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Classes of developmental trajectories of body mass index: Differences in motor competence and cardiorespiratory fitness

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ABSTRACT

The purpose was to identify classes of different developmental trajectories of BMI and testing them for differences in motor competence (MC) and cardiorespiratory fitness (CRF), in children and adolescents (4 to 13 years of age). This was a 5 years' longitudinal study with six cohorts. One hundred and forty-seven children (69 girls) divided into six cohorts participated. At baseline, the youngest and the oldest cohorts had 4 and 11 years of age, respectively. Height and weight were assessed, and BMI was calculated. MC was assessed with KTK and TGMD-2, and CRF was assessed with one-mile run/walk. Developmental trajectories of BMI were identified using latent class linear-mixed modelling. Latent class membership was explained according to covariates of MC and CRF. Two meaningful classes were identified. Class 1 (78.92% of the participants) showed lower initial BMI and a lower slope compared to class 2 (21.08% of the participants) (all ps < 0.001). Class membership only predicted trajectories in motor coordination, with children in class 1 having a better development.

In conclusion, this study identified two meaningful trajectories for children based on their BMI development across five time points. In line with previous research, children with slower increasing BMI showed better motor coordination improvements.

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KEYWORDS
Obesity; physical activity; motor skills; motor performance; longitudinal study

Introduction

Many recent studies have focused on understanding the relationships between motor competence, that is defined as a person's proficiency to execute motor skills (Utesch & Bardid, 2019) [see also Logan, Ross, Chee, Stodden, and Robinson (2018) and Utesch et al. (2016)], and health-related behaviours and attributes, like PA and body mass index (BMI). A meta-analysis on the relationships among motor competence (MC) and associated health benefits in children and adolescents (Lubans, Morgan, Cliff, Barnett, & Okely, 2010) indicated an inverse association between MC and weight status, and a positive relationship with PA, several facets of health-related physical fitness, and perceived MC. In both cross-sectional and longitudinal data, it is suggested that MC may be an important antecedent/consequent mechanism for promoting many aspects of health-related behaviours. Stodden et al. (2008) proposed a developmental and recursive model advocating that obesity trajectories may be triggered by the cumulative effects that lower levels of MC has on reducing movement opportunities, physical fitness, and perceived MC during childhood.

Several longitudinal research demonstrated the positive role of MC on the development of PA (Lopes, Maia, Rodrigues, & Malina, 2011; Utesch, Dreiskämper, Naul, & Geukes, 2018) subcutaneous adiposity levels (Lopes, Maia, Rodrigues, & Malina, 2012), and body mass index (BMI) (Martins et al., 2010) during childhood.

According to Stodden et al. (2008) model, physical fitness act as a mediator between MC and weight status, and several studies have shown its importance for a healthy weight status development during childhood (Lopes et al., 2012; Rodrigues, Stodden, & Lopes, 2016). Additionally, Lima et al. (2017) found that cardiorespiratory fitness (VO2peak) and MC were better body fatness predictors than physical activity, and that cardiorespiratory fitness had the largest negative association with body fatness.

From a longitudinal perspective, the use of individual developmental trajectories, or qualitatively meaningful classes/clusters of development trajectories, as opposed to a single measure in time and/or fixed effect, can be more appropriate to test the overall model. This way of looking for the developmental changes in the determinants of a healthy lifestyle has not been yet fully achieved. Some attempts have been made, namely when developmental trajectories of MC and physical fitness from 6 to 10 years-of-age proved to be predictors to weight status at the age of 10 (Rodrigues et al., 2016).

The purpose of this study was to identify in children and adolescents between 4 and 13 years of age, classes of different developmental trajectories of BMI and testing it for differences in MC and cardiorespiratory fitness development. Our hypothesis was that children with higher BMI at 4 years of age, and manly children that demonstrate a larger increase over time will display lower motor competence and cardiorespiratory fitness development.

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Methods

We conducted a longitudinal study lasting 5 years that has started in 2009, combining 6 different cohorts with, respectively, 4, 5, 6, 7, 8, and 9 years of age at baseline. All measurements were done in the fall of each year.

