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The Influence of IQ Levels on Clinical Features of Developmental Coordination Disorder

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Abbreviations

DCD= Developpemental Coordination Disorder

IM= Ideomotor

VSC = Visuospatial/ or visuoconstructional

MX = mixed subtype

VCI = Verbal Comprehension Index

VSI = Visual Spatial Index

FIQ = Full IQ

NP-MOT = Developmental neuropsychomotor battery

Abstract

Objective: There is no study exploring the correlation between motor coordination dysfunction and high cognitive functioning. We aim to explore the influence of IQ (≥120) on clinical features of DCD.

Method: We collected data from 38 children (average age: 9 years old, 2.7 SD) with DCD based on criteria of DSM-5. Two matched groups of DCD were studied according to the IQ: 19 typical children (IQ = 90-110) and 19 HIQ-HIP children. Within this last group, we distinguished superior IQ (120-129) (HIQ), and very superior IQ (≥130) (HIP). All participants completed assessments of neuropsychological, neurovisual, and neuropsychomotor functions.

Result: We displayed less Ideomotor (IM), Visio-Spatial/Constructive (VSC)-DCD and more Mixed (MX)-DCD in HIQ-HIP compared to typical children DCD. We showed significant correlations between IM-DCD and executive functions disorders (ρ=+0.519 [95% CI, 0.163 to 0.795], p=0.001), between visuo-constructional task and VSC-DCD subtype (ρ= -0.651 [95% CI, -0.899 to -0.406], p=0.006). A statistical difference between both groups was shown in adiadochokinesia and bimanual coordination disorder in favor of typical children. There is no significant difference between HIP and HIQ. More left-handed in functional laterality was found with IQ≥130, $\chi 2$ (1)=4.571, p=0.033, [95% CI, 0.052 to 0.061].

Conclusion: Both groups displayed similar clinical features of DCD. HIQ-HIP groups have better executive functions and visio-spatial functioning than typical children with DCD but worse auditory attention and memory, and more neurological soft signs related to the high rate of MX-DCD. The findings are useful for clinical decision-making processes.

1. Introduction

There is still no consensus in the literature regarding the definition of giftedness but there are different theoretical concepts. The gifted children have been shown to excel in their academic achievements in a supportive environment (social, scholarly) [1-3]. Thus, multiple selection criteria for giftedness screening are used such as standardized tests and other informal sources as teacher's opinion, parent's observations, and creativity [4-7]. Certain studies underline an early neurophysiological maturation in gifted children allowing the early emergence of postural, locomotors acquisitions, and visuo-manual coordination as well as language and cognitive processes [8-12]. Authors in the literature have only studied cognitive performances and assume a systematic asynchrony between intellectual and motor performances in gifted children [13-15].

Normal distribution considers a superior IQ from 120 to 129 (6.7% of the general population) according to the Gaussian curve of the Wechsler intelligence scale [16]. Full IQ (FIQ) within that range is qualified as a High Intellectual Quotient (HIQ). Very superior IQ beginning at 130 (2.5%), two standard deviations from the mean, is

qualified as High Intellectual Potential (HIP). Therefore, children with HIP are considered gifted children according to the World Health Organization [17].

Moreover, it is common to think that HIQ/HIP children cannot have learning disabilities because there are few studies on this subject [18, 19]. Empirical evidence proves otherwise, but the link has yet to be explored [20-22]. Developmental coordination disorder (DCD) is one of the least studied, while attention deficit-hyperactivity disorder is more investigated [23-26]. DCD can be defined as a non-verbal neuropsychological dysfunction which can give rise to behavioral and learning disabilities [27]. It is not a form of brain injury as in adult apraxia, it is an impairment linked to the maturation process of the central nervous system. The developmental approach explains that children with DCD have never acquired the capacity to perform complex motor actions adapted to age, that is not due to an intellectual disability, nor by visual impairment and nor is it due to neurological brain involvement (e.g., muscular dystrophy, cerebral palsy) [28]. It is a common disorder in school-aged children with an estimated prevalence of 5-6% between 5 and 11 years old [28]. Researchers and clinician practitioners must use DSM criteria as recommended since 1994 by London International consensus [29] and as advised by the European Academy of Childhood Disability [30]. However, the authors have rarely investigated DCD in relation to cognitive functions including IQ level. We do not know the specificity of clinical features in children with HIQ/HIP. Are they different or similar?

