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Original research

Longitudinal association of movement behaviour and motor competence in childhood: A structural equation model, compositional, and isotemporal substitution analysis

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A B S T R A C T

Objectives: The aim of this study was to analyse the association between physical activity and motor competence in primary school children using traditional and compositional data analysis approaches over time (time 1 and time 2).
Design: A longitudinal observational design was used to study 124 typically developed children (45.2% girls), 5–10 years old at baseline.
Methods: Children's objectively measured physical activity and sedentary behaviour, actual and perceived motor competence were assessed at two time points, one year apart. Longitudinal association of movement behaviors with actual and perceived motor competence, in locomotion, ball skills and overall motor competence was explored using structural equation models, compositional analysis, and isotemporal substitution.
Results: When adjusted for sex, age, and body mass index, structural equation models and the composition consistently predicted actual and perceived motor competence at time 1 and time 2 ($p < 0.01$). Reallocation of 10 min from sedentary to light, or to moderate-to-vigorous physical activity, was associated with changes in actual motor competence, which was consistent from time 1 to time 2. Additionally, regarding self-perception, in time 1, isotemporal substitution of sedentary to light physical activity was the only reallocation associated with increases in perceived motor competence. In time 2, however, such positive associations were only found when reallocating time from sedentary or light to moderate-to-vigorous physical activity.
Conclusions: Achieving adequate levels of moderate-to-vigorous physical activity, at the expense of sedentary and light physical activity, is associated with increases of actual and perceived motor competence over time.
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Practical implications

- The analysis of the association of PA with actual and perceived MC by using different approaches (traditional and CoDA) can be useful to ascertain appropriate conclusions and to contribute to the implementation of specific strategies to improve children's health.
- In 5–10 year-old children, the association between PA composition and actual MC (overall & locomotor skills) remains stable in T1 and T2.
- The longitudinal findings suggest practicing MVPA may imply greater time spent performing the skills, and/or greater exposure to significant others' orientation, which in turn is associated with increases in both actual MC and perceived MC in locomotion.
- Light PA might not be always an adequate manner of fostering MC; during light PA, children might not experience joy, with negative consequences in the future, such as not wanting to participate or find suitable possibilities to participate in PA.
- Daily reallocation of 10 min of sedentary behaviour or light PA to MVPA could be achieved by integrating movement within the academic lessons, which might contribute to increases of MC.

1. Introduction

During childhood, the benefits of adequate levels of physical activity (PA) are well documented,[1,2] with impact on health in the short and long term.[1,3] In primary school children (5–12 years-old), some PA is better than none, whilst more PA, and less sedentary behaviour, is better

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for optimal health outcomes.[4] Specifically, engagement in 60 min or more of moderate-to-vigorous PA (MVPA) daily is recommended because it provides health improvements in adiposity, skeletal, cardiometabolic, cognitive, and psychological development.[3,4] However, a large percentage of children do not engage sufficiently in PA.[5]

In addition to PA, another factor that helps children develop a healthy and active lifestyle is motor competence (MC), which refers to the degree of proficiency in performing a wide range of motor skills, as well as the underlying mechanisms required in daily life activities and for participation in more complex physical activities[6–8]; MC is usually classified according to the type of fundamental movement skill (FMS): locomotion (i.e., running, sliding or skipping) and object control skills (i.e., throwing, kicking or catching).[9] Limited proficiency in MC and/or its domains is associated with greater sedentary behaviour.[6] Accordingly, a conceptual model has outlined the role of MC in multiple health-related aspects of children development, where, during childhood, this model posits the existence of bidirectional paths of MC and PA. That is, children with higher levels of actual MC in combination with higher levels of perceived MC are more likely to participate in PA and the reverse.[8]

Throughout childhood, individuals typically engage in increasingly complex PA that requires appropriate levels of actual and perceived MC. However, cross-sectional evidence in the association of MC with PA engagement is identified as inconsistent depending, for instance, upon the type of FMS assessed (i.e., overall, locomotor or ball skills),[10] and a recent systematic review showed indeterminate longitudinal evidence for the association between MC and PA.[11] Whereas some longitudinal studies in childhood showed actual MC (ball skills and overall) is associated with subsequent PA,[12,13] and others exhibited that PA predicted MC in future,[14,15] the limited longitudinal meta-analytical evidence[3,11] does not support nor refute the conceptual model of motor development in terms of the longitudinal association between PA and MC.[8]

