptions of how good they were at each skill over time is presented in Table S1, wherein the majority of the children's self-reports are 'pretty good' and 'very good'. Accordingly, it is seen that the majority of participants in the current study tend to exhibit and self-report below average and moderate-high levels of AMC and PMC, respectively.

In Fig. 1, an increase of AMC in locomotion (a), object control (b), and overall AMC (c) over time is depicted, which is corroborated in Table 3 that shows a significant main effect of age in locomotion ($\beta = 2.09, p < .001$), object control ($\beta = 2.99, p < .001$) and overall AMC ($\beta = 5.05, p < .001$). A main effect of sex (in favour of boys) was exhibited in locomotion ($\beta = 2.66$, $p = .001$), object control ($\beta = -13.16$, $p < .001$) and overall AMC ($\beta = -10.50, p < .001$). The interaction effect sex x age was also found; that is, each year the increase in boys' object control ($\beta = 1.27, p < .001$) and overall AMC ($\beta = 1.03, p < .001$) was higher than in girls but not in locomotion ($\beta = -0.24$, $p = .180$). Standardized effect size is reported in Table 3.

Moreover, Table 3 also shows the results from the longitudinal mixed effects models with repeated measures. That is, children's perceptions suggest that there is no significant association between AMC and PMC ($\beta = 0.20$, $p = .149$) and there is no significant trend over time either ($\beta = -0.01$, $p = .919$). This non-significant association can be found in the trends depicted in Fig. 1 wherein the slope for children's AMC and PMC is heterogeneous in both components of motor competence. Whereas AMC increases over time, PMC in locomotion tends to decrease and PMC in object control tends to keep flat. The three-way interaction term (PMC x Sex x Time) did not exhibit significant association for locomotion ($\chi^2 = 0.03$, $p = .859$), object control ($\chi^2 = 1.44$, $p = .229$) and AMC ($\chi^2 = 0.26$, $p = .609$).

The model for parents' proxy report of child AMC (Table 3) suggests that their report is not associated with children's overall AMC ($\beta = 0.26$, $p = .162$) and there is no significant trend over time ($\beta = -0.15$, $p = .256$). This non-significant association is similar for locomotion and object control skills. No PMC x sex × time interaction effect was found for locomotion ($\chi^2 = 0.12, p = .731$), object control ($\chi^2 = 0.17, p = .682$) and AMC ($\chi^2 = 0.22$, $p = .636$).

Table 2
Descriptive statistics (mean and standard deviation) of children's actual motor competence and children's, parents' and PE teachers' perception of children's motor competence in locomotion, object control, and overall motor competence.

Variable	Year 1			Year 2			Year3		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Age	108	6.42	1.26	108	7.49	1.31	106	8.34	1.32
Children's AMC									
Locomotion	108	30.90	6.38	107	33.91	4.42	105	36.20	3.14
Object control	108	32.89	8.68	107	36.52	7.13	105	39.70	6.54
Overall	108	63.79	13.51	107	70.43	9.79	105	75.90	8.06
Motor quotient	108	98.18	9.00	107	97.41	8.16	105	99.31	7.23
Percentile	108	46.31	20.64	107	44.06	18.97	105	48.64	16.96
Children's PMC									
Locomotion	108	19.68	2.32	107	19.83	2.23	106	19.28	2.68
Object control	108	18.88	2.91	107	18.80	3.25	106	17.99	3.31
Overall	108	38.56	4.27	107	38.64	4.70	106	37.27	5.11
Parents' PCMC									
Locomotion	98	17.16	3.95	96	17.27	3.73	92	17.90	3.63
Object control	98	14.36	3.56	96	14.77	3.81	92	15.36	3.75
Overall	98	31.52	6.42	96	32.04	6.66	92	33.26	6.27
Teachers' PCMC									
Locomotion	102	17.5	4.3	106	17.5	3.3	106	19.5	3.5
Object control	102	15.3	3.9	106	15.7	3.8	106	18.2	3.8
Overall	102	32.75	7.77	106	33.16	6.38	106	37.67	6.99

Note. AMC refers to actual motor competence. PMC refers to perceived motor competence. PCMC refers to perception of children's motor competence. Range of motor quotient according to normative values of the Test of Gross Motor Development - third edition 47–158.

