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Motor performance and daily participation in children with and without probable developmental coordination disorder

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ABBREVIATIONS

ADL	Activities of daily living
DCD	Developmental coordination disorder
DCDDaily-Q	DCDDaily-Questionnaire
PLS-SEM	Partial least squares-based structural equation modelling

AIM To test the mediating role of motor performance in the relationship between individual and environmental constraints, delayed learning of activities of daily living (ADL), and daily participation in typically developing children and children with probable developmental coordination disorder (DCD).

METHOD Parents of 370 randomly selected children aged 5 to 10 years (194 females; mean age [SD] 7y 5mo [1y 10mo]) were included in the study (321 typically developing, 49 probable DCD). Motor performance, ADL learning, and participation were assessed using the DCDDaily-Questionnaire. Individual variables included child's age and sex, and environmental variables included mother and family educational level, presence of siblings, and area of residence. Direct, indirect, and mediating effects were tested using a partial least squares-based structural equation modelling approach.

RESULTS The model explained 44.5% of the variance of daily participation. Motor performance significantly mediated the effect of individual and environmental constraints, and ADL learning on daily participation.

INTERPRETATION Results suggest that the effect of individual and environmental constraints and delayed learning of ADL on daily participation is mediated by motor performance in typically developing children and children with probable DCD. These findings provide further evidence that interventions to promote participation in children with probable DCD should adopt ecological, task-oriented approaches. Further studies should evaluate model generalizability with clinical samples.

About 5% to 6% children of school-age present with developmental coordination disorder (DCD),[1] and as many as 12% to 25% of children are at risk of motor coordination issues.[2–5] In children with DCD, the execution of motor coordination skills is substantially below age-matched typically developing peers, which cannot be explained by any intellectual impairment, or neurological or developmental condition.[1] The deficits in motor skills are usually expressed in slower learning of motor skills and less accurate motor performance, and these difficulties are more significant in complex ADL.[6] So far, the etiology of DCD is unclear, but several hypotheses have been developed to contribute to the understanding of this disorder.[1]

The activity deficit hypothesis[7] proposes that children with low motor proficiency usually avoid engaging in motor activities, which eventually widens the motor skill gap between these children and typically developing children as they grow older. Research shows that delayed learning of motor skills and motor-based activities of daily living (ADL) is associated with poorer execution,[6,8] which in turn predicts reduced participation both in children with and without DCD.[9]

Satisfactory participation is defined as active engagement in meaningful ADL.[10] Participation in daily contexts is considered a major component of health and well-being.[11] Therefore, the impact of DCD and poor motor skills transcends motor performance. Literature has widely reported that deficits in motor ability reduce participation in children with DCD.[1,6] Consequently, recommendations have been made to pay special attention to how motor performance difficulties impact daily participation in children with DCD.[1,12] According to the results of a systematic review, children with DCD participate less than typically developing children in self-care and self-maintenance ADL, social and motor-based leisure ADL, school-related ADL, and instrumental ADL.[12] During the last decade,

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new studies have explored participation in DCD, further supporting the influence of motor performance on daily participation,[9,13,14] but evidence regarding which sociodemographic factors are associated with both motor performance and daily participation is scarce.

Newell's constraints model is useful to investigate which factors account for motor performance deficits and reduced participation.[1,15] According to this model, both individual and environmental constraints impact motor performance. This is in line with the International Classification of Functioning, Disability, and Health for Children and Youth, which argues that children's ADL performance and participation in daily contexts are influenced by environmental and personal factors.[11] This theoretical framework is further supported by research showing that both motor performance and participation are influenced by individual (i.e. neurological factors, age, sex)[2,4,5,16] and environmental constraints (i.e. family-related factors, like family socioeconomic and educational level, having siblings, area of residence, and cultural background).[3,5,16,17–20] Although previous research showed that individual and environmental constraints influence motor performance and participation, it is unknown whether these constraints have a direct influence on participation or whether motor performance plays a mediating role in this relationship, as suggested by the activity deficit hypothesis.

