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ABSTRACT

The aim of this study was twofold: first, to examine the stability of the hypothesized conceptual model of motor development (without and with including various types of motivation) when children are followed up one-year later, and second to examine longitudinally whether changes in one model variable predict changes in other variables, according to the hypothesized pathways in the model. A sample of 361 Spanish students (50.7% girls, 8–11 years old) voluntarily participated in this study. In relation to the first aim, structural equation modeling revealed the expected positive relationship between the model variables in both measurement times. That is: actual motor competence (MC) predicted physical activity (PA) ($p < .001$), perceived MC mediated the relationship between actual MC and PA ($p < .001$), and autonomous motivation mediated the relationship between perceived MC and PA ($p < .05$). Moreover, the comparison of the invariance analysis showed non-practical differences between the unconstrained model and the constrained model, supporting the stability of the model over time. In relation to the second aim, the hypothesized model in Time 2 controlling for Time 1 values showed that changes in children's actual MC positively predicted changes in their perceived MC ($p < .001$), which in turn, predicted changes in their autonomous motivation ($p < .001$), and PA ($p < .001$) at Time 2. Based on these findings Physical Education teachers are recommended to foster children's actual and perceived MC as well as their autonomous motivation over time in order to promote PA strategies for lifelong health.

1. The mediational role of motivation in the model of motor development in childhood: A longitudinal study

Physical activity (PA) participation is associated with benefits in children's social, mental, and physical health and prevents non-communicable (e.g., obesity, cardiovascular, etc.) diseases (World Health Organization, 2021), both in the short- and long-term (Janssen & LeBlanc, 2010). Meeting the daily recommended PA guidelines (i.e., children 5–12 years old should accumulate at least 60 min per day of moderate-to-vigorous PA; Bull et al., 2020) is also positively associated with academic achievement and cognitive development (World Health Organization, 2021). However, PA participation declines markedly with increasing age during childhood (Farqood et al., 2018). Actually, global estimates indicate that over 80% of young people in school are not meeting the aforementioned recommendations (World Health Organization, 2021). So, preventing PA declines is a global endeavour (Bull et al., 2020).

Two factors that, according to the conceptual model of motor development, account for children to develop a healthy and active lifestyle are actual and perceived motor competence (MC) (Barnett et al., 2022; Stodden et al., 2008). Actual MC refers to the degree of proficiency in performing a wide range of fundamental motor skills, as well as its underlying mechanisms, both of which are required in daily life activities as well as for participation in more complex physical activities (Robinson et al., 2015). Perceived MC is considered one's perception of his/her MC (Estevan & Barnett, 2018). Prior systematic reviews (Babic et al., 2014; Barnett et al., 2022) synthesize the evidence that children and adolescents with a combination of higher levels of actual and

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perceived MC are more likely to participate in PA (Stodden et al., 2008) as both factors can contribute to produce a positive spiral of PA engagement (Barnett et al., 2022).

In their most recent systematic review, Barnett et al. (2022) emphasized the need for stronger evidence in terms of longitudinal and prospective research in relation to the evidences of the relationships between the variables included in the conceptual model of motor development. The present study responds to this call by longitudinally following up on a previously examined sample of Spanish children (Menescardi, De Meester et al., 2022) to explore how actual MC relates to PA level through perceived MC. Those studies up to date that have analysed the relations of the model of motor development in a longitudinal manner (Britton et al., 2019; Ryu et al., 2021; Sallen et al., 2020) found that actual MC predicted future PA participation. Such evidence was provided in 7- to 9-year-old U.S. children followed over 7–8 months (Ryu et al., 2021), in 10- to 11-year-old German followed over 10 months (Sallen et al., 2020), and in 11- to 12-year-old Irish children who were followed over a one-year period (Britton et al., 2019). Additionally, Britton et al. (2019, 2020), found that actual MC predicts future perceived MC. Regarding the longitudinal mediational role of perceived MC in the association between actual MC and PA level, the evidence is inconclusive. Britton et al. (2019, 2020), and Ryu et al. (2021) did not find evidence for the (mediational) role of perceived MC in the relationship between actual MC and PA level; while Sallen et al. (2020) found a mediation effect of percevied MC in the relation between actual MC and later PA.

Recent evidence regarding the conceptual model of motor development further suggests that, apart from actual and perceived MC, it is important to consider the role of motivation (Menescardi, De Meester et al., 2022). Self-Determination Theory (SDT; Deci & Ryan, 2002; Ryan & Deci, 2017), is a relevant motivational theory in this respect, as it explains how individuals who feel more satisfied in their need for competence (i.e., the need to feel effective and successful) become more autonomously motivated (i.e., intrinsic and identified regulations), which means that they act out of enjoyment, or because the behaviour aligns with their own values and interests. According to SDT (Ryan & Deci, 2017), when students engage in PA out of enjoyment or because they experience satisfaction directly from participation in it, they are intrinsically motivated, with the latter reflecting the most self-determined regulation of behaviour. For that reason, participating out of enjoyment can be considered as one of the key factors in motivation to PA engagement (De Meester et al., 2022). On the other hand, if people feel ineffective, they are more likely to act due to internal or external pressures (fears, regrets, rewards, punishments, or threats; Koestner et al., 2008), that is, in a controlled manner (throughout introjected and external regulations). Although the need to feel competent as defined in SDT is somewhat more generic than perceived MC (De Meester et al., 2017), which more directly refers to children's perceptions of their actual MC (Estevan & Barnett, 2018), the theoretical premises of SDT can complement the conceptual model of motor development (Menescardi, De Meester et al., 2022). Children who have higher perceived MC are assumed to be more autonomously motivated and in turn more physically active (Coppens et al., 2021; De Meester et al., 2016; Estevan, Bardid et al., 2021; Wang & Chen, 2022), while those who have a lower perceived MC could be at risk of developing controlled motivation (Estevan, Bardid et al., 2021) and in turn become less physically active. Motivation would thus be important to consider, in particular in the association between perceived MC, and children's PA levels.