Children were recruited as a convenience sample in four schools in the northeast region of Portugal. Permission was obtained from the respective school director, parents or guardians gave informed consent, and children assented. A total of 144 children (68 girls, 47.2%) participated in the study and were grouped in 6 ascending age cohorts (Table 1 in supplemental material). At baseline children of all cohorts were classified in stage I or II of sexual maturation (Morris & Udry, 1980). All children were assessed in their attended school, during the morning period. Trained research assistants, supervised by one of the authors, conducted the assessments. The ethics committee of the institution of the first author approved this study.

Stature and body mass were measured using a stadiometer (Seca, model 217) and a scale (Seca, model 869). Values were recorded to the nearest 0.1 cm and 100 g, respectively. The BMI, weight (kg)/height squared (m^2), was calculated.

Motor competence was assessed with the body coordination test for children (KTK) (Kiphard & Schilling, 1974, 2007), and with the Test of Gross Motor Development Second Edition (TGMD-2) (Ulrich, 2000). Given the MC definition (Utesch & Bardid, 2019) as well as established motor competence models (i.e., locomotion, object control, coordination/stability); (cf. Rudd et al., 2015) the two battery tests were included since they are complementary in the evaluation of children MC, given that one assesses motor skills and the other motor coordination.

The KTK battery consists of four items:

(1) Balance – each child walks backwards three times on three balance beams 3 m in length with decreasing widths: 6 cm, 4.5 cm, 3 cm; the number of successful steps is recorded per trial with a maximum of 72 steps.
(2) Jumping laterally – the child jumps consecutively from side to side over a small beam (60 cm x 4 cm x 2 cm) as fast as possible for 15 sec. The number of correct jumps is recorded and averaged across two trials.
(3) Hopping on one leg over an obstacle – the child is instructed to hop on one foot at a time over a stack of foam squares (50 cm x 20 cm x 5 cm). The first, second or third trial of each height was awarded by three, two or one point(s), respectively. The maximum test score was 39 points for each leg, resulting in a maximum of 78 points with both legs.
(4) Shifting platforms – The children had two identical wooden platforms (size 25 cm × 25 cm, height 5.7 cm) and after stepping to one, they had to transfer another one sideways for the next transition. The total of transitions was summed over two 20-s trials.

The final "motor quotient", a global indicator of motor coordination adjusted for age and gender, was calculated using the four items (Kiphard & Schilling, 1974, 2007).

The TGMD-2 consists of two subtests with 6 gross motor skills each: object control skills (catch, striking a stationary ball, stationary dribble, overhand throw, underhand roll and kick) and locomotor skills (hop, run, gallop, slide, horizontal jump and leap) (Ulrich, 2000). Each gross motor skill consists of 3 to 5 behavioural components that are individually rated as performance criteria. Each participant was videotaped performing one practice trial, followed by two trials that were rated. The sum of the observed successfully performed criteria for each subscale comprises the total raw score (0–48 points).

Cardiorespiratory fitness was evaluated with the one-mile run/walk. The test consists on running one mile, in a flat ground, in the fastest possible time. If participants desire, walking may be interspersed with running, however, they were encouraged to cover the distance in a short a time as possible. The one-mile run/walk test is easy to administer and particularly useful for unmotivated or unfit children, it has good intraclass reliability (0.83) for both boys and girls in Grades 2 to 4 (Rikli, Petray, & Baumgartener, 1992) (Sung, Collier, DuBose, David Kemble, & Mahar, 2017), but less reliable for children in Grades K and 1 ($.34 < R < .56$) (Rikli et al., 1992). Its criterion-related validity using VO2max is moderate ($r = -0.59$). Reliability for the present study was estimated by the extrapolation to a zero-interval of a linear regression between the inter-age correlations at different intervals, and the correspondent age interval., the result found was 0.60.

Descriptive statistics (mean and standard deviation) were calculated for all variables for boys and girls. A linear-mixed modelling was conducted to estimate the overall (fixed effects) and individual within (random effects) developmental trajectories of BMI. The multilevel modelling approach is an appropriate analysis especially for longitudinal data, because it considers the nested structure of the data (Snijders & Bosker, 2011). In this study, data was nested as measurement time/age (level 1) within individual children (Level 2). Using a conditional empty model, we estimated the variance components within individuals (across time) and between individuals and demonstrated that 18.9% of the variance in BMI was on the within-person level and 81.1% of the variance in BMI was on the between-person level. Therefore, we decided to run a series of models to identify and cluster different idiosyncratic developmental trajectories of BMI development.