Therefore, the aims of this study are: (1) to explore a model to test the influence of environmental and individual constraints on motor performance and daily participation in children with and without probable DCD; (2) to examine the mediating role of motor performance on the relationship between individual and environmental constraints and daily participation; and (3) to examine the mediating role of motor performance on the relationship between ADL learning and daily participation.

The hypotheses of this study are as follows: (1) motor performance will have a significant influence on daily participation. (2) Environmental (a) and individual (b) constraints will have a significant influence on motor performance. (3) Environmental (a) and individual (b) constraints will have a significant influence on daily participation. (4) Motor performance mediates the relationship between environmental (a) and individual (b) constraints and daily participation. (5) Learning of daily activities will have a significant influence on motor performance. (6) Motor performance mediates the relationship between ADL learning and daily participation.

METHOD

Procedures and participants

Children were eligible if they were aged 5 to 10 years, in mainstream education, and did not have a diagnosis of a neurodevelopmental disorder, learning disability, or medical condition affecting movement. Participants were parents of children from 15 randomly selected mainstream preprimary and primary schools from seven regions in Spain. Parents received a dossier containing the DCDDaily-Questionnaire (DCDDaily-Q), a sociodemographic ad hoc questionnaire, and an informative letter explaining the aims of the study through school intermediation. Only those parents who gave informed consent filled in the questionnaires at home. To keep the identity of the patients anonymous, we did not ask for additional written consent. This study received ethical clearance from the Autonomic Research Ethics Committee of Galicia (code 2018-606). The final sample comprised 370 children without a previous reported diagnosis of neurodevelopmental disorder (194 females; mean age [SD] 7y 5mo [1y 10mo], age range 5–10y). For a more detailed description of the sample size estimation and selection see Appendix S1 (online supporting information).

What this paper adds

- Individual and environmental constraints influence motor performance and daily participation in children with and without developmental coordination disorder.
- Motor performance mediates the relationship between individual and environmental constraints, activities of daily living (ADL) learning, and daily participation.
- Individual and environmental constraints, ADL learning, and motor performance help explain daily participation.

DCDDaily-Q

Parents completed the Spanish version of the DCDDaily-Q, which explores 23 ADL in children aged 5 to 10 years. It includes motor performance (how well the child performs the activity), daily participation (the extent to which the child participates in the activity), and ADL learning (if the child took longer to learn the activity in comparison to their peers).[21,22] Motor performance is rated from 1 to 3 (1=good performance, 2=medium performance, 3=poor performance), while participation is rated from 1 to 4 (1=the child does the activity regularly [every day], 2=the child does the activity sometimes [every now and then], 3=the child seldom or rarely does the activity, 4=the child never does the activity), meaning that higher scores show poorer performance and lower participation respectively. The total score of the learning subscale indicates the number of activities the child took longer to learn, ranging from 0 (the child did not take longer to learn any activity) to 23 (the child took longer to learn every activity). The 23 items are subdivided in self-care and self-maintenance activities (10 items), fine motor activities (seven items), and gross motor playing activities (six items).

The DCDDaily-Q has good discriminant capacity to identify children with DCD (sensitivity=88%; specificity=92%).[21] A cross-cultural adaptation and validation study in Spanish children showed that this measure has good internal consistency (Cronbach's alpha=0.7–0.8) and good criterion validity with the DCD Questionnaire (r=0.406, p<0.001).[22,23] Additionally, the structure of the factors proposed for the Dutch DCDDaily-Q (i.e., how items are organized within the questionnaire) was confirmed in Spanish children, providing further evidence of its construct validity (Satorra χ^2 [227]=405.86, p<0.05;

Satorra χ^2/degrees of freedom=1.79; comparative fit index=0.940; non-normed fit index=0.933; root mean square error of approximation=0.054, 90% confidence interval=0.045–0.062).[21,22] Reliability of the participation and learning scales in this sample was also good (Cronbach's alpha for participation=0.7–0.8; learning=0.7–0.8). Children were identified as having probable DCD according to the total score of the DCDDaily-Q motor performance scale (total score >85th centile; criterion B of the DSM-5 DCD diagnosis).[1,23,24,25] For a more detailed description of the identification of probable DCD see Appendix S2 (online supporting information).

