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Original article

Cognitive development and adaptive functions in children with Down syndrome at different developmental stages

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SUMMARY

Background

Children with Down syndrome (DS) have learning difficulties resulting in mild to severe intellectual disability, whereas their adaptive functions are generally more preserved. Little is known about the developmental trajectories of cognitive and adaptive functions in this population. In the present study, cognitive and adaptive functions were assessed in children with DS at different developmental stages.

Methods

Cognitive and adaptive functions were assessed in a total of 53 children with DS: 20 children aged 2 to 6 and 33 children aged 10 to 15. Cognitive development was assessed using the Griffiths Mental Development Scales 2-8 for younger children and the Wechsler Intelligence Scale for Children-Fourth Edition for older children. Adaptive functions were evaluated with the Vineland Adaptive Behavior Scale in both age groups.

Results

Among cognitive functions, working memory was the most significantly affected, whereas the visuo-spatial component was relatively preserved. In terms of adaptive functions, children reported the lowest mental age in the expressive communication domain, and the highest mental age in the daily living skills. Adaptive functions were comparatively worse in the older group, whereas cognitive profiles were impaired to a similar degree between the two age groups.

Conclusions

Adaptive functions appear to be relatively more impaired than cognitive functions in older children with DS. The increasing demands from the environment that children have to deal with during pre-adolescence and adolescence might contribute to selectively affect their adaptive skills.

Key words: adaptive functions, cognitive development, down syndrome, intellectual disability

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Conflict of interest
The Authors declare no conflict of interest

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Background

Down syndrome (DS) is the most common genetic cause of intellectual disability across all ethnic and socio-economic groups [1]. Despite the consistent increase in maternal age in developed Countries, the prevalence of DS births has remained stable as a result of increasing use of prenatal diagnostic procedures [2].

Children with DS have learning difficulties which result in mild to severe intellectual disability [3]. The mental age is rarely over 8 years old, although a few cases of normal Intelligence Quotient (IQ) in children with DS have

been reported [4]. IQ scores are known to progressively decrease with age [5,6], especially in the first decade of life [7-12], before reaching a plateau in adolescence which persists throughout adulthood [7]. Interestingly, cognitive functions do not appear to be equally affected: children with DS report more severe deficits in language compared to visuo-spatial skills, compared to children of the same mental age with mental retardation of different etiology or with typical development [13].

Fewer studies have focused on adaptive functions in children with DS. A study by Dykens et al. [14] on 80 children with DS aged between 1 and 11.5 years showed more significant deficits in communication skills (especially expressive language) compared to daily living and socialization skills. A subsequent study by Dressler et al. [3] on 75 individuals with DS aged between 4 and 53 years showed similar findings, although in this study socialization was the most severely impaired domain in the age group 4-10 years. Overall, children with DS were shown to have a good degree of adaptive functioning within the broader population of individuals with mental retardation.

Studies on the development of adaptive functions in relation to age in individuals with DS have reported controversial results. Dressler et al. [3] found that adaptive functions gradually and steadily increase with age up to 30 years, after which they undergo a progressive decline, whereas earlier studies had showed that adaptive functions worsen with age [7,15,16]. The findings of Dykens et al. [14] supported the hypothesis of an advance-plateau pattern of adaptive development [17,18]: these authors observed that while children aged 1 to 7 showed significant age-related gains in adaptive behaviour, older subjects (7 to 11.5 years) showed no association between chronological age and adaptive behaviour.

The aim of the present study was to assess cognitive development and adaptive functions in two groups of children with DS at different developmental stages (2-6 versus 10-15 years of age). This should provide a better understanding of the trajectory of cognitive development and adaptive skills in children with DS, thus contributing to the implementation of more effective and targeted educational strategies and treatment interventions.