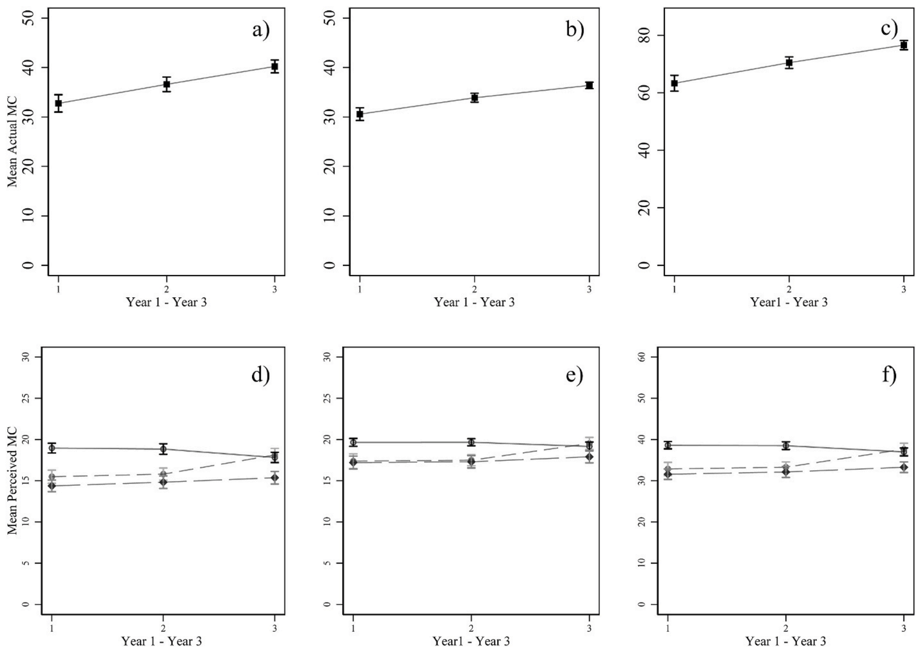

Fig. 1. Evolution of children's motor competence and children's, parents' and PE teachers' perception of children's motor competence in locomotion, object control and overall motor competence
Note. Children's actual motor competence in (a) locomotion, (b) object control, and (c) overall motor competence. Perception of children's motor competence in (d) locomotion, (e) object control and (f) overall motor competence. In (d), (e) and (f), solid line represents children's perceived motor competence, long dashed line represents parents' proxy reports, and short dashed line represents physical education teachers' proxy-report.

Table 3
Longitudinal models – Mixed effects models with repeated measures and random intercept (PE teachers).