Several empirical studies have provided either direct or indirect evidence for the importance of motivation in the conceptual model. Being autonomously motivated has been consistently reported to positively relate with higher levels of PA in a variety of settings (e.g., in and out-of-school, daily exercise, etc.) and age groups, such as children and adolescents (e.g., Castillo et al., 2020; Owen et al., 2014) or college students and adults (Teixeira et al., 2012); while controlled motivation tends to be negatively or not related with PA (e.g., Teixeira et al., 2012). Previous cross-sectional (Coppens et al., 2021; De Meester et al., 2016; Estevan, Bardid et al., 2021; Wang & Chen, 2022) and longitudinal research (Adank et al., 2021), also highlighted the central role of actual and perceived competence for children to participate out of enjoyment in PA, which constitutes an aspect of autonomous motivation. The relationships between controlled motivation and actual/perceived MC were less consistent across different studies as both negative and null relationships have been reported in previous studies (Ensrud-Skraastad & Haga, 2020; Estevan, Bardid et al., 2021).

There is little evidence about longitudinal studies that have examined the role of motivation/enjoyment in the relationship between perceived competence satisfaction and PA over time (e.g., Adank et al., 2021; Ferriz et al., 2016). On the one hand, Adank et al. (2021) found that 10- to 12-year-old Dutch children's actual MC and enjoyment were both positive predictors of their level of PA one year later. They also measured children's satisfaction of the basic psychological need for competence (Deci & Ryan, 2000) and found that it positively influences PA enjoyment over time. On the other hand, Ferriz et al. (2016) found that satisfaction of the need for competence and autonomous motivation in Spanish adolescents (15- to 17-years old) were related to future competence satisfaction and autonomous motivation, which influenced PA at the end of the academic year.

Menescardi, De Meester et al. (2022) were among the first to add motivation in the conceptual model of motor development involving measures of actual MC, perceived MC, and PA. In their cross-sectional study, they provided direct evidence for the mediating role of intrinsic motivation in the relationship between children's perceived MC and their PA levels. Children who had higher actual MC and felt more competent (i.e., higher perceived MC) appeared to enjoy PA more and were in turn more physically active. Longitudinal evidence is now needed to examine whether these prior cross-sectional findings can be replicated.

1.1. *The present study*

To bridge the research gaps, the present study aims to examine whether the hypothesized conceptual model of motor development including various types of motivation can be replicated when children are followed up one-year later, so, we aim to test the invariance of the model over time. According to SDT and prior findings (Menescardi, De Meester et al., 2022), it is expected that actual MC will positively relate to perceived MC and in turn to children's PA one year later. It is also expected that the addition of motivation to this model will increase the explained variance in PA. Based on our prior work, we expect that autonomous motivation will mediate the relationship between perceived MC and PA. As relations for controlled motivation have been inconclusive in relation to PA (Teixeira et al., 2012), the role of controlled motivation will be explored in a more exploratory fashion.

Due to the lack of previous studies that analysed the model (Fig. 1) in a longitudinal manner, the second aim is to examine these relationships longitudinally. By adopting a longitudinal research design, we want to examine whether changes in children's PA co-varied with changes in our hypothesized antecedents of PA, namely, actual and perceived MC, and motivation. We expect that changes in actual MC will predict changes in perceived MC, which will predict changes in autonomous motivation, and in turn in PA. Overall, this goal aimed to extend the results of cross-sectional models (aim 1) to provide more information about the dynamic associations between children's actual MC and PA.

2. Method

2.1. *Study design and participants*

A convenience sample of 361 students (183 girls, 50.7%) between 8 and 11 years old at baseline ($M \pm SD = 8.92 \pm 0.65$ years) from five

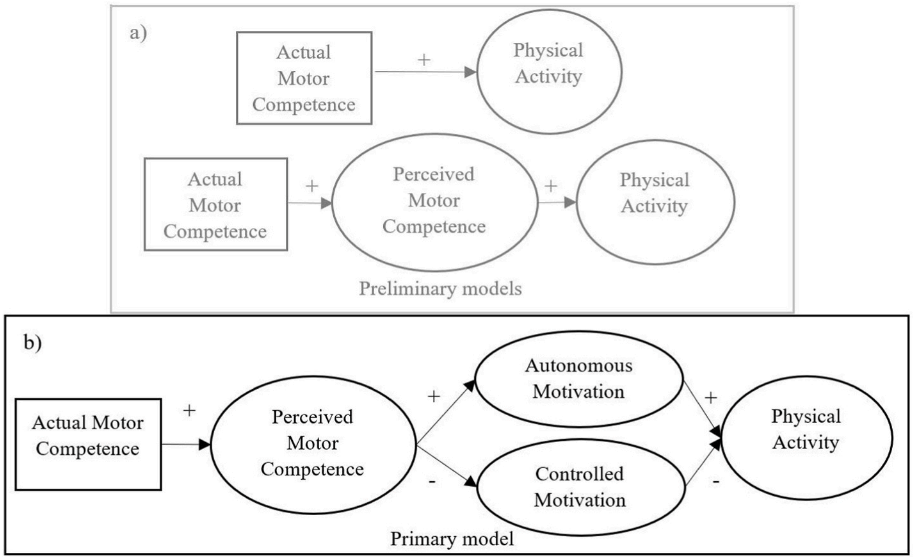

Fig. 1. Hypothesized preliminary and primary structural model of the associations between actual and perceived motor competence, motivation, and physical activity.

