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Gross motor proficiency and intellectual functioning

A comparison among children with Down syndrome, children with borderline intellectual functioning, and typically developing children

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Abstract

This cross-sectional study examines differences in gross motor proficiency as a function of different intellectual functioning profiles. Two motor areas have been investigated as being equally essential to gross motor functions in every-day life: locomotion and object control.

It aims to compare gross motor skills endorsed by children with Down syndrome (DS), children with borderline intellectual functioning (BIF), and typically developing children (TDC).

Group 1 was composed of 18 children with DS (chronological age = 8.22), group 2 was composed of 18 children with BIF (chronological age = 9.32), and group 3 was composed of 18 children with typical development (TD) (chronological age = 9.28).

Gross motor skills were measured through the test of gross motor development (TGMD-Test) composed of locomotion and object control tasks.

Children with DS showed worse gross motor skills compared with children with BIF and typically developing children by underscoring both on all locomotion (e.g., walking, running, hopping, galloping, jumping, sliding, and leaping) and all object control tasks (e.g., throwing, catching, striking, bouncing, kicking, pulling, and pushing).

In DS group strengths were found on run and slide skills, in BIF group strengths were on run, long jump and slide skills and in TDC group strengths were on run and slide skills. For all of the 3 groups the locomotor worst performed task was jump forward with arm swing.

Findings suggest implications for further practice to develop evidence-based exercise programs aimed to rehabilitate gross motor skills through the regular participation in structured exercise activities.

Abbreviations: BIF = borderline intellectual functioning, BMI = body mass index, BW = body weight, DS = Down syndrome, GMQ = gross motor quotient, ID = intellectual disability, IQ = intelligence quotient, L = locomotion, OC = object control, TD = typical development, TDC = typically developing children, TGMD-Test = test of gross motor development.

Keywords: borderline intellectual functioning, Down syndrome, gross motor development, locomotion, object control, sport rehabilitation

1. Introduction

Children with intellectual disorders show a delay on motor development with important impairments in adaptive functioning and daily living skills limiting their autonomy and independence as well as their participation in social activities.[1–3] Increasing research has targeted the gross motor proficiency in Down syndrome (DS) people, a genetic syndrome characterized by intellectual disability (ID).[4–6] In contrast little research has been produced on the relationship between motor and intellectual proficiency in population with borderline intellectual functioning (BIF).

Children with DS show a delayed motor development corresponding to an atypical cerebrum size and maturation disorders of central nervous system.[7–9] Motor deficits in Down people population have been categorized by a rating scale and subdivided into: mild impairment characterized by motor patterns that are similar to those of children with typical development (TD); moderate impairment characterized by the ability to initiate, adapt, and maintain movements with minor efficiency, high motion, wide base of support, limited balance and insufficient muscle tone; severe impairment characterized by difficulty in initiating, adapting and maintaining movements, reduced balance, scarce muscle tone, and limited voluntary control.[6]

The milestones of motor development are not normally reached but show a gap increasing with the growth and the complexity of motor tasks.[10–12] Children with DS were found to

Editor: Jose Muyor.

Funding: Erasmus+ Sport Programme (2017–2019) Call EAC/A04/2015 – Round 2 E+ SPORT PROJECT-579661-EPP-1-2016-2-IT-SPO-SCP "Enriched Sport Activities Program"—Agreement number 2016-3723/001-001.

The authors have no conflicts of interest to disclose.