Methodological issues regarding traditional methods of analysing PA data may prevent effective assessment of the co-dependence among PA domains,[16] which should be considered simultaneously.[17] Notwithstanding, there is a tendency of PA levels to decline, concomitant to an increased amount of leisure-time sedentary behaviour across childhood[17] that might impact MC proficiency.[11] As a result, the available evidence suggests that more robust longitudinal studies to test the suggested paths in the conceptual model of motor development considering the compositional nature of PA domains are required.[1,18] Although compositional data analysis (CoDA) of cross-sectional data has shown a higher proportion of MVPA and sedentary behaviour was positively and negatively associated, respectively, with actual overall MC and ball skills but not locomotor skills,[16] to the authors' knowledge, no longitudinal study has been conducted utilizing CoDA to analyse the aforementioned association (PA domains-MC). So, the purpose of the current study was to longitudinally examine the association of PA domains with actual and perceived MC, according to the type of FMS (i.e., overall MC, locomotion, and ball skills) in primary school children using traditional and CoDA. We were interested in whether 1) the strength of the association between movement behaviours and actual/perceived MC varies from time 1 (T1) to time 2 (T2), and 2) changes in PA domains impact actual/perceived MC over time.

2. Methods

For the current observational longitudinal study, a sample size calculation was computed by using the G*Power 3.1 software (University of Düsseldorf, Düsseldorf, Germany), where setting variance explained by predictor was set at 0.29 (effect size $f^2 = 0.39$), an α-level at 0.05, and a statistical power at 0.8. Accordingly, this showed the sample size needed per group was 23 participants, which was set as the minimum sample size per school. A sample of 136 children (44.9% girls), from 5 to 10 years old, at baseline were recruited by convenience from four (two public and two private; two coastal and two inland cities) primary schools chose by the formal list of the Valencia region, Spain. Parental or guardian consent to participate in the study was obtained. Approval was obtained from The Institutional Review Board of the University (H1446557620395). Data were collected at two time points (February–April 2017 and 2018), one year apart.

Children were included in the analyses when complete actual and perceived MC, and PA data for year 1 and/or year 2 were obtained. After inspecting missing data, 12 children were excluded, so a total of 124 children (91.2% of initial sample; 45.2% girls; age 7.4 ± 1.3 years; 1.25 ± 0.09 m; 27.27 ± 7.83 kg; body mass index (BMI) 16.92 ± 2.99 kg/m^2) were included.

Children's movement behaviour (PA and sedentary behaviour) was objectively assessed by using accelerometry (Actigraph GT3X+, Pensacola, FL, USA), affixed on the right hip for seven consecutive days and the first day was omitted from analysis to avoid reactivity. Data analyses were conducted by using the ActiLife 6.11.9 software. Data were collected at a frequency of 30 Hz and were aggregated to 15-second epochs and non-wear time was considered strings of 60 or more minutes of 0 counts. A valid day was one in which the accelerometer was worn for a minimum of 10 h per weekday or 8 h per weekend day. Children had to have at least 4 valid days, with at least 1 weekend day. PA was scored using the Evenson cutoff points[19] to calculate the amount of time spent in sedentary behaviour, light, moderate and vigorous PA.

Participants' actual MC and perceived MC were assessed in their respective school. To assess children's *actual MC* the Test of Gross Motor Development third edition (TGMD-3) Spanish validated version was used.[20] Each participant completed all 13 skills (6 for locomotion and 7 for ball skills) that conform to the TGMD-3; for each skill, task components were marked as "present" = 1 or "absent" = 0. The sum of each skill informs the total skill score ranging 0–100. This test has excellent internal consistency, intra- and inter-rater reliability in children.[20] In the current study, two raters were involved in video coding exhibiting excellent inter-rater reliability (intra-class correlation coefficient, ICC) in overall MC (ICC = 0.96), locomotion (ICC = 0.94) and ball skills (ICC = 0.94), and acceptable to good intra-rater reliability one week apart ($ICC_{overall} = 0.84$, $ICC_{locomotion} = 0.73$, $ICC_{ball\ skills} = 0.78$). Good to excellent test–retest reliability based on 21 videos ($ICC_{overall} = 0.87$; $ICC_{locomotion} = 0.88$; $ICC_{ball\ skills} = 0.95$) was also found. Children's *perceived MC* was assessed by using the pictorial scale of the Perceived Movement Skill Competence (PMSC) Spanish version.[21] It is composed of thirteen pictographic tasks; matched to the skills in the TGMD-3. The perceived MC for each skill was rated on a 4-point scale (with a higher score indicating high perceived competence) following an interview using a dichotomy two staged process. The range of scores for the total scale was 13–52, with subscales ranging from 6 to 24 for locomotion and 7 to 28 for ball skills. This scale has acceptable internal consistency and test–retest reliability for primary school children.[21] The internal consistency of the PMSC measured by the ordinal alpha was 0.77 and 0.80 in overall MC for T1 and T2, respectively; 0.50 and 0.69 in locomotion for T1 and T2, respectively; and 0.73 and 0.74 in ball skills for T1 and T2, respectively.