Methods

Participants

A total of 53 children with DS aged 2 to 15 (35 males, 66%) participated in this cross-sectional study conducted at the outpatient Child and Adolescent Mental Health Clinic, San Gerardo Hospital, Monza, Italy. In our clinical sample there were two separate age groups: 20 children aged 2 to 6 years (12 males, 60%; mean age 3.8 ± 1.6) and 33 children aged 10 to 15 years (23 males, 70%; mean age 12.6 ± 1.5). These age groups correspond to two important stages of psychomotor development: from early childhood to the beginning of school age, when children have to cope with new social and academic demands, and from pre-adolescence to adolescence, when conflicts related to their identity and physical changes begin to emerge.

All children were born in the northern part of Italy. The ethnic distribution was homogeneous: a Mediterranean European origin was reported by 90% children in the younger group (where two parents were from Asia and one from Africa) and 94% in the older group (where two parents were from Eastern Europe and one from Central Europe). The socioeconomic level was evaluated using the Hollingshead index, with values ranging from 1 (low socioeconomic level) to 5 (highest socioeconomic level)[19]. The socioeconomic level of the children in the younger group had the following distribution: 73% level 4, 16% level 2, 11% level 3. The socioeconomic level of the children in the older group 2 had a similar distribution, with the majority of participants in the intermediate socioeconomic layers: 50% level 4, 25% level 2, 14% level 1, 11% level 3.

Written informed consent was obtained from the participants' parents or guardians. The study protocol was approved by the San Gerardo Hospital Ethics Committee.

Methods

A standardized battery of psychometric instruments was administered by trained psychologists, psychomotor therapists and neuropsychiatrists according to the instructions provided in the instruments' manuals.

Cognitive development was assessed using the Italian translation of the Griffiths Mental Development Scales (GMDS-ER) 2-8 for the younger group of children [20] and the Italian version of the WISC-IV for the older group of children [21]. Both instruments yield standardised z scores for the analysis of GMDS-ER General Quotient (GQ) and WISC-IV core subtests.

Adaptive functions were evaluated by administering the Vineland Adaptive Behavior Scales (VABS) to one of the parents [22]. The parents of one child in the younger group and seven children of the older group did not give their consent to complete the questionnaire; therefore VABS scores were collected for 19 children in the younger group and 26 children in the older group. The difference between chronological and mental age (DELTA parameter) was calculated in order to assess the patterns of change of adaptive skills with increasing age.

Statistical analysis

Data distribution was assessed by the Anderson-Darling test, Shapiro-Wilk test and Kolmogorov-Smirnov test. The non-parametric Wilcoxon test was used to

compare the WISC-IV indices, with the exception of normally distributed scores, which were analysed using the paired samples t test. The bivariate correlation of Spearman was used to assess the correlation between continuous variables, whereas the relationship between DELTA and chronological age was analysed using the second-order polynomial regression model because of the quadratic trend in data distribution. The level of statistical significance was set at $p < 0.05$ and all statistical analyses were performed using the statistical software R version 3.0.1.

Results

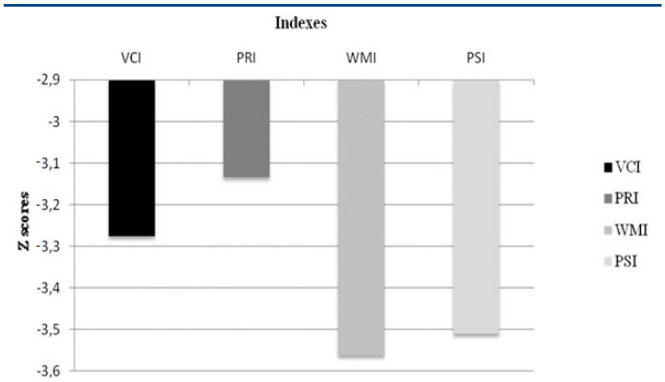
Cognitive functions

Griffiths Mental Development Scales (GMDS-ER) 2-8

All the subjects in group 1 had a GQ < -2.33, except for one who scored -1.77 (almost two standard deviations below the mean). Most of the children had a degree of intellectual disability between mild and moderate (14 children out of 20, 70%); 4 children (20%) had severe intellectual disability and 2 children (10%) had profound intellectual disability (Tab. I).

Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV)

Only 4 out of the 33 subjects had an IQ ≥ 40 (two children scored 40, one 43 and one 49). Most children's z scores were consistent with an intellectual disability range between mild and moderate according to DSM guidelines (26 children out of 33; 79%). The remaining 7 children (21%) had severe intellectual disability (Tab. II).



Abbreviations. VCI: Verbal Comprehension Index; PRI: Perceptual Reasoning Index; WMI: Working Memory Index; PSI: Processing Speed Index

FIGURE 1. *Four indexes of the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV).*

Among the four indexes (Verbal Comprehension Index, VCI; Perceptual Reasoning Index, PRI; Working memory Index, WMI; and Processing Speed Index, PSI), the highest scores were reported in PRI, whereas the lowest scores were reported in WMI (Fig. 1).

The results of the Wilcoxon test showed statistically significant differences between PRI and WMI (p-value = 0.048), and between PRI and PSI (p-value = 0.006).

Adaptive functions

Vineland Adaptive Behavior Scales (VABS)

In group 1 the mean mental age was 2 years and 4 months, with an average difference between chrono-

TABLE I. *Degrees of intellectual disability in children with Down syndrome aged 2 to 6 years.*

Degrees of intellectual disability	IQ levels	z scores (mean)	Number of subjects	z scores of participants (mean ± sd)
Profound	< 20-25	< -5.0	2 (10%)	-7.7 ± 0.9
Severe	from 20-25 to 35-40	≥ -5.0 and < -4.0	4 (20%)	-4.8 ± 0.2
Moderate	from 35-40 to 50-55	≥ -4.0 and < -3.0	10 (50%)	-3.7 ± 0.3
Mild	from 50-55 to 70	≥ -3.0 and < -2.0	4 (20%)	-2.6 ± 0.4

TABLE II. *Degrees of intellectual disability in children with Down syndrome aged 10 to 15 years.*

Degrees of intellectual disability	IQ levels	z scores (mean)	Number of subjects	z scores of participants (mean ± sd)
Profound	< 20-25	< -5.0	0	
Severe	from 20-25 to 35-40	≥ -5.0 and < -4.0	7 (21%)	-4.1 ± 0.1
Moderate	from 35-40 to 50-55	≥ -4.0 and < -3.0	17 (52%)	-3.4 ± 0.2
Mild	from 50-55 to 70	≥ -3.0 and < -2.0	9 (27%)	-2.7 ± 0.3

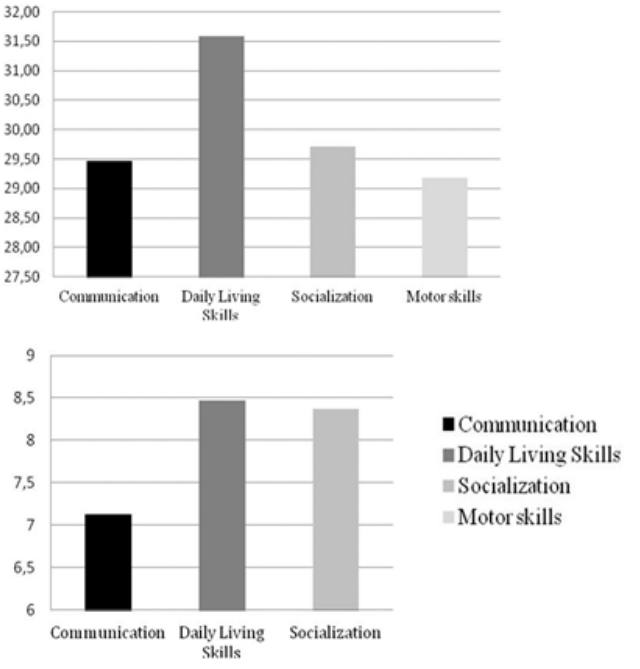


FIGURE 2 *(above). Vineland Adaptive Behavior Scales (VABS) scores in children with Down syndrome aged 2 to 6 years; (below). Vineland Adaptive Behavior Scales (VABS) scores in children with Down syndrome aged 10 to 15 years.*

