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Heba E. Abo El Wafa

Alexandria University

Soha A. Ibrahim

Alexandria University

Youssef S. Barsoum

youssefshady01@gmail.com

Alexandria University

Ahmed M. Salama

Alexandria University

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Efficacy of digital therapeutic video games (Lumosity games) in treating ADHD

A prospective comparative study

Heba E. Abo El Wafa¹, Soha A. Ibrahim¹, Youssef S. Barsoum¹ (corresponding author), Ahmed M. Salama¹

¹ Psychiatry department, Alexandria Main University Hospital, Faculty of Medicine, Alexandria University, Alexandria, Egypt

Abstract

Purpose

Attention-Deficit/Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental disorder characterized by a range of symptoms that affect individuals across various domains of functioning

Recent advancements in the treatment of attention deficit hyperactivity disorder (ADHD) have emphasized a multimodal approach, incorporating pharmacological and behavioral interventions tailored to individual needs.

Digital therapeutic video games have emerged as a promising adjunctive treatment option for attention-deficit/hyperactivity disorder.

Lumosity games, developed by Lumos Labs, have gained attention as a potential intervention for ADHD in children.

Methods

We hereby present a prospective comparative study in ElHadra university hospital- Child and Adolescent Psychiatry Clinic to assess the role of digital therapeutic video games (Lumosity game) in the treatment of ADHD.

60 random children and adolescents diagnosed with ADHD aged between 13 and 18 years old were divided into 2 groups (30 children each), group A received non stimulants (Atomoxetine) in addition to behavioral and parenting modification according to individual needs and they were subjected to at least 20 minutes 3 times weekly sessions of digital therapeutic video games (Lumosity game) for 12 weeks and group B which served as active controls received non stimulants (Atomoxetine) in addition to behavioral and parenting modification according to individual needs

All the participants in both groups were assessed with Conners' continuous performance test 3rd edition (CPT 3) and Barkley Deficits in Executive Functioning Scale (BDEFS-CA) before treatment and at the end of treatment after 12 week

Results

Group A (active group) showed more improvement than group B (controls) in almost all of the parameters of the CPT 3rd edition, however, the difference between the degree of improvement between both groups was not statistically significant

Group A (active group) showed more improvement than group B (controls) in almost all of the parameters of the Barkley deficits in executive functions scale and the difference between the degree of improvement in both groups was statistically significant in 2 parameters which are self management to time and self regulation of emotions ($p = 0.043$ and 0.012 respectively)

Univariate Linear regression analysis for the parameters affecting improvement in self regulation of emotions and self management to time was done and showed that

female sex was a significant predictor for the improvement of ADHD symptoms with digital therapeutic video games.

Conclusion

Children receiving the game showed significant improvement over children only receiving medications and behavioral modification in both self management to time and self regulation of emotions parameters of Barkley deficits in executive functions scale

Female sex was a strong predictor for the improvement of ADHD symptoms with Digital therapeutic video games

Digital therapeutic video games are a promising new treatment in improving both ADHD core symptoms and executive functions. These games can be used with medications and behavioral and modifications.

Disclosure

No conflict of interest, no funding received

Keywords

1.ADHD

2.Digital therapy

3.Therapeutic video games

Corresponding author: Youssef Shady Barsoum

Email: youssefshady01@gmail.com

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder characterized by a range of symptoms that affect individuals across various domains of functioning.⁽¹⁾ The Diagnostic Statistical Manual of Fifth Edition, or DSM-5, defines ADHD as a pattern of persistent hyperactivity and/or inattention, impulsivity that interferes with daily functions or development.⁽²⁾

According to recent studies, 6.7% to 7.8% of children are thought to have ADHD; however, cross-national prevalence varies greatly, ranging from 0.1% to 10.2% of children and adolescents.^(3,4) This incidence is higher in Arab nations; recent research from Egypt and Saudi Arabia indicates that the prevalence is as high as 20.9% and 11.6%, respectively.^(5,6) In a ratio of 3:1, boys are diagnosed with ADHD more often than girls.⁽⁷⁾

Research indicates that children with ADHD who receive appropriate interventions are more likely to succeed in school and develop positive relationships with peers and family members.⁽⁸⁾ Moreover, early and effective treatment can prevent or delay the development of comorbid psychiatric conditions, such as anxiety and depression, which frequently accompany ADHD and can further complicate a child's functioning.⁽⁹⁾

Recent advancements in the treatment of attention deficit hyperactivity disorder (ADHD) have emphasized a multimodal approach, incorporating pharmacological and behavioral interventions tailored to individual needs. Pharmacotherapy depends mainly on stimulants like Amphetamines and Methylphenidate and non stimulants like Atomoxetine.⁽¹⁰⁾

Behavioral interventions play a crucial role in the comprehensive management of attention deficit hyperactivity disorder. A study by Daley et al. (2019) published in the *Journal of Child Psychology and Psychiatry* examined the efficacy of behavioral interventions, such as parent training programs and classroom-based interventions, in reducing ADHD-related impairments. The study found that these interventions were associated with significant improvements in behavior, academic performance, and social functioning among children with ADHD.⁽¹¹⁾

The integration of digital technology into the treatment of psychiatric disorders represents a transformative shift in mental health care, offering new solutions to longstanding challenges such as accessibility, engagement, and treatment efficacy. Digital interventions encompass a wide range of tools, including mobile applications, telepsychiatry, online therapy platforms, and wearable devices, all developed to enhance the delivery of mental health services. These technologies not only facilitate remote access to care but also provide real-time data collection and personalized treatment options, which can significantly improve patient outcomes.⁽¹²⁾

Digital therapeutic video games have emerged as a groundbreaking intervention for treating ADHD. These games offer a novel solution by providing an engaging platform that can enhance treatment adherence and efficacy while also being enjoyable for children and adolescents.⁽¹³⁾

The neurobiology underlying digital therapeutic video games for ADHD treatment involves the targeted engagement and reinforcement of neural circuits responsible for attention and cognitive control. These games are designed to provide stimuli that activate the prefrontal cortex and strengthen top-down regulatory processes. Through repeated, adaptive gameplay that rewards focus and impulse inhibition,

these interventions promote neuroplasticity, potentially leading to sustained improvement in inattention and executive functions by modulating the very brain networks that are dysregulated in ADHD.⁽¹⁴⁾

Lumosity, developed by Lumos Labs, is a popular brain-training program that offers a variety of games designed to improve cognitive functions. The platform's games are designed to target specific cognitive domains such as memory, attention, and problem-solving skills providing users with exercises that adapt to their performance to keep them engaged and challenged.⁽¹⁵⁾

Lumosity games have been explored as a potential tool for treating ADHD by targeting the cognitive deficits commonly associated with the disorder, such as inattention, impulsivity, and poor working memory. A study by Osman et al. (2025) found evidence of cognitive and attentional benefits in a real-world cohort of adults who reported having received a lifetime diagnosis of ADHD from training with Lumosity under real-world conditions.⁽¹⁶⁾

The current study is aimed at assessing the role of digital therapeutic video games (Lumosity games) in the treatment of ADHD and at comparing between the efficacy of medications in addition to behavioral and parenting training combined with digital therapeutic video games (Lumosity games) and the efficacy of medications in addition to behavioral and parenting training only in treating ADHD in children and adolescents.

Methods:

Design and participants

This study employed a two-stage design consisting of an initial screening and recruitment phase followed by a parallel-group simple randomization study with pretest, posttest, and three months follow-up assessments.

Sample size and power considerations

Sample size was calculated using Power Analysis and Sample Size Software (PASS 2020) “NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/pass”. A minimal total hypothesized sample size of 40 eligible children and adolescents (20 per group) is needed to determine the efficacy of digital therapeutic video games (Lumosity game) in treating ADHD; taking into consideration 5% level of significance, effect size of 30% and 80% power using Chi Square-test.

The study was conducted on 60 children (30 in each group), 10 children dropped out from group A and 8 children dropped out from group B during the period of the study, so at the end of the study group A contained 20 children and group B contained 22 children (still fulfilling the minimum requirements).

Inclusion criteria

1. Children and adolescents who met criteria of ADHD according to DSM-5-TR
2. Age between 13 and 18 years old.
3. Both genders.
4. Child ascent, adolescent and parent informed written consent.

Exclusion criteria

1. Current medical or surgical acute illness.

2. Other psychiatric disorders (mood disorders, anxiety disorders, psychotic disorders etc..).
3. Previous head injury or neurological diseases.
4. IQ less than 85
- 5- Children less than 13 years of age (minimum age for Lumosity games)

Study setting

ElHadra university hospital- Child and Adolescent Psychiatry Clinic (CAPC) in Alexandria.

Study sample

Simple randomization method was used as 60 children and adolescents aged 13-18 meeting the diagnostic requirements for ADHD according to DSM-5 revised were randomly selected from El Hadara university hospital Child and Adolescent Psychiatry clinic and enumerated according to their order of presentation to the clinic and divided into 2 groups (even numbers formed group A and odd numbers formed group B)

Group A which included 30 children and adolescents diagnosed with ADHD according to DSM-5-TR.

They received non stimulants (Atomoxetine with a dose of 0.5 to 1.2 mg per kg according to guidelines) in addition to behavioral (positive reinforcement, clear expectation, consistent consequences, structured environment) and parenting (effective communication, modeling behavior, emotional support, behavioral contracts) modification according to individual needs and they were subjected to at least 20 minutes 3 times weekly sessions of digital therapeutic video games (Lumosity games) for 12 weeks

Group B which included 30 children and adolescents diagnosed with ADHD.

They served as active controls receiving non stimulants (Atomoxetine) in addition to behavioral and parenting modification according to individual needs.

Data collection methods

All studied sample was subjected to the following sequence of tools and techniques:

1. A predesigned Semi-structured interview questionnaire was used to collect the following data:

- A. Socio-demographic data as age, residence and educational level
- B. History taking (developmental, social, educational, past medical and drug history), mental state and neurological examination.

2. Psychometric studies:

- A. Stanford Binet IQ test 4th edition Arabic version
- B. Conners' continuous performance test 3rd edition
- C. Conners rating scale for ADHD Arabic version
- D. The Barkley Deficits in Executive Functioning Scale for children and adolescents (BDEFS-CA) Arabic version:
- E. General Health Questionnaire (GHQ-28) Arabic version (GHQ-28)

All the participants in both groups were assessed using Conners' continuous performance test 3rd edition (CPT 3) and Barkley Deficits in Executive Functioning Scale (BDEFS-CA) before treatment and at the end of treatment after 12 weeks

Ethical considerations

The study adhered to strict ethical guidelines and received approval from the Institutional Research Ethics Board (IREB) of the Alexandria Faculty of Medicine, Alexandria University, Egypt. An informed written consent was taken from patients and caregivers before conducting the study. Participation was entirely voluntary and the patients were free to decline without any consequences.

Consent to participate

Written informed consent was obtained from all participants prior to enrollment in the study.