Height and weight were assessed by using a tape measure and stadiometer scale (SECA, Hamburg, Germany) and a bioelectrical impedance scale (Tanita BC-601, Japan). Following previous procedures,[7] body mass index was determined in accordance with children's sex and age.[22]

Traditional (non-compositional) correlation, multiple linear regression and structural equation modelling (SEM) in both T1 and T2, as well as longitudinal cross-lagged relations over time were conducted by using the SEM approach with Mplus v.8. Model fit was reported as the Comparative Fit Index (CFI) and Root Mean Square Error of Approximation (RMSEA). Values of CFI ≥0.90 and RMSEA <0.10 indicate an adequate fit. The strength of using a cross-lagged model approach is that it explores the autoregressive and cross-lagged pathways, and identifies possible bidirectional relationships of variables over time. The purpose of these analyses is not to compare the findings of standard regression models to findings of compositional regression models, but to complement traditional approaches with compositional data analysis.[23]

So, alternate to the standard arithmetic mean, the compositional mean was obtained by computing the geometric mean for each isolated behaviour and subsequently normalizing the data to the same constant (time-use data) as the raw data.[24] The variability of the data was summarized in a variation matrix that contains all pair-wise log-ratio variances,[18] where a value close to zero indicates that time spent in two respective behaviours is highly proportional. We adopted a CoDA based on an isometric log-ratio (ilr) data transformation, adapted from Hron et al.[25] to adequately adjust the models for time spent in the other behaviours. Briefly, the ilr coordinates were created using a sequential binary partition process. The final ilr's were constructed as normalized log ratios of the geometric mean of parts.[23] All CoDA were conducted in R (http://cran.r-project.org) using the compositions (version 1.40-1), robCompositions (version 0.92-7), and lmtest (version 0.9-35) packages.

The waking day composition (daily time spent in sedentary, light, and MVPA) was referred to in terms of central tendency, i.e. the geometric mean of time spent in each component, linearly adjusted so that all components summed to the waking day for interpretation in minutes per day, which for purposes of this study, was bound to 800 min (i.e., the waking portion of the day in this study). Multivariate dispersion of the composition was described using pairwise log-ratio variation.[18,24]

Multiple linear regression models were used to investigate the relationship between PA composition and each MC tenet (i.e., actual MC, locomotor and ball skills; perceived MC, perceived locomotor and ball skills), with age, sex and BMI as covariables. Prior to inclusion in the regression model, the composition was expressed as a set of two *ilr* co-ordinates. The *ilr* multiple linear regression models were further checked for linearity, normality, homoscedasticity, and outlying observations to ensure assumptions were not violated. The significance of the PA composition (i.e., the set of *ilr* coordinates) was examined with the 'car::Anova()' function, which uses a Chi squared test with a Wald distribution to calculate Type II tests, according to the principle of marginality, testing each covariate after all others.

The above *ilr* multiple linear regression models were used to predict differences in the outcome variables associated with the reallocation of a fixed duration of time (10 min) between two movement behaviours, whilst the third remains unchanged. Ten minute reallocation has been shown to be feasible to be implemented with children and within the school setting.[1] This was achieved by systematically creating a range of new activity compositions to mimic the reallocation of 10 min between all activity behaviour pairs, using the mean composition of the sample as the baseline, or starting composition. These *ilr* differences (each representing a 10 min reallocation between two behaviours) were used in the linear models to determine estimated differences (95% CI) in all outcomes. The same process of *ilr* computation in T1 was repeated for T2.