Few studies have used clusters analysis to identify distinct subtypes of DCD and not all the authors use the same motor assessments. They used a few cognitive and neuromotor tests (e.g., imitation of gestures, gnosis, neurovisual, and neurological soft signs). Thus, it is not easy to compare studies. Only one subtype is common to all the studies: a group with impairments in global and fine motricity [31-32]. Some studies identified groups with visuospatial DCD or visuo-motor integration disorder [33-39] and only three studies used transitive gestures and motor sequencing to identify ideomotor impairment [31, 39, 40].

Recent studies [31, 34, 36] provided a better understanding of the DCD based on a standardized developmental assessment with quantitative and qualitative measures. They use age-related normative data to identify subtypes of DCD, using multidimensional clinical and statistical approaches. The authors identified two to three pure types of DCD and the specific diagnostic markers: Ideomotor (IM) (8%), visuospatial/ or visuoconstructional (VSC) DCD (52%), and a mixed subtype (MX) (40%). Children with IM-DCD were characterized by significant impairments in digital perception, manual praxis, and imitation of gestures, while the VSC subgroup appeared to have deficiencies in visual motor integration, visual spatial motor structuring, and/or constructional abilities (with difficulties in Lego blocks to follow a model). Finally, the MX group shares common impairments to IM and VSC and exhibited the specific deficits in motor coordination of the lower-upper limbs, poor manual dexterity, neurological soft signs (e.g. synkinesis, adiadochokinesia), and certain comorbidities (e.g., executive functions disorders, auditory-memory deficits, and auditory-attention difficulties).

The aims of the current study were to analyze multivariate associations between DCD subtypes and several neuropsychological, neuropsychomotor, and neurovisual characteristics, in order to refine the specific features of DCD depending on IQ score and define motor profiles according to cognitive abilities and IQ index scores. The first hypothesis suggests a relationship between early psychomotor development and high IQ. The second explores if there are specific DCD clinical features in HIQ versus HIP with DCD compared to typical children also with DCD and examined subtypes of DCD.

2. Material and Methods

2.1 Participants

Data from 38 DCD children (average age: 9 years old, 2.7 SD) based on criteria of Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [28] were collected. Inclusion criteria were strict: Children with sensory deficit, dyslexia, and attention deficit-hyperactivity disorder (based on DSM criteria), psychiatric abnormalities or general medical abnormalities, and traumatic brain injury were not included, nor was any child born premature (<37 weeks), and no physical therapy neither medication.

Children from 6-12 years old were recruited in the outpatient consultation of the child psychiatry department at Necker Hospital in Paris, France. All of them met the criterion A for DCD described in the DSM-5 [28], with acquisition and execution of motor skills which are clearly below the level expected given the subject's chronological age and despite learning and using opportunities of these skills with standardized tests [41-43]. Children who meet inclusion criteria were assigned to the three DCD subtypes validated in a previous study and described above [31, 34].

Two matched groups were studied: 19 typical children with DCD (IQ=90-110) and another group including 19 HIQ-HIP (high intellectual quotient or high intellectual potential) children. Within this last group, we distinguished superior IQ starting at +1.33 SD (HIQ=120-129), and very superior IQ at +2 SD (IQ≥130) who are identified as gifted children (HIP) by the Wechsler intelligence scale [16-17]. The two groups were matched according to sociodemographic data, age, no language disorder, and no ophthalmological abnormalities. Only IQ scores are identified as differentiation criterion. The Institutional ethic committee of Paris Descartes University, Sorbonne Paris city, approved the study (CER-PD 2018-72; CER-PD 2019-49). Participants provided written informed consent before the start of the study, signed by a parent or legal representative and children before enrolment in the study.