The first model examined the change of BMI from the first to the fifth measurement time point. To do so, we have included a time variable into the model (coded 0, 1, 2, 3, 4). In addition, we allowed individual differences in BMI starting point by adding a random intercept and tested if a random slope (individual development) significantly improved the model. Furthermore, this first model was updated with the starting age of all persons

Table 1. Sample characteristics.

Cohort	*n*	Age									
1	11	4	5	6	7	8					
2	12		5	6	7	8	9				
3	28			6	7	8	9	10			
4	42				7	8	9	10	11		
5	36					8	9	10	11	12	
6	15						9	10	11	12	13

as a control variable for the cohort design in order to check if BMI development was different between age groups (interaction). Only the best and final model is presented in the results section. Significance level was set to $p < .05$.

In a second step, we used latent class analysis to explore qualitatively meaningful between-person similarities (groups/clusters) in the within-person developmental trajectories. These models are called latent class linear-mixed models or heterogeneous linear-mixed models. In these models, it is assumed that populations – for instance, the qualitatively different developmental trajectories – are generally divided in a finite number of qualitatively meaningful latent classes (i.e., groups of participants). Each latent class is then characterised by an individual fixed trajectory that is modelled by a class-specific linear-mixed models. The final model (i.e., final number of latent classes) is identified by inspecting the log-likelihood function and corresponding relative model fit between all estimated models using Bayesian Information Criteria (BIC). The BIC adjusts the predictive accuracy of a model relative to its parsimony (complexity) and has a global minimum for a final number of classes. Therefore, a series of models with an increasing number of latent classes (starting with one latent class) and sex as a covariate are estimated and the model with the lowest BIC will be selected. As a follow up, children's latent class membership will be explained according to covariates of motor performance (i.e., motor competence, cardiorespiratory fitness).

Statistical analyses were executed using *R* (R Core Team, 2015) and primarily the *nlme* (Pinheiro, Bates, DebRoy, Sarkar, & Core Team, 2018) and *lcmm* packages (Proust-Lima, Philipps, & Liquet, 2017). Open code is provided in this study (osf.io/blind for review).

Results

Descriptive statistics (mean and standard deviation) for somatic variables (height, weight, and BMI) are shown in Table 2 (supplemental material) and in Table 3 (supplemental material) the descriptive statistics for MC and cardiorespiratory fitness variables are presented. The results are presented for boys and girls by year (measurement time point) and by cohort.

Results from the multilevel models are presented in Table 4. The covariate sex did not have an effect in any of the models and was therefore omitted in the final model. Results from the first and second model that included the time variable as well as the covariate cohort (i.e., starting age of the children) showed that older children start with higher BMI (b = 0.43, p = 0.002), but there was no interaction effect (p = 0.842) indicating any difference in their developmental trajectories. However, time was a significant predictor of BMI (b = 0.49, p < 0.001) and adding the random effect time (re = 0.43) to the model improved the model significantly (p < 0.001). Based on this finding, the latent class linear-mixed model was estimated as a third model. Two latent classes showed the best model fit as indicated by the minimum of the BIC with 78.92% of the participants in class 1 and 21.08% in class 2 (Table 5). Beyond the BIC, class membership indicates descriptively, that the 3-class solution and the 4-class solution were not meaningfully improving the model fit, because they splitted existing classes with less

Table 2. Means and standard deviations for height, weight, and BMI for boys and girls in each year of evaluation by cohort.