elementary schools in Valencia (Spain) participated in the current study during two school years (M age $_{\text{Time 2}} = 10.06 \pm 0.80$ years). Data were collected at two time points one year apart, between November 2019 to March 2020 (Time 1) and November 2020 to March 2021 (Time 2). As a consequence of the COVID pandemic, a drop-out of 28.4% was experienced from Time 1 to Time 2. Part of the Time 1 data was already used in a previous cross-sectional study (Menescardi, De Meester et al., 2022) in which the relationships of the model of motor development, with the addition of the four motivational regulations, were tested cross-sectionally (Menescardi, De Meester et al., 2022). Written consent from a parent or guardian was obtained for all participants, as well as child assent, prior to participation. The study was approved by the Ethics Committee of the first author's university (Reference Code 1564606).

2.2. Measures

2.2.1. Actual motor competence

The Spanish version of the Canadian Agility Movement Skill Assessment (CAMSA) (Longmuir et al., 2017; Menescardi, Villarrasa-Sapiña et al., 2022), a valid and reliable hybrid-oriented test that includes both process- and product-oriented measures, was used to assess actual MC. Children's performance was assessed by means of a process and a product evaluation. For the process evaluation, participants performed seven motor tasks (i.e., two-footed jumping, sliding from side to side, catching a ball, throwing a ball at a wall, skipping, one-footed hopping, and kicking a ball), and were then evaluated on different criteria per skill resulting in 14 items assessing the quality of movement patterns (process-based criteria), and participants received one point for each skill performance criteria that was correctly executed, resulting in a score between 0 and 14. For the product evaluation, participants' time to complete the obstacle course as fast as possible (product-based criteria) was used. The timekeeping started when the participant began two-footed jumping and was stopped when the participant kicked the ball (Figure S1). Time was converted into a score between 1 and 14 points with a higher score representing a faster time (Longmuir et al., 2017). Time and skill scores were summed to provide the total CAMSA score (range of 1–28) (Longmuir et al., 2017; Menescardi, Villarrasa-Sapiña et al., 2022).

Each participant performed the CAMSA twice according to the protocol (Longmuir et al., 2017). The best of the two trials was considered for actual MC. The reliability was established by means of inter-, and intra-rater reliability with a 1-week interval to calculate intra-class correlation coefficients (ICCs). ICCs were moderate-to-excellent (Fleiss, 1981) for times score, skill score and CAMSA scores (Table S1).

2.2.2. Perceived motor competence

The Perceived Movement Skill Competence (PMSC; Johnson et al., 2016) validated in Spanish (Estevan et al., 2019) in addition to the Perceived movement skill competence in stability (Estevan, Menescardi et al., 2021) were used to assess self-perceived MC using twenty pictographic tasks (run, gallop, hop, jump, step slide, skip, overhand throw, catch, kick, two-handed strike, bounce, underhand throw, one-handed strike, single-leg balance, walking backwards, hopping for a height, jumping sideways, moving sideways, single-leg superman/superwoman, and balance on an unstable surface). According to the validated protocol, the child's perception in each skill was rated from 1 (lower perception) to 4 (higher perception) by using a double dichotomy process in an interview conducted by a research assistant (Johnson et al., 2016). The scores of the 20 items were averaged, providing a minimum score of one and a maximum score of four. The scale in this study showed good reliability ($\alpha = 0.77$ and 0.87, respectively for Time 1 and Time 2).

2.2.3. Motivation

The validated Spanish version (Menescardi, De Meester et al., 2022) of the shortened child-adapted version of the Behavioural Regulation in Exercise Questionnaire (Sebire et al., 2013) was used to measure participants' motivational regulations. This questionnaire consists of 12 items grouped into four dimensions of three items each: intrinsic motivation (e.g., "… being active is fun"), identified regulation (e.g., "… it is important to me to do active things"), introjected regulation (e.g., "… when I am not active, I feel bad about myself"), and external regulation (e.g., "… other people say I should"). The questionnaire begins with the statement "I am active because …", and the answers are collected on a Likert scale ranging from 1 (*not true for me*) to 5 (*very true for me*). As in previous research (Koestner et al., 2008), autonomous motivation was calculated as the mean of intrinsic and identified ratings, whereas controlled motivation was calculated as the mean of introjected and external regulations. Item 3 ("… when I'm not active I feel bad") was removed from the scale as $\lambda < 0.30$ (Field, 2018). Internal consistencies were acceptable to good in this study, with Cronbach's alphas of 0.74 and 0.68 for autonomous and controlled motivation, respectively at Time 1, and 0.77 and 0.68 for autonomous and controlled motivation, respectively at Time 2 (Hair et al., 2014).

2.2.4. Physical activity

The Spanish version of the Physical Activity Questionnaire for Children (PAQ-C; Kowalski et al., 2004) was used (Menescardi, De Meester et al., 2022). The PAQ-C is a self-reported 7-day recall questionnaire that assesses participation in different types of sports (e.g., handball, soccer, basketball, footing, swimming, etc.), as well as the level and frequency of PA during Physical Education (PE), lunch break, recess, after school, in the evenings (e.g., "… on how many times did you do sports, dance, or play games in which you were very active?"), and at weekends by the use of nine items scored on a five-point Likert scale ranging from 1 (*low*) to 5 (*high*). Item 2 (PA during PE lesson) was removed from the scale as $\lambda < 0.30$. The scale showed good reliability ($\alpha = 0.72$ and 0.76, respectively for Time 1 and Time 2). The scores of the eight items were averaged, providing a minimum score of one and a maximum score of five.