2.2 Measures

2.2.1 Neuropsychological assessment: All children recruited in DCD sample had completed a standard measure of intelligence, the Wechsler Intelligence Scale for children according to the age (WISC-IV) [16]. Verbal Comprehension Index (VCI), Visual Spatial Index (VSI), and Full IQ (FIQ) scores were expressed as standardized

scores (mean 100, SD=15). We have completed cognitive investigations by visual-motor integration, constructional and visuospatial structuring (Khos' cubes), and executive functions (Tower of London test and Porteus Labyrinths) assessments [44].

2.2.2 Neuropsychomotor developmental assessment: All children were assessed with a developmental neuropsychomotor battery (NP-MOT) [42] with age-related normative data to evaluate neuropsychomotor physical functions. It is applicable to children from 4 years old. It is a standardized and validated assessment and it has been found to have adequate test-retest reliability and internal consistency. Correlation coefficients of the NP-MOT with the Bruininks-Oseretsky Test Motor Proficiency (BOTMP) [45] range from 0.72 to 0.84, for motor coordination and balance [36]. NP-MOT battery allows physical standardized assessment of passive/active muscular tone of limbs and axial tone, highlighting NSS such as synkinesis, the presence of a pyramidal tract dysfunction (hypertonia), bodily spatial integration, basic motor function, control and regulation in gross motor tasks (gait, balance, coordination), laterality, manual dexterity, manual praxis, digital perception, rhythmic, and auditory attention tasks, completed by imitation of gestures (see [32] for a synopsis of NP-MOT battery tasks).

2.2.3 Neurovisual assessment and other measures: Electro-physiological neurovisual examination including Electroretinogram (ERG) test, with smooth visual pursuits, and Visual Evoked Potential (VEP) test [46] was used to analyze the sensory and visual motor pathways. To detect dysgraphia, we have used Ajuriaguerra standardized scale of handwriting [43], a score of 19 to 25 indicates significantly dysgraphic handwriting. Finally, an anamnesis form was also used to collect data about pregnancy and delivery, psychomotor development (e.g., sitting alone, walking), and any difficulties with constructional play, such as puzzles and Lego blocks following a model relative to developmental markers found in previous study [31]. The child school report book was examined to identify if there are some learning difficulties (such as mathematics, written French).

2.2.4 Statistical analyses: We used R software [47] for statistical treatment. Data were analyzed according to the intention-to-treat principle. We used p-values at 0.05 to indicate statistical significance and p-values at 0.001 if reached. We also applied the Bonferroni method to adjust for multiple comparisons. To analyze the dependence between IQS and all DCD variables (continuous outcomes according to one or more classification factors), parametric Multivariate Analysis of Variance (MANOVA) was used. Two-group comparisons of scale scores were performed using Student T-test (t) and Pearson's chi-square test ($\chi 2$) was carried out to analyze dichotomic variables (Two-way cross-classification between qualitative variables). Variables were coded as 0 for success to a test (meaning no disorder) or 1 for failure (indicating a probable disorder) based on regular scoring (standard deviation: $1 <$ SD or $<$ 20th percentile according to the test). A Pearson's correlation test (r) for numeric continuous variables and Spearman's ρ test (ρ) for non-parametric correlations were used.

