Research Article

Do Children with High Intellectual Potential have an Early Motor Development and What is the Impact on IQ Profile?

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Abstract

Objective: The neuropsychomotor development in children with high intellectual potential (HIP, IQ≥130) remains poorly studied. We aimed to explore their developmental trajectory of motor milestones and anamnestic data regarding their IQ profile.

Methods: Wechsler Intelligence Scale for children (WISC-V), health record, and anamnestic questionnaires were analyzed in 68 healthy children (50 HIP/18 neurotypical), aged 6-13 years-old (mean 10y; SD 2.2). Fifty HIP-children were involved in intra-group analysis. Two groups were matched: 18 neurotypical (90≤IQ≤110) and 18 HIP (IQ≥130) random children.

Results: Significant-negative correlations were shown in the whole sample between full IQ and sitting (7 months) (r=-0.32, p=0.01, [95%CI=-0.52 to-0.09]), walking (12 months) (r=-0.30, p=0.03, [95%CI=-0.51 to-0.01], and the first sentences (18 months) (r=-0.60, p<0.001, [95%CI= -0.71 to-0.39]); with significant high rate of earlier development in HIP compared to neurotypical-children. Verbal-Comprehension-Index (VCI) was significantly higher in heterogenous profile while Visual-Spatial-Index (VSI), Fluid-Reasoning-Index (FRI), Working-Memory-Index (WMI), Processing-Speed-Index (PSI), were significantly higher in homogenous profile. Significant correlations (p<0.05) were shown between VSI, WMI, PSI and clumsiness in daily life activities, games and scholar abilities explaining 41% of the variance in the heterogenous profile of HIP-children.

Conclusion: An early motor development was found in HIP compared to neurotypical-children. We displayed an important part of the heterogeneous profile, highlighting the DSM-5 criteria of a developmental coordination-disorder which is early tracked down with significant difficulties impacting on daily life activities, games and scholar abilities. The findings underline the importance that clinicians analyze the variability of the index scores in the IQ profile at school-age in relation with the anamnestic data.

Keywords: Gifted children; High Intellectual Quotient; High Intellectual Potential; Motor development; Daily life abilities; Developmental coordination disorder; Homogeneous/Heterogeneous IQ profile; IQ indexes

Abbreviations: HIP-High Intellectual Potential; IQ-Intellectual Quotient; VCI-Verbal Comprehension Index; VSI-Visual Spatial Index; FRI-Fluid Reasoning Index; WMI-Working Memory Index; PSI-Processing Speed Index; FIQ- Full IQ; DCD-Developmental Coordination Disorder; PIQ-Performance Intelligence Quotient; VIQ-Verbal Intelligence Quotient; DSM-Diagnostic and Statistical Manual of Mental Disorders 5th edition, WHO-World Health Organization.

1. Introduction

The intelligence of children with a high intellectual potential (HIP) "gifted children" keeps on authors' interest for three centuries [1-4]. The unanimous definition is based on the Wechsler psychometric scale as recommended by World Health Organization (WHO) [5]: FIQ≥130, two standard deviations from the mean according to the Gaussian curve (2.2% of the population) [4, 5]. Many studies have focused on analyzing cognitive functioning at school age to illuminate these children's profiles. The verbal field confirms better linguistic skills in HIP children than in neurotypical children [6-8].

Recent studies showed that early language skills are the cognitive field that best predicts IQ [9]. It does not provide information on the grouping of the data placement to judge the motor field's representativeness without subjectivity (absence of factor analysis or another statistical test for this). Vaivre-Douret [8-10] looked retrospectively at the developmental trajectory before four-years-old of a HIP children sample assessed at school age with homogenous IQ profile. She obtained cognitive-developmental norms in a french sample of HIP children by comparing french psychomotor developmental scales as Brunet-Lézine norms [11] and developmental motor scales DF-MOT [12]. She highlighted in accordance with the literature the advance of the language acquisitions: babbling around four months, imitation of animal noises around 22 months, the association of two words in order to express the "first sentence" is around 18 months. Other authors have noted motor development advance in HIP child but this field remains less deeply investigated in the literature [8, 10, 13-23]. Arffa [14] has particularly explored executive functions at school age and he showed a positive correlation between high FIQ and these functions, including working memory, resistance to interference during attention tasks, planning, and mental flexibility.

Some studies [8, 10, 17, 22] underlined an early emergence of neuro-postural and locomotor acquisitions in HIP children following an early axial cephalocaudal and proximodistal maturation. Another study on 561 HIP children also confirmed advanced development of independent walking compared to neurotypical children [13]. The retrospective studies of a sample [8, 22] have established motor development norms in a french sample of HIP children in comparison with the typical norms of the Brunet-Lezine scale of psychomotor development of early childhood [11] and DF-MOT motor scale [12, 10, 24-27]. They have specified an advance around two months, two standard deviations above the mean: holds head in the axis at one month (m) + 1 week (w) versus three months in neurotypical children, voluntary grasp at 3 m + 1w versus 4 m, turning overresponse around 4 m + 4 w versus 8 m, sitting without support at 6 m + 3 w versus 10 m, sits up alone around 7 m + 3 w versus 10 m, takes a bead between thumbs and forefinger 8 m + 2 w versus 9 m, independent walking 12 m + 4 w versus 14 m, start eating with a spoon on his own 12 m + 2 w versus 17 m, climbs stairs 15 m + 2 w versus 17 m + 1 m, comes down stairs with help without alternating feet 16 m + 3 w versus 19 m + 1 m, climbs stairs alone without support alternating feet 24 m + 1 w versus 34 m + 2 m, puts slippers on without help 24 m + 3 w versus 30 m + 1 m, rides a bike with stabilizers 24 m + 3 w versus 36 m + 1 m.