2.3. Data analysis

2.3.1. Preliminary analysis

In order to examine the hypothesized models (Fig. 1), a two-step approach was followed (Balaguer et al., 2012; González et al., 2016). First, we conducted a set of preliminary analyses. We tested the factorial invariance of each scale in Time 1 and Time 2 (M0a and M0b) by confirmatory factor analyses (CFA) with Mplus Version 8 (Muthén & Muthén, 2017) to determine whether the indicators were related to the latent factors in a satisfactory manner (see supplementary material, Figures S2-S4 and Tables S2-S4) to each group-time separately. Then, a baseline model testing the structural invariance (M1) was established. Finally, invariance of factor loadings (M2) was specified to examine the equality of measurement across time groups. The model goodness of fit was examined using the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). Cut off values were established at CFI >0.90, and RMSEA <0.08 to indicate a good fit of the data (Hu & Bentler, 1999). In order to assess the fit of the models, differences not larger than 0.01 among CFI values and differences not larger than 0.015 among RMSEA values were considered an indication of negligible practical differences between models (Chen, 2007). Second, after a satisfactory fit was achieved for the measurement model, we tested the fit of the structural model (see Fig. 1). To compute the structural model, one-way repeated measures ANOVAs were conducted to investigate the effect of time and time*sex on each variable. Effect sizes were calculated according to partial eta squared (η_p^2) criteria (Cohen, 1988), where 0.01, 0.06 and 0.14 represented small, medium and large effect sizes respectively. Additionally, correlations were computed to analyse whether significant associations between study variables are in line with the hypothesized model. As a significant sex and age effect was found, models were computed with age and sex as covariates (see preliminary results).

2.3.2. Aim 1: Invariance of the model over time

According to the first aim of this study, we then conducted a multi-sample analysis to assess differences by time measurement in the models. To do this, different nested models were tested to analyse their invariance across two consecutive time points. First, the hypothesized baseline model was separately tested for each time point (Time 1 and Time 2) to determine that the proposed model was acceptable for each group. Second, the multi-sample unconstrained model was calculated to be used as a baseline for fit comparisons against the more restricted model. Third, a total invariance (constrained) model addressed the equality constraints of all the parameters across the time points. Thus, this model tested whether all the relationships between the variables in the model held invariant across the two time points. To establish the structural models, parcels were created by combining the highest and lowest factor loadings together to compound three parcel scales (in perceived MC, autonomous motivation, and PA) and two parcels in the controlled motivation scale.

Due to the lack of longitudinal evidence of the relationships presented in the primary model of Fig. 1, in this manuscript the purposed model was tested throughout a stepwise strategy in which: firstly, the relationship between two variables (actual MC and PA) were tested longitudinally (Ryu et al., 2021; Sallen et al., 2020). Secondly, and according to the model of motor development, the model with three variables (actual and perceived MC, and PA) was tested (Sallen et al., 2020). Thirdly, including motivational variables as derived from SDT (Menescardi, De Meester et al., 2022), the model with five variables (actual and perceived MC, autonomous and controlled motivation, and PA; Fig. 1) was tested.

2.3.3. Aim 2: Longitudinal changes in the variables in the model

Once the stability of the model in terms of time was checked, our second aim was to determine whether a) changes in actual MC predicted changes in perceived MC, b) changes in perceived MC predicted changes in motivation and PA, c) changes in motivation predicted changes in children's PA levels over two time point measurements, separated one school year. Due to scarce literature, preliminary models were tested to analyse whether changes in one of the variables of the model predicted changes in any of the variables of the model. To this end, we have controlled Time 1 values for each variable in Time 2 (González et al., 2016; Quested & Duda, 2011). The same goodness of fit indices mentioned in the analysis of measurement invariance were used, as well as the same stepwise testing strategy outlined in the previous paragraph. The conjunction of both models (i.e., the stability over time and the change-adjusted model) reports not only the consistency of the model over time, but also the changes in the variables.

3. Results

3.1. Preliminary analysis

All the scales had satisfactory fit indices at the two time points (CFI range = 0.91–0.98, RMSEA = 0.03–0.06). Results of the CFA provided support for the hypothesized structure of the instruments. The multi-sample CFA supported the structural invariance of the scales over time, providing evidence of the replicability of the factor structures over time. Finally, factor loadings invariance of all instruments was supported (see supplementary material Figures S2-S4 and Tables S2-S4).

The repeated-measures ANOVA revealed no significant time x sex interaction in actual and perceived MC, motivation or PA levels. However, the results showed a significant effect for time on actual MC (F (1, 330) = 99,775, $p < .001$, Wilk's $\lambda = 0.77$, $\eta_p^2 = 0.23$), perceived MC (F (1, 348) = 50,246, $p < .001$, Wilk's $\lambda = 0.87$, $\eta_p^2 = 0.13$), autonomous motivation (F (1, 351) = 31,905, $p < .001$, Wilk's $\lambda = 0.92$, $\eta_p^2 = 0.08$), controlled motivation (F (1, 351) = 56,074, $p < .001$, Wilk's $\lambda = 0.86$, $\eta_p^2 = 0.14$) and PA (F (1, 347) = 15,095, $p < .001$, Wilk's $\lambda = 0.96$; $\eta_p^2 = 0.04$), with actual MC increasing over time whereas perceived MC, autonomous and controlled motivation, and PA decrease from Time 1 to Time 2.