3. Results

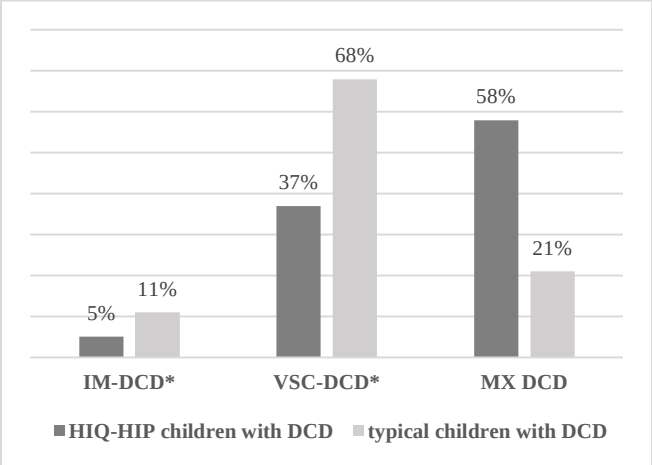
3.1 Sample characteristics

Table 1 shows sociodemographic, cognitive, and medical characteristics of 38 children with DCD. Groups were matched according to sociodemographic data; age (t= -0.069, df=18, p=0.94, [95% CI, 95.16 to 124.24]), absence of language disorder $\chi 2$ (1)=0.3, p=0.73, [95% CI, 0.72 to 0.74], and absence of ophthalmological abnormalities $\chi 2$ (1)=0, p=1, [95% CI, 1 to 1]. Only IQ scores are identified as differentiation criterion of groups (t=12.87, df=18, p<0.0001, [95% CI, 127.36 to 138.01]). In HIQ-HIP children with DCD, we identified high rate of MX, low rate of IM and VSC-DCD compared to typical children with DCD (Figure 1). HIQ compared to HIP, there is no significant difference in MX-DCD frequency (respectively 56% vs 60%). Mathematical difficulties were strongly present in the whole sample, comparing typical DCD children and HIQ-HIP DCD, 100% vs 20% of mathematical difficulties in VSD-DCD $\chi 2$ (1)=4.5, p=0.07, [95% CI, 0.067 to 0.077], but in MX-DCD, 100% vs 90.91%. It does not appear in the IM-DCD.

	Typical children group (n=19)	**HIP children group** (n=10)	**HIQ children group** (n=9)
Age (Months) Mean (SD)	109.84 (33.72)	118.66 (31.45)	100.5 (28.88)
Gender:			
Female (%)	5	10	11
Male (%)	95	90	89
FIQ mean (SD)	100.79 (6.83)	122.78 (2.97)	143.1 (7.65)
FIQ (min-max)	90-114	120-128	134-157
No language disorder (%)	84	100	98
No ophthalmological disorder (%)	68	97	97
Pure Visuospatial DCD (%)	0	10	22
Pure Visuo-constructive DCD (%)	0	0	0
Auditory-memory deficit (%)	16	20	33
Auditory-attention difficulties (%)	5	40	33
Mathematical difficulties (%)	89	90	89

Legend: HIP: High intellectual potential (gifted children); HIQ: High intellectual quotient; SD: standard deviation. FIQ: full intellectual quotient.

Table 1: Sample characteristics with sociodemographic, cognitive, and medical data in DCD groups (typical children vs HIP-HIQ).



Legend: HIQ: High Intellectual Quotient (IQ = 120-129)

HIP: High Intellectual Potential (gifted children; IQ ≥130)

IM-DCD: Ideomotor-DCD

VSC-DCD: Visuo-Spatial/ or Constructional-DCD

*: significant difference $p \leq 0.05$

Figure 1: IM and VSC-DCD frequency in HIQ-HIP group compared to typical children with DCD.

3.2 Relationship between IQ and neuropsychomotor development

In HIQ-HIP children, there are negative and significant correlations between main IQ index scores (VCI, VSI, and FIQ) and the developmental milestones to sit, to walk and language. VSI was negatively correlated to age of language acquisition (r= -0.366 [95% CI, -0.587 to 0.135], p=0.024). These correlations show that children with DCD having a high VSI (from 110) developed language and sitting early. Regarding VCI, the earlier a child develops walking, sitting and language, the higher is his VCI. It is correlated with sitting (r= -0.425 [95% CI, -0.651 to -0.167], p=0.008), walking (r= -0.421 [95% CI, -0.626 to -0.147], p=0.009) and language (r= -0.514 [95% CI, -0.701 to -0.319], p=0.001). Finally, FIQ is negatively and significantly correlated with sitting (r= -0.356 [95% CI, -0.626 to -0.008], p=0.028), walking (r= -0.41 [95% CI, -0.621 to -0.122], p=0.01) and language (r= -0.624 [95% CI, -0.766 to -0.462], p<0.0001). Therefore, children whose score is very high on Wechsler test, are more likely to have an early psychomotor development.