Disclosure

No conflict of interest, no funding received

RESULTS

The results of this work will be presented as follow:

Part I

- 1- Demographic characteristics of the study sample
- 2- Analysis of dropouts

Part II

- 3- Pre intervention relational study
- 4- Comparison between the 2 groups pre and post treatment
- 5- Post intervention regression analysis

Part I

1) Descriptive study

Table 1 shows the demographic data of the total sample, most children were males, their age ranged from 13 to 16 years old, their IQ ranged from 86 to 97 and most of them were from urban areas (as the place of the study was a hospital located in an urban area).

Table (1): Distribution of the study sample according to demographic data in total sample (n = 60)

	No.	%
Sex		
Male	40	66.7
Female	20	33.3
Age (years)		
Min. – Max.	13.0 – 16.0	
Mean $\pm$ SD.	13.38 $\pm$ 0.72	
Median (IQR)	13.0 (13.0 – 14.0)	
Family history		
Negative consanguinity	35	58.3
Positive consanguinity	25	41.7
Residency		
Rural	20	33.3
Urban	40	66.7
Informant		
Mother	50	83.3
Father	8	13.3
Sister	1	1.7
Grandma	1	1.7
IQ		
Min. – Max.	86.0 – 97.0	
Mean $\pm$ SD.	89.98 $\pm$ 2.75	

Median (IQR)	90.0 (88.0 – 92.0)
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Table 2 shows the education of the informants, most informants were highly educated (university education).

Table (2): Distribution of the study sample according to Informant education in total sample (n = 60)

	No.	%
Informant education		
Uneducated	2	3.3
Preparatory school	3	5.0
Primary school	6	10.0
Secondary school	6	10.0
University	43	71.7

Table 3 shows the results of the general health questionnaire in the total sample, all children were normal as this was a selection requirement for this study.

Table (3): Distribution of the study sample according to General health questionnaire in total sample (n = 60)

	No.	%
General health questionnaire [Normal]	60	100.0

Table 4 shows the results of the conners parent rating scale according to severity and subtypes in the total sample where combined type prevailed (75%) followed by inattentive type (15%) and then hyperactive type (10%). Conners Parents Rating Scale (CPRS) scores are interpreted accordingly: 45-55: average, 56-60: slightly above average, 61-65: above average, 66-70: far above average, more than 70: extremely above average. 24 children (were extremely above average (40%) while 17 children were above average (28.3%). 14 children were far above average (18.3%) and 5 children were slightly above average (8.3%)

Table (4): Distribution of the study sample according to Conners parent rating scale in total sample (n = 60)

	No.	%
Conners rating scale ADHD severity		
Slightly above average	5	8.3
Above average	17	28.3
Far above average	14	23.3
Extremely above average	24	40.0
Conners rating scale ADHD subtypes		
Mainly inattentive	9	15.0
Mainly hyperactive impulsive	6	10.0
Combined	45	75.0

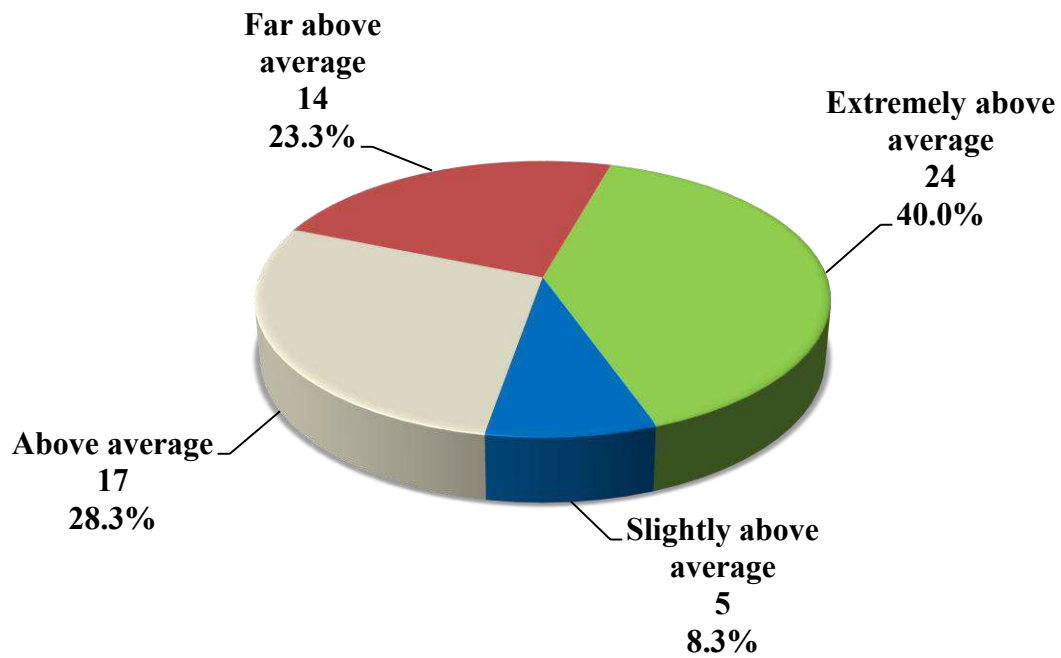


Figure (1): Distribution of the studied cases according to Conners parent rating scale ADHD severity in total sample (n = 60)

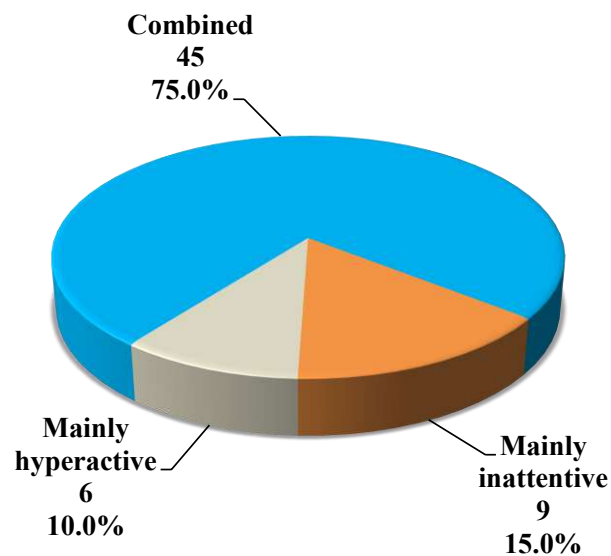


Figure (2): Distribution of the studied cases according to Conners rating scale ADHD subtypes in total sample (n = 60)

Table 5 shows that there was no significant difference between the 2 groups in the sex, age, informant, IQ and atomoxetine mean dose criteria.

Table (5): Comparison between the two remaining groups after dropouts exclusion according to demographic data

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Sex						
Male	17	85.0	16	72.7	$\chi^2=$ 0.937	^{FE} p= 0.460
Female	3	15.0	6	27.3		
Age (years)						
Min. – Max.	13.0 – 16.0		13.0 – 15.0		U= 182.00	0.182
Mean ± SD.	13.50 ± 0.89		13.18 ± 0.50			
Median (IQR)	13.0(13.0 – 14.0)		13.0(13.0 – 13.0)			
Informant						
Mother	16	80.0	20	90.9	$\chi^2=$ 3.153	^{MC} p= 0.260
Father	3	15.0	1	4.5		
Sister	1	5.0	0	0.0		
Grandma	0	0.0	1	4.5		
IQ						
Min. – Max.	86.0 – 97.0		86.0 – 95.0		t= 0.786	0.436
Mean ± SD.	90.15 ± 2.81		89.45 ± 2.91			
Median (IQR)	90.0(88.0 –91.50)		89.0(87.0 – 92.0)			
Atomoxetine dose						
Min. – Max.	25.0 – 60.0		25.0 – 60.0		U= 206.50	0.723
Mean ± SD.	44.25 ± 13.31		43.86 ± 9.87			
Median (IQR)	50.0(32.50 –55.0)		45.0 (40.0 – 50.0)			

IQR: Inter quartile range
t: Student t-test
MC: Monte Carlotest

SD: Standard deviation
 χ^2 : Chi square test

U: Mann Whitney test
FE: Fisher Exact test

p: p value for comparing between the two studied groups

Table 6 shows that there was no significant difference between the 2 groups as most informants were highly educated (university education).

Table (6): Comparison between the two remaining groups after dropouts exclusion according to informant education

	Group A (n = 20)		Group B (n = 22)		χ^2	^{MC}p
	No.	%	No.	%		
Informant education						
Uneducated	0	0.0	1	4.5	2.965	0.792
Preparatory school	1	5.0	0	0.0		
Primary school	1	5.0	1	4.5		
Secondary school	1	5.0	3	13.6		
University	17	85.0	17	77.3		

χ^2 : Chi square test MC: Monte Carlotest
p: p value for comparing between the two studied groups

Table 7 shows that there was no significant difference between the 2 groups according to Conners parent rating scale in both severity of ADHD and its subtypes.

Table (7): Comparison between the two groups after excluding dropouts according to conners parent ADHD rating scale

	Group A (n = 20)		Group B (n = 22)		χ^2	^{MC}p
	No.	%	No.	%		
Conners rating scale ADHD severity						

Slightly above average	2	10.0	1	4.5	0.771	0.967
Above average	7	35.0	7	31.8		
Far above average	4	20.0	5	22.7		
Extremely above average	7	35.0	9	40.9		
Conners rating scale ADHD subtypes						
Mainly inattentive	6	30.0	2	9.1	3.006	0.287
Mainly hyperactive	1	5.0	2	9.1		
Combined	13	65.0	18	81.8		

χ^2 : Chi square test MC: Monte Carlo test
p: p value for comparing between the two studied groups

Table 8 shows that there was no significant difference between the scores of the two groups according to CPT parameters.

Table (8): Comparison between the two whole study groups according to CPT parameters pre treatment

	Group A (n = 30)	Group B (n = 30)	t	p
Detectability				
Min. – Max.	58.0 – 75.0	52.0 – 75.0	0.807	0.423
Mean $\pm$ SD.	67.40 $\pm$ 4.69	66.40 $\pm$ 4.91		
Median (IQR)	68.0 (65.0 – 70.0)	67.0 (65.0 – 68.0)		
Omissions				
Min. – Max.	54.0 – 90.0	54.0 – 90.0	0.849	0.399
Mean $\pm$ SD.	70.07 $\pm$ 12.23	72.77 $\pm$ 12.39		
Median (IQR)	65.0 (60.0 – 83.0)	71.0 (62.0 – 85.0)		
Commissions				
Min. – Max.	50.0 – 72.0	47.0 – 70.0	0.312	0.756
Mean $\pm$ SD.	59.30 $\pm$ 5.74	58.83 $\pm$ 5.85		
Median (IQR)	60.0 (54.0 – 62.0)	59.50 (54.0 – 62.0)		

Hit reaction time				
Min. – Max.	53.0 – 86.0	49.0 – 90.0		
Mean ± SD.	69.53 ± 8.77	69.17 ± 10.13	0.150	0.881
Median (IQR)	68.50 (65.0 – 76.0)	69.50 (64.0 – 76.0)		
Hit reaction time block change				
Min. – Max.	41.0 – 90.0	47.0 – 85.0		
Mean ± SD.	63.77 ± 11.80	63.03 ± 10.0	0.260	0.796
Median (IQR)	64.0 (55.0 – 73.0)	61.0 (57.0 – 67.0)		
Perseverations				
Min. – Max.	48.0 – 79.0	47.0 – 90.0		
Mean ± SD.	62.93 ± 6.35	62.23 ± 10.68	0.309	0.759
Median (IQR)	64.0 (60.0 – 67.0)	60.0 (56.0 – 67.0)		

IQR: Inter quartile range

SD: Standard deviation

t: Student t-test .