3. Results

Descriptive statistics of participants' height, weight, body mass index, actual and perceived MC, and PA levels for T1 and T2 as well as correlation analysis are reported in Table 1. When comparing T1 and T2, there were significant mean differences among overall actual MC ($t = -8.73$, $p < 0.01$, $d = 0.62$), locomotion ($t = -6.23$, $p < 0.01$, $d = 0.55$), ball skills ($t = -7.07$, $p < 0.01$, $d = 0.49$), overall perceived MC ($t = 2.40$, $p = 0.02$, $d = -0.22$), perceived ball skills ($t = 2.05$, $p = 0.04$, $d = -0.18$), sedentary ($t = -8.11$, $p < 0.01$, $d = 0.52$), light PA ($t = 9.38$, $p < 0.01$, $d = -0.74$), and MVPA ($t = 6.42$, $p < 0.01$, $d = -0.49$), with actual MC and sedentary behaviour increasing whilst perceived MC, light PA, and MVPA decreasing over time.

Table 1
Descriptive statistics of actual and perceived motor competence (overall, locomotor, and ball skills), and physical activity in time 1 and time 2.

Factors	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. $AMC_{overall}$ T1	70.28	9.83	38.0	90.0	–																
2. $AMC_{overall}$ T2	75.79	8.07	51.0	91.0	0.55^{**}																
3.$AMC_{locomotion}$ T1	33.77	4.52	14.0	45.0	0.71^{**}	0.37^{**}															
4. $AMC_{locomotion}$ T2	35.94	3.34	23.0	42.0	0.43^{**}	0.70^{**}	0.48														
5. $AMC_{ball\ skills}$ T1	36.51	7.24	17.0	50.0	0.85^{**}	0.49^{**}	0.24^{**}	0.24^{**}													
6. $AMC_{ball\ skills}$ T2	39.86	6.47	23.0	52.0	0.46^{**}	0.90^{**}	0.19^{*}	0.31^{**}	0.50^{**}												
7. $PMC_{overall}$ T1	41.34	5.76	26.0	52.0	0.30^{**}	0.09	0.22^{*}	0.07	0.26^{**}	0.07											
8. $PMC_{overall}$ T2	40.10	5.69	24.0	52.0	0.32^{**}	0.17	0.25^{**}	0.11	0.25^{**}	0.16	0.46^{**}										
9. $PMC_{locomotion}$ T1	19.73	2.48	11.0	24.0	0.24^{**}	0.09	0.15	0.10	0.21^{*}	0.06	0.77^{**}	0.29^{**}									
10. $PMC_{locomotion}$ T2	19.21	2.79	11.0	24.0	0.31^{**}	0.12	0.26^{**}	0.12	0.23^{**}	0.08	0.33^{**}	0.83^{**}	0.22^{**}								
11. $PMC_{ball\ skills}$ T1	21.61	4.23	9.0	28.0	0.28^{**}	0.07	0.21^{**}	0.04	0.23^{**}	0.06	0.92^{**}	0.46^{**}	0.46^{**}	0.32^{**}							
12. $PMC_{ball\ skills}$ T2	20.90	3.80	10.0	28.0	0.25^{**}	0.17	0.17	0.07	0.21^{*}	0.18^{*}	0.45^{**}	0.90^{**}	0.27^{**}	0.50^{**}	0.46^{**}						
13. SB T1	420.53	70.63	240.2	596.1	-0.27^{**}	−0.15	−0.18	-0.19^{*}	-0.25^{**}	−0.08	−0.14	−0.06	−0.05	−0.08	−0.17	−0.03					
14. SB T2	460.31	83.45	259.2	761.2	−0.12	−0.11	−0.11	−0.09	−0.09	−0.08	−0.13	−0.10	−0.08	−0.08	−0.13	−0.09	0.68^{**}				
15. LPA T1	306.58	45.68	194.5	431.0	0.02	−0.12	−0.02	−0.07	0.05	−0.12	0.15	−0.11	0.19^{*}	−0.08	0.10	−0.11	-0.48^{**}	−0.17			
16. LPA T2	272.68	46.43	149.5	378.6	0.13	0.07	0.10	0.12	0.10	0.02	0.28^{**}	0.06	0.25^{**}	0.04	0.23^{**}	0.06	-0.23^{**}	-0.34^{**}	0.51^{**}		
17. MVPA T1	71.57	23.34	17.9	126.1	0.30^{**}	0.17	0.28^{**}	0.33^{**}	0.20^{*}	0.02	0.12	0.16	0.08	0.22^{**}	0.12	0.07	-0.52^{**}	-0.36^{**}	0.25^{**}	0.27^{**}	
18. MVPA T2	60.25	23.31	6.9	140.9	0.28^{**}	0.22^{*}	0.22^{*}	0.31^{**}	0.22^{*}	0.09	0.15	0.21^{*}	0.06	0.24^{**}	0.17	0.13	-0.37^{**}	-0.48^{**}	−0.06	0.18^{*}	0.64^{**}

Note. AMC means actual motor competence. PMC means perceived motor competence. SB means sedentary behaviour. LPA means light physical activity. MVPA means moderate-to-vigorous physical activity.
* Significant at $p < 0.05$.
** Significant at $p < 0.01$.