3.3 Relationship between IQ index scores and DCD subtypes

Our findings display that IM-DCD had an influence on FIQ [F (1, 36)=4.67, p=0.035] and VSI [F (1, 36)=4.91, p=0.031]. VSC-DCD had an influence on FIQ [F (1, 36)=5.28, p=0.025]. DCDs being present in both groups (HIQ-HIP and Typical children), these results show that an IM and VSC-DCDs are less likely to be found in children with high IQ. Comparing data, results show that children without IM or VSC-DCD scored higher IQ in the tests, which could imply a relationship between DCD subtypes and IQ (Table 2). There is no significant difference between HIP

and HIQ. Furthermore, to better understand how IQ influences DCD subtypes, we have analyzed neuropsychomotor and cognitive profiles in the sample. We tested each variable's dependence on IQ.

		Whole sample of DCD children (N=38)					
DCD subtypes		VSI		VCI		FIQ	
		Mean	SD	Mean	SD	Mean	SD
IM-DCD	no	96.03	19.38	116.52	19.55	107.91	19.51
	yes	84.00	21.26	99.32	21.96	92.00	22.20
	Total	90.38	21.02	108.19	22.33	10.,44	22.15
VSC-DCD	no	103.56	20.26	121.07	17.39	115.94	15.92
	yes	86.16	19.63	104.24	22.33	95.48	21.68
	Total	90.38	21.02	108.19	22.33	100.44	22.15

Legend: VSI : Visual Spatial Index ; VCI : Verbal Compréhension Index ; FIQ : Full Intellectual Quotient ; SD : Standard Deviation ; DCD subtypes : Developpemental Coordination Disorder subtypes ; IM-DCD : Ideomotor DCD ; VSC-DCD : Visuo-Spatial/ or Constructional DCD.

Table 2: Mean of scores in IQ scale for each DCD subtypes in whole sample.

3.4 Relationship between IQ and neuropsychomotor features

Regarding neuropsychomotor features evaluated by NP-MOT battery, we compared HIQ-HIP DCD children to typical DCD children : 84% vs 47%, respectively, achieved object spatial orientation skill but not significantly, 84% vs 37% of adiadochokinesia $\chi 2$ (1)=5.4, p=0.02, [95% CI, 0.033 to 0.041], and 10% vs 87% of bimanual coordination disorder $\chi 2$ (1)=9, p=0.003, [95% CI, 0.003 to 0.005] (Table 3). There is no significant difference between HIP and HIQ. Outcomes showed better scores in favor of HIQ-HIP group for the "objects spatial orientation" item, but they had worse scores than typical children with DCD regarding "spatial orientation on others" and "body integration of spatial orientation" item (Table 4). Regarding functional laterality, we found a statistical difference beginning at QI=130, between HIP and typical children $\chi 2$ (1)=4.571, p=0.033, [95% CI, 0.052 to 0.061], with 33% of right-handed and 67% of left-handed versus 65% of right-handed and 35% of left-handed respectively. There is no statistical difference in this aspect between HIQ and typical children neither between HIP and HIQ children; HIQ presents 80% of right-handed and 20% of left-handed children (see Table 4).

NP-MOT Tasks: Success with age-related normative data			Whole sample of DCD children and IQ levels (N = 38)							
			HIP (n=10)		HIQ (n=9)		HIP-HIQ (n=19)		Typical (n=19)	
			n	%	n	%	n	%	n	%
Manual Praxis	Bimanual coordination	yes	9	90	8	88.89	17	89.47	5	26.32
		no	1	10	8	11.11	2	10.53	14	73.68
Muscle tone	Adiadochokinesis	yes	8	80	8	88.89	16	84.21	7	36.84
		no	5	50	8	88.89	15	78.95	12	63.16

Legend: HIP: High Intellectual Potential (gifted children); HIQ: High Intellectual Quotient

Table 3: IQ's influence on neuropsychomotor tasks of NP-MOT battery (Vaivre-Douret, 2006) and neurovisual functions.