Table 9 shows that there was no significant difference between the scores of the two groups according to Barkley deficits in executive functions scale parameters.

Table (9): Comparison between the two whole study groups according to Barkley deficits in executive functions scale parameters pre treatment

	Group A (n = 30)	Group B (n = 30)	t	p
Self-management to time				
Min. – Max.	88.0 – 99.0	88.0 – 99.0		
Mean ± SD.	95.27 ± 2.70	94.90 ± 2.63	0.532	0.596
Median (IQR)	95.50 (94.0 – 97.0)	95.0 (94.0 – 97.0)		
Self-organize				
Min. – Max.	80.0 – 99.0	87.0 – 99.0		
Mean ± SD.	95.10 ± 3.60	95.77 ± 2.66	0.815	0.418
Median (IQR)	96.0 (94.0 – 97.0)	96.0 (95.0 – 97.0)		
Self-restraint				

Min. – Max.	90.0 – 99.0	92.0 – 99.0		
Mean ± SD.	95.47 ± 2.22	96.17 ± 1.88	1.317	0.193
Median (IQR)	96.0 (94.0 – 97.0)	97.0 (95.0 – 98.0)		
Self-motivate				
Min. – Max.	88.0 – 99.0	87.0 – 99.0		
Mean ± SD.	95.03 ± 2.33	94.60 ± 2.91	0.637	0.526
Median (IQR)	95.0 (94.0 – 96.0)	94.0 (93.0 – 97.0)		
Self-regulation of emotions				
Min. – Max.	90.0 – 99.0	92.0 – 99.0		
Mean ± SD.	94.93 ± 2.52	95.67 ± 2.11	1.224	0.226
Median (IQR)	95.0 (94.0 – 97.0)	96.0 (94.0 – 97.0)		
Executive-functions				
Min. – Max.	94.0 – 99.0	95.0 – 99.0		
Mean ± SD.	96.70 ± 1.18	96.47 ± 1.17	0.771	0.444
Median (IQR)	97.0 (96.0 – 98.0)	96.0 (96.0 – 97.0)		

IQR: **Inter quartile range**

SD: **Standard deviation**

t: **Student t-test**

p: p value for comparing between the two studied groups

2) Analysis of dropouts

Table 10 shows that there was a statistically significant difference between the remaining group and the dropout group according to residency ($p=0.017$), most dropouts were from rural areas.

There was also a trend towards significance when we compare the 2 groups according to informant education ($p=0.053$), the informants of the dropout group had lower level of education.

Table (10): Comparison between the remaining children and the dropouts according to demographic data

	Remaining	Dropout	Test of	p
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	(n = 42)		(n = 18)		Sig.	
	No.	%	No.	%		
Residency						
Rural	10	23.8	10	55.6	$\chi^2=$ 5.714*	0.017*
Urban	32	76.2	8	44.4		
Age (years)						
Min. – Max.	13.0 – 16.0		13.0 – 15.0		U= 318.00	0.212
Mean ± SD.	13.33 ± 0.72		13.50 ± 0.71			
Median (IQR)	13.0(13.0 – 13.0)		13.0(13.0 – 14.0)			
Informant						
Mother	36	85.7	14	77.8	$\chi^2=$ 2.562	^{MC} p= 0.630
Father	4	9.5	4	22.2		
Sister	1	2.4	0	0.0		
Grandma	1	2.4	0	0.0		
Informant education						
Uneducated	1	2.4	1	5.6	$\chi^2=$ 8.054	^{MC} p= 0.053
Preparatory school	1	2.4	2	11.1		
Primary school	2	4.8	4	22.2		
Secondary school	4	9.5	2	11.1		
University	34	81.0	9	50.0		

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

FET: **Fisher Exact test**

p: p value for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

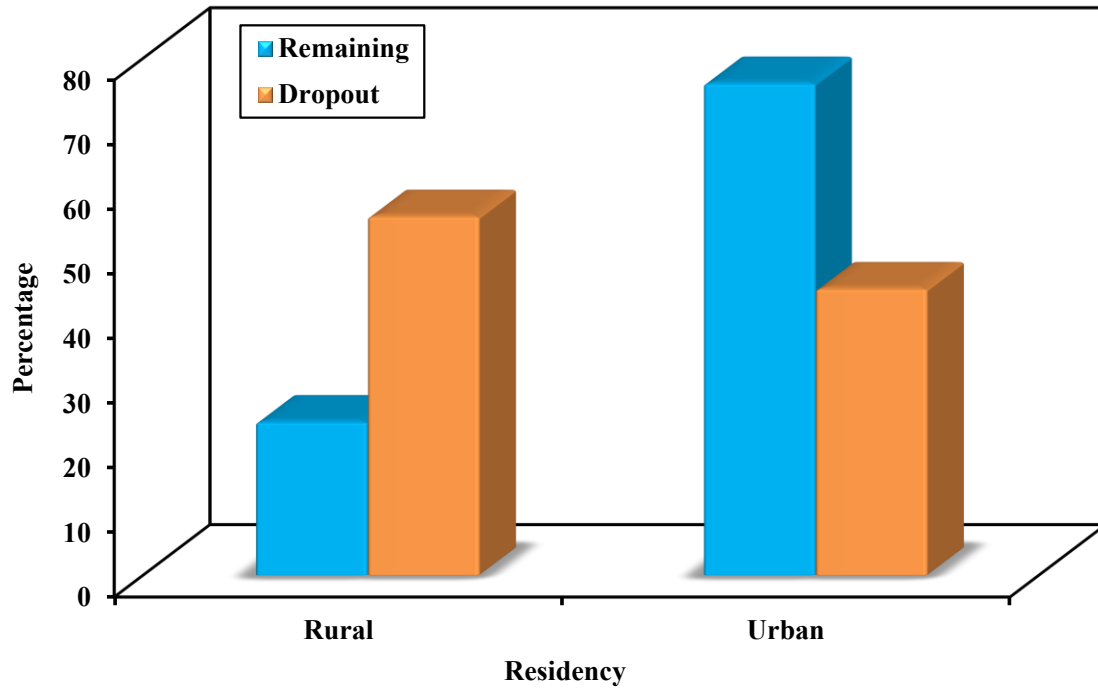


Figure (3): Comparison between the remaining group and the dropout group according to Residency

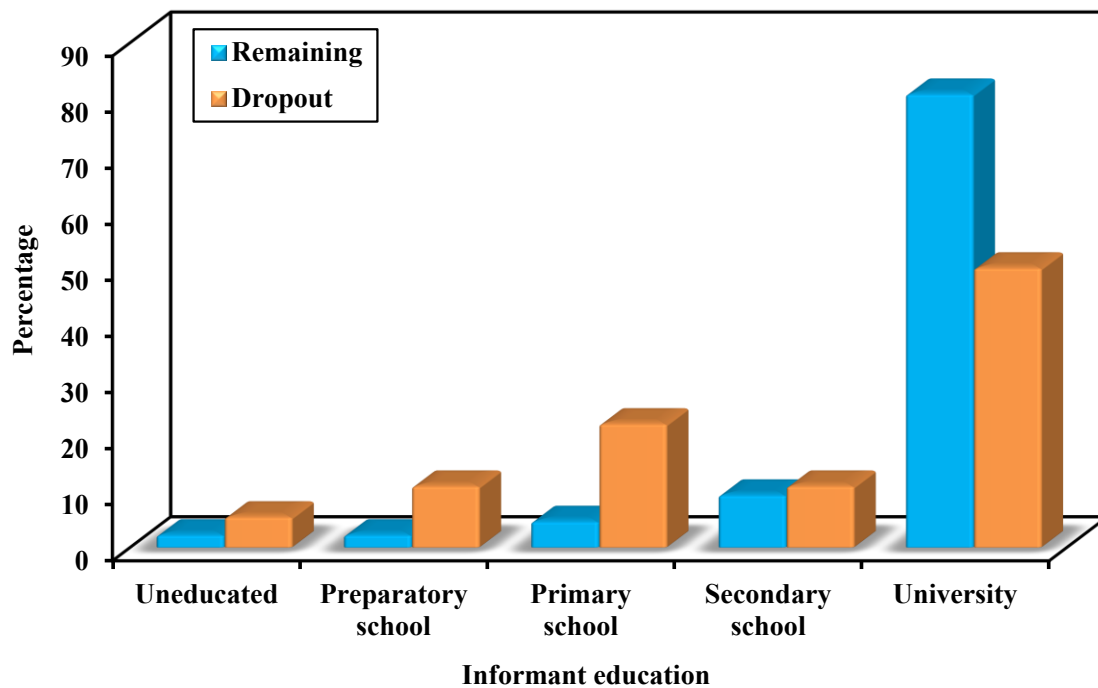


Figure (4): Comparison between the remaining group and the dropout group according to Informant education

Part II

3) Pre intervention relational studies

Tables from 11 to 34 show the relation between every CPT and barkley deficits in executive functions scale parameter and demographic data in the full sample, there was no statistically significant relation between any of the parameters with demographic data.