Likewise, it showed that preterm HIP children (IQ≥130) can present a developmental motor advance without significant difference from the HIP children born at term. Analysis of retrospective anthropometric data (Head Circumference, Height, Weight) has significantly revealed more neonatal hypertrophia (≥90 percentile) in these preterm children identified as HIP at school age and with a favorable environment [28, 21]. Moreover, the only longitudinal studies [10, 22] specified that the motor development advance's results had concerned HIP children with a homogeneous IQ profile (no more than 12 points between the indexes VIQ and PIQ). A good level of PIQ similar to VIQ would be protective of disorders [10]. Thus, what about HIP children with a heterogeneous IQ profile? Is developmental advance a general phenomenon of HIP children? Why individual HIP children diagnosed at school age would not have this motor development precocity? Could inter and intra-individual variability in development be explained by some environmental conditions or by some abnormalities?

In the literature, IQ (WISC-III and WISC-IV) is considered heterogeneous with 15 points of difference between the highest and lowest index, often between PIQ and VIQ [29]. Grégoire [30] considers 12 points as a dispersion threshold that remains a frequent phenomenon (40% of the general population) against a third of the general population with a difference of 15 points. A difference of 20 points is rare since it appears for only one-sixth of the population. Concerning the WISC-V [4], the profile is considered heterogenous from 23 points when considering the maximum difference between the highest and lowest index [31]. A difference of 23 points is only reached by 8% to 18% of the population, depending on the indexes. Nevertheless, when all the indexes are taken into account, 52.8% of the population reach the 23 points difference [32].

In HIP children, a significant dissociation between the indexes appears more frequently observed. Hence, certain authors [33-37] consider a heterogeneous IQ profile a typical developmental characteristic specific to this population. According to these authors, HIP children have more irregular and heterogeneous profiles than neurotypical children. Other authors showed that this heterogeneity could be the origin of some neurodevelopmental disorders or abnormalities as learning disabilities (e.g., developmental coordination disorder (DCD)/dyspraxia, dyslexia, dysgraphia) or neuromotor impairment never examined [25, 10, 38-44]. Moreover, specific cognitive or socio-cognitive, psycho-affective difficulties could also explain a part of the heterogeneity [38, 40, 45-52]. Terrassier [53] suggested dyssynchrony or, as he calls it, "psychomotor/intellectual disharmony" as a developmental fact in HIP children, psychomotor development following the typically developing child. Vaivre-Douret [8, 10] underlines that psychomotor disharmony, described by Terrassier, appears more likely to impair abilities similar to neurotypical children than as a fundamental characteristic of HIP children.

Boschi et al.'s study [46] pointed out that the homogeneous HIP children had better memory and motor skills at school age than the heterogeneous HIP children. Vaivre-Douret [38] asserts that advanced neurophysiological maturation in HIP children with a homogeneous IQ allows the early emergence of postural-locomotors, visual-manual coordination as well as language and cognitive processes. It appears a methodological bias in studies confirming a heterogeneous IQ profile as a developmental characteristic of HIP children. Most of the authors recruited their samples only in clinical consultations with the bias to find mainly heterogeneous IQ profiles. Thus, it appears evident that these children are more at risk of having a disorder. It appears essential to better understand these children's developmental trajectories and to analyze the data regarding IQ indexes.

The current study aimed to analyze the IQ profile of high intellectual potential and neuropsychomotor development data in HIP children compared to neurotypical children. The first hypothesis suggests a relationship between early neuropsychomotor development reported in anamnestic data and high IQ collected at school age. The second explores the neuropsychomotor development regarding IQ profile to determine and understand the links between homogeneous versus heterogeneous HIP children's profiles.

2. Material and Methods

2.1 Population

The current study is transversal and retrospective, focusing respectively on psychometric assessment and anamnestic data. The study population included 68 children aged 6 to 13 years old (mean=10 years four months; SD=2.2) recruited in different schools in Paris, France. Into some of these schools, there are particular cursus for HIP enabling the inclusion of 50 HIP children identified with the Wechsler intelligence scale [4]. Eighteen neurotypical children (NTC) are the focus in our previous study.

Regarding data analysis in intra-group, we used the whole HIP sample (n=50). To compare HIP to neurotypical children, we selected two matched groups following the Gaussian curve of the Wechsler intelligence scale [4]: 18 neurotypical random children ($90 \leq IQ \leq 110$) and 18 HIP random children ($IQ \geq 130$). The two groups are matched according to age and sample size. Inclusion criteria were strict: children with a sensory deficit, several visual abnormalities (e.g., strabismus, nystagmus, amblyopia), a diagnosis of severe language disorder, genetic disorder, psychiatric abnormalities (according to DSM-5 criteria) [54], or general medical abnormalities, and traumatic brain injury are not included. Nor was any child born premature (< 37 weeks) and no physical therapy neither medication.

The Institutional ethic committee of Paris Descartes University, Sorbonne Paris city, approved the study (CER-PD 2019-93). Participants provided written informed consent before starting the study, signed by a parent or legal representative, and children before enrollment in the study.

2.2 Material

Anamnestic data were obtained through the personal child health record, a semi-directive interview, and a retrospective anamnestic questionnaire filled by the parents. The questionnaire was about pregnancy, delivery mode, family, and medical history. In addition to developmental history (childcare from birth to 6 years-old), psychomotor development (e.g., sitting alone, walking), daily life (dressing, cutlery use, tying shoelaces, riding a bicycle, swimming) and response to the milestone about clumsiness, school activities (cutting, drawing according to a model, coloring), and hobbies (especially difficulties with constructional play such as puzzle and Lego following a model). We also asked about language and communication (e.g., babbling, first sentences). Answers could be either quantitative (age, grades at school, for example) or dichotomic ("yes" coded as 1 or "no," coded as 0 for questions such as "Did he/she like to draw?").