NP-MOT Tasks: Success with age-related normative data			Whole sample of DCD children and IQ levels (N = 38)								χ^2 HIP-HIQ /Typical		
			HIP (n = 10)		HIQ (n = 9)		HIP-HIQ (n = 19)		Typical (n = 19)				
			n	%	n	%	n	%	n	%	value	df	p-value
Bodily spatial orientation	**In relation to self**	yes	8	80	9	100	17	89.47	17	89.47	0.003	1	0.86
		no	2	20	0	0	2	10.53	2	10.53			
	Spatial orientation with 2 to 3 objects	yes	8	80	8	88.89	16	84.21	9	47.37	1.96	1	0.224
		no	2	20	1	11.11	3	15.79	10	52.63			
	Spatial orientation in relation to other	yes	5	50	4	44.44	9	47.37	11	57.89	0.43	1	0.51
		no	5	50	5	55.56	10	52.63	8	42.10			
	Spatial cues (e.g. under)	yes	10	100	9	100	19	100	17	89.47	0.11	1	0.74
		no	0	0	0	0	0	0	2	10.53			
Manual Praxis	**Imitation of gestures: hands**	yes	10	100	9	100	19	100	17	89.47	0.47	1	0.49
		no	0	0	0	0	0	0	2	10.53			
	Imitation of gestures: Fingers	yes	7	70	6	66.67	13	68.42	13	68.42	0.03	1	0.86
		no	3	30	3	33.33	6	31.58	6	31.58			
	Digital Praxis	yes	5	50	4	44.44	9	47.37	11	57.89	0.22	1	0.64
		no	5	50	5	55.56	10	52.63	8	42.10			
	Buccofacial Praxis	yes	9	90	9	100	18	94.73	12	63.16	0.50	1	0.21
		no	1	10	0	0	1	5.26	7	36.84			
	Bimanual symmetric pronation-supination	yes	10	100	9	100	19	100	16	84.21	0.47	1	0.49
		no	0	0	0	0	0	0	3	15.79			
	Bimanual asymmetric pronation-supination	yes	7	70	6	66.67	13	68.42	9	47.37	0.39	1	0.53
		no	3	30	3	33.33	6	31.58	10	52.63			
	Hypertonia: pyramidal distal disorder	yes	3	30	1	11.11	4	21.05	8	42.11	1	1	0.312
		no	7	70	8	88.89	15	78.95	11	57.89			
	Hypotonia	yes	5	50	3	33.33	8	42.11	7	36.84	0.17	1	0.68
		no	5	50	6	66.67	11	57.89	12	63.16			

Muscle tone	**Sitting tone/ pushes control**	yes	3	30	2	22.22	5	26.32	9	47.37	1.5	1	0.22
		no	7	70	7	77.78	14	73.68	10	52.63			
	Knee jerk reflex (left-right)	yes	5	50	6	66.67	11	57.89	9	47.37	0.43	1	0.51
		no	5	50	3	33.33	8	42.11	10	52.63			
	Passive angles (lower limbs)	yes	7	70	6	66.67	13	68.42	9	47.37	0.47	1	0.50
		no	3	30	3	33.33	6	31.58	10	52.63			
	Synkinesis	yes	1	10	5	55.56	6	31.58	13	68.42	0.8	1	0.37
		no	9	90	4	44.44	13	68.42	6	31.58			
Coordination	**Standing tone control**	yes	5	50	1	11.11	4	21.05	7	36.84	0.33	1	0.56
		no	5	50	8	88.89	15	78.95	12	63.16			
	Static balance	yes	5	50	8	88.89	13	68.42	9	47.37	0.39	1	0.53
		no	5	50	1	11.11	6	31.58	10	52.63			
	Dynamic balance	yes	5	50	7	77.78	12	63.16	9	47.37	1.47	1	0.23
		no	5	50	2	22.22	7	36.84	10	52.63			
	Upper-lower coordination difficulties	yes	10	100	1	11.11	11	57.89	11	57.89	0.73	1	0.39
		no	0	0	8	88.89	8	42.11	8	42.11			
Gnosis	**Bilateral gnosis disorder**	yes	1	10	1	11.11	2	0	3	15.79	0.13	1	0.72
		no	9	90	8	88.89	17	100	16	84.21			
	Unilateral gnosis disorder	yes	1	10	1	11.11	2	10.53	4	21.05	0.13	1	0.72
		no	9	90	8	88.89	17	89.47	15	78.95			
Laterality	**Upper tonic laterality**	yes	2	20	3	33.33	5	26.31	7	36.84	0.60	1	0.81
		no	8	80	0	0	8	42.11	8	42.10			
		Indeterminate	0	0	6	66.67	6	31.58	4	21.05			
	Lower tonic laterality	yes	3	30	4	44.44	7	36.84	6	31.58	0	1	1
		no	6	60	2	22.22	8	42.11	8	42.10			
		Indeterminate	1	10	3	33.33	4	21.05	5	26.31			
	Upper functional laterality	yes	5	50	7	77.78	12	63.16	14	73.68	0.15	1	0.70
		no	5	50	2	22.22	7	36.84	3	15.79			
		Indeterminate	0	0	0	0	0	0	2	10.53			
	Lower functional laterality	yes	8	80	8	88.89	16	84.21	15	78.95	0.03	1	0.86
		no	2	20	1	11.11	3	15.79	2	10.53			
		Indeterminate	0	0	0	0	0	0	2	10.53			
	Gestual+ psychosocial + spontaneous homogenous laterality	yes	0	0%	6	66.67	6	31.59	11	61.11	0.17	1	0.68
		no	7	70%	1	11.11	8	42.11	2	5.56			
		Indeterminate	3	30%	2	22.22	5	0	6	33.33			
	Horizontal pursuit	yes	6	60	8	88.89	14	73.68	14	73.68			