The results also show a significant effect for sex on actual MC ($F = 28{,}415$, $p < .001$, $\eta_p^2 = 0.08$), perceived MC ($F = 12{,}809$, $p < .001$, $\eta_p^2 = 0.04$), PA ($F = 11{,}239$, $p < .001$, $\eta_p^2 = 0.03$) with boys having higher MC and PA levels than girls. No significant sex effect was found for autonomous ($F = 1{,}481$, $p = .22$) or controlled motivation ($F = 1{,}192$, $p = .27$).

3.2. Relationships between the study variables and model analysis

In both time measurements, the study variables that were significantly correlated were in the expected direction (see Table 1). That is, actual MC was positively correlated with perceived MC, and both variables were positively correlated with autonomous motivation and PA at both time points. Autonomous motivation was also positively associated with PA at both time points. Controlled motivation was not significantly related to PA at either time.

Table 1
Descriptive statistics (mean and standard deviation) and bivariate correlations between study variables.

Variables	Range	Total Sample Mean (SD)	1	2	3	4	5	6	7	8	9	10	11
1. Gender (boys = 1; girls = 2)	1–2	–	–										
2. Age Baseline	8–11	8.92 (0.65)	−.05										
3. Actual Motor Competence Time 1	1–28	18.33 (3.58)	−.23**	.32**									
4. Actual Motor Competence Time 2	1–28	19.89 (3.39)	−.28**	.23**	.67**								
5. Perceived Motor Competence Time 1	1–4	3.03 (0.37)	−.13*	−.01	.22**	.20**							
6. Perceived Motor Competence Time 2	1–4	2.84 (0.48)	−.20**	−.12*	.31**	.31**	.40**						
7. Autonomous Motivation Time 1	1–5	4.56 (0.53)	−.07	−.11*	.25**	.26**	.34**	.37**					
8. Autonomous Motivation Time 2	1–5	4.37 (0.59)	−.05	−.11*	.14*	.19**	.25**	.46**	.39**				
9. Controlled Motivation Time 1	1–5	2.91 (1.00)	−.03	−.11*	−.08	−.10	.10	−.03	.12*	.02			
10. Controlled Motivation Time 2	1–5	2.46 (0.88)	−.08	.04	−.06	−.03	.15**	.04	−.02	.10	.30**		
11. Physical Activity Time 1	1–5	3.22 (0.73)	−.15**	.03	.19**	.17**	.27**	.29**	.37**	.32**	.10	.01	
12. Physical Activity Time 2	1–5	3.03 (0.70)	−.16**	−.14**	.16**	.16**	.26**	.43**	.32**	.48**	.05	.08	.38**

The results of the hypothesized model (Fig. 1) fitted the data well at the two time points for all the models tested; that is actual MC-PA (Table S5), and actual MC- perceived MC- PA (Table S6), as well as the preliminary model including motivation (Table 2 and Figure S5). Thus, it can be concluded that the same pattern of relationships between variables was able to fit the data from each measurement time. Although the model fits in each group, it is clear that it provides a better fit at Time 2 than Time 1 (see Table 2). The percentage of PA variance explained in Time 1 and Time 2 were 29% and 47%, respectively (Figure S5).

As we can see in Table 2, the comparison of the invariance analysis showed non-practical differences between the unconstrained model (i. e., in which no constraints were imposed on the model's paths) and the constrained model (i.e., the model of total invariance with all the paths constrained), supporting the invariance of all the paths (Fig. 2). In line with the hypothesized model, in both time points there were significantly positive paths between actual and perceived MC, which in turn was positive related to autonomous motivation. Finally, autonomous motivation was positively associated with higher levels of PA.

Finally, according to the second aim of this study, the hypothesized model in Time 2 controlling for Time 1 values presented an adequate fit to the data (χ^2 (273) = 461.628; RMSEA = 0.045; CFI = 0.929; Fig. 3). For the preliminary models, also data presented good fit (See Figure S6). The results showed that changes in children's actual MC positively predicted changes in their perceived MC ($\beta = 0.24$, $p < .001$), which in turn, positively predicted changes in children's autonomous motivation ($\beta = 0.40$, $p < .001$), which positively predicted changes in their PA ($\beta = 0.38$, $p < .001$) at Time 2. Additionally, changes in children's perceived MC positively predicted changes in their PA levels ($\beta = 0.21$, $p < .001$). The model also revealed indirect paths from changes in actual MC through changes in perceived MC to changes in autonomous motivation (standardized indirect effect = 0.09, $p < .001$) and from changes in perceived MC through changes in autonomous motivation to changes in PA (standardized indirect effect = 0.15, $p < .001$). The percentage of PA variance explained in this model was 49%.

4. Discussion

Given the scarcity of longitudinal evidence in support of the hypothesized mediating role of perceived MC in the relationship between children's actual MC and their PA (Barnett et al., 2022) and the emerging - yet limited - cross-sectional proof of the mediating effect of (autonomous) motivation in the same relationship (Menescardi, De Meester et al., 2022; De Meester et al., 2017), the current study aimed to examine the hypothesized models in a stepwise fashion (i.e., starting with a model only including the relationship between actual MC and PA, followed by the inclusion of perceived MC and motivation, respectively as mediators at two time points). We also tested their invariance over time, and whether changes in one model variable (i.e., 1. actual MC, 2. perceived MC, and 3. autonomous motivation) predicted changes in other model variables (i.e., 1. perceived MC, 2. PA and autonomous motivation, and 3. PA).