Effect	Locomotion					Object Control					Overall AMC				
	β coeff	95% CI		*p*-value	Std ES	β coeff	95% CI		*p*-value	Std ES	β coeff	95% CI		*p*-value	Std ES
		LL	***UL***				***LL***	***UL***				***LL***	***UL***		
Children															
Girls*	2.66	0.85	4.47	.001	0.65	−13.16	−16.08	−10.24	<.001	−2.56	−10.50	−14.64	−6.37	<.001	−1.39
Baseline age	2.09	1.76	2.43	<.001	0.52	2.99	1.89	4.09	<.001	0.58	5.05	3.99	6.11	<.001	0.67
Sex x Age	−0.24	−0.58	0.11	.180	−0.06	1.27	0.88	1.65	<.001	0.25	1.03	0.33	1.73	.004	0.14
Time	2.49	−0.67	5.64	.122	0.61	3.75	−4.45	11.95	.370	0.73	6.85	−2.65	16.34	.158	0.91
PMC	0.06	−0.07	0.18	.372	0.01	0.14	0.08	0.36	.221	0.03	0.20	−0.07	0.48	.149	0.03
PMC x Time	0.01	−0.11	0.11	.921	0.01	−0.01	−0.23	0.23	.968	−0.01	−0.01	−0.30	0.27	.919	−0.01
Constant	14.93	9.25	20.60	<.001		10.79	0.34	21.24	.043		25.36	15.11	35.62	<.001	
Parents															
Girls*	1.76	−1.20	4.72	.244	0.44	−13.11	−16.11	−10.11	<.001	−2.52	−11.11	−16.64	-5–59	<.001	−1.48
Baseline age	2.14	1.83	2.45	<.001	0.54	3.17	2.07	4.26	<.001	0.61	5.40	4.42	6.37	<.001	0.72
Sex x Age	−0.12	−0.62	0.39	.646	−0.03	1.24	0.77	1.72	<.001	0.24	1.08	0.13	2.03	.026	0.14
Time	5.45	−1.78	12.69	.140	1.36	5.27	2.25	8.29	.001	1.01	10.61	0.34	20.88	.043	1.41
PMC	0.16	−0.09	0.42	.203	0.04	0.14	−0.01	0.29	.072	0.03	0.26	−0.11	0.63	.162	0.04
PMC x Time	−0.09	−0.27	0.10	.364	−0.02	−0.06	−0.14	0.01	.092	−0.01	−0.15	−0.40	0.11	.256	−0.02
Constant	11.36	2.66	20.50	.010		10.73	1.45	22.92	.084		22.86	4.10	41.62	.017	
PE Teachers															
Girls*	1.27	−0.21	2.75	.09	0.33	−14.50	−17.54	−11.47	<.001	−2.89	−13.21	−17.49	−8.93	<.001	−1.84
Baseline age	1.74	1.45	2.02	<.001	0.45	2.68	1.82	3.53	<.001	0.53	4.34	3.53	5.15	<.001	0.61
Sex x Age	0.01	−0.24	0.26	.957	0.01	1.46	0.92	2.00	<.001	0.29	1.47	0.69	2.25	<.001	0.21
Time	3.54	−0.20	7.27	.064	0.91	6.83	4.67	8.99	<.001	1.36	10.26	4.90	15.62	<.001	1.43
PMC	0.20	0.09	0.30	<.001	0.05	0.22	0.06	0.37	.007	0.43	0.42	0.18	0.65	.001	0.06
PMC x Time	−0.04	−0.11	0.04	.325	−0.01	−0.10	−0.15	−0.05	<.001	−0.02	−0.13	−0.23	−0.03	.008	−0.02
Constant	12.92	7.37	18.48	<.001		10.93	0.02	21.84	.050		24.06	(9.45	38.67	.001	

Note. In children, number of observations (N) = 320, number of participants (n) = 108; in Parents, N = 286, n = 103; in PE Teachers, N = 313, n = 104. CI = confidence interval. Std ES = standardized effect size. *LL* = lower limit; *UL* = upper limit. * Boys' data are used as the reference value. AMC = actual motor competence. PMC = perceived motor competence. PE = Physical Education.

In the PE teachers' models (Table 3) there is a significant positive association for teacher proxy report and children's locomotion ($\beta = 0.20$, $p = .001$) and overall AMC ($\beta = 0.42$, $p = .001$) with a significant interaction (PMC x time) effect in overall AMC ($\beta = -0.13$, $p = .008$). Whereas in object control, a significant trend over time was found ($\beta = -0.10$, $p < .001$). The interaction PMC x sex x time did not show an association for locomotion ($\chi^2 = 2.72$, $p = .10$), object control ($\chi^2 = 0.03$, $p = .868$) and AMC ($\chi^2 = 0.26$, $p = .608$).