			Cohort											
			1		2		3		4		5		6	
Year			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Girls	0	Height	102.0	3.7	112.2	3.9	119.3	6.0	123.3	4.7	129.5	4.7	134.7	6.1
		Weight	17.2	1.4	23.3	3.7	23.3	4.7	26.8	4.9	32.4	6.2	32.7	4.0
		BMI	16.5	0.5	18.4	2.3	16.2	1.9	17.6	2.6	19.2	2.9	18.0	1.8
	1	Height	106.4	2.3			126.8	8.0	126.9	5.5	134.1	5.1	138.9	6.3
		Weight	18.5	2.3			29.3	5.9	27.8	5.7	35.6	7.0	34.8	3.9
		BMI	16.3	1.4			18.1	1.9	17.1	2.4	19.7	3.0	18.1	1.7
	2	Height					133.0	6.5	135.3	5.1	138.2	6.3		
		Weight					31.3	6.2	35.1	7.1	36.8	8.8		
	3	Height	118.4	4.6	129.4	4.7	136.2	6.9	139.4	5.8	145.9	5.8	151.7	5.3
		Weigh	23.8	4.3	34.3	7.0	33.5	6.7	37.4	8.9	42.2	8.1	45.5	8.6
		BMI	16.9	2.3	20.4	3.2	18.0	2.7	19.1	3.8	19.7	3.1	19.7	2.9
	4	Height	124.5	4.8	135.1	5.6	142.5	8.0	144.8	7.0	151.2	6.3	156.5	4.7
		Weight	27.0	5.7	39.3	9.0	38.8	8.5	42.9	11.1	48.0	9.4	47.5	6.1
		BMI	17.3	2.9	21.4	3.5	18.9	2.7	20.3	4.2	20.9	3.5	19.4	2.2
Boys	0	Height	108.5	4.0	112.4	5.2	120.6	4.7	123.2	6.3	132.2	8.1	135.0	4.1
		Weight	20.7	2.7	20.3	3.3	25.3	4.3	28.3	5.6	33.0	7.9	33.7	5.4
		BMI	17.6	2.3	16.0	1.6	17.3	2.0	18.6	2.9	18.7	2.6	18.4	2.1
	1	Height	113.9	3.1	116.8	5.4	127.8	2.0	128.2	6.7	138.0	10.9	143.7	6.1
		Weight	22.7	3.1	22.4	2.6	31.7	4.0	30.4	5.0	38.1	8.9	39.5	10.1
		BMI	17.5	2.5	16.4	1.9	19.4	2.7	18.6	3.2	19.8	2.8	19.0	3.1
	2	Height			127.0	13.5	134.8	5.2	135.9	6.4	142.3	10.3		
		Weight			28.0	12.3	32.2	6.1	35.2	7.4	41.3	16.9		
	3	Height	124.4	2.1	130.3	6.4	137.5	5.0	139.3	6.5	147.7	8.9	150.2	5.2
		Weight	27.8	3.0	30.6	7.2	35.0	7.9	37.2	7.3	45.6	11.4	42.4	6.5
		BMI	17.9	1.9	17.9	2.8	18.4	3.5	19.1	2.9	20.7	3.3	18.7	2.1
	4	Height	131.4	3.1	135.7	6.6	143.6	6.0	142.9	5.9	153.5	10.8	156.6	7.0
		Weight	34.5	5.4	35.0	9.5	40.1	9.9	41.0	9.0	50.6	13.8	48.8	8.3
		BMI	19.9	2.7	18.7	3.4	19.3	4.0	20.0	3.7	21.2	3.8	19.9	2.9

Note. BMI = body mass index.

Table 3. Means and standard deviations for KTK, one-mile run/walk, object control and locomotor skills, for boys and girls in each year of evaluation by cohort.