Sociodemographic variables

Environmental and individual constraints of the children were measured using an ad hoc questionnaire. Variables regarding social and physical environment of the children included presence of siblings (only child/has siblings), education level of each parent (first or second level studies/university studies), family educational level (the highest level of one parent), type of school (public school/semi-private or private school), and area of residence (urban [>10 000 population]/semirural or rural [≤10 000 population]). Individual constraints evaluated were age group (ages 5–6y/7–10y) and sex (male/female).

Data analysis

Descriptive and bivariate analyses of the variables were calculated using SPSS v.24 (IBM Corp., Armonk, NY, USA). To test the hypotheses, two main statistics strategies were used. First, the independent two-sample *t*-test analyses were conducted to identify significant differences in motor performance and daily participation according to environmental and individual variables. Because of the sufficient sample sizes in all of the subgroups that were examined, *t*-tests relying on the central limit theorem were used. Differences in performance and participation between the probable DCD and typically developing group were also examined. Second, the environmental and individual variables that showed independent significant differences in at least one subarea of daily motor performance and participation were entered alongside the scores on the three subscales of the DCDDaily-Q (motor performance, daily participation, and ADL learning), into the hypothesized model of this study (Fig. 1). The model was tested with a partial least squares-based structural equation modelling (PLS-SEM) approach using Smart PLS v3.2.9 (Ringle, Wende, and Becker, Bönningstedt, Germany).

The PLS-SEM analysis was conducted using a two-step procedure.[26] First, we explored the measurement model in order to analyse the relationships between the observable variables (i.e. indicators) and the underlying constructs (i.e. latent variables) and to ensure that the estimation was technically valid. Second, we explored the structural model to analyse the relationships among the latent variables and to test the hypotheses of the study. Finally, we examined the mediating effect of motor performance in the relationship between individual and environmental constraints, ADL learning, and daily participation using the guidelines of Zhao et al. as reported by Hair et al.[26] For a detailed description of the PLS-SEM analysis see Appendix S3 (online supporting information).

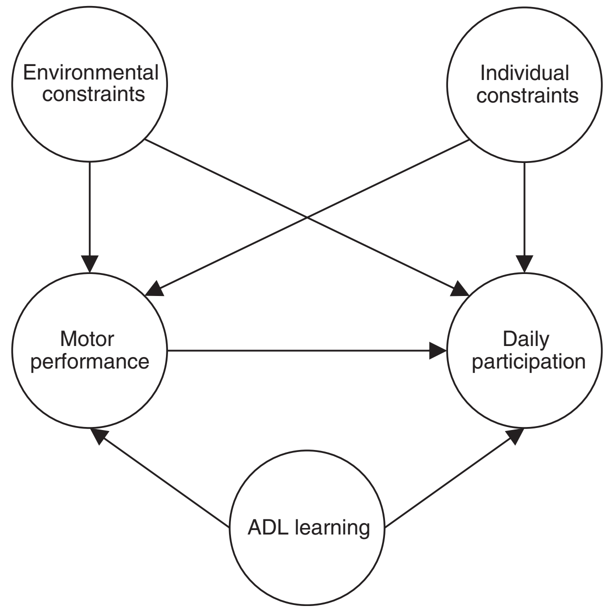

Figure 1: Conceptual framework of the mediating effects of motor performance on daily participation. ADL, activities of daily living.