logical age and mental age of approximately 12 months (± 10.6 SD). In this group most children scored below the baseline on all scales (< 18 months) (Fig. 2; above). In group 2 the mean mental age was 7 years and 5 months, with an average difference between chronological age and mental age of approximately 5 years (± 2.0 SD). Figure 2 (below) and Table III show the scores reported in all scales and subscales, respectively (the Motor Skills scale was not analysed because this domain is assessed only in children younger than 6 years old, unless they present with motor skills deficit).
The Expression subscale was the most affected domain within the Communication scale. In the Daily Living Skills domain, both the Community subscale and the Personal subscale were more affected than the Domestic subscale. There were minor differences in the three subscales of the Socialization scale. Finally, the overall IQ deviation score was 113 (± 8.0 SD).

Clinical correlates of adaptive functions

Spearman bivariate correlation analysis showed a statistically significant positive correlation between DELTA values (difference between chronological and mental age) and chronological age (p-value = 0.000), whereas there was no statistically significant correlation between z scores and chronological age (p-value = 0.168). Results of the second-order polynomial regression analysis showed that DELTA values increase with chronological age until approximately 12 years, after which they become stable (Fig. 3).

TABLE III. *Mental age in scales and subscales of the Vineland Adaptive Behavior Scales (VABS).*

Scales and subscales	Mental age (in years) Mean ± SD
Communication	7.1 ± 2.8
- Receptive	7.0 ± 2.9
- Expressive	5.8 ± 2.3
- Written	8.0 ± 2.8
Daily Living Skills	8.5 ± 2.5
- Personal	7.3 ± 1.7
- Domestic	11.3 ± 3.4
- Community	7.1 ± 2.6
Socialization	8.4 ± 3.3
- Interpersonal Relationships	8.2 ± 4.7
- Play and Leisure Time	7.5 ± 3.5
- Coping Skills	9.2 ± 3.0
Mental age	7.5 ± 2.8

Discussion

Children with DS have different degrees of intellectual disability and impairment in their capacity to cope with the demands of the social context in which they live. A both intellectual trajectories and life demands change

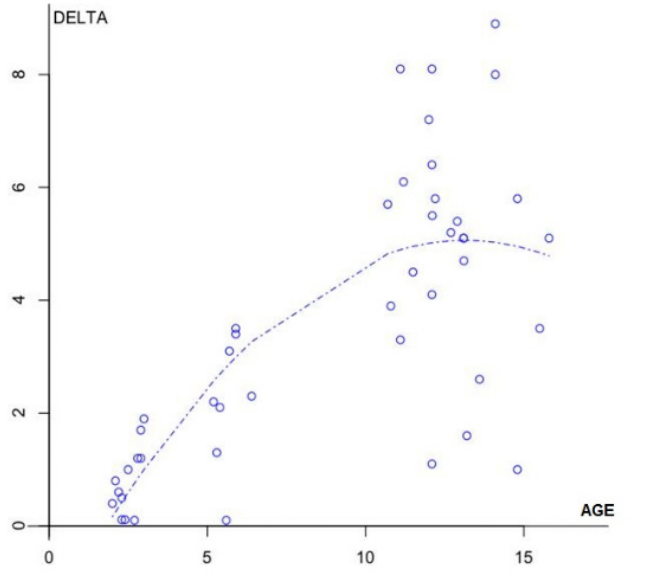


FIGURE 3. *Second-order polynomial regression analysis of DELTA values (difference between chronological and mental age) in children with Down syndrome.*

with age, this study investigated cognitive and adaptive functions in children with DS at different developmental stages. Our study groups had a degree of intellectual disability ranging from mild to severe, in line with existing data from other studies in the DS population [13]: 90% of children aged 2-6 years and 100% of children aged 10-15 years had a degree of disability which was rated as less than profound.