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Medicine (2018) 97:41(e12737)

Received: 23 January 2018 / Accepted: 17 September 2018

http://dx.doi.org/10.1097/MD.0000000000012737

achieve the fundamental motor skills of standing and walking between the ages of 18 months and 3 years old (14% by 18 months, 40% by 24 months, and 73% by 30 months) and the motor skills of running, walking up, and jumping between the ages of 3 and 6 years with improvement proportionally corresponding to the complexity of movement, the stability of support base, the rate of necessary motor control.[6] Furthermore, from early age, children with DS showed impairment in early postural control, motor speed, balance, and fluency.[13,14] In contrast performances in fine motor, such as drawing, were specifically characterized by higher speed but lower accuracy.[15,16]

Low motor proficiency is associated with high body mass index (BMI); people with DS showed a significantly higher BMI in comparison with people with TD ($P < .05$).[17] This is maintained and often exacerbated by a documented sedentary lifestyle and scarce motivation to physical activities participation.[18–20]

Poor research has been produced on gross motor skills endorsed by children with BIF. BIF is a heterogeneous lifelong condition generally identified as scoring between 1 and 2 standard deviations below the intelligence quotient (IQ) mean and associated with adaptive dysfunctions.[21] BIF is described as an atypical development condition enclosing heterogeneous groups of children with cognitive diseases requiring a wide neuropsychological assessment (e.g., language development, learning abilities such as reading, writing and calculation, visual-spatial abilities, executive functions, motor skills, etc.) as well as mental health and social functioning evaluation.[22] Recent research has highlighted delays in walking, deficits in fine motor skills, writing difficulties, and low manual dexterity abilities in this population.[23,24] Only 2 studies have deepened the gross motor development in BIF population by demonstrating how BIF children underscored on the subcomponents of locomotion (e.g., walking, running, hopping, galloping, jumping, sliding, and leaping) and object-control (e.g., throwing, catching, striking, bouncing, kicking, pulling, and pushing).[24] Object-control abilities appeared to be more impaired than locomotion ones. This is because of their higher cognitive load characterizing the object-control tasks compared with the locomotion tasks. The performance on tasks as throwing, catching and striking involves more sophisticated cognitive process linked to goal-directed behaviors or executive functions.[25]

In light of these theoretical premises, this study aims to analyze gross motor skills as a function of different intellectual profiles by comparing locomotion and object control skills endorsed by children with DS, children with BIF, and typically developing children (TDC). BIF children were chosen as comparison group because of their particular intellectual profile. Compared with peers with ID, BIF children show a higher IQ scoring between 1 and 2 standard deviations below the IQ mean (range 70–85). As a consequence, they are an interesting control group to deepen the relationship between intellectual level and motor skills because they have a profile characterized by lower intellectual functioning, compared with children with TD, and higher intellectual functioning, compared with children with DS. We hypothesize that children with DS would show worse gross motor skills compared with BIF and TDC by having lower performance on locomotion (e.g., walking, running, hopping, galloping, jumping, sliding, and leaping) and object control tasks (e.g., throwing, catching, striking, bouncing, kicking, pulling, and pushing). Moreover children with BIF would perform poorly on locomotion and object control tasks, compared with TDC, and better if compared with children with DS.

2. Method

2.1. Participants

Participants were 54 children subdivided into 3 groups. Group 1 was composed of 18 DS children (13 boys and 5 girls) with a chronological age of 8.22 ± 2.82 years and a BMI of 23.39 (weight: 31.05 ± 10.66 kg; height: 1.19 ± 0.18 m). They reported a diagnosis of trisomy 21 with moderate intellectual disability which had been previously certified by a national public health institution. All subjects had been engaged in structured speech therapy and psychomotor activity from early childhood but, at that moment, they did not attend any additional physical activity programs in or out of school.

Group 2 was composed of 18 BIF children (9 boys and 9 girls) with a chronological age of $9.32 \pm .61$ years and a BMI of 18.83 (weight: 38.06 ± 8.22 kg; height: 1.40 ± 0.82 m). They showed a profile of BIF with IQ scores ranging from 70 to 85 and impaired adaptive behaviors, as previously assessed.[26] They did not report any co-occurrence of neurological impairments, speech and language disorders, perceptual deficits, emotional, or behavioral problems. All children were attending the fourth grade of primary school.