RESULTS

Descriptive analysis

Individual and environmental variables of the participants are presented in Table 1 alongside the mean (SD) scores on the motor performance, daily participation, and ADL learning subscales for self-care, fine motor, and gross motor activities. A total of 49 children (13.2%) were identified as having probable DCD according to the total score on the motor performance scale of the DCDDaily-Q. Differences in performance and participation between both groups are shown in Table S1 (online supporting information; effect sizes=0.8–2.3).

Differences in mean motor performance and daily participation scores between environmental and individual variables are shown in Tables S2 and S3 (online supporting information). The two individual variables (age group and sex) showed significant differences between mean scores of at least one subarea of motor performance and daily participation ($p<0.05$). Regarding environmental variables, mother and family education level, presence of siblings, and area of residence had significant differences between mean scores of at least one subarea of motor performance and daily participation ($p<0.05$), and therefore were included in the PLS-SEM model. Age, being female, having siblings, coming from families in which at least one parent had a university degree, and living in semirural or

Table 1: Individual and environmental constraints and means, standard deviations, and score range on the DCDDaily-Q subscales

	n	%	Mean (SD)	Range
Individual constraints				
Age	370		7y 5mo (1y 10mo)	5–10
5–6y	137	37.0		
7–10y	233	63.0		
Sex	369			
Male	175	47.4		
Female	194	52.6		
Environmental constraints				
Siblings	368			
Only child	110	29.9		
Has siblings	258	70.1		
Father education level	324			
First or second level studies	199	61.4		
University studies	125	38.6		
Mother education level	358			
First or second level studies	177	49.4		
University studies	181	50.6		
Family education level	369			
First or second level studies	154	41.7		
University studies	215	58.3		
Area of residence	370			
Urban (>10 000 population)	296	80.0		
Semirural or rural (≤10 000 population)	74	20.0		
Type of school	370			
Public school	197	53.2		
Semi-private or private school	173	46.8		
Daily motor performance, participation, and ADL learning				
Motor performance	370		31.3 (6.0)	23–57
Self-care	370		13.1 (2.8)	10–25
Fine motor	370		8.9 (2.1)	7–18
Gross motor	370		9.3 (2.4)	4–16
Daily participation	370		36.2 (6.8)	23–71
Self-care	370		14.6 (3.3)	10–35
Fine motor	370		9.3 (2.3)	7–18
Gross motor	370		12.3 (2.9)	6–21
ADL learning	370		0.6 (1.6)	0–17
Self-care	370		0.2 (0.7)	0–7
Fine motor	370		0.2 (0.7)	0–5
Gross motor	370		0.2 (0.7)	0–6

DCDDaily-Q, DCDDaily-Questionnaire; ADL, activities of daily living.

rural areas led to significantly lower mean scores ($p<0.05$) on at least one subarea of daily motor performance and participation (i.e. better performance and more participation).

PLS-SEM analysis

Assessment of the measurement model

The assessment of the measurement model indicated that the hypothesized model had good reliability and validity, as all indicators of reflective constructs and most indicators of formative constructs met the recommended criteria. See Appendix S4 and Table S4 (online supporting information) for a detailed description of the assessment of the measurement model.

Assessment of the structural model

Figure 2 shows the path coefficients and measures of the explained variance in the structural model including the standardized parameter estimates. Environmental constraints, individual constraints, and ADL learning together explained 31.4% of the variance in motor performance, while the overall model explained 44.5% of the variance in daily participation. The Q^2 values for motor performance and daily participation were 0.203 and 0.262 respectively, indicating that the hypothesized model had a significant medium predictive capacity for daily participation.

Mediating effect of motor performance

Environmental constraints, individual constraints, and ADL learning had a significant direct effect on motor-based activities performance ($p<0.01$; Fig. 2). As shown in Table 2, environmental constraints, individual constraints, and ADL learning also had a significant indirect effect on daily participation through motor performance, but only environmental constraints had a significant direct effect on daily participation.