			Cohort											
			1		2		3		4		5		6	
Year			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Girls	0	KTK			78.3	6.7	73.2	5.3	69.7	12.3	67.1	11.7	61.4	9.8
		OC	16.5	5.5	25.3	2.8	23.6	6.5	26.8	8.0	28.2	6.2	30.7	7.4
		LO	24.0	6.2	34.3	2.9	33.3	6.9	34.3	4.1	35.2	5.4	35.7	3.9
		1 mile					14.1	1.2	14.6	1.7	16.1	2.9	12.9	1.8
	1	KTK					83.3	3.3	84.4	13.8	83.3	20.0	81.9	11.9
		OC	17.0	7.0	25.0		32.8	5.1	34.0	6.5	35.3	5.6	36.6	5.1
		LO	20.3	14.4	38.0		34.8	11.6	39.0	5.4	42.4	2.8	43.8	3.3
		1 mile					12.6	1.2	14.7	2.4	14.5	2.6	13.8	2.3
	2	KTK					87.8	11.8	79.4	12.2	71.3	23.8	76.0	
		OC					37.3	5.7	36.7	4.4	34.4	7.6	30.0	
		LO					41.6	4.7	42.7	3.6	42.6	4.8	41.0	
		1 mile					14.7	2.2	14.5	2.2	15.1	2.4	15.7	
	3	KTK	90.8	11.9	85.3	5.4	82.1	10.8	74.8	12.8	80.5	15.5	82.6	10.2
		OC	23.8	9.1	28.3	3.3	29.7	6.4	27.1	6.0	25.9	3.7	27.8	4.7
		LO	32.5	4.0	32.5	1.3	31.9	4.3	33.9	4.4	32.9	4.4	31.3	5.3
		1 mile	14.2	3.8	15.9	1.1	12.4	1.2	13.0	2.4	13.0	2.3	11.9	1.7
	4	KTK	97.0	15.6	87.5	5.8	84.2	11.4	78.0	14.3	84.0	20.3	82.3	9.4
		OC	31.5	7.0	32.8	5.6	35.0	6.2	33.3	5.6	38.0	3.7	36.6	4.9
		LO	37.0	6.2	39.0	5.0	39.5	6.9	37.8	5.0	41.5	2.5	37.8	8.0
		1 mile	12.2	2.7	12.7	.2	13.6	1.8	13.1	1.9	11.9	2.2	10.5	1.8
Boys	0	KTK			87.7	8.5	78.0	8.7	75.7	14.0	71.8	13.1	81.7	9.8
		OC	22.7	6.6	24.5	4.7	29.8	6.7	32.1	7.1	34.1	6.1	34.5	5.8
		LO	22.6	8.8	30.6	9.4	34.0	7.6	36.1	5.1	35.3	4.8	37.0	4.5
		1 mile					12.4	1.5	12.8	2.1	13.0	5.0	10.3	2.4
	1	KTK			92.0		81.3	10.5	84.7	13.3	81.2	15.5	89.3	15.1
		OC	28.2	7.6	33.4	5.4	33.0	10.5	36.3	5.8	40.5	3.4	42.3	2.3
		LO	30.4	11.2	34.2	8.0	32.3	10.2	42.1	5.6	40.9	5.1	41.3	9.0
		1 mile			12.2		14.6	2.2	12.9	3.1	12.1	2.5	11.7	4.3
	2	KTK			98.5	12.0	87.4	12.0	90.0	14.7	79.8	11.2		
		OC			32.0	4.2	39.3	4.5	40.4	6.2	42.2	1.9		
		LO			45.5	.7	40.6	5.7	40.9	4.4	39.0	9.3		
		1 mile			13.9	4.6	12.0	2.7	12.2	2.5	13.7	2.4		
	3	KTK	94.3	9.9	90.5	7.4	85.0	14.1	86.3	16.5	78.8	17.6	91.7	15.7
		OC	27.8	10.8	29.5	8.0	36.6	6.7	34.6	4.9	33.4	5.2	37.0	3.8
		LO	32.5	7.8	31.5	3.4	30.8	4.7	33.9	5.8	32.3	3.4	37.5	5.1
		1 mile	13.3	1.0	10.2	1.3	10.6	2.0	11.3	3.0	11.0	2.8	9.2	1.8
	4	KTK	100.0	3.6	97.3	11.6	88.3	10.0	92.4	20.1	83.7	19.6	99.2	9.1
		OC	40.0	4.2	39.8	5.2	38.4	6.3	42.5	3.5	40.6	4.1	44.3	2.1
		LO	38.3	6.2	43.2	4.5	37.7	8.0	41.8	4.1	38.9	5.0	40.3	6.7
		1 mile	15.9	1.2	11.9	1.5	11.7	1.5	11.1	2.6	11.6	4.1	9.9	3.9

Note. KTK = body coordination test for children; OC = object control skills; LO = locomotor skills; 1 mile = One mile run/walk.

than 2% membership in some classes. Participants in class 1 can be described as children that start with a lower BMI (I_{C1} = 16.80, $p < 0.001$) compared to class 2 (I_{C2} = 21.50, $p < 0.001$). Further, participants in class 2 (b_{C2}= 0.72, $p < 0.001$) show greater BMI increase over time compared to their peers in class 1 (b_{C1}= 0.42, $p < 0.001$). Results from random effects indicate that there is a similar intercept variance and that the random slope variance has substantially decreased in model 3 compared to model 1 and model 2.

After the 2-class solution fitted the data best, class-specific characteristics were explored in terms of the corresponding developmental trajectories in motor competence (i.e., coordination, object control, locomotion) and cardiorespiratory fitness. However, class membership of different qualitatively meaningful developmental trajectories in BMI did neither predicted participants' cardiorespiratory fitness nor locomotor or object control skills level (all ps > 0.05). Furthermore, class membership did only predicted trajectories in coordination, with children in class 1 showing a more positive development ($b = -1.44$, $p = 0.039$; cf. Table 6).