The association of sex, baseline age, and its interaction term (sex x age) in addition to comparison across models using the complete case models and multiple imputations are reported in Table S2 and Table S3, respectively. The lowest AIC and BIC values across all models in locomotion, object control, and overall AMC were found in the PE teachers' models (see Table S4). In this table, pseudo R^2 showed in locomotion, that children, parents and PE teachers' perception of children's AMC explained 37.8%, 35.7% and 41.0% of the variance of children's AMC. The explained percentage of variance in object control increased to 46.9%, 46.6% and 45.9% for children, parents and PE teachers, respectively. Finally, the explained percentage of variance in overall AMC increased to 56.3%, 55.9% and 55.7% for children, parents and PE teachers, respectively. In addition, predicted marginal means from adjusted models for sex, age and a sex × age interaction in each year for children's, parents' and PE teachers' perception of children's AMC in locomotion and object control are depicted in Fig. 2 and Fig. 3, respectively.

4. Discussion

The purpose of this study was firstly to analyse the trends in the evolution of the association between children's AMC and PMC according to the source of information (children, parents, and PE teachers) in a three-year follow-up. Indeed, a positive trend of children's AMC was found over time, but this was not the case for PMC. The potential non-linear path of PMC over time might impact the association between AMC and PMC with influence on broad health outcomes such as physical activity participation and weight status (Estevan et al., 2021). In this line and according to our results (Table 3, Table S2, and S3) girls may be at a higher risk of maintaining unhealthy behaviours (Barnett, Lai, et al., 2016), as compared to boys. Being a girl was associated with lower object control (and overall AMC - primarily due to the contribution by object control) which is consistent with previous studies (Barnett et al., 2022; Barnett, Lai, et al., 2016; Masci et al., 2018), and this is persistent over time. Even though Noordstar et al. (2016) found similar changes in boys' and girls' object control over time, the recent study by Coppens et al. (2019) in primary school (6-9 years-old at baseline) Belgian children support our findings in terms of the interaction effect (sex x age), wherein girls made less progress than boys; that is, in our study, boys exhibited higher object control and overall AMC at baseline, and their increases as a function of age were higher than girls. Notwithstanding, the positive linear change in children's AMC over time was not absent of large variability, [also found in other longitudinal studies see (Coppens et al., 2019)], which accompanied by the potential non-linear path of PMC might result in a high diversity of individual trajectories. This could be the reason why in children, the association between actual and perceived competence is low with small, pooled effects (De Meester et al., 2020).

A parallel purpose of our longitudinal study was to analyse whether children, parents, and PE teachers can report on children's AMC longitudinally (considering the children's age, sex, and the type of MC). In children, the role of PMC becomes apparent as childhood cognition develops (Capio & Eguia, 2021), nonetheless, according to the results of the current study, regardless of the domain of FMS, children's PMC was not longitudinally associated with their AMC. The lack of longitudinal association between AMC and PMC is purported to result in potential unhealthy movement behaviours (Barnett et al., 2022; Stodden et al., 2008). However, our results should be taken with caution because the reliability of children's self-reports is between poor and good (Table 1). Alternatively, proxy reports showed higher (good to excellent) reliability and might lead children to recognise their AMC (Estevan, Molina-García, Bowe, et al., 2018).

It is worth noting that proxy reports can be seen as an alternative to drive children's PMC with an impact on children's health behaviors (Menescardi & Estevan, 2021). For instance, due to parents' role in child development, parents were identified as key in reporting on children's AMC; however, their capability was not confirmed (Estevan, Molina-García, Bowe, et al., 2018). Cross-sectional evidence shows inconclusive results, with parents' proxy report, either not associated with child skill (Lalor et al., 2016), weakly associated (Estevan, Molina-García, Bowe, et al., 2018) or moderately associated (Estevan, Molina-García, Bowe, et al., 2018; Liong et al., 2015) - and this depends on the type of FMS domain. Indeed, parents' perception of children's AMC might be largely influenced by the socio-cultural environment (e.g., cultural and gender role stereotypes, values, attitudes) with important ramifications to their expectations (Horn, 2018). In our longitudinal approach, there was not a significant association between parent proxy report and children's AMC over time which suggests parents are not capable enough in proxy reporting their child's AMC. This could be because parents do not have the knowledge of what these skills are. A recent study with parents of pre-schoolers reported that parents' knowledge of FMS was limited (Agard, Zeng, McCloskey, Johnson, & Bellows, 2021). Parent education regarding how skills are performed and what constitutes a good or poor performance is a potential future strategy.

