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NEUROCOGNITIVE IMPLICATIONS OF CONGENITAL HEART DISEASES IN ADOLESCENTS

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SUMMARY

Background: The study of neurocognitive functions in the context of congenital heart disease (CHD) is a field of recognized importance, due to its implications for the psychoeducational development of young people. The goal of our study was to characterize the neurocognitive functioning of adolescents with several types of CHD.

Material/ Methods: Our sample comprised 49 subjects ranging in age from 13 to 18 years, organized in two groups: a control group (CG, n= 17) and a group with congenital heart disease (CHD, n=32). Selected neuropsychological tests were administered to both groups, covering a wide range of neurocognitive functions, such as short term memory (verbal and visuoconstructive), working memory, processing speed, attention (divided and selective), and planning.

Results: Our results revealed significant differences between the two groups, favoring the CG, on every test except for a logical memory task. No differences were found between the different types of CHD.

Conclusions: These results are highly suggestive of the need to implement neuropsychological rehabilitation programs directed to this population, in order to minimize cognitive and school-related consequences.

Key words: cognitive functions, neuropsychological assessment, pediatric cardiology

INTRODUCTION

Congenital heart defects are the most common group of cardiac malformations. It is believed that one in every 120 babies is born with a heart defect (Berkow, 2006). Congenital heart diseases (CHD) are the most common group of birth defects, and may consist of an abnormal development of the walls or valves of the heart, or abnormalities in the blood vessels that enter or leave the heart. Several of these defects are severe; some, in spite of being present at birth, are not diagnosed until later ages (Berkow, 2006; Manual Merck, 1987; Manual Merck, 2008).

CHD can be divided into cyanotic and acyanotic subtypes, each with a distinct clinical presentation. The cyanotic subtype implies a significant reduction of blood oxygen, which is thought to be an important factor in functional impairment in the cognitive and psychological domains (Anjos, 2003; Delamater & Grus, 2002).This subtype encompasses several diagnoses, such as pulmonary atresia, Fallot´s tetralogy and transposition of the great arteries. The acyanotic subtype includes interventricular communication, interatrial communication, atrial-ventricular septal defect, and coarctation of the aorta (Anjos, 2003; Delamater & Grus, 2002).

In recent decades, advances in the diagnosis and treatment of CHD has significantly increased the longevity of these patients, leading to new challenges in the identification of the sequelae and risk factors for morbidity in the long- term (Massaro, El-dib, Aly & Glass, 2008; Kenny & Stuart, 2009).

Due to the significant increase in the number of CHD children who survive to school age, interest in exploring the long-term consequences of cardiac disease has increased (Brosig, Mussatto, Kuhn & Tweddell, 2007). Several studies have reported alterations in executive functions, attention and information processing speed, visual constructive abilities, motor functions and behavioral difficulties, which appear to be areas of relative susceptibility in children with CHD, leading to functional limitations (Wright & Nolan, 1994, Bellinger et al. 2003b; Dominguez, Gaynor & Wernovsky, 2007; Hövels-Gürich et al. 2007a; Miatton, De Wolf, Francois Vingerhoets & Thiery, 2007; Majnemer et al., 2008).

Despite the ongoing effort, there are few studies that focus on adolescents. Most studies evaluate the early years of life, not giving the opportunity to assess certain late-maturing capacities, such as executive functions or complex problem solving (Bellinger & Newburger, 2010). Additionally, there are no studies on the Portuguese CHD adolescent population addressed to the neuropsychological consequences of the disease. The aim of this study is to explore the performance of adolescents with CHD in several areas of neurocognitive functioning.

PATIENTS AND METHODS

The sample consists of 49 participants, between 13 and 18 years of age, divided in two groups: a congenital heart disease group (CHD), composed of 32 patients recruited from the outpatient pediatric cardiology clinic at the Hospital de São João (Porto); and a group control (CG), made up of 17 adolescents from

Table 1. Characteristics of the sample

	C	CHD
Age (Mean / SD)	15.82 / 1.51	15.78 / 1.52
Gender (male / female)	11 / 6	13 / 19
Education (Mean / SD)	10.24 / 1.39	9.09 / 1.87

Table 2. Frequencies of congenital heart disease's diagnoses

CHD Types	N	%
Pulmonary Atresia	4	8,2
Interatrial communication	4	8,2
Interventricular communication	9	18,4
Coarctation of the Aorta	3	6,1
Atrioventricular septal defect	2	4,1
Fallot's Tetralogy	6	12,2
Transposition of Great Arteries	4	8,2

several schools in the Porto city area (Table 1). The CHD group included individuals with different types of congenital heart disease, as shown in Table2. The presence of neurological or systemic disturbances in the medical history, other than CHD for the clinical group, was an exclusion criterion for both groups.