All HIP children completed a standard measure of intelligence with Wechsler Intelligence Scale for children according to the age (WISC-V) [4]. Verbal Comprehension Index (VCI), Visual-Spatial Index (VSI), Fluid Reasoning Index (FRI), Working Memory Index (WMI), Processing Speed Index (PSI), and Full IQ (FIQ) scores were expressed as standardized scores (mean 100, SD=15).

2.3 Statistical procedures

We used SPSS software [55] for statistical treatment. Data analysis according to the intention-to-treat principle. We used a p-value of 0.05 to indicate statistical significance. We also applied the Bonferroni method to adjust for multiple comparisons. To analyze the statistical difference between HIP and neurotypical children, we used two-group comparisons of scale scores through Student T-test (t) for quantitative data and a Chi-square test (χ^2) for dichotomic data. A Pearson's correlation test (r) for continuous numeric variables and Spearman's ρ test (ρ) for non-parametric correlations were used. To analyze retrospective neuropsychomotor development data regarding IQ profile (homogeneous/heterogeneous) in HIP children, we used 23 points as dispersion threshold [32] between the highest and lowest index.

3. Results

3.1 Sample descriptive analyzes

Table 1 showed comparisons between IQ index scores in our HIP children group and the french psychometric characteristics in HIP children [4]. The findings confirmed our sample's representativeness compared to the national average for HIP children, with significantly higher VCI, FRI, WMI, and FIQ scores. Table 2 showed sociodemographic, anthropometric, and psychometric characteristics of the whole sample compared to the two matched groups (18 HIP vs. 18 neurotypical children group). Only IQ scores were identified as differentiation criterion of both groups ($t= -12.85$, $df=34$, $p<0.001$, [95% CI= -38.03 to -27.64]). The findings showed no statistical difference between both groups concerning delivery mode, substance use during pregnancy, APGAR at 5 and 10 minutes, pregnancy complications, neither anthropometric data.

IQ indexes	Sample of HIP children (n=50)	WISC-V norms for HIP (n=95)	t-test score	p-value	df	95% CI
VCI (mean, SD)	138.66 (11.22)	127.7	6.91	<0.001*	49	7.77 to 14.15
VSI (mean, SD)	124.26 (12.22)	121.2	1.77	0.08	49	-0.41 to 6.53
FRI (mean, SD)	126.72 (10.84)	120.3	4.19	<0.001*	49	3.34 to 9.5
WMI (mean, SD)	123.48 (13.5)	117.9	2.92	0.005*	49	1.74 to 9.42
PSI (mean, SD)	113.34 (13.39)	112.9	0.232	0.81	49	-3.36 to 4.24
FIQ (mean, SD)	133.68 (7.54)	127.5	5.79	<0.001*	49	4.04 to 8.32

Note. HIP: High intellectual potential; WISC-V: Wechsler Intelligence Scale for Children 5th edition; SD = Standard deviation. FIQ = Full Intellectual Quotient. VCI = Verbal Comprehension Index. VSI = Visual Spatial Index. FRI = Fluid Reasoning Index. WMI = Working Memory Index. PSI = Processing Speed Index.

Table 1: Comparison between IQ indexes in the HIP children sample and the french characteristics psychometric of HIP children [4].

Sociodemographic, psychometric, and anthropometric data	HIP sample n=50	Matched groups n=36		χ^2 (1) or t-test (df=34) HIP/NTC		
		HIP children group (n=18)	NTC children group (n=18)	Value	p-value	95% CI
Gender (%):						
Male	64	61.11	66.67	0.04	1	1 to 1
Female	36	38.89	33.33	0.07	1	1 to 1
Age (mean, SD)	130.06 (19.13)	112.94 (15.31)	110.33 (34.63)	-0.3	0.77	-21.05 to 15.83
FIQ (mean, SD)	133.68 (7.54)	133.17 (8.51)	100.33 (6.72)	-12.85	<0.001*	-38.03 to -27.64
Delivery mode:						
Vaginal (%)	31	18	15	0.27	0.73	0.72 to 0.74
Caesarean (%)	19	0	3	1.8	0.37	0.36 to 0.38
Substance use during pregnancy (%):						
Alcohol	14	6	6	0	1	1 to 1
Tobacco	12	3	3	0	1	1 to 1
Pregnancy complications (%):						
Hypertension	0	0	0	0	1	1 to 1
Preeclampsia/toxemia	2	0	0	0	1	1 to 1
Diabetes	0	0	0	0	1	1 to 1
Placenta previa	2	0	0	0	1	1 to 1
Contractions	2	0	5.56	0.33	1	1 to 1
Hemorrhage	0	0	0	0	1	1 to 1
Oligoamnios	0	0	0	0	1	1 to 1

Twin pregnancies	0	0	0	0	1	1 to 1
MAP	2	5.56	0	0.33	1	1 to 1
Weight (Kg) at birth (mean, SD)	3.49 (0.57)	3.49 (0.57)	3.36 (0.29)	-1.37	0.18	-0.58 to 0.12
Height (cm) at birth (mean, SD)	50.26 (3.2)	50.26 (3.19)	49.77 (2.17)	0.1	0.92	-2.23 to 2.47
Head circumference at birth (mean, SD)	35 (1.35)	35 (1.35)	35.23 (1.86)	0.47	0.63	-0.85 to 1.37
APGAR (mean, SD):						
5 minutes	9.56 (0.84)	9.56 (0.84)	10	-0.6	0.55	-0.57 to 0.31
10 minutes	10 (0)	10 (0)	10	0	1	1 to 1