These findings indicate an indirect-only (full) mediation of motor performance on the effect of individual constraints and ADL learning over daily participation. Conversely, the effect of environmental constraints on daily participation was partially complementary mediated through motor performance (Table 2). Motor performance was the latent construct with the larger effect size on daily participation (f^2=0.498). Individual constraints had a large effect on motor performance (f^2=0.285), while ADL learning and environmental constraints had a small effect size on motor performance (f^2=0.028–0.138).

DISCUSSION

The current study showed that environmental and individual constraints played a role in both motor performance and daily participation in typically developing children and children with probable DCD but without other neurodevelopmental disorders (such as attention-deficit/hyperactivity disorder or autism spectrum disorder). First, it was assessed whether motor performance and daily participation differed for several individual and environmental variables, including family and environmental factors. In line with findings from previous studies,[2–5,16–20,27] older children were more proficient in motor activities and more frequently engaged in ADL, and males performed better and participated more frequently than females in gross motor activities, while females outperformed males in fine motor activities and participated more in self-care and overall activities.[2,4,5,16,23,28] In addition, children from families with higher education levels showed better motor skills and participated more in certain daily domains,[3–5,16,17,27] and children living in rural settings tended to engage in a broader range of activities and did so more frequently than children living in urban areas.[18] Lastly, having siblings was associated with better motor skills and with more daily participation in some areas in both