Regardless of AMC, high PMC has been a stimulus associated with motivation for sport and physical activity participation (De Meester et al., 2016). So, the marginal increase of parent report scores of their children over time can be important for children's development and socialization, because it might help to reduce the negative effects of children's low self-perception by encouraging them to remain persistent,

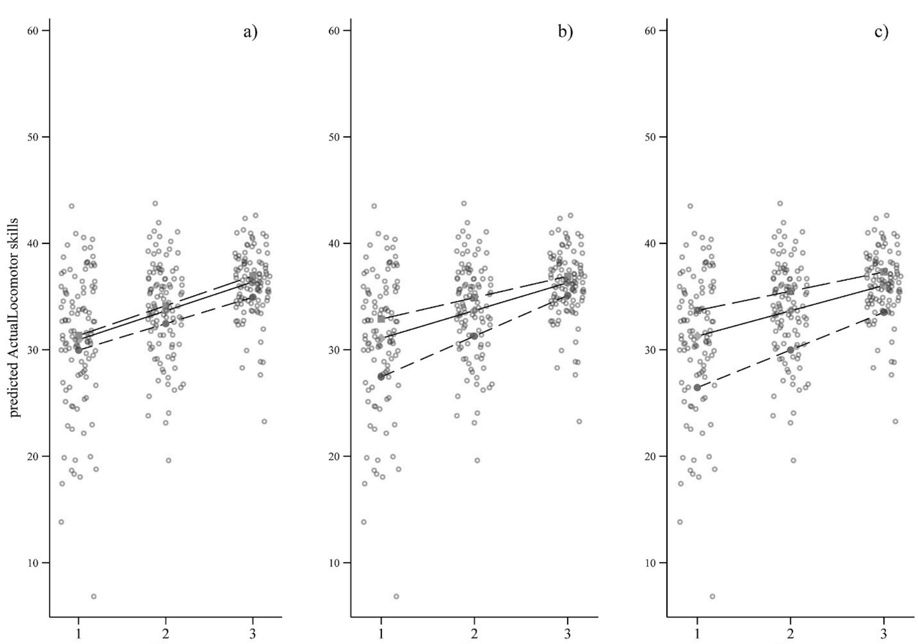

Fig. 2. Predicted marginal means from adjusted models in each year for a) children's, b) parents' and c) PE teachers' perception of children's motor competence in locomotion

Note. The graphs have been generated from the mixed models which have adjusted for sex, age and a sex × age interaction. The values represent the amount of change in actual motor competence with a one unit change in Year (time) while holding perceived motor competence constant at different values (i.e., minimum represented by short dashed, maximum represented by long dashed and median values represented by solid lines). For children, minimum = 10, median = 20, maximum = 24. For parents and teachers, minimum = 6, median = 18, maximum = 24.