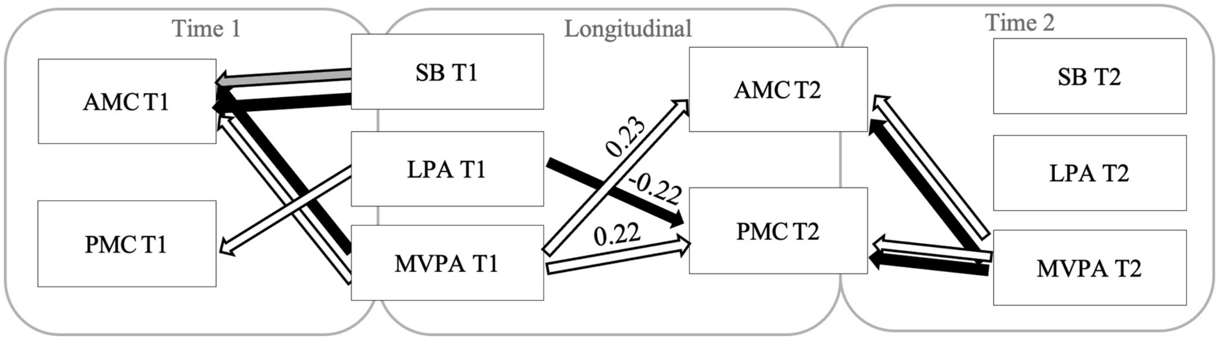

Fig. 1. Cross-sectional (left refers to time 1, right refers to time 2) and longitudinal (middle) pathways summarized for each actual and perceived MC tenant based on the findings of the current study. AMC means actual motor competence. PMC means perceived motor competence. SB means sedentary behaviour. LPA means light physical activity. MVPA means moderate-to-vigorous physical activity. T1 and T2 refer to time 1 and time 2, respectively. Black arrow indicates relation for overall MC, white arrow indicates relation for locomotion whilst grey arrow indicates relation for the ball skill tenant. Path coefficients are standardized. Only significant relations ($p \leq 0.05$) are shown.

Table S1 details the results of the traditional multiple linear regression models and Fig. S1 shows the results of the SEMs. The SEMs indicated that the data fit all age-, sex- and BMI-adjusted models in T1, T2 (Fig. S1) and longitudinal cross-lagged models over time (Fig. S2) (CFI range: 0.998–1.00; RMSEA range: 0.00–0.06). Fig. 1 shows the summarized pathway results of the longitudinal cross-lagged models between PA and actual and perceived MC.

From a compositional approach, the variability of the data for T1 and T2 is summarized in the variation matrix (Table S2) containing all pairwise log-ratio variances. In T1 and T2, time spent in MVPA is the least co-dependent on sedentary time.

Data were considered as a composition, adjusted for age, BMI and sex; in T1, PA composition predicted overall actual MC ($p < 0.0001$; $r^2 = 0.19$), locomotor ($p = 0.001$; $r^2 = 0.15$), ball skills ($p < 0.0001$; $r^2 = 0.22$), overall perceived MC ($p = 0.001$; $r^2 = 0.11$) and perceived ball skills ($p = 0.001$; $r^2 = 0.15$). However, no association was found for perceived locomotor skills ($p = 0.32$; $r^2 = 0.02$) (Table 2). In T2, PA composition predicted overall actual MC ($p < 0.0001$; $r^2 = 0.20$), locomotor ($p = 0.003$; $r^2 = 0.14$), and ball skills ($p < 0.0001$; $r^2 = 0.29$). Moreover, the waking-day composition also significantly predicted perceived MC ($p = 0.004$; $r^2 = 0.13$), perceived locomotor ($p = 0.03$; $r^2 = 0.06$), and perceived ball skills ($p < 0.0001$; $r^2 = 0.17$).