The two groups did not differ significantly with respect to age ($U = 268$, $p = .932$), gender ($\chi 2 = 2.576$, $p =.096$) or years of education ($U = 178$, $p =.065$).

Neuropsychological Assessment

All participants underwent a brief neuropsychological assessment, designed to cover an appropriate number of neurocognitive functions over a short period of time. The following tasks were administered:

- Wechsler's **Digit Test**, in direct (**DD**) and indirect (**ID**) form, in order to assess immediate auditory-verbal attention and working memory, respectively;
- Wechsler's **Symbol Search** (**SS**), to evaluate psychomotor performance, speed of execution, perceptive organization, and persistence;
- **Rey's Complex Figure**, copy (**RC**) and reproduction from memory (**RM**) three minutes after image exposure, allowing the assessment of visual constructional ability and visual constructional memory;
- **Key Search Test** (**KS**) from the Behavioural Assessment of the Dysexecutive Syndrome- Children, for the assessment of the capability for efficient planning;
- **Color-Word Stroop Test** (**ST**), to assess attention efficiency;
- the **Trail Making Test**, part A (**TMT A**) to evaluate visual spatial orientation, psychomotor speed, and part B (**TMT B**), to assess divided attention;
- Wechsler´s **Logical Memory Task** was administered in order to assess verbal memory.

Procedure

This research protocol was approved by the hospital ethics committee. The participants were recruited from the pediatric cardiology outpatient clinic at the

Table 3. Frequency of the subtypes of congenital heart disease

	N	%
Cyanotic	14	28.6
Acyanotic	18	36.7

Hospital de S. João EPE, according to analyses of the clinical charts. Patients with other health conditions, either neurologic or systemic, were excluded. The neuropsychological assessment was performed by the same neuropsychologist in a closed room. Identical procedures were taken for the assessment of the control group. Parents or legal guardians gave their informed consent.

Statistical analysis

Statistical analysis was carried out using the program PASW for Windows, version 18. A comparison of the obtained results on the neuropsychological tests by the two groups was made through the Mann-Whitney's U test. The Kruskal-Wallis H test was used to compare the results obtained by individuals with different diagnoses of CHD. Significance was determined with $p \leq .05$.

RESULTS

The results obtained by the two groups on neuropsychological tests are presented in Table 4.

Table 5 shows significant differences on neurocognitive performance between groups. CHD obtained worst results on every neuropsychological task, except

Table 4. Results obtained by two groups on neuropsychological tests

	C	CHD
Direct Digits (Mean / SD)	12.53 / 1.38	9.56 / 2.87
Indirect Digits (Mean / SD)	8.12 / 1.54	3.81 / 2.32
Rey Copy (Mean / SD)	35.53 / 0.72	31.44 / 6.75
Rey Memory (Mean / SD)	26.41 / 3.26	20.00 / 7.47
Symbol Search (Mean / SD)	44.00 / 4.05	33.59 /11.01
Key Search (Mean / SD)	11.12 / 2.62	6.41 / 4.35
Sroop Test (Mean / SD)	53.35 / 8.59	37.94 / 10.99
TMT A (Mean / SD)	21.00 / 7.37	42.06 / 23.90
TMT B (Mean / SD)	40.06 / 9.54	90.34 / 50.57
Logical Memory (Mean / SD)	13.24 / 2.31	11.44 / 5.43

Table 5. Comparison of results obtained by the two groups

	C	CHD		
	Mean Rank	Mean Rank	U	p
Direct Digits	35,26	19,55	97.5	**.000**
Indirect Digits	39,38	17,36	27.5	**.000**
Rey Copy	33,47	20,50	128.0	**.002**
Rey Memory	33,76	20,34	123.0	**.002**
Symbol Search	34,68	19,86	107.5	**.001**
Key Search	35,71	19,31	90.0	**.000**
Stroop Test	37,21	18,52	64.5	**.000**
TMT - A	13,26	31,23	72.5	**.000**
TMT - B	12,82	31,47	65.0	**.000**
Logical Memory	27,97	23,42	221.5	.286

on Weschler's logical memory where the performance was similar to CG. There are no differences on neurocognitive performance according to different CHD diagnosis. The same is observed when the clinical sample was divided according to the presence of cyanosis.