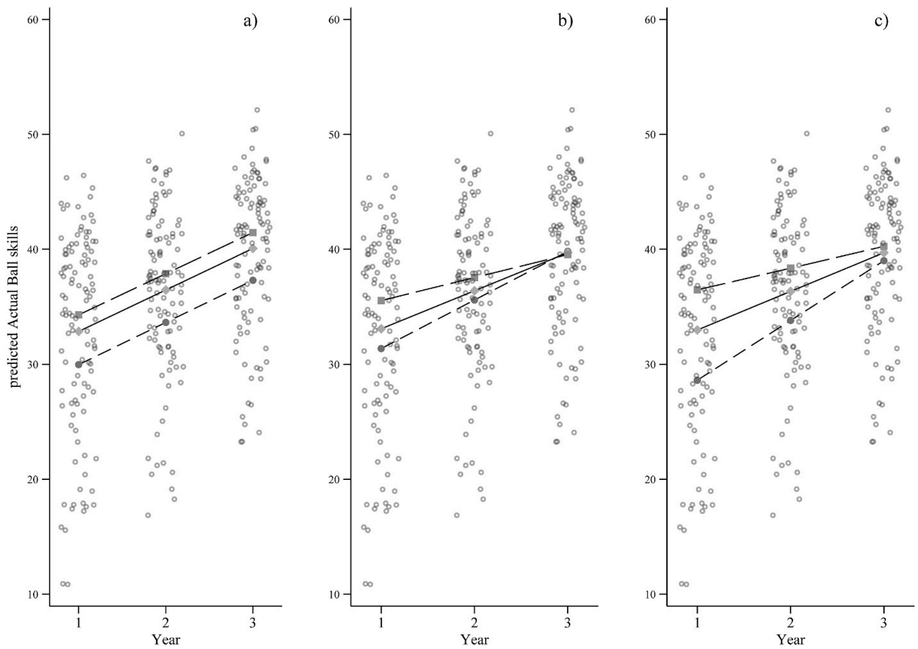

Fig. 3. Predicted marginal means from adjusted models in each year for a) children's, b) parents' and c) PE teachers' perception of children's motor competence in object control skills

Note. The graphs have been generated from the mixed models which have adjusted for sex, age and a sex × age interaction. The values represent the amount of change in actual motor competence with a one unit change in Year (time) while holding perceived motor competence constant at different values (i.e., minimum represented by short dashed, maximum represented by long dashed and median values represented by solid lines). For children, minimum = 9, median = 19, maximum = 24. For parents, minimum = 7, median = 14, maximum = 24. For teachers, minimum = 6, median = 16, maximum = 24.

as well as allowing children to develop useful skills that build their perceived competence (Shen et al., 2018).

An alternative to parent reports are PE teacher proxy reports. In the current study, PE teachers were the only source of information who proxy reported over time effectively (Table 3). PE teachers' perception was associated with children's AMC in locomotion; furthermore, an interaction effect (PE teachers' proxy report x time) was shown in object control and overall motor competence. The negative interaction suggests that when adjusted for age and sex, PE teachers' reports tended to decrease over time. This might suggest that PE teachers may expect children to exhibit a higher specific age-related level of AMC than what the children actually showed. Previous evidence in Europe highlighted primary school children present with low levels of overall motor proficiency (Duncan et al., 2020) and therefore PE teachers might report that children's AMC is not increasing at the expected path to their correspondent age.

The predicted marginal means from the longitudinal models (Fig. 2 and 3), show that for children, regardless of whether their perception score starts low, high or median, the lines are parallel over time, indicating a lack of an interaction (PMC x time) effect. That is, the trend of children's PMC over time will be similar regardless of their level at year 1. This is similar for parent report. For PE teachers however, a child who has a low report at year 1 tends to have a steeper increase in score, compared to a child who starts at a higher level. This could simply be because the low scoring child has more room for development than a child already scoring well, that is, when children exhibit low AMC, they tend to achieve higher levels over time (Estevan et al., 2021). This could also be seen as encouraging because for children who are perceived as low competent there is potential chance for motor competence to increase.

The current study is the first longitudinal research involving children, parents, and PE teachers analysing the association between AMC and PMC using aligned measures. However, the study is not without limitations. Even though the TGMD and the PMSC are aligned, the fact of using not complete aligned versions (i.e., AMC was assessed by using the TGMD-3 and PMC was assessed with an aligned version of the PMSC with the TGMD-2) might limit the strength of the association found between both variables. Another plausible reason why there is limited strength in the association between children's AMC and PMC is the poor reliability in their self-reports in locomotion. Alternatively, in object control which is considered an easier type of skills to observe and evaluate, reliability was acceptable and the strength of the association was evidenced (Estevan, Molina-García, Abbot, 2018). Furthermore, parents' capability in proxy reporting their children's AMC may be different according to parent sex because parents may show gender-typed behaviours with their children (Iivonen & Sääkslahti, 2014), yet parents' sex was not recorded or controlled for. In addition, in our study, only six PE teachers participated which limits generalisation. Future longitudinal cohort studies involving a larger number and diversity of PE teachers and controlling for parents' sex are needed. With the aim of appropriately understanding the trend in the evolution of the association between children's AMC and PMC, longitudinal cohort studies throughout childhood using fully aligned AMC and PMC assessments are also warranted.