Neurovisual functions		no	4	40	1	11.11	5	26.32	5	26.32	0	1	1
	Vertical pursuit	yes	6	60	4	44.44	10	52.63	7	38.89	0.53	1	0.47
		no	4	40	5	55.56	9	47.37	11	61.11			
	Visual Evoked Potential (VEP) test	yes	8	80	9	100	17	89.47	17	89.47	0	1	1
		no	2	20	0	0	2	10.53	2	10.53			
	Electoretinogram (ERG) neurovisual test	yes	10	100	9	100	19	100	19	100	0	1	1
		no	0	0	0	0	0	0	0	0			

Legend: HIP: High Intellectual Potential (gifted children); HIQ: High Intellectual Quotient; IQ: Intellectual Quotient; *: Significant difference $p \leq 0.05$; df: Degrees of freedom.

Table 4: IQ's influence on neuropsychomotor tasks of NP-MOT battery (Vaivre-Douret, 2006) and neurovisual functions.

3.5 Relationship between DCD subtypes and cognitive functions

In whole sample, IM-DCD had a significant, strong and positive correlation with executive functions disorder (FE) (ρ = +0.519 [95% CI, 0.163 to 0.795], p=0.001), and a significant, strong, and negative correlation between Khos cubes test failure and VSC-DCD (ρ= -0.651 [95% CI, -0.899 to -0.406], p=0.006). There is no significant difference between HIP and HIQ.

4. Discussion

This study displayed similar clinical features of DCD in both groups HIQ-HIP and typical children. High IQ DCD children have significantly better executive functions and visio-spatial constructional functioning than typical children with DCD but worse auditory attention and memory, and more neurological soft signs. These outcomes underline better skills of mental representation and evocation through internal language in HIQ-HIP children with DCD allowing them to better plan and control gestures that contribute to less Ideomotor or Constructive pure DCD.

They are in accordance with the literature; on one hand concerning the link between intelligence and executive functions [48]. In HIQ-HIP children, it highlights better activation and connectivity of the frontoparietal lobe and cerebral cortex improving fluid reasoning [49]. On the other hand, VSC-DCD is characterized by specific disorders of "visuo-spatial motor structure", "visuo-motor integration"," visuo-spatial motor construction", associated with ocular pursuit disorders [31, 46]. Two systems are considered in visual perception [50] but the occipital-parietal dorsal pathway ("where") is focused on localization and action to direct the gesture with vision. This pathway is impaired in the VSC subtype [31, 46] and involves thalamus, basal ganglia, and cerebellum, this last affecting also visual pursuits [32, 46]. Desco's study [51] shows bilateral activation patterns and increased activation in the parietal and frontal regions of gifted children and demonstrates that these activations are associated with improved skills in visuospatial treatment and logical reasoning. We identified more left-handed in HIP children (IQ $\geq$ 130) confirming more involvement of the right cortex in HIP group. This may open more in-depth research fields to better understand the neurological impairments involved in DCD in this population.