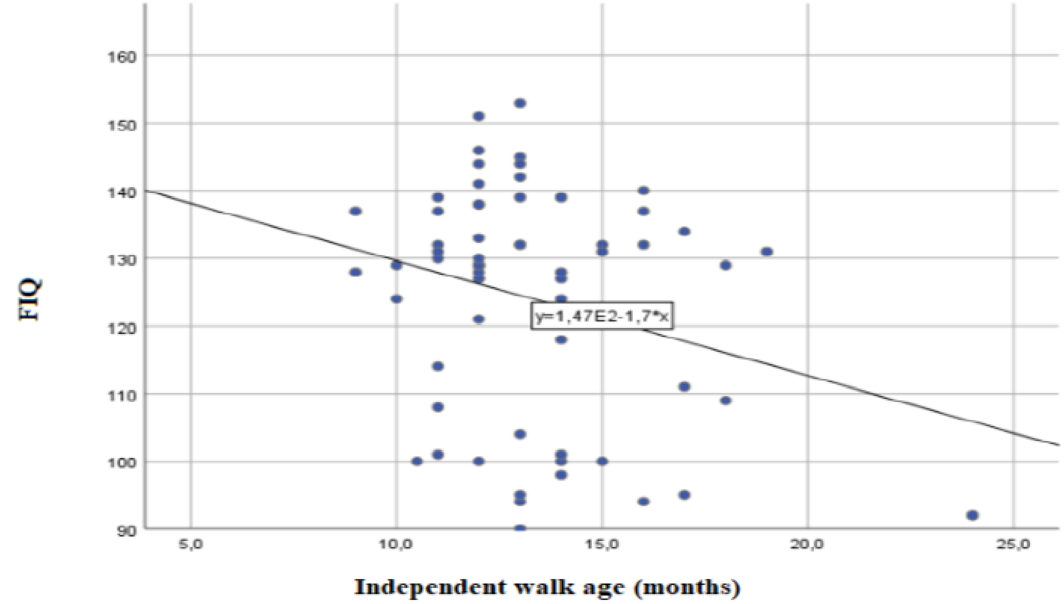
Note. HIP: High intellectual potential; NTC: Neurotypical children; FIQ: Full Intellectual Quotient; MAP: Mean Arterial Pressure

Table 2: Sample characteristics with sociodemographic, psychometric, and anthropometric data in HIP and neurotypical children (NTC).

3.2 Relationship between IQ and neuropsychomotor development

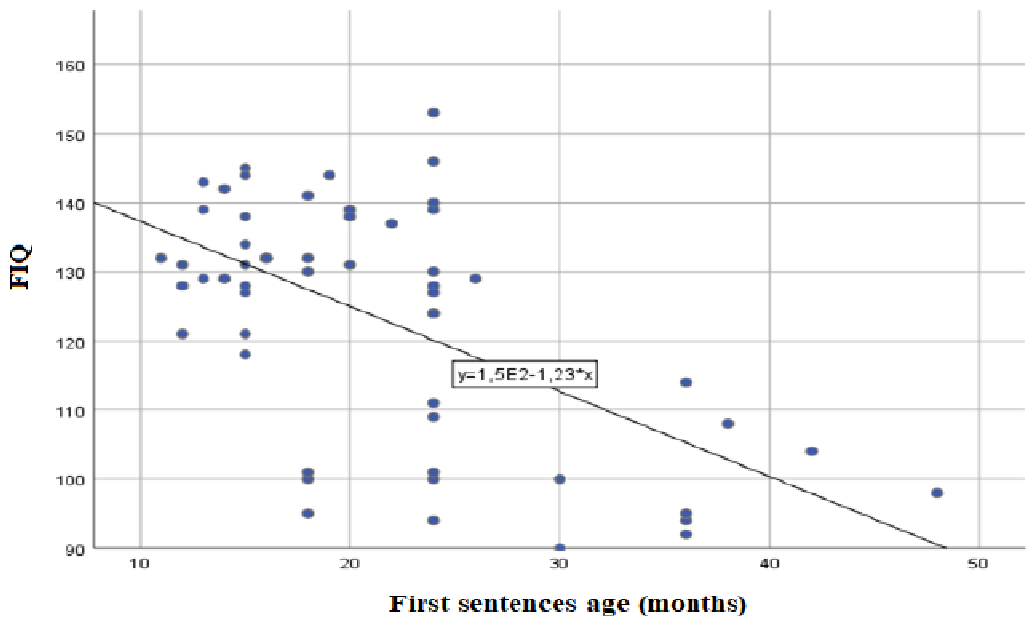
In the whole sample, there are significant and negative correlations between FIQ and sitting without support (around 7 months on average) (r=-0.32, p=0.01, [95% CI= -0.52 to -0.09]), independent walking (around 12 months on average) (r=-0.30, p=0.03, [95% CI=-0.51 to -0.01] (Figure 1), and the first sentences (around 18 months on average) (r=-0.60, p<0.001, [95% CI= -0.71 to -0.39]) (Figure 2). These correlations showed that children with high FIQ have an early development (two months advance on average) of sitting, walking, and language according to the developmental norms of Brunet-Lézine [11] and DF-MOT motor scale [12]. We identified high rate of earlier development of sitting, walking, and language in HIP children compared to neurotypical children group (Figure 3). The comparison of the two groups, showed that sitting without support (t= 2.23, df=34, p=0.03, [95% CI= -1.7 to -0.08]), independent walking (t= 3.42, df=34, p=0.001, [95% CI=4.43 to -1.13]), and expression of first sentences (t= 5.23, df=34, p<0.001, [95% CI=17.05 to -7.51]) were significantly early developed in HIP children compared to the neurotypical children.