Group 3 was composed of 18 children (9 boys and 9 girls) with a chronological age of $9.28 \pm .81$ years and a BMI of 17.82 (weight: 36.28 ± 9.40 kg; height: 1.40 ± 6.45 m). Their IQ scores ranged from 35th to 75th percentile revealing an average intellectual functioning. The additional eligibility criteria for these children were the exclusion of a history of neurological impairments, speech and language development problems, atypical perceptual skills concerning hearing and visual acuity, motor delays and emotional or behavioral disorders.

All subjects were from average socioeconomic backgrounds and attended primary school.

2.1.1. Materials and procedure. Prior to the start of the study, the approvals of the school heads and of the local ethical committee were obtained. Written informed consent was provided by each participant's parents.

DS children were recruited through a public general hospital of Palermo (Sicily, Italy) and not-for-profit associations delivering support and community resources for people with DS and their families. BIF children and TDC were recruited in their mainstream school on the basis of their borderline or average intellectual functioning.

DS parents were contacted by medical or educational practitioners supporting their children, while remaining parents were contacted by the head or teachers of the school attended by their children. All parents received flyers announcing the research project and explaining in detail the goals of the study and its procedures and were invited to allow their children to participate in the study.

Following this recruitment phase, 54 children participated in the study on the basis of provided written consent and met inclusion criteria (as described in the Participants section). These children fell into 3 groups: DS children (N = 18), BIF children (N = 18), and TDC (N = 18).

They were given a motor assessment aimed at measuring their BMI and their gross motor skills.

Body weight (BW) and height were measured according to standardized procedures recommended at the Airlie Conference.[27] Height was measured by a standard stadiometer (maximum height recordable, 220 cm; resolution, 1 mm) with the subjects barefoot and standing upright. BW was measured by a

Seca electronic scale (maximum weight recordable, 300 kg; resolution, 100 g) (Seca Deutschland, Hamburg, Germany). BMI was calculated as bodyweight divided by height squared ($kg \cdot m^{-2}$).

Gross motor skills were measured through the test of gross motor development (TGMD) (At the time of the assessment, only the TGMD was available in its Italian version.[28] The TGMD-2 was not yet translated and adapted to Italian context.[29]). This is a criterion-referenced test, composed of 2 subtests aimed at measuring 2 skill sets: 7 locomotion (L) and 5 object control (OC) skills. Locomotion tasks required children to run as fast as possible for 15 m (L1), gallop for 10 m (L2), hop on 1 leg for 5 m (L3), jump forward (L4), do a long jump (L5), skip forward (L6), and slide laterally (L7). In contrast object control tasks required children to catch a ball with a tennis racket (OC1), bounce off the ball (OC2), catch a ball (OC3), kick the ball running (OC4), and throw a ball with the hand (OC5). Based on the Examiner's Manual guidelines, participants were required to repeat each trial 3 times and a score of 1 was assigned if the subject reached a good performance twice; while a score of 0 was given when the child underperformed the item. Raw scores were used in this study.

Two locomotion and object control raw total scores (maximum total score: 48) were computed by adding the items pertaining to each scale and then transformed into standard scores. Moreover, a global gross motor quotient (GMQ) was obtained by adding the 2 partial scores. A GMQ ranging from 90 to 110 was average. The reliability was of $\alpha = .96$ for locomotion subtest and $\alpha = .97$ for object control subtest. The test was originally developed and validated for TDC with chronological age ranging from 3 to 10 years but its validity was demonstrated for DS children.[30] Its test–retest and inter-relation validity were very high, being respectively of $\alpha = .96$ and $\alpha = .95$.

In study DS children were assessed in a quiet room of the association, while BIF children and TDC were assessed in a quiet school room.