Discussion

The purpose of the present study was to identify qualitatively meaningful classes of children that showed similar developmental trajectories of BMI during childhood (4 to 13 years of age), and testing it for differences in the physical performance development (i.e., MC and cardiorespiratory fitness). Two meaningful classes were identified. Participants in class 1 can be described as children with a lower BMI at 4 years of age and with lower BMI increase over time, till 13 years of age. On the contrary, children in class 2 have a higher baseline BMI and a greater BMI increase over time. As our hypothesis predicted participants with lower initial BMI, and lower BMI increase over time, presented better motor coordination development. However, object control and locomotor skills proficiency over time were not significantly different between the two BMI trajectories' classes, and the same pattern was shown for cardiorespiratory endurance.

Despite most of the previous studies on this thematic were cross-sectional, the results of the present study are in line with

Table 4. Summary of unstandardised estimates of multilevel models to predict BMI trajectories.

	Model 1			Model 2			Model 3		
	b	se	p	b	se	p	b	se	p
Fixed Effects									
Intercept class 1	14.60	1.01	< 0.001	14.64	1.03	< 0.001	16.80	0.21	< 0.001
Intercept class 2							21.50	0.47	< 0.001
Time class 1	0.49	0.04	< 0.001	0.53	0.22	0.020	0.42	0.05	< 0.001
Time class 2							0.72	0.11	< 0.001
Cohort	0.43	0.13	0.002	0.42	0.13	0.002			
Time * Cohort				−0.006	0.03	0.842			
Sex									
Random Effects									
Intercept	2.34			2.34			2.04		
Time	0.43			0.44			0.16		
Residual	0.76			0.75			0.75		

Note. Model 1 = final conventional linear-mixed growth model controlled for the cohort. Model 2 = linear-mixed growth model controlled for cohort and interaction of the cohort. Model 3 = final latent class linear-mixed model.
The covariate sex did not have an effect in any of the models and was therefore omitted.

Table 5. Summary and class membership of latent class linear-mixed modelling.

Nr of latent classes	loglik	npm	BIC	% Class 1	% Class 2	% Class 3	% Class 4
1	−980.78	6	1991.51	100			
2	−968.38	9	1981.68	78,92	21,08		
3	−958.87	14	1987.61	78,23	1,36	20,41	
4	−958.70	18	2007.24	35,37	42,85	1,36	20,42

previous research that demonstrated the negative associations between MC and BMI (D'Hondt, Deforche, Bourdeaudhuij, & Lenoir, 2009; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012). The results are also concordant with researches that used BMI to classify children weight status, proving that overweight children had worse MC than normal weight children (D'Hondt et al., 2011; Lopes, Stodden, & Rodrigues, 2014). It should be noted that the present investigation is longitudinal, which emphasises even more the relationship between BMI and MC in the development of a healthy weight status and higher levels of MC. Several longitudinal studies found that, during childhood, MC predicted BMI and other body fat indicators (Lopes et al., 2012; Martins et al., 2010), showing the positive role of MC on the development of a healthy weight. In the present research, we found that worse BMI development aligns with negative MC development during childhood, but not necessarily with cardiorespiratory fitness development. This is in consonance with a study by Cheng et al. (2016) that found that obesity leads to declines in MC levels across childhood and not the reverse. According to Robinson et al. (2015) the relationship between MC and BMI may have reciprocal effects, that is, MC could be both an antecedent and a consequence of weight status. And in fact, D'Hondt et al. (2014) found in a short-term longitudinal study in children (5–13 years) that a lower MC at baseline significantly predicted an increase in BMI, and conversely, a higher baseline BMI also predicted a decrease in MC.

We did not find significant differences between the two classes of participants with different trajectories of BMI development in the development of object control and locomotion skills, which also belong to the MC construct as motor coordination (Utesch & Bardid, 2019; Utesch et al., 2016). The assessment used (TGMD-2) is a process-oriented motor test that aiming to assess the quality of children's' motor skills from ages 3 through 10. However, it has been shown that it has a low sensitivity to differentiate children's performance and age-related improvements, especially with high proficiency, and in particular in locomotor skills (Bardid et al., 2016; Logan, Barnett, Goodway, & Stodden, 2017; Rocha, Marinho, Jidovtseff, Silva, & Costa, 2016). In fact, the reference population of the TGMD-2 shows a ceiling effect for both locomotor and object control scores in older children (Ulrich, 2000). This low sensitivity might have affected the possibility to assess within person developmental differences in the two classes showing different BMI trajectories.