Table (11): Relation between Detectability with demographic data in total patients (n = 60)

		Detectability		Test of Sig.	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	66.40 $\pm$ 5.0	67.50 (52.0 – 75.0)	1.148	0.256
Female	20	67.90 $\pm$ 4.28	67.50 (60.0 – 75.0)		
Family history					
Negative consanguinity	35	65.80 $\pm$ 4.75	66.0 (52.0 – 75.0)	2.172*	0.034*
Positive consanguinity	25	68.44 $\pm$ 4.48	68.0 (56.0 – 75.0)		
Residency					
Rural	20	67.25 $\pm$ 5.30	67.50 (52.0 – 75.0)	0.398	0.692
Urban	40	66.73 $\pm$ 4.57	67.50 (56.0 – 75.0)		
Informant					
Mother	50	66.82 $\pm$ 4.86	67.50 (52.0 – 75.0)	0.511	0.612
Father	8	67.75 $\pm$ 4.23	68.0 (59.0 – 74.0)		
Sister	1[#]		71.0 [#]		
Grandma	1[#]		60.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

*: Statistically significant at $p \leq 0.05$

Table (12): Correlation between Detectability with demographic data in total patients (n = 60)

	Detectability	
	r	p
Age (years)	0.041	0.755
IQ	0.167	0.202

r: Pearson coefficient

Table (13): Relation between Omissions with demographic data in total patients (n = 60)

		Omissions		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	71.45 $\pm$ 12.11	70.0 (54.0 – 90.0)	0.029	0.977
Female	20	71.35 $\pm$ 12.93	68.0 (54.0 – 90.0)		
Family history					
Negative consanguinity	35	72.71 $\pm$ 12.28	71.0 (54.0 – 90.0)	0.968	0.337
Positive consanguinity	25	69.60 $\pm$ 12.30	65.0 (54.0 – 90.0)		
Residency					
Rural	20	70.60 $\pm$ 12.97	67.50 (54.0 – 90.0)	0.362	0.719
Urban	40	71.83 $\pm$ 12.07	70.50 (54.0 – 90.0)		
Informant					
Mother	50	72.0 $\pm$ 12.36	71.0 (54.0 – 90.0)	1.006	0.319
Father	8	67.38 $\pm$ 9.84	63.50 (60.0 – 83.0)		
Sister	1 [#]		90.0 [#]		
Grandma	1 [#]		56.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case ($n = 1$)

Table (14): Correlation between Omissions with demographic data in total patients (n = 60)

	Omissions	
	r	p
Age (years)	-0.125	0.343
IQ	-0.090	0.494

r: Pearson coefficient

Table (15): Relation between Commissions with demographic data in total patients (n = 60)

		Commissions		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	58.63 $\pm$ 5.52	59.50 (47.0 – 72.0)	0.840	0.405
Female	20	59.95 $\pm$ 6.23	60.0 (50.0 – 72.0)		
Family history					
Negative consanguinity	35	58.46 $\pm$ 5.36	58.0 (50.0 – 70.0)	0.971	0.335
Positive consanguinity	25	59.92 $\pm$ 6.26	60.0 (47.0 – 72.0)		
Residency					
Rural	20	58.40 $\pm$ 6.05	58.0 (50.0 – 72.0)	0.632	0.530
Urban	40	59.40 $\pm$ 5.64	60.50 (47.0 – 72.0)		
Informant					
Mother	50	59.16 $\pm$ 5.87	60.0 (47.0 – 72.0)	0.128	0.899
Father	8	58.88 $\pm$ 5.72	60.0 (50.0 – 66.0)		
Sister	1		61.0 [#]		
Grandma	1		54.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (16): Correlation between Commissions with demographic data in total patients (n = 60)

	Commissions	
	r	p
Age (years)	-0.048	0.718
IQ	-0.228	0.080

r: Pearson coefficient

Table (17): Relation between Hit reaction time with demographic data in total patients (n = 60)

		Hit reaction time		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	69.85 $\pm$ 9.10	68.50 (52.0 – 90.0)	0.580	0.564
Female	20	68.35 $\pm$ 10.13	70.0 (49.0 – 86.0)		
Family history					
Negative consanguinity	35	69.11 $\pm$ 10.07	69.0 (49.0 – 86.0)	0.228	0.820
Positive consanguinity	25	69.68 $\pm$ 8.56	69.0 (54.0 – 90.0)		
Residency					
Rural	20	69.55 $\pm$ 11.78	68.50 (49.0 – 90.0)	0.116	0.908
Urban	40	69.25 $\pm$ 8.12	69.50 (53.0 – 86.0)		
Informant					
Mother	50	70.48 $\pm$ 8.84	69.50 (52.0 – 90.0)	1.993	0.051
Father	8	63.75 $\pm$ 9.05	65.0 (53.0 – 75.0)		
Sister	1		78.0 [#]		
Grandma	1		49.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (18): Correlation between Hit reaction time with demographic data in total patients (n = 60)

	Hit reaction time	
	r	p
Age (years)	-0.121	0.356
IQ	-0.203	0.120

r: Pearson coefficient

Table (19): Relation between Hit reaction time block change with demographic data in total patients (n = 60)

		Hit reaction time block change		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	63.78 $\pm$ 11.73	62.50 (41.0 – 90.0)	0.376	0.708
Female	20	62.65 $\pm$ 9.06	62.0 (47.0 – 85.0)		
Family history					
Negative consanguinity	35	63.49 $\pm$ 11.66	61.0 (41.0 – 90.0)	0.072	0.943
Positive consanguinity	25	63.28 $\pm$ 9.83	62.0 (47.0 – 85.0)		
Residency					
Rural	20	62.95 $\pm$ 12.06	61.50 (47.0 – 85.0)	0.225	0.822
Urban	40	63.63 $\pm$ 10.34	62.0 (41.0 – 90.0)		
Informant					
Mother	50	62.68 $\pm$ 10.77	61.0 (41.0 – 85.0)	0.874	0.386
Father	8	66.13 $\pm$ 6.71	64.50 (59.0 – 80.0)		
Sister	1 [#]		90.0 [#]		

Grandma	1 [#]	51.0 [#]		
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SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (20): Correlation between Hit reaction time block change with demographic data in total patients (n = 60)

	Hit reaction time block change	
	r	p
Age (years)	0.126	0.336
IQ	0.069	0.598

r: Pearson coefficient

Table (21): Relation between Perseverations with demographic data in total patients (n = 60)

		Perseverations		Test of Sig.	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	63.95 $\pm$ 9.63	64.0 (47.0 – 90.0)	1.747	0.086
Female	20	59.85 $\pm$ 5.80	60.50 (48.0 – 68.0)		
Family history					
Negative consanguinity	35	63.77 $\pm$ 10.13	64.0 (47.0 – 90.0)	1.255	0.214
Positive consanguinity	25	60.92 $\pm$ 6.05	62.0 (48.0 – 70.0)		
Residency					
Rural	20	60.10 $\pm$ 7.56	60.0 (47.0 – 79.0)	1.580	0.120
Urban	40	63.83 $\pm$ 9.07	64.0 (48.0 – 90.0)		
Informant					
Mother	50	62.76 $\pm$ 9.13	64.0 (47.0 – 90.0)	0.559	0.579

Father	8	60.88 ± 6.64	62.0 (48.0 – 68.0)		
Sister	1		70.0 [#]		
Grandma	1		60.0 [#]		

SD: **Standard deviation**

t: **Student t-test**

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (22): Correlation between Perseverations with demographic data in total patients (n = 60)

	Perseverations	
	r	p
Age (years)	-0.015	0.911
IQ	0.225	0.084

r: Pearson coefficient

Table (23): Relation between Self-management to time with demographic data in total patients (n = 60)

		Self-management to time		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	95.0 $\pm$ 2.65	95.0 (88.0 – 99.0)	0.342	0.734
Female	20	95.25 $\pm$ 2.71	95.50 (90.0 – 99.0)		
Family history					
Negative consanguinity	35	94.91 $\pm$ 2.70	95.0 (88.0 – 99.0)	0.581	0.563
Positive consanguinity	25	95.32 $\pm$ 2.61	96.0 (89.0 – 99.0)		
Residency					
Rural	20	95.50 $\pm$ 2.31	95.0 (90.0 – 99.0)	0.859	0.394
Urban	40	94.88 $\pm$ 2.81	95.0 (88.0 – 99.0)		
Informant					
Mother	50	94.96 $\pm$ 2.70	95.0 (88.0 – 99.0)	0.406	0.686
Father	8	95.38 $\pm$ 2.62	96.0 (90.0 – 99.0)		
Sister	1 [#]		96.0 [#]		
Grandma	1 [#]		98.0 [#]		

SD: Standard deviation t: Student t-test
p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (24): Correlation between Self-management to time with demographic data in total patients (n = 60)

	Self-management to time	
	r	p
Age (years)	0.144	0.273
IQ	-0.067	0.610

r: Pearson coefficient

Table (25): Relation between Self-organize with demographic data in total patients (n = 60)

		Self-organize		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	95.58 $\pm$ 2.25	96.0 (87.0 – 99.0)	0.396	0.695
Female	20	95.15 $\pm$ 4.52	97.0 (80.0 – 99.0)		
Family history					
Negative consanguinity	35	95.29 $\pm$ 3.64	96.0 (80.0 – 99.0)	0.425	0.672
Positive consanguinity	25	95.64 $\pm$ 2.38	96.0 (91.0 – 99.0)		
Residency					
Rural	20	95.75 $\pm$ 2.90	96.50 (87.0 – 99.0)	0.546	0.587
Urban	40	95.28 $\pm$ 3.30	96.0 (80.0 – 99.0)		
Informant					
Mother	50	95.46 $\pm$ 2.57	96.0 (87.0 – 99.0)	0.393	0.706
Father	8	94.63 $\pm$ 5.93	97.0 (80.0 – 97.0)		
Sister	1 [#]		98.0 [#]		
Grandma	1 [#]		98.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (26): Correlation between Self-organize with demographic data in total patients (n = 60)

	Self-organize	
	r	p
Age (years)	-0.150	0.253
IQ	0.011	0.936

r: Pearson coefficient

Table (27): Relation between Self-restraint with demographic data in total patients (n = 60)

		Self-restraint		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	95.83 $\pm$ 1.74	96.0 (92.0 – 99.0)	0.044	0.965
Female	20	95.80 $\pm$ 2.67	97.0 (90.0 – 99.0)		
Family history					
Negative consanguinity	35	95.94 $\pm$ 1.66	96.0 (93.0 – 99.0)	0.518	0.607
Positive consanguinity	25	95.64 $\pm$ 2.56	97.0 (90.0 – 99.0)		
Residency					
Rural	20	96.55 $\pm$ 2.21	97.0 (90.0 – 99.0)	1.988	0.052
Urban	40	95.45 $\pm$ 1.92	95.0 (90.0 – 99.0)		
Informant					
Mother	50	95.74 $\pm$ 2.10	96.0 (90.0 – 99.0)	0.013	0.990
Father	8	95.75 $\pm$ 1.98	96.50 (92.0 – 98.0)		

Sister	1	98.0 [#]		
Grandma	1	98.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (28): Correlation between Self-restraint with demographic data in total patients (n = 60)

	Self-restraint	
	r	p
Age (years)	0.060	0.650
IQ	-0.054	0.682

r: Pearson coefficient

Table (29): Relation between Self-motivate with demographic data in total patients (n = 60)

		Self-motivate		t	p
		Mean $\pm$ SD.	Median (min. – Max)		
Sex					
Male	40	94.70 $\pm$ 2.58	95.0 (87.0 – 99.0)	0.485	0.630
Female	20	95.05 $\pm$ 2.74	94.0 (89.0 – 99.0)		
Family history					
Negative consanguinity	35	94.83 $\pm$ 2.76	95.0 (87.0 – 99.0)	0.041	0.967
Positive consanguinity	25	94.80 $\pm$ 2.47	95.0 (89.0 – 99.0)		
Residency					
Rural	20	94.55 $\pm$ 2.84	94.50 (87.0 – 99.0)	0.554	0.582
Urban	40	94.95 $\pm$ 2.53	95.0 (88.0 – 99.0)		
Informant					
Mother	50	94.82 $\pm$ 2.56	95.0 (87.0 – 99.0)	0.446	0.658