Table 2
Goodness of fit indexes for the structural invariance models.

Models description	χ2	df	RMSEA	CFI	ΔRMSEA	ΔCFI
Baseline Time 1	99.061	63	.041	.965	–	–
Baseline Time 2	88.004	63	.034	.983	–	–
Invariance Analysis no constraints	210.933	140	.038	.972	–	–
Total Invariance (all constrained)	227.978	154	.037	.970	.001	.002

4.1. *The conceptual model (with and without motivation) and its invariance over time*

The results of the preliminary models (i.e., the actual MC - PA model, and the same model with the inclusion of perceived MC as mediator; Fig. 1a) confirmed the positive relationship between children's actual MC and their PA participation, as well as the mediating role of perceived MC in the actual MC- PA relationship. Even though the evidence regarding the mediating role of perceived MC in the relationship between actual MC and PA remains inconclusive to this day (Barnett et al., 2022; Robinson et al., 2015), the current study provides further evidence in favour of the hypothesized mediating role of perceived MC.

The results of the primary model including motivation (Figs. 1b and 2) further confirmed the hypothesized positive pathways from 1) actual to perceived MC (De Meester et al., 2020), 2) perceived MC to autonomous motivation (De Meester et al., 2016; Ferriz et al., 2016; Menescardi, De Meester et al., 2022), and 3) autonomous motivation to PA (Castillo et al., 2020; Owen et al., 2014; Teixeira et al., 2012) in both time points, irrespective of age and sex. The results also revealed indirect paths 1) from actual MC through perceived MC to autonomous motivation, and 2) from perceived MC through autonomous motivation to PA. These findings are in line with a recent cross-sectional study that found indirect paths 1) from actual MC through perceived MC to two sub-regulations of autonomous motivation (i.e., intrinsic and identified regulation), and 2) from perceived MC through intrinsic motivation to PA (Menescardi, De Meester et al., 2022), and further add to the body of evidence of the synergistic effect among actual MC, perceived MC, and autonomous motivation in relation to adapting and maintaining a physically active lifestyle (Adank et al., 2021; Coppens et al, 2021; De Meester et al., 2016). Controlled motivation was not found to be a significant mediator in the relationship between perceived MC and PA in the current study. Similar findings were already reported in previous studies (Ensrud-Skraastad & Haga, 2020; Estevan, Bardid et al., 2021).

In line with Menescardi, De Meester et al. (2022), the particularly strong relationships to and from autonomous motivation demonstrate that including autonomous motivation in the conceptual model

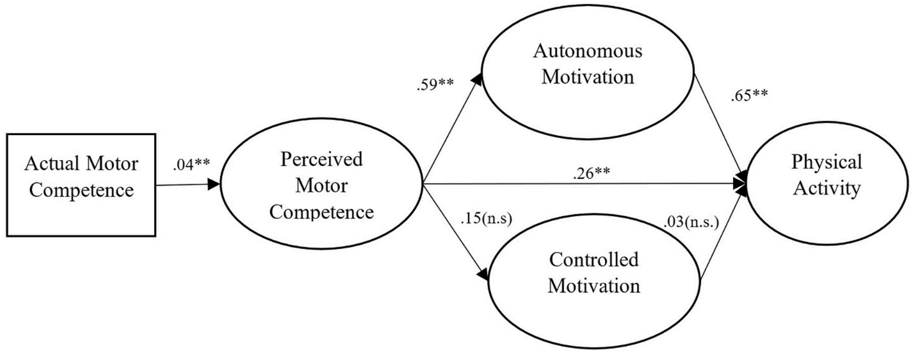

Fig. 2. Structural model of the model invariance of the associations between actual motor competence, perceived motor competence, autonomous and controlled motivation, and physical activity over the two time points. Representation of the unstandardized coefficients as estimated in the total invariance (all constrained) model. Sex and age were included as covariates in the model. **p < .001; *p < .05; n.s.: not significant.

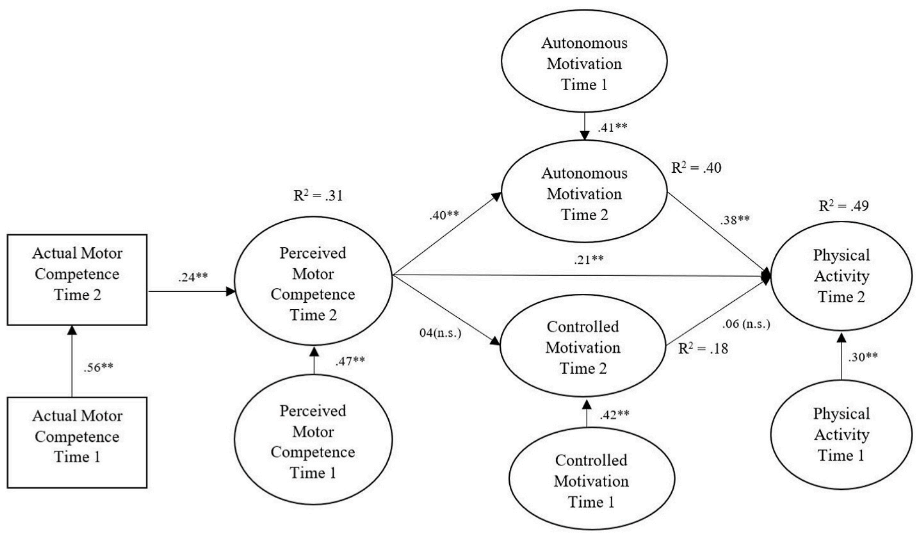

Fig. 3. Structural equation model of the associations between Actual Motor Competence, Perceived Motor Competence, Autonomous and Controlled Motivation, and Physical Activity for Time 2 controlling for Time 1. Representation of the standardized coefficients (β) as estimated in the full model. Sex and age at baseline were included as covariates in the model. **p < .001; *p < .05; n.s.: not significant.