The two classes of BMI development did not show significant differences in the development of cardiorespiratory endurance (one-mile run/walk test), contrary to our expectation. Actually,

Table 6. Summary of unstandardised estimates of multilevel models to predict motor performance trajectories based on BMI class membership.

	KTK			1 Mile			Object control			Locomotion		
	b	se	p	b	se	p	b	se	p	b	se	p
Fixed Effects												
Intercept	80.75	5.96	< 0.001	18.67	1.05	< 0.001	15.05	1.98	< 0.001	24.45	2.05	< 0.001
Sex	5.81	1.95	0.004	−1.72	0.31	< 0.001	4.70	0.68	< 0.001	−0.29	0.71	0.683
Cohort	−0.90	0.77	0.244	−0.58	0.13	< 0.001	1.79	0.26	< 0.001	1.53	0.27	< 0.001
Time	3.28	0.33	<0 .001	−0.49	0.09	< 0.001	1.46	0.21	< 0.001	0.63	0.20	0.001
Class	8.09	17.87	0.065	−0.80	2.89	0.781	0.48	5.22	0.926	0.61	5.42	0.910
Time * Cohort	−1.65	2.20	0.455	0.32	0.35	0.351	−0.28	0.65	0.672	−0.25	0.68	0.716
Time * Class	−1.44	0.70	0.039	−0.001	0.18	0.999	0.13	0.43	0.763	−0.21	0.41	0.613
Random Effects												
Intercept	9.66			1.64			2.36			2.86		
Time	1.92			0.49			0.07			0.01		
Residual	7.63			1.90			6.26			5.91		

Note. Class is coded as follows: 0 = class 1 (i.e., lower BMI intercept and lower BMI development) and 1 = class 2 (i.e., higher BMI intercept and higher BMI development).

several studies demonstrate a negative relationship between BMI and cardiorespiratory endurance. For instance, McGavock, Torrance, McGuire, Wozny, and Lewanczuk (2009) found that reductions in cardiorespiratory endurance were significantly associated with increasing BMI in youth. And, consequently, low cardiorespiratory endurance over time was significantly associated with weight gain and the risk of overweight in children 6–15 years old. Lopes et al. (2012) found that three physical fitness items (muscular strength and endurance, and cardiorespiratory endurance) and MC had a positive influence on body fat, attenuating the accumulation of subcutaneous adipose tissue during childhood (from 6 to 10 years of age). Rodrigues, Leitão, and Lopes (2013) found that several physical fitness test performance, including a cardiorespiratory endurance test (PACER), predicted changes on body fat growth over a 9-year period ranging from childhood (age 6) to adolescence (age 15) independently of sex. Rodrigues et al. (2016) found that children with a low rate of change in their developmental pathways of fitness demonstrated over a six-fold elevated risk (OR = 6.3) to become overweight or obese, compared to peers with a positive pathway. Despite the results of the present study are not totally aligned with the research found in the literature, children in class 1 (i.e., lower BMI intercept and lower BMI development) showed better cardiorespiratory performance than children did in class 2 (i.e., higher BMI intercept and higher BMI development). The small size of the sample, and the fact that class 2 had fewer children (21.08%) compared to class 2 (78.92%), might explain why this difference was not statistically significant.

The present study is not without limitations. The sample size was relatively small. Although missing data can be seen as a limitation, it is not a critical aspect since the multilevel model approach copes quite well with some missing data.

A strong point in this study was the longitudinal nature and analysis with a relatively wide age span (4 to 13 years of age), but at the same time, this can also be seen as a limitation since different developmental phases are present within this age span. Although the initial age was used as a covariate in order to allow the analysis of the different age cohorts as one bigger and longitudinal sample, this approach might be too simplistic to account for the real biological changes associated with growth and maturation and a larger sample might reveal more qualitatively different classes of BMI development.

In conclusion, according to the purpose of the study, two meaningful trajectories for children based on their BMI development across five time points were identified. In line with previous research and our hypothesis, children with slower increasing BMI showed better motor coordination development over time. In the future, we hope that this line of research identifying different MC and BMI development classes could be used to inspect the reciprocal effect argument that MC could be both a precursor and a consequence of weight status (Robinson et al., 2015)

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