DISCUSSION

In this study, the existence of congenital heart disease was related to a poor performance in almost all neurocognitive functions assessed. Analyzing the results, we found that adolescents with CHD obtained worst scores on all neuropsychological tasks, except on the logical memory test. The neurocognitive performance of the CHD group wasn't related to the specific CHD diagnosis neither to the presence of cyanosis. These observations are not consistent with those made by other authors that suggests a negative effect of additional diagnoses such as transposition of the great arteries (Bellinger et al., 2003b), hypoplastic left heart syndrome (Brosig et al., 2007) and Fallot's tetralogy (Hövels-Gürich et al., 2007) on attention. However, it should be noted that two previous studies were performed in younger children (8 and 7 years respectively). In addition, the number of patients within each diagnosis group in our sample was low. The existence of differences in neurocognitive functioning in cyanotic and acyanotic congenital heart diseases has been somewhat contradictory. Most of the studies are in accordance to our findings, pointing to similar performances in cyanotic and acyanotic patients (Wright & Nolan, 1994; Hövels-Gürich, et al., 2006; Miatton et al., 2007; Hövels-Gürich, et al., 2007b; Miatton et al., 2008), while others point to the existence of additional affectation in the cyanotic group (Majnemer et al., 2008).

The performance of CHD group on DD task, suggests difficulties in auditory-verbal immediate attention in these patients, a fact corroborated by previous studies (Bellinger et al., 2010; Brosig et al., 2007; Mahle et al., 2000; Mahle & Wernovsky, 2004). In addition, the performance on ST and TMT B points to the presence of alterations in the efficiency of attention and in the ability to divide it. These results are consistent with the idea that CHD survivors are at increased risk for attentional problems as Attention – deficit disorder (Gerdes & Flynn, 2010). For instance, Shillingfor and colleagues (Shillingfor et al., 2008), obtained ratings of behavior related to attention from the parents of CHD children with ages ranging from 5 to 10 years. They signal that 30% of the children were at high risk for inattention.

The performance of the CHD group on ID task, also points to working memory affectation in addition to attentional deficits. This finding is consistent with those of previous studies in younger children (Bellinger et al., 2003b).

The same consistency of findings is noted when referring to the visual constructional ability (RC) and visual constructional memory (RM) in CHD patients (Bellinger et al., 2003a). In fact, changes in visual constructive ability are assumed as a common denominator to several studies in younger children, independently of the neuropsychological test used (Bellinger et al., 2003b; Mahle & Wernovsky, 2004, Brosig et al., 2007; Miatton et al., 2007; Majnemer et al., 2008).

The obtained results on SS and on TMT A are common indicators of lower psychomotor speed in CHD. This is also corroborated by previous studies (Bellinger et al., 2003b). In addition, perceptive organization and visual spatial orientation both implied in these tasks, could account for the low performance on the visual constructional test (RC).

In the key search test the CHD group performance was significantly lower than the control group, thus revealing low efficiency in planning, organizing and problem-solving. Several studies have already indicated the existence of changes in executive functioning and problem solving in children with CHD (Bellinger et al., 1999; Mahle & Wernovsky, 2004; Majnemer et al., 2008); however, our results highlight the existence of deficits in the ability to plan and to formulate an effective strategy in order to achieve a goal. These deficits in CHD adolescents seem to have continuity in adulthood. Daliento and colleagues using other executive functioning test (Tower of London) have signaled the presence of planning deficits in adult patients. (Daliento et al., 2005).

These data reinforce the idea that children with CHD have more difficulties in performing complex mental tasks (Bellinger et al., 2003b; Hövels-Gürich, et al., 2007a; Miatton et al., 2008).

Despite several references in literature relating CHD to verbal memory impairment (Bellinger et al., 2003b; Majnemer et al.. 2008; Miatton et al., 2008), our study points to the perseveration of this cognitive function. This finding may be due to different age samples or to the use of different neuropsychological tasks. The assessment of this function in youngsters and in children is commonly carried by requesting the evocation of single words. In the present study it was demanded the immediate evocation a text, meaning that the elements to be evoked were integrated in a proper context and in relation with temporal coordinates. These characteristics may have accounted for the obtained results.

According to the above, adolescents with CHD showed marked impairments on several domains of attention as immediate auditory-verbal, selective and divided attention. Psychomotor speed, verbal working memory, visual constructional capacity and memory, planning ability are also affected. Verbal memory, with a logical context seems to be unimpaired. The described neurocognitve implications of CHD in adolescents, points to the need to implement neuropsychological interventions programs aimed to promote the development of cognitive skills in order to minimize educational impacts.

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