(Robinson et al., 2015; Stodden et al., 2008), could make the model significantly more comprehensive hereby accounting for a more substantial amount of variance in children's PA engagement (15% vs. 29% in Time 1, and 29% vs. 47% in Time 2). The lack of significant relationships to and from controlled motivation on the other hand, seems to imply that the inclusion of controlled motivation does not improve the conceptual model.

Finally, the results also provide evidence for the consistency of the conceptual model over time. To our knowledge, the current study is one of the first to measure all model variables (with the exception of physical fitness) by means of an invariance analysis, and as such to demonstrate the stability of the model over time.

4.2. The predictive utility of the model variables

The results showed that changes (from Time 1 to Time 2) in children's actual MC positively predicted changes in their perceived MC at Time 2. A recent systematic review (Barnett et al., 2022) that summarized the available mediation, longitudinal, and experimental evidence (published before November 2019) in relation to the conceptual model's pathways (Robinson et al., 2015; Stodden et al., 2008), only discovered one study (Lloyd et al., 2014) that longitudinally examined the relationship between actual and perceived MC. Lloyd and colleagues found that Canadian 5-7-year-olds' total actual MC positively predicted their perceived MC during adolescence (i.e., approximately 10 years later), and in early adulthood (i.e., approximately 20 years later).

These results are in line with recently published work from Britton et al. (2020), that found that children's object control in their final year of primary school predicted their perceived MC one year later. Another recently published study showed that German 10-11-year-olds' object control skills and their locomotor skills predicted their perceived object control skills and perceived locomotor skills, respectively ten months later (Sallen et al., 2020). However, Ryu et al. (2021) did not find a significant relationship between American 7-8- year-old children's actual MC measured at the start of the school year and their overall perceived MC, measured 7–8 months later. The current study provides additional evidence that (an increase in) actual MC in (late) childhood predicts (an increase in) perceived MC in (early) adolescence.

The results of the current study also revealed that changes in perceived MC positively predict changes in autonomous motivation, which, in turn positively predict changes in PA out of PE classes. Previous studies that examined longitudinal associations among self-perceptions in relation to one's competence, motivation, and PA, focused on competence satisfaction, rather than perceived MC (e.g., Adank et al., 2021; Ferriz et al., 2016). As mentioned before, both concepts are closely related yet slightly different from one another. Nonetheless, the findings of those studies [both conducted over the span of one (school) year] point towards the same conclusions as the current study since they found competence satisfaction to positively predict enjoyment in PA (Adank et al., 2021) and autonomous motivation for PA (Ferriz et al., 2016) in a sample of 10- to 12-year-old Dutch children and 15- to 17-year-old Spanish adolescents, respectively. Ferriz et al. (2016) also found that adolescents' competence satisfaction at the beginning of the school year positively predicted their PA participation at the end of the school year. All these findings combined, further highlights the importance of developing children's actual and perceived MC from an early age on, and also underlines the impact of children's motivation for the relationships included in the conceptual model (Robinson et al., 2015; Stodden et al., 2008).

4.3. Practical relevance

The results of the present study reiterate the importance of PE teachers, youth sports coaches and other health practitioners to enhance children's actual MC development, to foster a positive perceived MC and to create a need-supportive learning environment that stimulates autonomous motivation. As the literature (Goodway et al., 2012; Haywood & Getchell, 2022) has shown that children's actual MC development benefits more from engagement in organized movement activities rather than in free play, PE teachers have the important task of optimally using the allocated PE time for activities that allow children to discover, use and strengthen their fundamental motor skills.

At the same time, they can aim to endorse children's perceived MC and strengthen their autonomous motivation to be physically active. They can do so in three related ways. First, they can rely on need supportive teaching practices (Bruijn et al., 2022; Deci & Ryan, 2000; Fitton-Davies et al., 2021; Teraoka et al., 2020) or pedagogical models (Sierra-Díaz et al., 2019; Teraoka et al., 2020), by satisfying children's need for autonomy (e.g., by providing choice, involving children in decision making, formulating clear objectives), competence (e.g., through upward and downward extensions, positive feedback, and communicating expectations), and relatedness (e.g., by showing empathy, interest, respect, sincere care; Deci & Ryan, 2000). Second, they can try to provide children with developmentally appropriate instruction in a mastery-oriented environment (i.e., a setting in which the focus is on learning the content, mastering a skill and/or on self-improvement rather than on comparing one own's performance to that of others'; Ames, 1992). Third, they can try to foster a growth mindset (i.e., the belief that success can be attributed to effort and hard work, rather than to innate abilities; Dweck, 2006) by praising students for their effort rather than their abilities (Dweck, 2006), and by applying 'assessment for learning' strategies rather than 'assessment of learning' strategies (Broadfoot et al., 2002; Krijgsman et al., 2021).

In order to address the aforementioned aspects, the application of the SAAFE teaching principles (i.e., *Supportive* environments, *Active* lessons with reduced transition time and maximum opportunities for activity, creating conditions for students' *Autonomous* learning, promoting *Fairness*, and an *Enjoyable* experience by focusing on fun and variety) during PE lessons have been proposed (Lubans et al., 2017; Rudd et al., 2020), which also contributes to foster children's physical literacy (Whitehead, 2019). The provision of quality PE, and supportive environments that impart physical -and health-literacy is one of the pursuits of the World Health Organization (2021), for lifelong healthy, active lifestyles, prevention of non-communicable diseases and mental health disorders as well as strengthen academic outcomes.