3. Results

Analyses of covariance were performed to compare locomotion and object control outcomes for ID, BIF, and TDC groups. The independent variable was the intellectual level (ID, BIF, or TDC). The covariate was the participants' BMI. It was selected a priori because significant differences between groups were found as concern this variable [$F(2, 53) = 10.798$; $P = .00$, $\eta^2p = .30$]. DS children ($M = 23.39$) got higher BMI compared with BIF ($M = 18.83$) and TDC ($M = 17.82$).

For all statistical tests the level of significance was set at $P < .05$. The SPSS Software (Version 20 for Windows) was used.

The GMQ, locomotor, and object control subtest scores of the 3 groups are shown in Table 1.

On the whole analyses revealed significant differences for GMQ [$F(2, 53) = 61.303$; $P = .00$, $\eta^2p = .71$], locomotion [$F(2, 53) = 98.670$; $P = .00$, $\eta^2p = .80$] and object control skills [$F(2, 53) = 49.201$; $P = .00$, $\eta^2p = .67$] between the 3 groups.

As hypothesized, significant differences were found between DS and BIF children on GMQ [$F(1, 35) = 54{,}768$; $P = .00$, $\eta^2p = .62$], locomotion [$F(1, 35) = 92.279$; $P = .00$, $\eta^2p = .74$] and control object performance [$F(1, 35) = 46.300$; $P = .00$, $\eta^2p = .58$] with large effect sizes. Similarly, significant differences were found between DS children and TDC on GMQ [$F(1, 35) = 140.874$; $P = .00$, $\eta^2 p = .81$], locomotion [$F(1, 35) = 138.488$; $P = .00$, $\eta^2p = .81$] and control object tasks [$F(1, 35) = 70.605$; $P = .00$, $\eta^2p = .69$] with large effect sizes.

As the analyses per test items revealed, DS children showed worse gross motor skills compared with BIF and TDC by underscoring both on all locomotion (e.g., walking, running, hopping, galloping, jumping, sliding, and leaping) and all object control items (e.g., throwing, catching, striking, bouncing, kicking, pulling, and pushing).

Moreover, the BIF group differed significantly from the TDC group on global gross motor [$F(1, 35) = 12.223$; $P = .01$, $\eta^2p = .28$], locomotion [$F(1, 35) = 7.822$; $P = .01$, $\eta^2p = .19$], and object control scores [$F(1, 35) = 5.042$; $P = .03$, $\eta^2p = .14$] with small effect sizes. Analyses per test items revealed that BIF children, compared with TDC, significantly underperformed on the jump forward (L4), the slide laterally (L7), and the bounce off the ball (OC2). In these tasks BIF and TDC children got similar performances (see Table 2).

Finally children with BIF [$F(1, 17) = 7.60$; $P = .00$] and TDC [$F(1, 17) = 12.60$; $P = .00$] were found to show significant differences among their performances on object control tasks

Table 1

Descriptive statistics for gross motor measures as a function of group.

		DS children		BIF children		TD children	
	Measures	**M**	**SD**	**M**	**SD**	**M**	**SD**
Locomotor skills	L1	1.67	0.77	3.61	0.78	3.94	0.24
	L2	0.61	0.92	3.11	0.58	3.41	0.51
	L3	0.78	1.01	3.50	0.62	3.41	0.71
	L4	0.28	0.67	1.89	1.23	2.71	0.47
	L5	1.06	0.94	3.17	1.15	3.35	0.70
	L6	0.39	0.92	2.67	0.48	2.71	0.47
	L7	1.44	1.34	3.17	0.79	3.76	0.44
	LS score	**6.22**	**4.61**	**21.11**	**2.83**	**23.29**	**1.49**
Object control skills	OC1	0.94	0.93	2.61	1.09	3.12	0.86
	OC2	0.78	1	2.22	0.73	2.76	0.44
	OC3	2.44	1.65	3.72	0.75	3.76	0.56
	OC4	1.22	1.06	3.33	0.77	3.59	0.79
	OC5	1.22	1.06	3.50	0.86	3.65	0.61
	OC score	**6.61**	**4.2**	**15.39**	**2.30**	**16.88**	**1.61**
	GMQ	**53.83**	**6.6**	**82.58**	**11.72**	**95.12**	**10.74**