Father	8	94.38 ± 3.02	94.0 (89.0 – 99.0)		
Sister	1		94.0 [#]		
Grandma	1		99.0 [#]		

SD: Standard deviation

t: Student t-test

Table (30): Correlation between Self-motivate with demographic data in total patients (n = 60)

	Self-motivate	
	r	p
Age (years)	0.011	0.933
IQ	-0.210	0.108

r: Pearson coefficient

Table (31): Relation between Self regulation of emotions with demographic data in total patients (n = 60)

		Self regulation of emotions		t	p
		Mean ± SD.	Median (min. – Max)		
Sex					
Male	40	95.43 ± 2.22	96.0 (90.0 – 99.0)	0.584	0.561
Female	20	95.05 ± 2.58	95.0 (90.0 – 99.0)		
Family history					
Negative consanguinity	35	95.51 ± 1.90	96.0 (92.0 – 98.0)	0.840	0.404
Positive consanguinity	25	95.0 ± 2.84	95.0 (90.0 – 99.0)		
Residency					
Rural	20	95.20 ± 2.65	94.50 (90.0 – 99.0)	0.233	0.817
Urban	40	95.35 ± 2.19	95.50 (90.0 – 99.0)		
Informant					
Mother	50	95.26 ± 2.24	95.0 (90.0 – 99.0)	0.290	0.773

Father	8	95.0 ± 3.02	94.50 (90.0 – 99.0)		
Sister	1 [#]		97.0 [#]		
Grandma	1 [#]		98.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

Table (32): Correlation between Self regulation of emotions with demographic data in total patients (n = 60)

	Self regulation of emotions	
	r	p
Age (years)	-0.050	0.705
IQ	-0.023	0.862

r: Pearson coefficient

Table (33): Relation between Executive-functions summary score with demographic data in total patients (n = 60)

		Executive-functions summary score		t	p
		Mean ± SD.	Median (min. – Max)		
Sex					
Male	40	96.73 ± 1.11	97.0 (94.0 – 99.0)	1.337	0.187
Female	20	96.30 ± 1.26	96.0 (94.0 – 99.0)		
Family history					
Negative consanguinity	35	96.57 ± 1.20	97.0 (94.0 – 99.0)	0.093	0.927
Positive consanguinity	25	96.60 ± 1.15	96.0 (95.0 – 99.0)		
Residency					
Rural	20	96.70 ± 1.08	97.0 (95.0 – 98.0)	0.544	0.589
Urban	40	96.53 ± 1.22	96.0 (94.0 – 99.0)		
Informant					
Mother	50	96.52 ± 1.11	96.0 (94.0 – 99.0)	0.236	0.814

Father	8	96.63 ± 1.51	96.50 (94.0 – 99.0)		
Sister	1		98.0 [#]		
Grandma	1		98.0 [#]		

SD: Standard deviation

t: Student t-test

p: p value for Relation between different categories

#: Excluded from the (comparison) due to small number of case (n = 1)

Table (34): Correlation between Executive-functions summary score with demographic data in total patients (n = 60)

	Executive-functions	
	r	p
Age (years)	-0.049	0.710
IQ	-0.118	0.369

r: Pearson coefficient

4) Comparative study between the 2 groups pre and post treatment

Table 35 shows a that there was a statistically significant improvement in all CPT parameters in both groups except for one parameter (perseverations)

There was a statistically significant improvement in perseverations in Group A (active group) while the improvement in group B (control) was not significant.

Table (35): Comparison between the two groups pre and post treatment according to CPT parameters results

	Group A (n = 20)		Group B (n = 22)		t , p ₁	t , p ₂
	Pre	Post	Pre	Post		
Detectability						
Min. – Max.	58.0 – 75.0	53.0 – 68.0	52.0 – 75.0	50.0 – 70.0	t=0.913, p=0.367	t=0.565, p=0.576
Mean ± SD.	66.75 ± 5.0	60.60 ± 4.16	65.36 ± 4.84	61.50 ± 6.07		
Median (IQR)	67.50 (62.50–69.5)	61.0 (58.0 – 63.0)	66.0 (65.0 – 68.0)	61.0 (57.0 – 68.0)		
t₀ ,p₀	t ₀ =5.446* , p ₀ =<0.001*		t ₀ =3.291* , p ₀ =0.003*			
Omissions						
Min. – Max.	54.0 – 90.0	45.0 – 90.0	55.0 – 90.0	52.0 – 90.0	t=1.011, p=0.318	t=1.801, p=0.079
Mean ± SD.	70.75 ± 12.43	60.90 ± 13.99	74.59 ± 12.16	68.14 ± 12.04		
Median (IQR)	65.0 (60.0 – 83.50)	58.0 (50.50– 68.5)	73.50 (65.0 – 90.0)	66.0 (59.0 – 79.0)		
t₀ ,p₀	t ₀ =4.033* , p ₀ =0.001*		t ₀ =2.928* , p ₀ =0.008*			
Commissions						
Min. – Max.	50.0 – 72.0	39.0 – 65.0	47.0 – 70.0	40.0 – 70.0	t=0.444, p=0.659	t=0.053, p=0.958
Mean ± SD.	58.45 ± 5.49	52.70 ± 6.23	59.27 ± 6.42	52.82 ± 8.07		
Median (IQR)	58.50 (54.0 – 62.0)	54.0 (49.50 – 55.5)	60.0 (53.0 – 64.0)	52.50 (48.0 – 58.0)		
t₀ ,p₀	t ₀ =4.623* , p ₀ =<0.001*		t ₀ =6.515* , p ₀ =<0.001*			
Hit reaction time						
Min. – Max.	53.0 – 86.0	50.0 – 90.0	49.0 – 90.0	52.0 – 81.0	t=0.906, p=0.370	t=0.920, p=0.363
Mean ± SD.	71.10 ± 9.55	61.40 ± 9.32	68.36 ± 9.97	64.05 ± 9.30		
Median (IQR)	69.50 (65.5– 78.5)	60.0 (55.0 – 68.0)	69.0 (64.0 – 76.0)	62.50 (55.0 – 73.0)		
t₀ ,p₀	t ₀ =4.972* , p ₀ =<0.001*		t ₀ =2.117* , p ₀ =0.046*			
Hit reaction time block change						
Min. – Max.	41.0 – 90.0	27.0 – 75.0	47.0 – 85.0	50.0 – 75.0	t=0.000, p=1.000	t=0.679, p=0.501
Mean ± SD.	64.50 ± 12.15	59.30 ± 10.63	64.50 ± 10.86	61.09 ± 6.04		
Median (IQR)	66.50 (55.0– 71.5)	59.0 (54.0 – 68.0)	63.0 (54.0 – 68.0)	60.0 (59.0 – 63.0)		
t₀ ,p₀	t ₀ =2.459* , p ₀ =0.024*		t ₀ =2.383* , p ₀ =0.027*			
Perseverations						
Min. – Max.	48.0 – 79.0	44.0 – 80.0	47.0 – 90.0	47.0 – 90.0	t=0.348 , p=0.730	t=0.332, p=0.741
Mean ± SD.	63.80 ± 7.04	59.20 ± 8.62	62.77 ± 11.69	60.18 ± 10.34		
Median (IQR)	65.0 (62.0 – 67.50)	59.50 (54.5– 63.0)	59.0 (56.0 – 68.0)	58.0 (55.0 – 66.0)		

t₀ ,p₀	t₀=2.899* , p₀=0.009*	t₀=1.508 , p₀=0.146		
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IQR: Inter quartile range

SD: Standard deviation

t: Student t-test

t₀: Paired t-test

p₀: p value for comparing between **Pre** and **Post**

p₁: p value for comparing between the two studied groups **[Pre]**

p₂: p value for comparing between the two studied groups **[Post]**

*: Statistically significant at $p \leq 0.05$

Table 36 shows a quantitative comparison between the 2 groups according to degree of improvement in CPT parameters, although group A showed more improvement in almost all of the parameters, the difference in the degree of improvement between the two groups was not statistically significant.

Table (36): Comparison between the two studied groups according to degree of improvement in CPT parameters (Quantitative comparison)

	Group A (n = 20)	Group B (n = 22)	Test of Sig.	p
Detectability				
Min. – Max.	-3.0 – 15.0	-5.0 – 12.0	t= 1.398	0.170
Mean ± SD.	6.15 ± 5.05	3.86 ± 5.51		
Median (IQR)	6.0 (4.0 – 10.0)	3.50 (-1.0 – 9.0)		
Omissions				
Min. – Max.	-7.0 – 30.0	-11.0 – 21.0	U= 179.000	0.299
Mean ± SD.	9.85 ± 10.92	6.45 ± 10.34		
Median (IQR)	14.0 (.0 – 15.50)	8.0 (-2.0 – 14.0)		
Commissions				
Min. – Max.	-4.0 – 18.0	-4.0 – 13.0	t= 0.447	0.657
Mean ± SD.	5.75 ± 5.56	6.45 ± 4.65		
Median (IQR)	5.50 (1.50 – 9.50)	7.0 (4.0 – 10.0)		
Hit reaction time				
Min. – Max.	-7.0 – 25.0	-13.0 – 16.0	U= 150.000	0.077
Mean ± SD.	9.70 ± 8.72	4.32 ± 9.57		
Median (IQR)	12.0 (4.0 – 15.0)	8.50 (-5.0 – 13.0)		
Hit reaction time block change				
Min. – Max.	-16.0 – 20.0	-5.0 – 13.0	U= 150.000	0.077
Mean ± SD.	5.20 ± 9.46	3.41 ± 6.71		
Median (IQR)	6.50 (-3.0 – 13.50)	1.0 (-3.0 – 11.0)		
Perseverations				
Min. – Max.	-10.0 – 15.0	-10.0 – 17.0	t= 0.854	0.398
Mean ± SD.	4.60 ± 7.10	2.59 ± 8.06		
Median (IQR)	6.50 (1.0 – 9.50)	2.0 (-4.0 – 9.0)		