Moreover, it is also important to emphasize the influence of other social agents such as parents to provide social support for children's PA participation (Menescardi & Estevan, 2021). Previous studies suggested that, to increase children's autonomous motivation for PA, parents should engage in physical activities with their children (Lohbeck et al., 2022; Menescardi & Estevan, 2021). Parents can try to avoid the use of a controlling language with them because it undermines their motivation and is associated with need frustration (Ntoumanis et al., 2017), boredom and burnout (Álvarez et al., 2021). It would also be interesting to encourage parents to sign up for an educational intervention programme based on SDT (Lohbeck et al., 2022), so that they can create autonomy-supportive environments that avoid controlling behaviors, as well as on parental physical literacy (Ha et al., 2022; Álvarez et al., 2021), in order to promote greater engagement of children in PA and a higher quality physical experience.

4.4. Limitations, strengths and directions for future research

The first limitation of the present study is the potential impact of the COVID-19 pandemic in between the two points of data collection (i.e., November 2019 and March 2021, respectively). The repeated measured ANOVA exhibited a main effect of time with actual MC slightly increasing over time and perceived MC, and autonomous motivation slightly decreasing. Even though numerous studies have shown that the COVID-19 pandemic has had a significant impact on children's and adolescents' physical (Siegle et al., 2022) and mental health (Shah et al., 2020) worldwide, and more specifically their (actual and perceived) MC (Ayubia & Komainib, 2021; Pombo et al., 2021) and (motivation for) PA (Reece et al., 2021), it is difficult – if not impossible – to quantify the exact impact of the pandemic on the study variables.

The second limitation is the use of a convenience sample, which increases the risk of bias due to a potential inaccurate representation of the target population. However, based on our large sample size ($n = 361$), selected from five elementary schools, and the relatively low drop-out between the two measurement times (i.e., 28.4%), especially given the impact of the COVID-19 pandemic, we believe that the results of the current study are representative for the vast majority of Spanish students transitioning from late childhood into early adolescence.

Lastly, there is a minor methodological limitation to consider. The use of self-reported PA rather than a more objective PA measurement, increases the risk of under- and especially over-estimation of PA levels (Prince et al., 2008). However, the PAQ-C (Kowalski et al., 2004) is a valid (Menescardi, De Meester et al., 2022; Saint-Maurice et al., 2014) and reliable (Manchola-González et al., 2017) instrument to measure PA in older children, and showed good reliability for both time points in the current study.

This study also has some considerable strengths. Apart from the relatively large sample size, a major strength is the longitudinal design. A recently published systematic review (Barnet et al., 2022) of longitudinal evidence of the conceptual model (Robinson et al., 2015; Stodden et al., 2008) indicated the need for "robust longitudinal studies across childhood and adolescence that include all variables in the model, have multiple time points and account for potential confounding factors". Our study meets all those assumptions, with the exception of the inclusion of health-related physical fitness and BMI, but with the addition of autonomous and controlled motivation in the model. As such, the current study is a valuable contribution to the motor development literature.

Another strength is the use of the detailed, step-by-step Structural Equation Modelling (SEM) to analyse the data, which has some important advantages over the more traditional multivariate techniques to analyse data (Novikova et al., 2013). The majority of multivariate techniques do not model - and as such take into account - measurement error, while SEM models do estimate and take into account these error variance parameters for the included variables (Byrne, 2011). Furthermore, using SEM allowed us to both estimate latent variables from observed variables and to test how well our data fit the hypothesized conceptual model with the inclusion of motivation.

To further strengthen the body of evidence in support of the conceptual model (Robinson et al., 2015; Stodden et al., 2008), and to gain more insight into the added value of including motivation in the model (De Meester et al., 2017; Menescardi, De Meester et al., 2022), future studies should aim to 1) use a longitudinal design (preferably with at least three measurement points across several years), 2) assess a large, representative sample for the intended age group, 3) assess PA levels by using objective measures like accelerometers, 4) and include all original model variables (i.e., actual and perceived MC, PA, physical fitness, and weight status), as well as motivational regulations. It is also recommended to expand and/or adapt the currently existing PA-interventions in children and adolescents to simultaneously focus on improving children's actual and perceived MC, and their autonomous motivation to be physically active. As mentioned before, we believe that applying need-supportive teaching strategies (Deci & Ryan, 2000) embedded in the SAAFE principles (Lubans et al., 2017), is a beneficial strategy to achieve this goal.

5. Conclusion

This study, was the first to provide longitudinal evidence for the role of autonomous motivation in the relationship between perceived MC and PA as outlined in the conceptual model of motor development (Stodden et al., 2008). The inclusion of autonomous motivation (but not controlled) helped to explain a larger variance in children's PA. The study also reported the maintenance and corroboration of the model of motor development relationships over time (also including motivation into the model). School PA promotion initiatives should target the development of children's actual and perceived MC, and their autonomous motivation. To that end, PE lessons should be conducted in a need-supportive and mastery-oriented environment for developing students' competence, confidence, and motivation to provide physical literacy for long-lasting active lifestyles.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Given their role an Editorial Board member, Haerens L. had no involvement in the peer-review of this article and had no access to information regarding its peer-review. Given their roles of Guest Editors, Estevan, I. and De Meester, A., had no involvement in the peer-review of this article and had no access to information regarding its peer-review. All other authors have declared no conflicts of interest.

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.2023.102398.

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