4.1. Practical implications

When compared to children taught in PE by classroom teachers without specific FMS training, FMS trained teachers or PE specialists seem to be able to lead interventions that promote psychologically supportive environments irrespective of pupils' AMC level (Lander, Mergen, Morgan, Salmon, & Barnett, 2019). So, when taught by a specialist PE teacher, PE can be an opportunity for children to learn and engage in activities that develop not only their AMC, but also their self-perception (Scrabis-Fletcher et al., 2016). The higher the PMC, the greater the desire to engage in and persist with activities that require FMS (Scrabis-Fletcher et al., 2016). Children with high PMC tend to exhibit higher self-esteem, to exert greater effort and to select and persist within tasks that challenge their ability (Weiss & Amorose, 2005). An interesting aspect of our study is that PE teachers, as the only source of information capable in reporting AMC over time, can be seen as a potential source to empower children's AMC and PMC across primary school and thereby positively influence their life style.

Moreover, to foster motor competence across the lifespan we need: 1) PE pedagogies that account for physical literacy involving a repertoire of continued motor experiences (meaningful movement variability) of interactions with objects, and 2) significant others to help children foster their PMC and utilize new affordances which will encourage students to enhance AMC; both lead to adaptations of developing motor competence and engagement in lifelong physical activity (Rudd, Pesce, Strafford, & Davids, 2020). Parents and teachers should work together to provide opportunities for children to learn and practice FMS (O'Neill et al., 2014). Given the association between children's AMC mastery and physical activity, weight status and health, this is key in childhood (Barnett et al., 2022). In this line, specific and theory-based interventions aiming to empowering AMC and PMC are warranted because a low percentage of children master the expected levels of AMC to their age (Duncan et al., 2020), which if accompanied by a flat or negative trend of PMC (as observed in the current study), can make the fact of fostering positive trajectories of motor competence development a real challenge for PE teachers.

Considering childhood is a critical period influencing PMC (Crane et al., 2015; Estevan & Barnett, 2018), Scrabis-Fletcher et al. (2016) pointed out that perception of competence can be influenced not only by personal factors (e.g., student prior experience) but also social ones (e. g., PE teachers and how they structure the class and the type of interaction they have with the students, and parents). These personal and social factors play a role in developing the entry characteristics children bring to the movement experience that might influence and be influenced by such experiences; which in turns might drive children's PMC movement behaviour because if a child does not perceive himself or herself as being skilled and does not practice FMS appropriately, therefore feeling even less skilled, his or her movement experience may be negatively impacted (Scrabis-Fletcher et al., 2016). The responsibility of social agents' behaviours towards and with the child might affect the child's own domain-specific perception, beliefs and attitudes, influencing the type of behaviour, interest and engagement in various domains (Horn, 2018). Taking into account that in the current study, not parents, but PE teachers' perception is associated with children's AMC, it is recommended that PE teachers 1) share their points with parents so that both social agents perceive and promote children's AMC in a similar way over time and 2) provide enough feedback, direction and encouragement to children regarding their FMS (Robinson, 2011).

5. Conclusion

There is insufficient evidence analysing the association between AMC and PMC (Barnett et al., 2022), so the current longitudinal approach provides an insight into the field of motor development. Children's AMC and PMC (in locomotion, object control, and overall) were not associated over time. Parents did not provide evidence of capability to proxy report in their children's AMC. A potential source of information capable enough in proxy reporting children's AMC were PE teachers.

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Authors' contribution

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Cristina Menescardi: Data collection, Data curation, Writing-original draft preparation, Writing-review and editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2022.102331.

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