IQR: Inter quartile range
U: Mann Whitney test

SD: Standard deviation

t: Student t-test

p: p value for comparing between the two studied groups

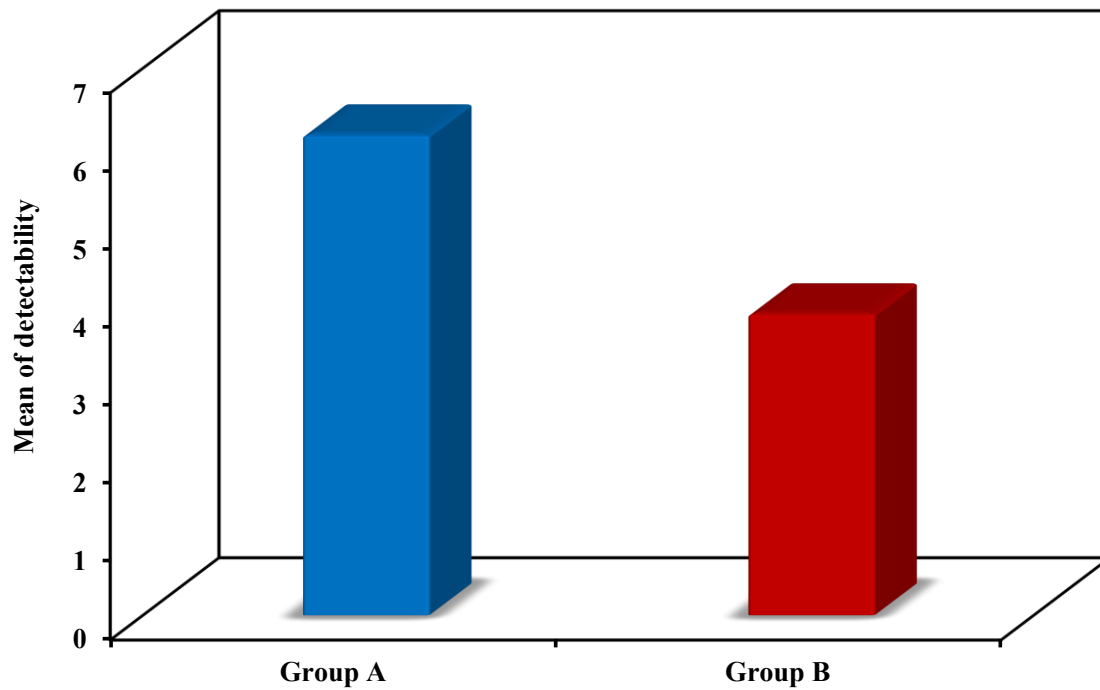


Figure (5): Comparison between the two studied groups according to degree of improvement of detectability

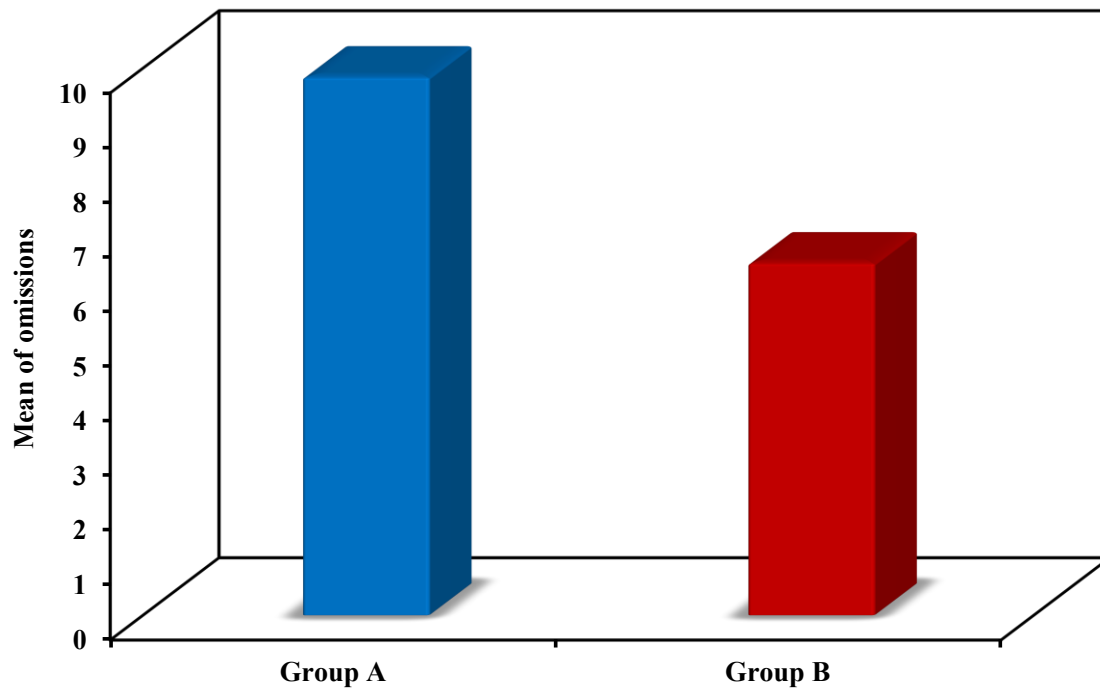


Figure (6): Comparison between the two studied groups according to degree of improvement of omissions

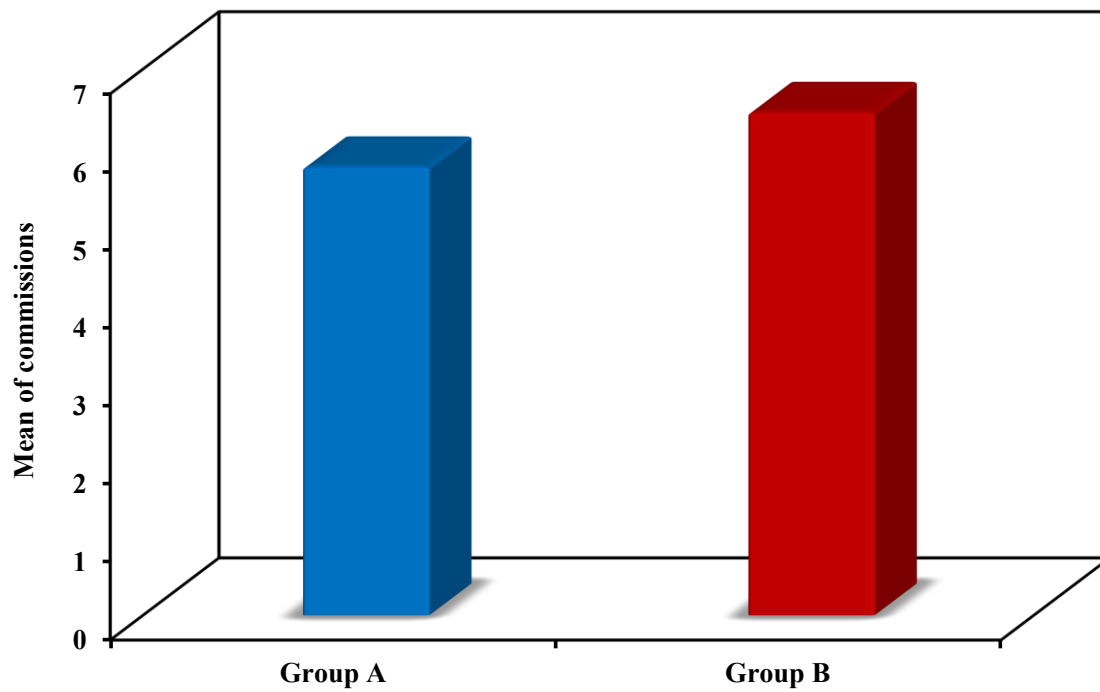


Figure (7): Comparison between the two studied groups according to degree of improvement of Commissions

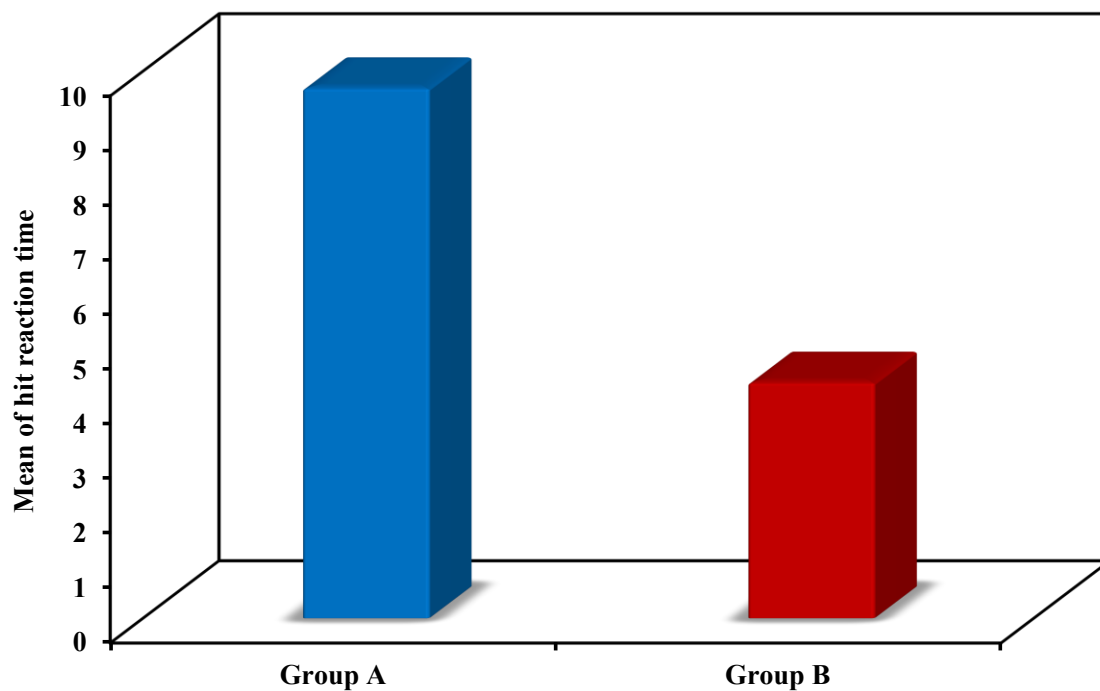


Figure (8): Comparison between the two studied groups according to degree of improvement of Hit reaction time

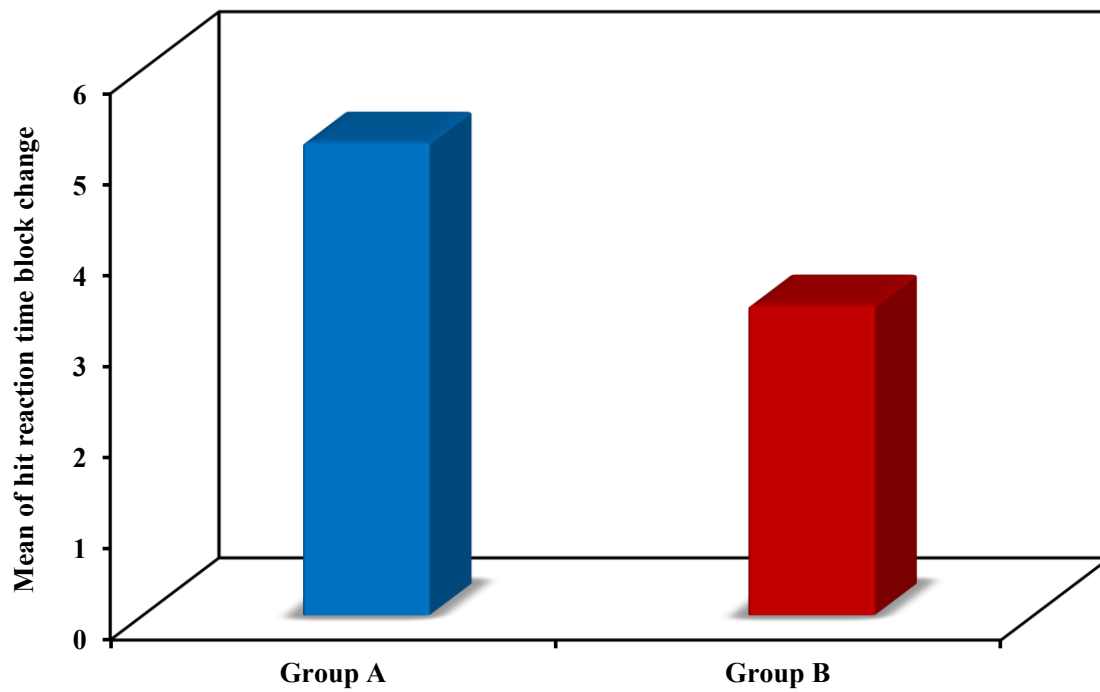


Figure (9): Comparison between the two studied groups according to degree of improvement of Hit reaction time block change