Based on the 95% CI's of isotemporal substitutions, we found in T1 and T2, any reallocation of 10 min between movement behaviours was associated a significant unit-change to actual MC (overall, locomotor, and ball skills). However, in T1, only the reallocation of 10 min between sedentary and light PA was associated with significant unit-changes in perceived MC and perceived locomotion, but not perceived ball skills (Table 2). In T2, the reallocation of 10 min between sedentary and light PA to MVPA was associated with significant unit-changes in perceived MC and perceived locomotion. In T1 and T2, there was no association of any reallocation in perceived ball skills.

4. Discussion

The purpose of the current study was to examine the association between PA domains and MC (actual and perceived), according to the type of FMS (i.e., overall MC, locomotor, and ball skills) in primary school children using traditional and compositional data analysis over time. In line with previous cross-sectional studies,[1,16] an association between movement behaviours with actual and perceived MC was found. Longitudinal evidence suggests that MVPA at T1 contributes to actual and perceived MC in locomotion at T2. Furthermore, adopting a compositional approach, sedentary and light PA maintain a co-dependent

Table 2
Isotemporal substitutions for actual and perceived motor competence, locomotor, and ball skills in Time 1 and Time 2.

Add	Remove	Actual MC	Actual locomotion	Actual ball skills	Perceived MC	Perceived locomotion	Perceived ball skills
		Total (95% CI)	Total (95% CI)	Total (95% CI)	Total (95% CI)	Total (95% CI)	Total (95% CI)
Time 1							
r^2		0.19***	0.15***	0.22***	0.11***	0.02	0.15***
SB	LPA	0.83 (0.57, 1.08)*	0.30 (0.18, 0.42)*	0.53 (0.34, 0.71)*	−0.17 (−0.33, −0.02)*	−0.08 (−0.15, −0.01)*	−0.10 (−0.21, 0.02)
SB	MVPA	−0.94 (−1.36, −0.51)*	−0.38 (−0.58, −0.17)*	−0.56 (−0.87, −0.25)*	−0.10 (−0.36, 0.16)	−0.02 (−0.13, 0.10)	−0.08 (−0.27, 0.11)
LPA	SB	−0.81 (−1.06, −0.56)*	−0.29 (−0.41, −0.18)*	−0.52 (−0.7, −0.34)*	0.17 (0.02, 0.33)*	0.08 (0.01, 0.15)*	0.10 (−0.02, 0.21)
LPA	MVPA	−1.74 (−2.29, −1.20)*	−0.67 (−0.93, −0.41)*	−1.08 (−1.47, −0.68)*	0.07 (−0.26, 0.41)	0.06 (−0.09, 0.21)	0.01 (−0.23, 0.25)
MVPA	SB	0.78 (0.40, 1.15)*	0.31 (0.14, 0.49)*	0.46 (0.19, 0.73)*	0.10 (−0.13, 0.33)	0.02 (−0.08, 0.12)	0.08 (−0.09, 0.24)
MVPA	LPA	1.61 (1.11, 2.11)*	0.61 (0.38, 0.85)*	0.99 (0.63, 1.35)*	−0.08 (−0.38, 0.23)	−0.06 (−0.20, 0.08)	−0.02 (−0.24, 0.20)
Time 2							
r^2		0.20***	0.14**	0.29***	0.13**	0.06*	0.17***
SB	LPA	0.57 (0.36, 0.78)*	0.20 (0.11, 0.29)*	0.37 (0.22, 0.53)*	0.04 (−0.12, 0.19)	0.03 (−0.05, 0.11)	0.01 (−0.09, 0.11)
SB	MVPA	−0.65 (−1.11, −0.19)*	−0.45 (−0.65, −0.26)*	−0.20 (−0.54, 0.15)*	−0.52 (−0.86, −0.19)*	−0.32 (−0.49, −0.15)*	−0.20 (−0.42, 0.02)
LPA	SB	−0.56 (−0.76, −0.35)*	−0.19 (−0.28, −0.10)*	−0.37 (−0.52, −0.21)*	−0.04 (−0.19, 0.12)	−0.03 (−0.10, 0.05)	−0.01 (−0.11, 0.09)
LPA	MVPA	−1.21 (−1.78, −0.64)*	-0.64 (−0.89, −0.4)*	−0.56 (−0.99, −0.13)*	−0.56 (−0.97, −0.14)*	−0.35 (−0.56, −0.13)*	−0.21 (−0.48, 0.06)
MVPA	SB	0.52 (0.13, 0.90)*	0.37 (0.21, 0.54)*	0.15 (−0.14, 0.44)*	0.44 (0.16, 0.72)*	0.27 (0.13, 0.41)*	0.17 (−0.01, 0.36)
MVPA	LPA	1.09 (0.59, 1.59)*	0.57 (0.35, 0.79)*	0.52 (0.14, 0.90)*	0.48 (0.11, 0.85)*	0.30 (0.11, 0.48)*	0.18 (−0.06, 0.42)
Δr^2 (T1-T2)		0.01	−0.01	0.07	0.02	0.04	0.02