BIF = borderline intellectual functioning, DS = Down syndrome, GMQ = gross motor quotient, L1 = run, L2 = gallop, L3 = hop on one leg, L4 = jump forward, L5 = horizontal jump, L6 = skip forward, L7 = slide laterally, LS = locomotion skills, M = media, OC = object control skills, OC1 = catch a ball with a tennis racket, OC2 = bounce of the ball, OC3 = catch a ball, OC4 = kick the ball running, OC5 = overhand throw, SD = standard deviation, TDC = typically developing children.

Bold values are total values obtained by values on subtests.

Table 2

Comparisons of the 3 study groups on the gross motor skills.

		DS vs BIF children			DS vs TDC children			BIF vs TDC children		
	Measures	**F**	***P***	**η^2 p**	**F**	***P***	**η^2 p**	**F**	***P***	**η^2 p**
Locomotor skills	L1	43.819	.00	.57	85.072	.00	.73	2.615	.12	.07
	L2	60.257	.00	.64	73.881	.00	.70	2.740	.12	.08
	L3	60.684	.00	.65	47.347	.00	.60	0.019	.89	.01
	L4	12.801	.01	.28	89.095	.00	.74	5.833	.02	.15
	L5	25.254	.00	.43	66.590	.00	.67	0.204	.65	.01
	L6	64.499	.00	.66	52.775	.00	.62	0.227	.64	.01
	L7	15.357	.00	.32	32.090	.00	.50	7.072	.01	.18
	LS score	**92.279**	**.00**	**.74**	**138.49**	**.00**	**.81**	**7.822**	**.01**	**.19**
Object control skills	OC1	19.376	.00	.37	38.639	.00	.55	2.468	.13	.07
	OC2	19.300	.00	.37	44.001	.00	.58	6.576	.01	.17
	OC3	5.88	.02	.15	8.040	.01	.20	0.052	.82	.00
	OC4	35.541	.00	.54	45.086	.00	.58	1.098	.30	.03
	OC5	36.966	.00	.53	49.601	.00	.61	0.298	.59	.01
	OC score	**46.300**	**.00**	**.58**	**70.605**	**.00**	**.69**	**5.042**	**.03**	**.14**
	GMQ	**54.768**	**.00**	**.62**	**140.874**	**.00**	**.81**	**12.223**	**.01**	**.28**

BIF = borderline intellectual functioning, DS = Down syndrome, GMQ = gross motor quotient, L1 = run, L2 = gallop, L3 = hop on one leg, L4 = jump forward, L5 = horizontal jump, L6 = skip forward, L7 = slide laterally, LS = locomotion skills, M = media, OC = object control skills, OC1 = catch a ball with a tennis racket, OC2 = bounce of the ball, OC3 = catch a ball, OC4 = kick the ball running, OC5 = overhand throw, SD = standard deviation, TDC = typically developing children.

Bold values are total values obtained by values on subtests.

and locomotion. Both groups underscored on object control tasks (BIF: M = 15.39; TDC: M = 16.89) compared with locomotion (BIF: M = 21.11; TDC: M = 23.33). In contrast children with DS did not show any significant difference between their competence on locomotion and object control.