Moreover, results from the WISC-IV test in the older group of children with DS showed that the most severely affected cognitive domain was working memory. Specifically, children reported marked difficulties in those subtests (Digit Span and Letter Number Sequencing) that involve verbal short term memory. Conversely, PRI scores showed that the visuo-spatial component was relatively well preserved. These findings were consistent with the results of previous studies [23-27].

Although children with DS can have substantial language deficits [13,24,28], especially in verbal production[29], differences between verbal comprehension and perceptual reasoning performances in our study did not reach statistical significance. This could be due to the fact that the subtests that make up the VCI scale of the WISC-IV assess the comprehension component of language rather than verbal production. Consistent with the results of previous studies [3,13,14], we found a significant difference between comprehension and verbal production on the VABS: subjects had the lowest mental age in the communication scale, with the most pronounced impairment in the expressive subscale.

In terms of adaptive functions, our results replicated previous findings about higher levels of functioning within the daily living skills domain [3,14]. In our study, children with DS reported relatively high scores on measures of social competence related to daily living capabilities, which rely more heavily on implicit memory and are frequently expressed within the family context. Specifically, the mean mental age in the domestic subscale was relatively preserved, possibly due to the fact that children with DS remain dependent on the attachment figures longer than their peers, both physically and psychologically.

Children in our study reported higher scores on the socialization subscale than on the communication scale, contrary to the findings of the study by Dressler et al. [3]. These differences could be explained at least in part by the high level of social integration in our sample: all children were attending school and were involved in sports or recreational activities with peers during or after school. They also benefitted from a strong social network and continuing family support. The average deviation IQ score showed that the participants in our study had overall good adaptive functions within the population of individuals with intellectual disabilities.

Finally, our study explored the correlation between intellectual disability, adaptive functions and chronological age. We found that adaptive functions, but not cognitive deficits, were relatively more compromised in the older group of children: these findings suggest that the progressively widening disparity between the development of children with DS and those with typical development could be more significantly affected by the adaptation component than cognition. Specifically, we found that the difference between chronological age and mental age increases with age, until it comes to a plateau, at about 12 years of age. It is possible that the physical and psychological changes of pre-adolescence and adolescence, along with the increasing environmental demands (school and other activities), might play a negative role on the older children's adaptive skills. These results have important clinical implications, also in consideration of the new criteria for intellectual disabilities described in the DSM-5, which emphasize the need to assess the severity of impairment on the basis of adaptive functioning, rather than relying on IQ scores alone [1]. A better understanding of the functioning profile of young patients with DS, with particular attention to their skills in everyday life activities, would allow to implement more targeted intervention strategies to improve their health-related quality of life.

Our study has limitations. The cross-sectional design allowed us to describe the status of cognitive and adaptive skills at a single time point and to compare these data between two different age groups, however a longitudinal evaluation over time would have been optimal to evaluate the patterns of change with age. A second limitation of our study was the relatively small sample size, as well as its source: we enrolled only children from the northern part of Italy, who had been referred to the local health care services and whose medical history was fully known. Further studies with larger and more representative samples would be needed to confirm our findings using different research paradigms. Further limitations are related to the choice of the psychometric instruments. For the assessment of cognitive functions, we chose to use two different, yet comparable, tools because a single scale for the comprehensive assessment of cognitive development across childhood and adolescence is not currently available. However intelligence testing in children with intellectual disabilities poses considerable challenges, because the most widely used tools are highly subject to floor effect: having been designed for use in individuals with typical development, these psychometric instruments do not provide a sensitive measurement of cognition in the low ability range. As expected, we found a significant floor effect for both GMDS-ER and WISC-IV: these findings are consistent with the results from a previous study on children

with fragile X syndrome and represent a major limitation of standardised intelligence testing [30]. Contrary to the WISC-IV and GMDS-ER, the VABS is a subjective tool assessing adaptive functions based on the parents' perspective, which can overestimate the difficulties of their children in a period of time in which the difference with their peers is more evident.

Despite these limitations, our findings that adaptive functions can be relatively more impaired than cognitive functions in older children with DS contribute to inform therapeutic interventions focused on strengths and weaknesses across different age groups.

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