Note. Actual MC means overall actual motor competence. Perceived MC means overall perceived motor competence. SB means sedentary behaviour. LPA means light physical activity. MVPA means moderate-to-vigorous physical activity. r^2 refers to the percentage of variance explained from multiple linear regression models. Δr^2 refers to the combined compositional regression.

* Significant at $p < 0.05$, based on 95% CI except r^2 values.

** Significant at $p < 0.01$.

*** Significant at $p < 0.001$.

behaviour, whilst MVPA is the least dependent domain of sedentary behaviour. Our findings also exhibited that compositions with more time in higher intensity activities may be better for MC proficiency; these results were consistent at baseline and in the one-year follow-up.

Indeed, traditional regression analyses and PA composition explained MC consistently (overall MC and ball skills) in both T1 and T2, which supports previous findings in primary school children.[16] In addition, regardless of children's age, sex and BMI, from every analytical approach the combination of movement behaviours predicted actual and perceived MC (overall and ball skills) in both T1 and T2. This is also corroborated in the SEM analysis over time (Fig. 1). Concordant with the conceptual model of motor development,[8] wherein it is postulated that, in childhood, the higher the PA participation the larger the increase of the MC level, cross-lagged analyses showed MVPA is associated with actual and perceived MC in locomotion longitudinally. In addition, according to the compositional approach slight increases in the percentage of variance explained in actual and perceived MC, mainly in actual ball skills, by PA composition from T1 to T2 were found. Although a previous study in early childhood did not find a longitudinal association between PA at 3.5 years-old with actual overall MC and ball skills at 5 years-old,[14] and a recent systematic review[11] highlighted the indeterminate evidence (because of inexistence of sufficient amount of studies) to support the longitudinal pathway PA–MC in locomotion and ball skills, SEM and compositional evidence seems to clarify the existence of such longitudinal relationship. As a result, PE teachers and practitioners should promote enjoyment and facilitate children PA participation because it is associated with the development of health-related aspects such as MC.[1,16] So, based on the longitudinal correlated evidence, it is recommended that future interventions seek to enhance children's motor development by focusing on increasing MVPA and fostering FMS.

Reallocation of PA domains suggested that a greater proportion of time spent in MVPA relative to light PA and/or sedentary behaviour was associated with increases in actual MC that were consistent in T1 and T2, regardless the type of FMS. This is a salient finding because it might help to provide novel insights into the impact of school time behaviours; in academic classes, children spend around 70% of the time engaged in sedentary behaviour in the classroom[26] which, due to the rigid school schedule, is not easily adapted. Likewise, strategies of replacing sedentary behaviour or light PA in favour of MVPA would likely be associated with increases in MC. Systematic review evidence suggests that teaching outdoors, decreasing class size, applying active breaks/classes and fostering perceived competence are associated with increases in PA levels[27] which, in turn, according to our longitudinal results, can be associated with empowering actual and perceived MC in locomotion over time. However, recurrent recommendations focused on recess as an ideal leisure space for active playing and socializing to promote MVPA might not be as effective as originally expected, and indeed recent meta-analyses have exhibited that school-based interventions have little or no effect in leisure and school time MVPA.[28] So, an alternative and effective method to increase MVPA could be made by considering structural changes, such as the integration of movement within the academic lessons[29] that is, to reallocate 10 min of sedentary behaviour or light PA to MVPA per day, because it may facilitate improvements in actual MC.