4. Discussion

The current study offers a comprehensive overview of gross motor proficiency as a function of the intellectual profile in children with DS compared with BIF children and TDC. Two motor areas have been investigated as being equally essential to gross motor functions in every-day life: locomotion and object control. On the whole, results provided evidence for differences among the 3 groups on motor profile. DS children got a GMQ significantly below the mean value. They performed poorly on locomotion and object control tasks, compared with TDC and BIF children. BIF children got an impaired GMQ by underscoring on locomotion and object control tasks compared with TDC. Taken together, these results corroborated findings obtained by previous research in this field; an impaired gross motor profile was shown by children with ID and BIF.[24,25]

As concern the locomotion, in DS group strengths were found on run and slide skills, in BIF group strengths were on run, long jump and slide skills and in TDC group strengths were on run and slide skills. For all of the 3 groups the locomotor worst performed task was jump forward with arm swing. This result is in agreement with several studies in the literature that demonstrated as children with atypical development had difficulty producing bimanual and interlimb coordination patterns such as required in jump forward with arm swing.[31] In a specific way, it was speculated that DS children would display difficulties in motor abilities involving bilateral coordination for their hypoplasia of *corpus callosum* and the cerebellum altered size.[12]

While, as concern the object control tasks, for all of the 3 groups strengths were on catching a ball and weaken on bounce off the ball. These findings could be explained in view of studies that found the relationship among perceptual ability, visual-motor integration, and motor development. To perform complex motor patterns, such as object control ones, the subject is skilled to process afferent information in a rapid and efficient way.[32,33] For example, to perform grasping and reaching movements, extrinsic (distance, orientation) and intrinsic (form, consistency) characteristics of the object need to be processed. As a matter of fact, a selective and substantial deficit in the perception of optic flow motion and a corresponding suppression of electroencephalographic activity was found in young DS individuals with mild intellectual disability compared with mental age-matched controls.[34] Nevertheless, children with DS were found to strengthen ball skills and running speed compared with balance, posture, or motor planning.[35,36]

BIF children showed worse competence on object control skills such as throwing, catching, striking, bouncing, kicking, pulling, or pushing than locomotor skills such as walking, running, hopping, galloping, jumping, sliding, or leaping. In contrast, in DS group no differences were found between the object control and locomotor components. We suppose that this is due to the cognitive load of tasks. The performance on tasks as throwing, catching, and striking requires a higher cognitive load and a more sophisticated cognitive process related to goal-directed behaviors and executive functions.[25] Nevertheless, locomotor tasks, such as walking, running, and hopping, involve stereotypic movements that encompass automatized cognitive functioning. The difference among locomotion and object control skills is more evident in participants with TD or BIF because at their age executive functions are not fully developed yet. Moreover, children with BIF show a specific weakness in the speed of information processing which limits the amount of information that can be processed in a given time interval.[22] This contributes to have difficulties in goal-directed motor tasks with higher cognitive load, such as object control. In contrast, in the DS group a lack of difference between performance on locomotor and object control tasks could be due to their lower IQ. Participants with DS had a moderate ID which is characterized by consistent impairment in global cognitive profile. As a consequence, given the close link among motor proficiency and intellectual functioning, a poor development in both goal-directed and automized movements, regardless of their cognitive load, is expected in this population.

The main strength of this study lies in contributing to the current research with respect to the gross motor proficiency in intellectual disability condition. To date, assessment programs addressing motor domain-specific abilities have been targeted mild ID or BIF level. So, in the current study we further extended previous studies by examining simultaneously 3 conditions of intellectual functioning: DS children with moderate intellectual disability; BIF; TDC. We chose to study these intellectual conditions because of the increasing interest in crucial role of gross motor impairment to influence or limit intellectual and adaptive development both in typically and atypically developing population. Up to now, research in this area has focused on intellectual functioning rather than broad profiles encompassing motor skills as key components in adaptive functioning.

However, our data need to be carefully interpreted because they derived from the analysis of limited sample size weakening the generalizability of the current findings.

5. Conclusions

Findings, while preliminary, contribute to underlie the urgent need of key policy to plan exercise intervention programs for welfare and health of people with intellectual impairments. Researchers and practitioners have to address increasing attention to implement exercise motor programs aimed to decrease DS children gross-motor impairments and enhance together specific adaptive abilities.

Author contributions

Conceptualization: Marianna Alesi, Giuseppe Battaglia, Annamaria Pepi.
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