Regarding IQ profile in HIP children, the results showed a significant difference between homogenous and heterogeneous profiles for babbling (4 months on average) (t=-1.99, df=49, p=0.05, [95% CI= -26.51 to 0.20]) and independent dressing age (3 years old on average) (t= 2.09, df=49, p=0.04, [95% CI= -3.47 to -0.02]). These data underlined the direct link between the homogeneous profile and the early ability to dress and babble. We showed a high rate of advanced motor development in HIP children with homogenous IQ profiles compared to heterogenous IQ profiles. On the contrary, we identified a high language development rate (first sentences around 18 months) in HIP children with heterogeneous compared to homogenous IQ profile (Figure 4).



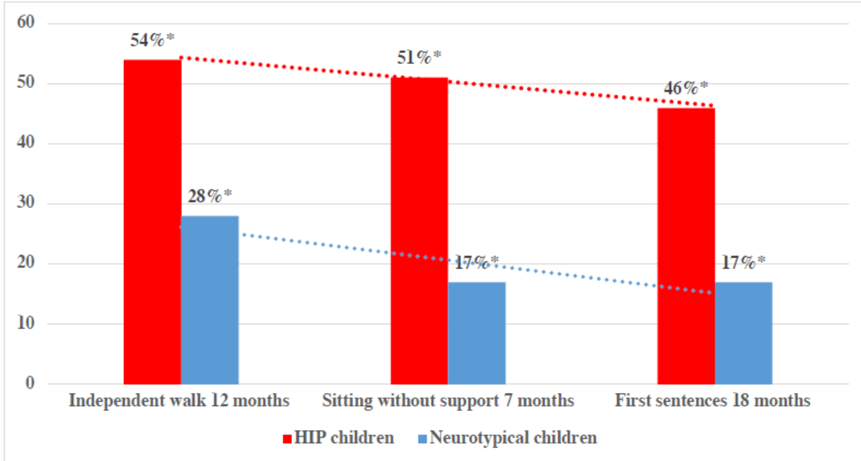
Note. FIQ: Full Intellectual Quotient

Figure 1: Significant and negative correlation between FIQ and independent walk age in the whole sample (n=68).



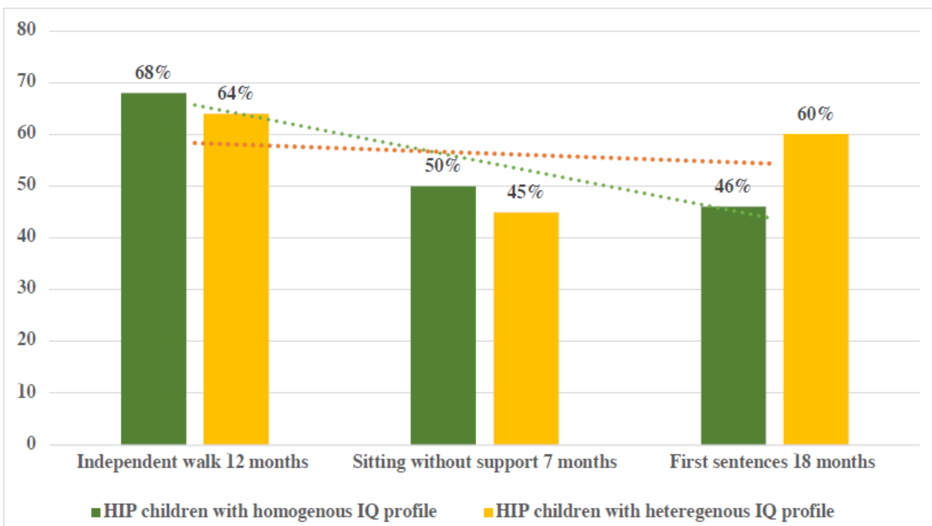
Note. FIQ: Full Intellectual Quotient

Figure 2: Significant and negative correlation between FIQ and first sentences age in the whole sample (n=68).



Note. *: Significant difference p<0.05; HIP: High intellectual potential

Figure 3: Percentages of advanced motor development and language between HIP children compared to neurotypical group according to the french developmental norms [11-12].



Note. HIP: High intellectual potential; IQ: Intelligence Quotient

Figure 4: Percentages of advanced motor development and language between HIP children with homogenous and heteregenous IQ profile according to the developmental norms [11-12].

3.3 Relationship between daily life abilities and IQ profiles (homogenous/heterogeneous)

Table 3 showed the average of IQ indexes in homogenous compared to heterogeneous profile concerning HIP children. The finding highlighted that VCI was higher in heterogenous profile while VSI, FRI, WMI, and PSI were higher in homogenous profile. A statistical difference between both groups regarding VCI (in favor of heterogenous profile), WMI, and PSI (in favor of homogenous profile) was shown. In whole sample of HIP children, the findings showed significant correlations between IQ indexes and neuropsychomotor development milestones on daily life abilities: "Struggling to put on his/her clothes correctly" was negatively significantly correlated with WMI (r= -0.30 p=0.02, [95% CI=-0.51 to -0.03]). "Struggling to button his/her coat" was significantly and negatively correlated with VSI (r=-0.33, p=0.01, [95% CI=-0.50 to -0.14]), WMI (r=-0.30, p=0.03, [95% CI=-0.5 to -0.01]) and FIQ [r=-0.30, p=0.02, [95% CI=-0.5 to -0.09]). "Using a knife correctly" was significantly and positively correlated with WMI [r=0.27, p=0.04, [95% CI=-0.03 to 0.5]) and PSI (r= 0.26, p=0.05, [95% CI=-0.01 to 0.51]). "Struggling using a fork" was significantly positively correlated with FRI (r=0.35, p=0.01, [95% CI=0.15 to 0.52]). "Clumsiness milestone" was significantly and negativity correlated with VSI (r= -0.3, p=0.02, [CI 95%= -0.5 to 0.07]), WMI (r= -0.31, p=0.02, [CI 95%= -0.50 to -0.08]), PSI (r= -0.75, p=0.04, [CI 95%= -0.50 to -0.02]).