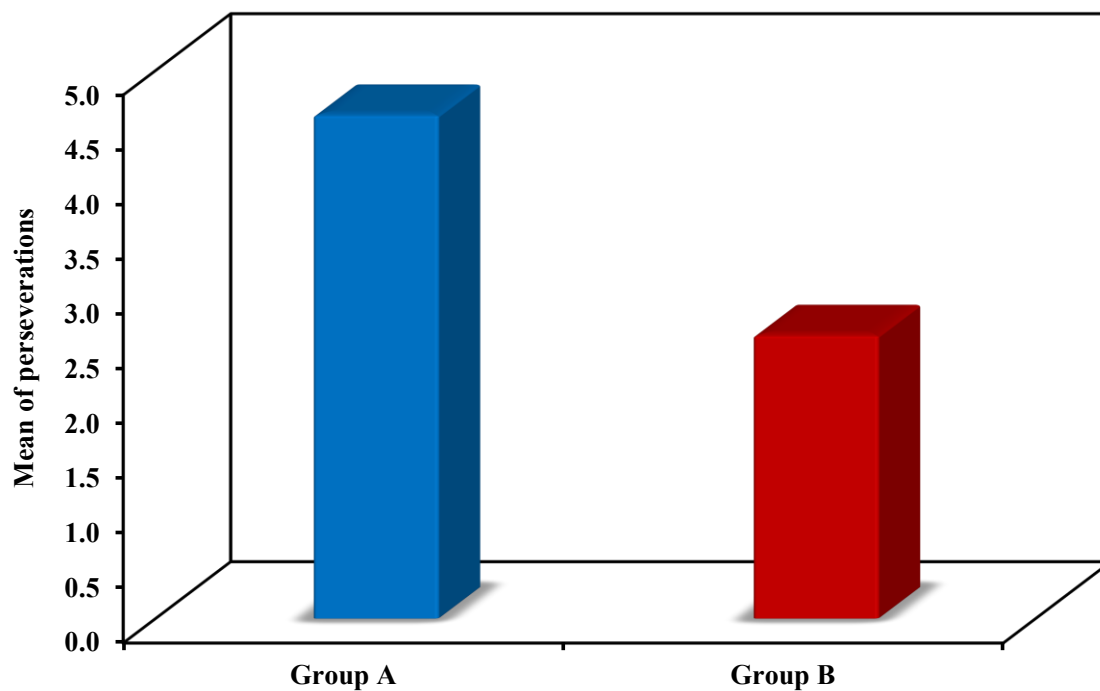


Figure (10): Comparison between the two studied groups according to degree of improvement of Perseverations

Table 37 shows a qualitative comparison between the two studied groups according to the number of children who improved in each CPT parameter, although the number of children who improved in group A is higher than the number of children who improved in group B in almost all of the parameters, the difference is not statistically significant.

Table (37): Comparison between the two studied groups according to improvement in CPT parameters (Qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		χ^2	p
	No.	%	No.	%		
Detectability						
Not Improved	4	20.0	9	40.9	2.143	0.143
Improved	16	80.0	13	59.1		
Omissions						
Not Improved	7	35.0	9	40.9	0.155	0.694
Improved	13	65.0	13	59.1		
Commissions						
Not Improved	3	15.0	4	18.2	0.076	FET p=1.000
Improved	17	85.0	18	81.8		
Hit reaction time						
Not Improved	5	25.0	10	45.5	1.909	0.167
Improved	15	75.0	12	54.5		
Hit reaction time block change						
Not Improved	7	35.0	13	59.1	2.438	0.118
Improved	13	65.0	9	40.9		
Perseverations						
Not Improved	5	25.0	10	45.5	1.909	0.167
Improved	15	75.0	12	54.5		
Overall Inattentiveness problems						
Not Improved	9	45.0	13	59.1	0.834	0.361
Improved	11	55.0	9	40.9		
Overall Sustained attention problems						
Not Improved	10	50.0	13	59.1	0.349	0.554
Improved	10	50.0	9	40.9		

χ^2 : Chi square test

FET: Fisher Exact test

p: p value for comparing between the two studied groups

Table 38 shows that both groups show statistically significant improvement in all of the parameters of Barkley deficits in executive functions scale.

Table (38): Comparison between the two groups pre and post treatment Barkley deficits in executive functions scale parameters results

	Group A (n = 20)		Group B (n = 22)		t , p ₁	t , p ₂
	Pre	Post	Pre	Post		
Self-management to time						
Min. – Max.	88.0 – 99.0	83.0 – 97.0	88.0 – 98.0	87.0 – 98.0		
Mean ± SD.	95.0 ± 2.60	92.65 ± 3.69	94.86 ± 2.51	93.73 ± 2.80	t=0.173	t=1.072
Median (IQR)	95.0 (94.0 – 96.50)	94.0 (92.0 – 95.0)	95.0 (94.0 – 96.0)	93.50 (92.0 – 96.0)	p=0.864	p=0.290
t , p	t= 4.615* , p=<0.001*		t=2.302 , p=0.032*			
Self-organize						
Min. – Max.	80.0 – 99.0	77.0 – 98.0	87.0 – 99.0	85.0 – 99.0		
Mean ± SD.	94.80 ± 4.02	92.60 ± 4.20	95.45 ± 2.84	93.55 ± 3.14	t=0.614	t=0.831
Median (IQR)	96.0 (94.0 – 97.0)	94.0 (91.50–94.50)	96.0 (95.0 – 97.0)	93.0 (93.0 – 95.0)	p=0.543	p=0.411
t , p	t=4.881* , p=<0.001*		t=3.881 , p=0.001*			
Self-restraint						
Min. – Max.	93.0 – 99.0	90.0 – 97.0	93.0 – 98.0	91.0 – 98.0		
Mean ± SD.	95.80 ± 1.61	93.95 ± 1.85	96.36 ± 1.68	94.27 ± 1.88	t=1.109	t=0.560
Median (IQR)	95.50 (95.0 – 97.0)	94.0 (93.0 – 95.0)	97.0 (95.0 – 98.0)	94.0 (93.0 – 95.0)	p=0.274	p=0.579
t , p	t=4.796* , p=<0.001*		t=5.095* , p=<0.001*			
Self-motivate						
Min. – Max.	88.0 – 98.0	88.0 – 98.0	87.0 – 99.0	83.0 – 99.0	t=0.444	t=1.260
Mean ± SD.	94.60 ± 2.09	92.25 ± 2.47	94.95 ± 2.97	93.45 ± 3.57	p=0.660	p=0.215

Median (IQR)	94.50(94.0 – 96.0)	92.0 (91.0 – 93.0)	95.0 (93.0 – 97.0)	94.0 (92.0 – 95.0)		
t , p	t=5.306*, p=<0.001*		t=3.200*, p=0.004*			
Self regulation of emotions						
Min. – Max.	90.0 – 99.0	87.0 – 99.0	92.0 – 98.0	91.0 – 98.0		
Mean ± SD.	95.55 ± 2.24	92.80 ± 2.76	95.41 ± 2.04	94.27 ± 1.98	t=0.214	t=1.998
Median (IQR)	96.0 (94.50 – 97.0)	93.0 (92.0 – 94.0)	95.50 (94.0 – 97.0)	94.0 (92.0 – 96.0)	p=0.832	p=0.052
t , p	t=5.537*, p=<0.001*		t=3.039*, p=0.006*			
Executive-functions						
Min. – Max.	94.0 – 98.0	90.0 – 97.0	95.0 – 99.0	92.0 – 98.0		
Mean ± SD.	96.55 ± 1.15	94.40 ± 1.79	96.68 ± 1.17	95.23 ± 1.82	t=0.368	t=1.482
Median (IQR)	97.0 (96.0 – 97.0)	95.0 (94.0 – 95.50)	97.0 (96.0 – 98.0)	95.0 (94.0 – 97.0)	p=0.715	p=0.146
t , p	t=5.537*, p=<0.001*		t=3.988*, p=0.001*			

IQR: **Inter quartile range**SD: **Standard deviation** t: **Student t-test** t₀: **Paired t-test**

p₀: p value for comparing between **Pre**and **Post**

p₁: p value for comparing between the two studied groups [**Pre**]

p₂: p value for comparing between the two studied groups [**Post**]

*: Statistically significant at $p \leq 0.05$

Table 39 demonstrates that group A shows more improvement in almost all of the parameters and shows statistically significant difference in the degree of improvement in self management to time and self regulation of emotions.