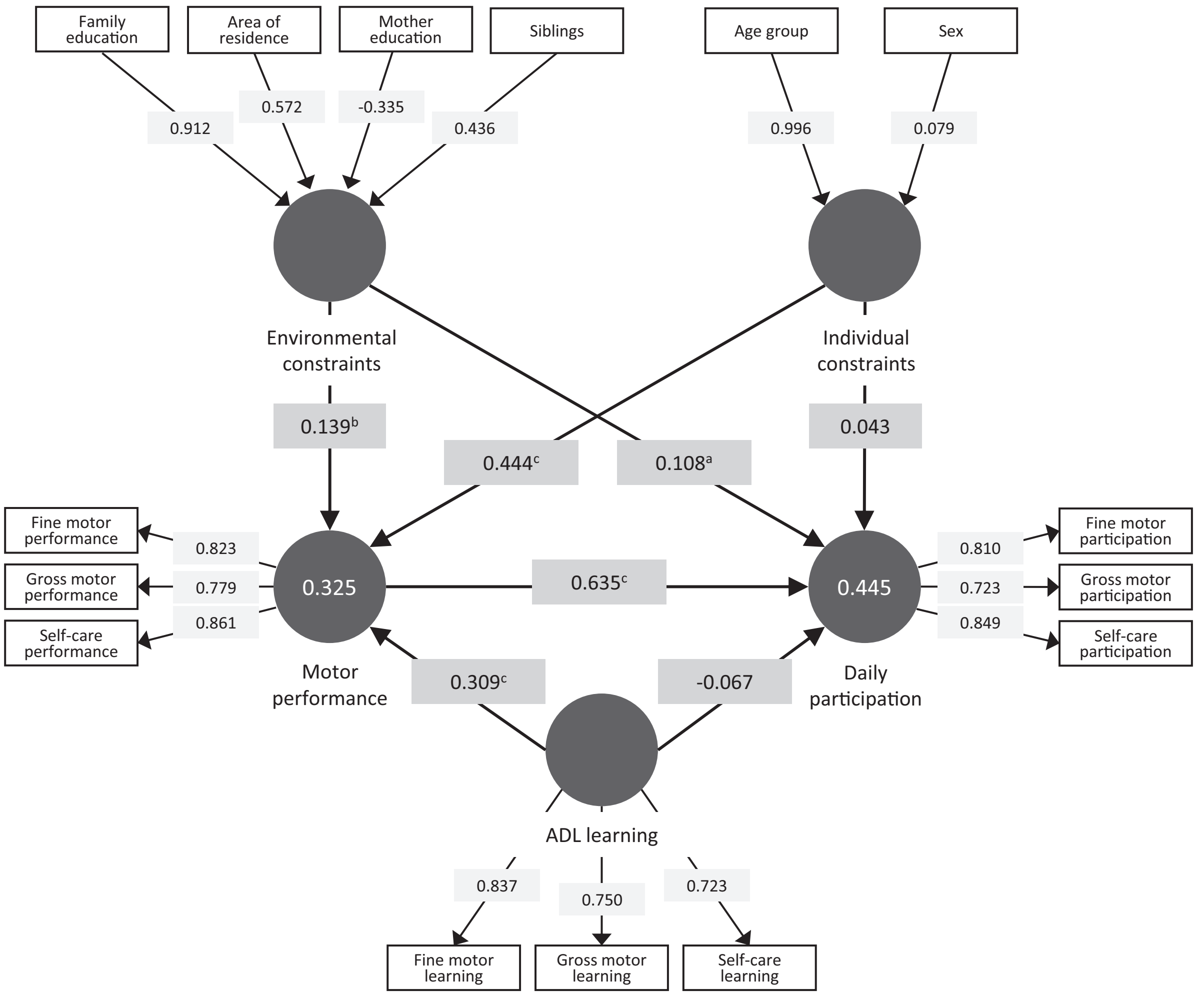

Figure 2: Path analysis of the mediating role of motor performance. In light grey (rectangles) standardized parameter estimates; in medium grey (rectangles) path coefficients; in dark grey (circles) explained variance. [a]$p<0.05$; [b]$p<0.01$; [c]$p<0.001$. ADL, activities of daily living.

Table 2: Hypotheses testing for direct and mediated relationships

Hypotheses	Path coefficients		p	f^2	Mediation type	Supported
(1) MP → DP	Direct	0.635	<0.001	0.498	—	Yes
(2a) EC → MP	Direct	0.139	0.002	0.028	—	Yes
(2b) IC → MP	Direct	0.444	<0.001	0.285	—	Yes
(3a) EC → DP	Direct	0.108	0.023	0.020		Yes
(3b) IC → DP	Direct	0.043	0.351	0.003	—	No
(4a) EC → MP → DP	Direct	0.108	0.023	0.020	Complementary (partial mediation)	Yes
	Indirect	0.088	0.003			
	Total	0.196	<0.001			
(4b) IC → MP → DP	Direct	0.043	0.351	0.003	Indirect-only (full mediation)	Yes
	Indirect	0.282	<0.001			
	Total	0.325	<0.001			
(5) AL → MP	Direct	0.309	<0.001	0.138	—	Yes
(6) AL → MP → DP	Direct	–0.067	0.144	0.007	Indirect-only (full mediation)	Yes
	Indirect	0.196	<0.001			
	Total	0.128	0.015			

MP, motor performance; DP, daily participation; EC, environmental constraints; IC, individual constraints; AL, activities of daily living learning.

typically developing children and children with neurodevelopmental disorders.[20,27]

Next, we investigated the mediating role of motor performance in the relationship between individual and environmental constraints and daily participation. Both individual and environmental constraints showed a significant direct effect on motor performance and a significant indirect effect on daily participation. The influence of environmental constraints on daily participation was partially complementary mediated by motor performance, indicating that some but not all the effects of environmental constraints on daily participation can be explained by motor performance. As stated in the literature, environmental constraints, and particularly family-related factors, are associated with daily participation in both typically developing children and children with disabilities.[14,27,28] Our findings suggest that, though family-related environmental factors can directly affect participation in ADL, this relationship may be even more significant if the child has motor coordination issues. Conversely, motor performance was found to fully mediate the relationship between age and sex, and daily participation. This finding may suggest that some individual constraints, like age and sex, influence daily participation through motor performance.