Regarding IQ profile, we showed a significant correlation between homogenous/heterogeneous profile and "struggling to put clothes correctly, "difficulties putting clothes on the right side," "difficulties tying shoelaces," and "correct use of a knife" (Table 4). These daily life abilities were significantly and positively correlated with "Clumsiness milestone": "difficulties putting clothes on the right side" (r=0.30, p=0.005), "difficulties tying shoelaces" (r=0.44, p=0.005), "correct use of knife" (r= -0.55, p=0.001). We identified 41% of HIP children with heterogenous IQ profile (vs. 7% in homogenous IQ profile), which presents difficulties in at least two filed of these daily life abilities. In HIP children with heterogenous profile, we identified VCI (mean=148) and RFI (mean=124) as highest indexes, the lower were PSI (mean=107), WMI (Mean=119), and VSI (mean=122). These three indexes were significantly and negatively correlated to “clumsiness milestone” (respectively p=0.02; r= -0.30, p=0.04; r= -0.30, p=0.03; r= -0.31).

3.4 Relationship between games-scholar abilities and IQ profiles (homogenous/heterogeneous)

Regarding games and scholar abilities in HIP children, we showed a significant correlation between homogenous/heterogeneous profile and "play puzzles without difficulty," "play construction games without difficulties," "autonomy difficulties," "attention difficulties," and "adaptability in collective games" (Table 5). We identified 14% of HIP children with heterogenous IQ profile (vs. 7% in homogenous IQ profile), which presented difficulties in at least two filed of this scholar's abilities. In addition, we identifed high percentage of difficulties of handwriting, drawing copy, and coloring abilities in heteregenous IQ profile compared to homogenous one (respectively 64%, 62%, 67% vs 34%, 34%, 41%). While no reading difficulties were noted in either of the two profiles.

IQ indexes	Heterogeneous HIP children (n=28)	Homogeneous HIP children (n=22)	t-test score	p-value	df	95% CI
VCI (mean, SD)	147.09 (6.87)	132.04 (9.41)	-6.3	<0.01*	48	-19.86 to -10.25
VSI (mean, SD)	121.64 (14.69)	126.32 (9.65)	1.36	0.18	48	-2.26 to 11.63
FRI (mean, SD)	123.91 (10.97)	128.93 (10.41)	1.65	0.1	48	-1.08 to 11.12
WMI (mean, SD)	117.95 (12.53)	127.82 (12.8)	2.73	0.01*	48	2.6 to 17.13
PSI (mean, SD)	106.55 (10.5)	118.68 (13.13)	3.53	<0.01*	48	5.23 to 19.03
FIQ (mean, SD)	132.73 (7.55)	134.43 (7.59)	0.7	0.43	48	-2.64 to 6.04

Note. HIP: High intellectual potential. SD = Standard deviation. FIQ = Full Intellectual Quotient. VCI = Verbal Comprehension Index. VSI = Visual Spatial Index. FRI = Fluid Reasoning Index. WMI = Working Memory Index. PSI = Processing Speed Index.

Table 3: Comparison between IQ indexes in homogeneous and heterogeneous HIP children (n=50).

Daily life abilities		HIP children (n=50)		Spearman's ρ test (ρ)	
		Heterogeneous (n=22)	Homogeneous (n=28)	value	p-value
Struggling to put clothes correctly	Yes	6 (27.27%)	1 (3.57%)	0.356	0.022*
	No	16 (72.73%)	27 (96.43%)		
Difficulties putting clothes on the right side	Yes	7 (31.82%)	1 (3.57%)	-0.412	0.008*
	No	15 (68.18%)	27 (96.43%)		
Difficulties tying shoelaces	Yes	9 (40.91%)	2 (7.14%)	-0.397	0.011*
	No	13 (59.09%)	26 (92.86%)		
Correct use of knife	Yes	8 (36.36%)	25 (89.29%)	0.341	0.029*
	No	14 (63.64%)	3 (10.71%)		

Note. HIP: High intellectual potential

Table 4: Daily life abilities regarding IQ profiles (homogenous/heterogenous) in HIP children group.

Scholar abilities		HIP children (n=50)		Spearman's ρ test (ρ)	
		Heterogeneous (n=22)	Homogeneous (n=28)	value	p-value
Play puzzles without difficulties	Yes	17 (77.27%)	26 (92.86%)	-0.325	0.035*
	No	5 (22.73%)	2 (7.14%)		
Play construction games without difficulties	Yes	17 (77.27%)	26 (92.86%)	-0.278	0.072*
	No	5 (22.73%)	2 (7.14%)		
Autonomy difficulties	Yes	5 (22.73%)	1 (03.57%)	0.371	0.016*
	No	17 (77.27%)	27 (96.43%)		
Attention difficulties	Yes	8 (36.36%)	5 (17.76%)	0.28	0.069*
	No	14 (63.64%)	23 (82.14%)		
Adaptability in collective games	Yes	17 (77.27%)	26 (92.86%)	0.325	0.035*
	No	5 (22.73%)	2 (7.14%)		

Note. HIP: High intellectual potential

Table 5: Scholar abilities and games regarding IQ profiles (homoenous/heterogenous) in HIP children group.