This is concordant with previous CoDA studies by Burns et al.[16] and Mota et al.,[1] who suggested that increases of MVPA at the expense of light PA resulted in higher levels of actual MC. In T1 and T2, the proportion of time spent in MVPA at the expense of 10 min changes in light PA and/or sedentary behaviour showed similar results in locomotor and ball skills. On the contrary, the association between substitutions of PA domains and perceived MC exhibited inconsistent findings in T1 and T2. Whereas in T1, 10 min reallocation of sedentary behaviour in favour of light PA resulted in increases of perceived overall MC and locomotor skills (Table 2), in T2, the isotemporal substitution exhibited a different path. That is, in T2, reallocations between sedentary behaviour and light PA and vice-versa did not indicate any association with perceived MC, but a greater proportion of time spent in MVPA relative to light PA and/or sedentary behaviour was associated with increases in perceived overall MC and locomotor skills. Furthermore, longitudinal SEM approaches showed that MVPA is associated with increases in perceived locomotion, but light PA might negatively influence perceived MC one year later. So, when considering the association of PA with perceived MC in childhood, researchers should be cautious because even children seem to have limited ability to accurately estimate their MC[30]; indeed, perceived MC is dynamic and dependent on children's sex and the type of FMS,[7] and this is a sensible period wherein cognitive development matures and perception starts becoming more aligned with the reality[30] which might be influenced by movement behaviour. In light of our longitudinal results, wherein both increasing MVPA is associated with an enhancement in actual and perceived locomotion, but not in ball skills, and increasing light PA is related to decreases in perceived overall MC, perceived locomotion skills seem to be an appropriate target variable to be considered when the effect of movement behaviour is analysed in the field of motor development.

From a methods perspective and the influence of PA in MC, traditional cross-sectional designs might not provide a complete picture of the children's perceived MC development in relation to their movement behaviour. Indeed, in line with the longitudinal negative influence between light PA and perceived overall MC, a previous longitudinal study analysing actual and perceived MC in relation to PA[7] showed low PA is associated with low perceived MC, which in turn highlights perceived MC can be also an adaptable key factor to be targeted in interventions. In sum, and according to our reallocated findings, future interventions aimed to improve children's lifestyles should be focused on increasing high-intensity PA, actual MC, and perceived locomotor skills.

A salient aspect of the current study is that totally aligned instruments of actual (TGMD-3) and perceived MC (PMSC) assessments were used, which offers an insight in clarifying the longitudinal association between PA with actual and perceived MC. The full MC instrument alignment helps to understand how the association between PA and MC varies as means of the type of FMS (locomotor and ball skills) and MC assessment (objective or subjective) rather than the type of construct related to self-perception (e.g., perceived MC or physical self-perception).[30] Though a novel and appropriate method, characterized by the combination of traditional and CoDA, was used, which supports the indeterminate or null evidence regarding the association between PA and MC,[11] this study is not absent of limitations. 1) Even though an a priori sample size calculation was conducted, no generalizability analysis has been computed, furthermore, cross-sectional and prospective approaches should be considered with caution, because of the lack of causality inferences. 2) Twelve children were excluded from the analyses because of some missing data, due to the potential impact on the results and conclusion, nevertheless, future studies should consider including participants with missing data into the analyses. 3) In spite of evidence of validity and reliability in both TGMD-3 and PMSC, limited reliability for perceived MC in locomotion was found, which might impact the association with movement behaviours. As individual interviews are necessary for assessing perceived MC, they are time consumptive and provide limited reliability; thus, we suggest new methods of assessment (e.g., supervised group administration) be considered. 4) The association of PA with MC was analysed in locomotor and ball skills, but not in stability skills. In order to examine the association of PA domains with actual and perceived MC thoroughly, future studies should use similar approaches to analyse the three types of FMS, stability, locomotor, and ball skills.

5. Conclusion

In addition to the analytical approaches of PA, the relevance of this study lies in the combination of cross-sectional and longitudinal designs and the thorough examination of the children's MC by assessing actual and perceived MC (overall MC, locomotor and ball skills) using fully-aligned instruments. Regardless of age, BMI, and sex, high-intensity PA predicted actual and perceived MC in locomotion over time. In addition, PA domains and compositions explained percentages of actual and perceived MC in T1 and T2. The degree to which PA composition explains MC depends on the type of FMS, mainly in perceived MC. Although PA composition explained perceived ball skills, it did not predict perceived locomotor skills in T1 and T2. Substitutions in PA to MVPA influenced actual MC over time, and, regardless of the type of FMS, changes from light PA to MVPA exhibited the highest impact in actual MC, and this was consistent over time.

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Declaration of interest statement

The authors of this study do not have any conflict of interest.

Confirmation of ethical compliance

The Institutional Review Board of the University of Valencia approved the current study design (H1446557620395).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2022.05.010.

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