Higher frequency of MX-DCD can be explained by the fact that fewer primary school children (with high IQ) consult for pure DCD such as VSC or IM subtype because they can easily compensate the disorder by mental strategies and better executive functions. Recent studies [31, 32, 34, 36] showed that MX subgroup shares impairments common to IM and VSC, and is characterized by specific impairments regarding motor coordination of the lower and upper limbs, poor manual dexterity, neurological soft signs suggesting synkinesis and/ or adiadochokinesia, and some comorbidities (e.g., auditory-memory deficits, auditory-attention difficulties...). Based on these findings, our outcomes identified more auditory attention and memory, significant adiadochokinesis deficits and bimanual coordination disorder in HIQ-HIP group, allowing to better explain the high rate of MX subtype in this group. Adiadochokinesia is the difficulty to perform alternative prono-supination movements of the hand and evoke more neurological soft signs in HIQ-HIP children [36, 52], highlighting cerebellum impairment. It is often associated with learning disabilities and our findings confirm higher risks of comorbidity in DCD [22, 25, 53], particularly in MX by that is the common subtype in the main DCD studies [32]. It is important not to neglect comorbidity's influence on IQ scores for HIQ children as it might lower the FIQ (120-129).

To be gifted does not prevent a neurodevelopmental disorder such as DCD and possible learning disability may lower the FIQ. For example, mathematical difficulties (applying calculation with a handwritten operation, geometry, problem to solve) are strongly present in both groups in our sample with no significant difference. This is in line with literature proving that mathematics skills are particularly affected in DCD [31, 36]. Our finding displayed mainly mathematic difficulties in MX-DCD subtype and very few in VSC-DCD for HIQ-HIP, confirming the better compensation strategies in high IQ children with DCD concerning pure subtype as VSC subtype [34].

Regarding psychomotor development, the finding highlight early milestones in high IQ DCD but the quality of motor skills still deficient and those from early childhood. These are in accordance with category C of the diagnosis criteria of DSM-5 [28]. Motor milestones are not systematically delayed by a DCD as confirmed by previous studies [8, 32], but the acquisition of coordinated motor skills remains below chronological age (criterion A of DSM-5) [28]. It is therefore fundamental to differentiate psychomotor development (acquisition of walking, sitting...) from neuromotor skills (coordination, praxis...) because, despite an early maturation in high IQ children, motor performance of intentional gestures or the ability to perform complex motor actions can be disturbed by a neurological dysfunction [36] as in typical children.

5. Conclusion

In conclusion, the findings of the present study are relevant to attest that HIQ-HIP children DCD have similar clinical features compared to typical children with DCD. They present lower rates of pure VSC and IM-DCD than typical children with DCD because they appear to use mental evocation with visual representation and internal language necessary for better planning. Thus, we can recommend for clinicians to use these strategies in the remediation for cognitive difficulties in typical children, do not overlook that the higher the IQ, the more HIP

children can mask learning disabilities [8, 18, 54] with a heterogeneous profile of index level scores between VSI and VCI [8, 55, 56], VSI being more affected by DCD, that the presence of a subtype of DCD decreases the IQ index scales and therefore also FIQ. Thus, it is possible to misdiagnose some HIP in HIQ group. That questions the validity of the IQ cutoff score of the 130 thresholds for the IQ of HIP. Therefore, regarding our findings, it appears essential to evaluate in-depth with multidimensional assessments (neuropsychological and neuropsychomotor batteries) the child presenting some heterogeneous index scores or subtests in his IQ profile. Finally, it underlines also that it is important to take into account multiple selection criteria to define HIP gifted children, such as behavioral, socio-emotional and cognitive skills, informal sources (parents and teachers) [4, 5].

The strengths of the study are in the detailed neuropsychological profile provided on the children, and the history of early development. The results demonstrate important implications for future clinical research, and it is useful for clinical decision-making processes. The limitations are in the small numbers, especially with the division of the samples into DCD subtypes. Future research could replicate the current study with a larger sample and assess in addition to socio-cognitive and psycho-affective components.

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Declaration of Interest Statement

The authors declare that they have no conflict of interest.

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