4. Discussion

The current study displayed an advance of neuropsychomotor and language development in HIP children with an advance of two months on average compared to neurotypical children. Sitting without support (around seven months), independent walking (12 months), and language (first sentences around 18 months) were significantly early developed, about 2 months, in HIP children (IQ≥130). The french scale norms rather showed than these acquisitions emerged at ten months, 14 months, and 21 months in neurotypical children [10-12]. These results are following the literature; Vaivre-Douret [25, 26, 8, 10] confirmed advanced neuropsychomotor development in HIP children from birth (longitudinally collected), especially about the data collected in our current study concerning sitting without support (around six months + 3 week), independent walking (12 months) as well as language (first sentences at 21 months old). These data have been collected retrospectively, it would have been complex and biased to require more effort to remember the dates of several milestones. Thus, we collected these data from the personal child health record. Vaivre-Douret has confirmed in their different studies cited above about HIP children's neonatal characteristics, a maturation developmental specific to HIP children at different levels, neurosensory and neuromotor maturation, and dynamic tone allowing the early emergences of posturo-locomotor acquisitions and visual-manual coordination, language, and cognitive processes.

However, she specified that these characteristics do not prejudge the future of these functions at school age. Indeed, if the physiological and neurobiological characteristics show early cerebral maturity allowing early neuropsychomotor and intellectual development, environmental factors with good health, a stimulating context at school and within the family, individual experience, and the educational factors would have a positive influence on the expression of this developmental advance and vice towards that. This advance was evidenced by previous researches [10, 21, 28, 56-58].

One of the oldest studies [13] on a large sample of HIP children (n=561) also confirmed an advanced development of independent walking compared to neurotypical children. Bildiren [23] showed with a retrospective and qualitative study using the interview questionnaires, that parents mainly recognize precocious walking and talking in HIP children between 0 and 2 years-old, as well as early reading skills between 4 and 6 years-old. In their longitudinal study on 19 HIP children over 18 years, Winisdorffer & Vaivre-Douret [22] highlighted in their longitudinal study a statistically advanced development in postural and locomotor acquisitions as well as cognitive and linguistic skills. Indeed, the synchronicity between intellectual development and neuropsychomotor development at an early age has already been confirmed in literature by different authors [8, 10, 13-17, 22, 23, 25]. However, certain studies contrast with these findings showing that HIP children seem to be not in advance in the neuropsychomotor field despite their high intellectual development [53, 59]. These conclusions were obtained through a population reached in the "National Association for Children with High Intellectual Potential," which can bias the sample. Children who contact this association are asking for assistance. Hence, the sample is not representative of HIP children's general population as the results of the other studies cited above. To explain our results confirming this advanced neuropsychomotor development in HIP children, we hypothesize an early cerebral maturation of the motor pyramidal pathway allowing earlier voluntary motor skills. Moreover, our findings could corroborate the neuroimaging results from the neurosciences studies that highlighted a better neuronal synapses connectivity in HIP children than in neurotypical children [60]. Nusbaum et al. [61] have demonstrated better connectivity of the frontal lobe and cerebral cortex involving many functional regions, including the primary motor area used for voluntary movements of the skeletal muscles. The premotor area is used for learned or automatic motor activities, and the additional motor area coordinates different movements and the motor area of speech (Broca's area), which could explain this developmental advance both at the motor and verbal level.

Other studies [8, 10, 62] suggest that advanced neuropsychomotor development can be explained by an early maturation of myelination and, therefore, faster and earlier propagation of signals in the brain related to the sheath's width. Therefore, there would be cerebral neurological properties specifics to these children, especially in the myelin sheath. Vaivre-Douret [10, 38] has discussed the particularity of myelin sheath, glial cells (astrocytes provide energy to neurons with glucose and oligodendrocytes make the myelin sheath), ion channels, and axons, in particular in protein constructs. They have a primordial role in the conduction, accelerating the nerve impulse along the nerve channels necessary for sensitive and motor functions in the central and peripheral nervous system.

The present study is the only one in the literature which analyzed developmental data regarding the IQ profile (homogeneous/heterogeneous). Although motor milestones (sitting without support, independent walking) are correlated to IQ level, they are not dependent on IQ profile but hence specific to HIP. However, there is a significant difference between homogenous and heterogeneous profiles regarding certain milestones: age of independent dressing (3 years old) and babbling (4 months) involving the bucco-praxis skills [8] in favor of homogenous IQ profile. There is a high rate of advanced language development (first sentences around 18 months) in HIP and all the more in heterogenous IQ profile, pointing out linguistic skills [63]. The HIP children with this heterogeneous profile probably compensate the motor abilities by the language. Thus, the indexes' distribution appears coherent with this finding as the VCI was higher in heterogenous profile while VSI, FRI, WMI, and PSI were higher in homogenous profile. This is in accordance with literature [42, 64, 65].

Any statistical correlation was shown with the IQ level and heterogeneity in our study. This is in opposition with the recent Brasseur and Goldschmidt's Belgium study [66] finding that the more the IQ increases, the more the dispersion between indexes appears. This study is only based on 28 children (IQ≥125) and without comparison with neurotypical children, without intra-group analysis, neither supplemental data such as developmental trajectory.