Results from our model showed that delayed learning of ADL did not directly influence daily participation but had a full indirect effect through motor performance, meaning that motor performance accounts for all the effects that delayed learning may have on daily participation. Children with DCD do not have a learning deficit as such, as they are able to acquire and retain new motor skills.[6] However, when learning complex activities, children with DCD take longer, use less efficient strategies, and need more practice and tailored feedback,[8,29] which gradually leads to less participation in motor-based activities, preventing these children from improving their motor skills.[6] Van der Linde et al.[9] explored the relationships between ADL learning, performance, and participation in children with and without DCD. Similar to findings of the present study, the authors found that delays in motor learning predicted poor motor performance in children with DCD, which in turn predicted less daily participation in both groups.[9] It can be concluded that delayed motor learning may be partially responsible for the deficits in motor performance present in DCD and probable DCD, which will reduce the child's active and motivated involvement in motor-based activities, beginning a negative cycle that persists and widens during childhood.[29,30]

Overall, this study suggests that motor performance plays a crucial role in the participation of children with and without probable DCD, as it significantly mediated the effect of individual and environmental constraints and delayed ADL learning on daily participation in ADL. Moreover, results support the influence of both individual and environmental constraints on performance and participation of children. This is not only in line with the International Classification of Functioning, Disability and Health and Newell's constraints model,[11,15] but also with other theoretical frameworks such as the Person-Environment-Occupation model and the Ecology of Human Performance framework.[31] Therefore, this further emphasizes that motor coordination issues and daily participation should be assessed within the personal, family, and cultural context of the child.

Altogether, these findings have several implications for future research and clinical practice. Researchers can further explore this model by including environmental and individual constraints that were not assessed in the present study (i.e. findings from neuroimaging studies on brain structure and connectivity, or deficits in executive functioning). As for the clinical practice implications, clinicians can use our findings to design comprehensive assessment protocols that evaluate the variables that may influence both motor performance and daily participation in children with coordination difficulties. In addition, this research raises awareness for possible participation restrictions in children with and without probable DCD because of motor performance difficulties. Moreover, this model may provide further evidence for individually tailored interventions, and family-centred, activity-oriented approaches aimed to support participation in meaningful daily contexts in children with DCD.[1]

Strengths and limitations

The main strengths of the study are the large and representative sample of children, and the use of a mediating analysis to explore the relationships between the variables. However, only particular individual and environmental constraints were evaluated, which could explain the medium explanatory power and predictive capacity of the model. In addition, this study did not establish causality between variables. Moreover, it is possible that motor performance and daily participation share a bidirectional relationship, which could not be tested in the present study because of limitations of the statistical analysis. Finally, this study relied on parental information, so the findings should be interpreted with caution. Although parents are able to provide accurate information regarding daily participation and motor performance of the child, future studies would benefit from using motor batteries to objectively measure motor performance. In addition, future research should individually assess all DSM-5 DCD diagnosis criteria. More studies are needed to test the construct validity of the DCDDaily-Q participation subscale.

CONCLUSIONS

The present study showed that motor performance had a direct effect on daily participation, and that it mediated the influence of individual and environmental constraints and delayed learning of ADL in children with and without probable DCD. While both individual and environmental constraints and ADL learning had a direct effect on motor performance, only environmental variables retained a direct effect on daily participation as well. These findings suggest that motor performance plays a crucial role in the influence of individual and environmental variables on daily participation. Hence, individually tailored task-oriented interventions should be used to promote functioning in children with probable DCD.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

SUPPORTING INFORMATION

The following additional material may be found online:

Table S1: Differences in motor performance and daily participation between the probable DCD and typically developing groups.

Table S2: Independent samples *t*-tests between environmental and child-related factors and daily participation.

Table S3: Independent samples *t*-tests between environmental and child-related factors and motor performance.

Table S4: Assessment of the measurement model (reflective and formative constructs).

Appendix S1: Sample size estimation and selection.

Appendix S2: Identification of probable developmental coordination disorder.

Appendix S3: PLS-SEM analysis.

Appendix S4: Results from the assessment of the measurement model.

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