Besides, we have thoroughly explored the development of other motor activities of daily life in our sample. We showed that "struggling to put clothes correctly," "difficulties putting clothes on the right side," "difficulties tying shoelaces," and "correct use of a knife" was depended on IQ profile with a high rate of difficulties in HIP children in the heterogeneous profile group (respectively 27% vs. 4% in homogenous profile; 32% vs. 4%; 41% vs. 7%; 64% vs. 11%). These difficulties of daily life abilities were significantly and positively correlated with "Clumsiness milestone". In addition, regarding games and scholar abilities, there is also a significant relationship between heterogeneous profile and difficulties to "play puzzles" (23% vs 7% in homogenous profile), to "play construction games", (23% vs 7%) "autonomy difficulties" (23% vs 4%), "attention difficulties" (36% vs 18%), and "difficulties in adaptability to collective games" (23% vs 7%).

These findings highlight the difficulties in the acquisition of coordinated motor skills in heterogeneous profile concerning criterion A of the developmental coordination disorder diagnosis (DCD) in DSM-5 [54]: "The acquisition and execution of coordinated motor skills are substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike or participating in sports)". Thus, the finding confirmed a significant and consistent impact on daily life activities, hobbies, games, and scholarly abilities. There is also under Criterion B of DSM-5: "The motor skills deficit in criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and affects academic/school productivity, prevocational and vocational activities, leisure and play." When we check the DSM-5 criteria, we find that our heterogeneous HIP sample meets all the diagnosis criteria (A and B) of the DCD and criterion C, "Onset of symptoms is in the early developmental period." Moreover, criterion D: "The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurologic condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder)."

The early neuromotor milestones development in HIP children was highlighted in the current study because it followed the specific advance of maturation process. The quality of motor coordination skills which are linked to a motor learning skill depends on IQ profile in our sample of heterogeneous profile and from early childhood. This is congruent with literature that showed that motor milestones are not systematically delayed by a DCD [8, 67, 68], but the acquisition of coordinated motor skills remains below chronological age as DSM-5 criteria [54]. This DCD diagnosis is undoubtedly overlooked in the HIP population because the high level of language is often dominant, and most psychologists taking only into account the superior verbal level in IQ even if the other indexes are in average. Our relevant findings confirm our previous study [69], pointing out the similarity of clinical features DCD in HIP children compared to neurotypical children with DCD. Thus, we can again assert that HIP children can mask learning disabilities with a heterogenous IQ profile, VSI being more affected by DCD. This questions why a lower FIQ (120-129) may emphasize a misdiagnosis of the HIP. Moreover, in our present study, we noted that the FIQ of the heterogeneous group was lower than the FIQ of the homogeneous group. This could highlight the limit of the WHO criterion considering HIP (FIQ≥130) [4-5]. The current study shows that 41% of heterogeneous profiles present suspicion of DCD, which is a high rate of the total heterogeneity variance. We suppose that the profile could be differently influenced by index scores.

We demonstrated the links between WMI, PSI, VSI indexes and the difficulties in acquiring coordinated motor skills mentioned above. Also, in HIP children with heterogeneous profiles, we identified the same indexes as lower scores, and they are significantly and negatively correlated to the clumsiness milestone. In the literature, a study [70] showed that DCD is associated with visuospatial impairment and deficits in short-term working memory, underlining an influence on the WMI index. Certain studies [67, 69,71] about subtypes DCD have specified that Visio-Spatial/Constructive DCD is characterized by specific disorders in visuomotor integration and visuospatial motor construction, associated with ocular pursuit disorders which could be related to the low VSI index in these children attesting that the VSI index could be affected by DCD. Also, a meta-analysis [72] based on 50 studies showed a significant gap in visual-spatial processing with impairments in kinesthetic and intermodal processing in DCD. This meta-analysis highlights the unanimity of studies supporting visual perception problems associated with motor coordination difficulties.

Regarding the PSI index, a study [73] showed that children with DCD have a heterogeneous cognitive profile showing difficulties with the processing speed index (PSI), a key element in motor tasks. Another study [74] confirmed that children with DCD were significantly slower on all tasks, especially WMI and PSI, supporting past evidence of a timing deficit in these children. The latest study of Vaivre-Douret [75] demonstrated from an IQ profile of a case study that the significant decrease of indexes related to the high score of verbal indexes was linked to neurodevelopmental disorders (mainly motor function and DCD) not sparing the HIP child. Furthermore, there are 59% of the variance that could explain other disorders in HIP children with heterogeneous IQ profile as they have already shown in studies as attention-deficit hyperactivity disorder (ADHD), psycho-socio-affective disorders, learning disabilities [40-44].

5. Conclusion

This study highlights in a representative sample a relevant early motor development similarly to the language advance for HIP children compared to neurotypical children; around 2 months on average. The findings about difficulties with daily life abilities in HIP suggest a great interest to assess early motor coordination skills to identify future DCD relative to DSM-5 criteria. The analysis of HIP IQ profile at school age showed that VCI was higher in heterogenous profile while VSI, FRI, WMI, and PSI were higher in homogenous profile outlining protective factors.

In addition, we displayed that an important part of the heterogeneity (41%) could be explained by a suspicion of DCD which be early tracked down with significant difficulties impacting on daily life activities, games and scholar abilities. VSI being more affected by DCD, children may have lower FIQ (120-129) which may emphasize a misdiagnosis of HIP at school age pointing out the importance that clinicians analyze in depth the variability of the index scores in the IQ profile. Thus, these motor developmental features may be useful measure as a following outcome of HIP to take into account by pediatrics and psychomotor therapists. However, it is important to assess with standardized normative developmental scale. These findings have significant implications for research and clinical practices. The first limitations of the present study suggest to confirm the data in a larger sample size, and to use the similar anamnestic data for neurotypical children because it was obtained from our previous study. Secondly, there are possible relative errors linked to parents' responses regarding retrospectives data. Thirdly, further analyzes of the rest of the variance may provide other factors to understand heterogeneity of the IQ profile.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationship that might be perceived as posing a conflict or bias could influence the work reported in this paper.

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