Table (39): Comparison between the two studied groups according to degree of improvement in Barkley deficits in executive functions scale parameters

	Group A (n = 20)	Group B (n = 22)	Test of Sig.	P
Self-management to time				
Min. – Max.	-1.0 – 7.0	-2.0 – 8.0	U=	0.043*

Mean $\pm$ SD.	2.35 $\pm$ 2.28	1.14 $\pm$ 2.32	140.50*	
Median (IQR)	3.0 (.0 – 4.0)	1.0 (-1.0 – 3.0)		
Self-organize				
Min. – Max.	-3.0 – 5.0	-2.0 – 7.0	U=	0.536
Mean $\pm$ SD.	2.20 $\pm$ 2.02	1.91 $\pm$ 2.31	196.00	
Median (IQR)	3.0 (2.0 – 3.0)	2.0 (0.0 – 3.0)		
Self-restraint				
Min. – Max.	-1.0 – 4.0	-2.0 – 5.0	U=	0.590
Mean $\pm$ SD.	1.85 $\pm$ 1.73	2.09 $\pm$ 1.93	199.00	
Median (IQR)	2.0 (0.0 – 3.0)	2.0 (0.0 – 4.0)		
Self-motivate				
Min. – Max.	-3.0 – 5.0	-3.0 – 5.0	t=	0.197
Mean $\pm$ SD.	2.35 $\pm$ 1.98	1.50 $\pm$ 2.20	1.311	
Median (IQR)	3.0 (1.50 – 4.0)	2.0 (0.0 – 3.0)		
Self regulation of emotions				
Min. – Max.	-1.0 – 7.0	-4.0 – 4.0	t=	0.012*
Mean $\pm$ SD.	2.75 $\pm$ 2.22	1.14 $\pm$ 1.75	2.625*	
Median (IQR)	3.0 (1.0 – 4.0)	1.0 (0.0 – 2.0)		
Executive-functions				
Min. – Max.	0.0 – 5.0	-1.0 – 6.0	U=	0.129
Mean $\pm$ SD.	2.15 $\pm$ 1.57	1.45 $\pm$ 1.71	161.00	
Median (IQR)	2.0 (0.50 – 3.0)	1.0 (0.0 – 2.0)		

IQR: Inter quartile range

SD: Standard deviation

t: Student t-test

U: Mann Whitney test

p: p value for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

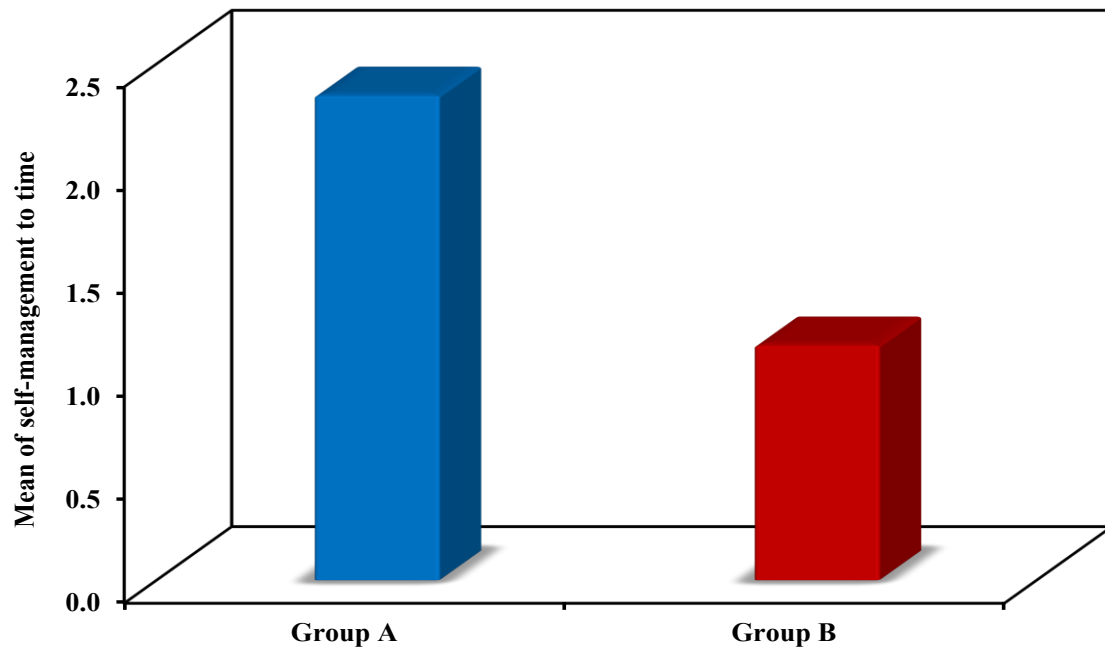


Figure (11): Comparison between the two studied groups according to degree of improvement of Self management to time

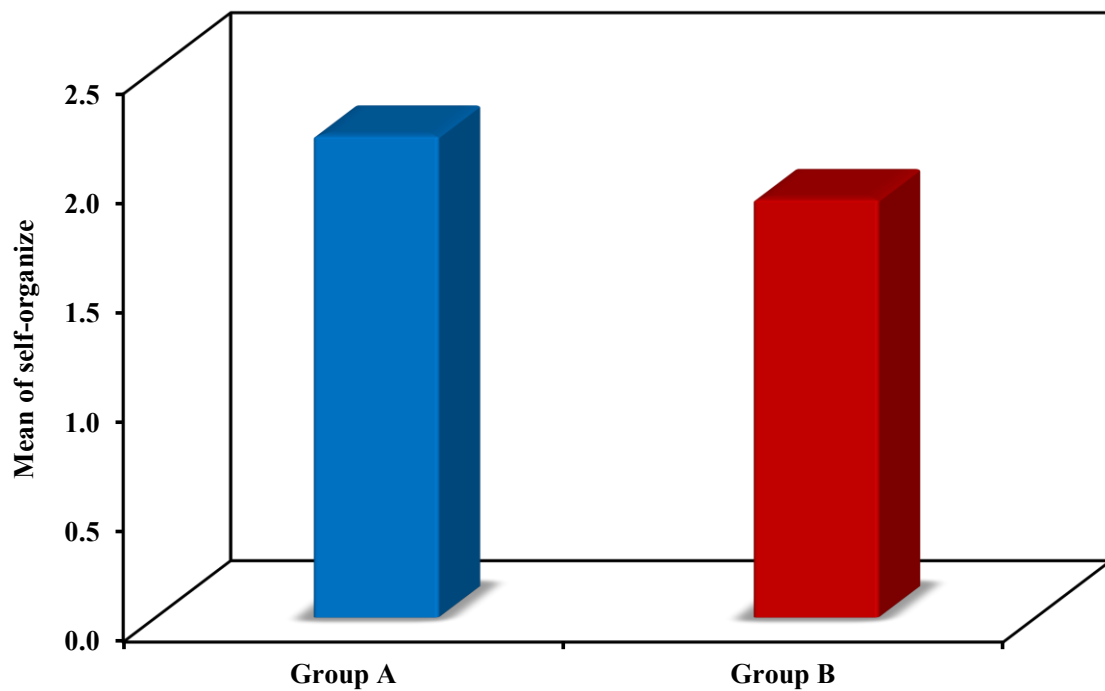


Figure (12): Comparison between the two studied groups according to degree of improvement in Self organize

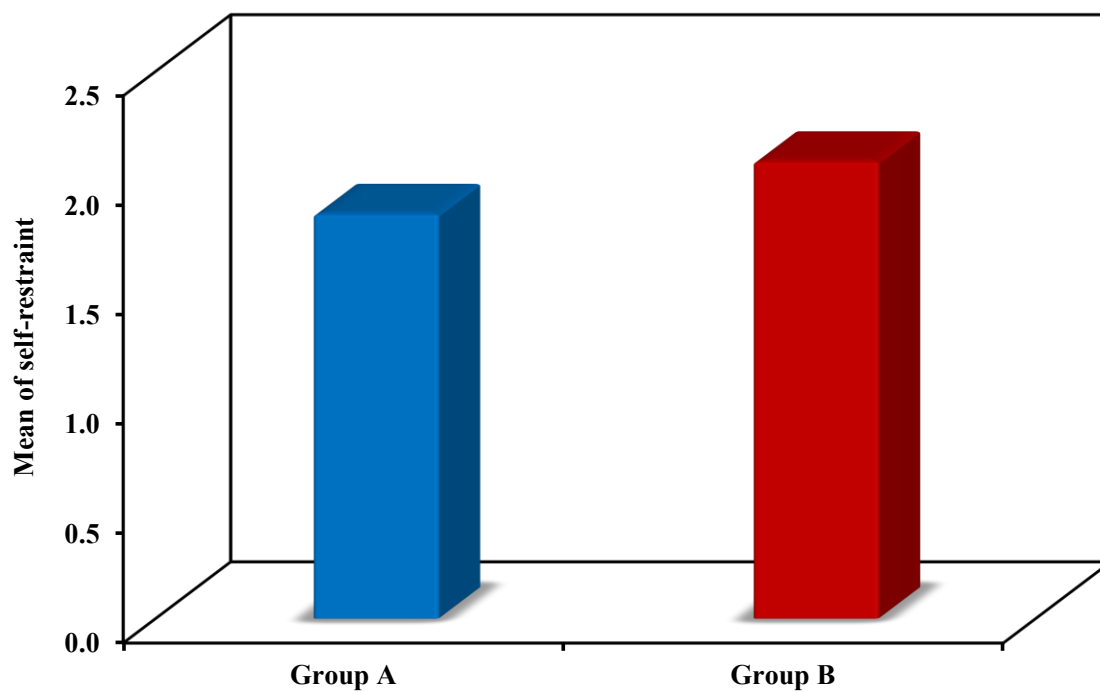


Figure (13): Comparison between the two studied groups according to degree of improvement in Self restraint

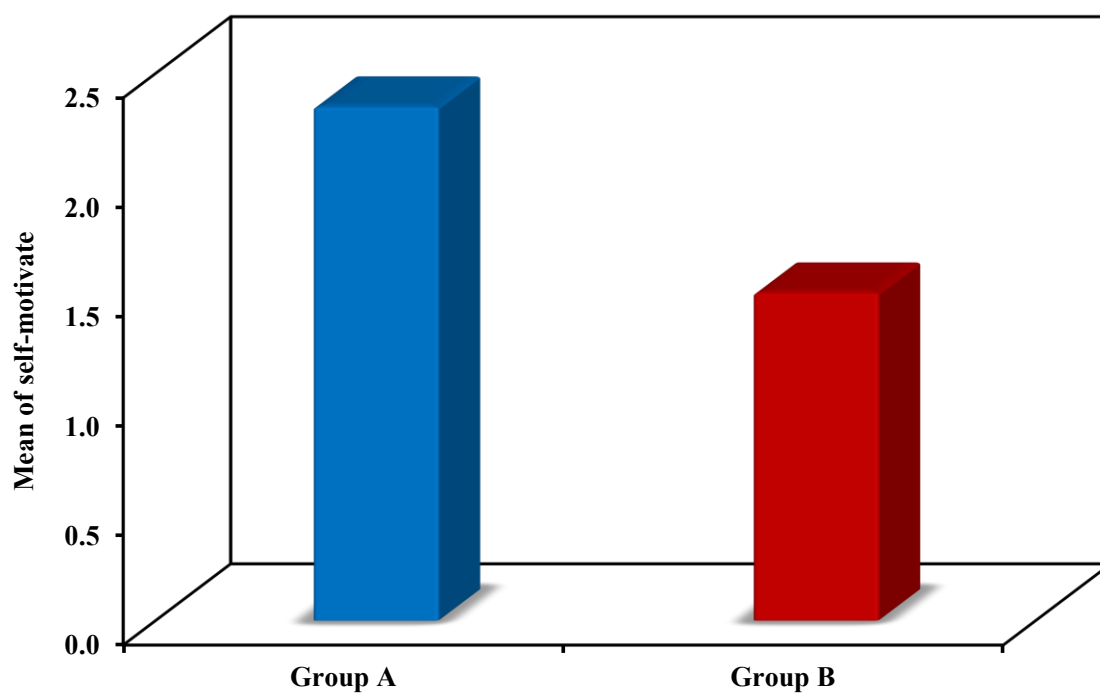


Figure (14): Comparison between the two studied groups according to degree of improvement in Self motivate

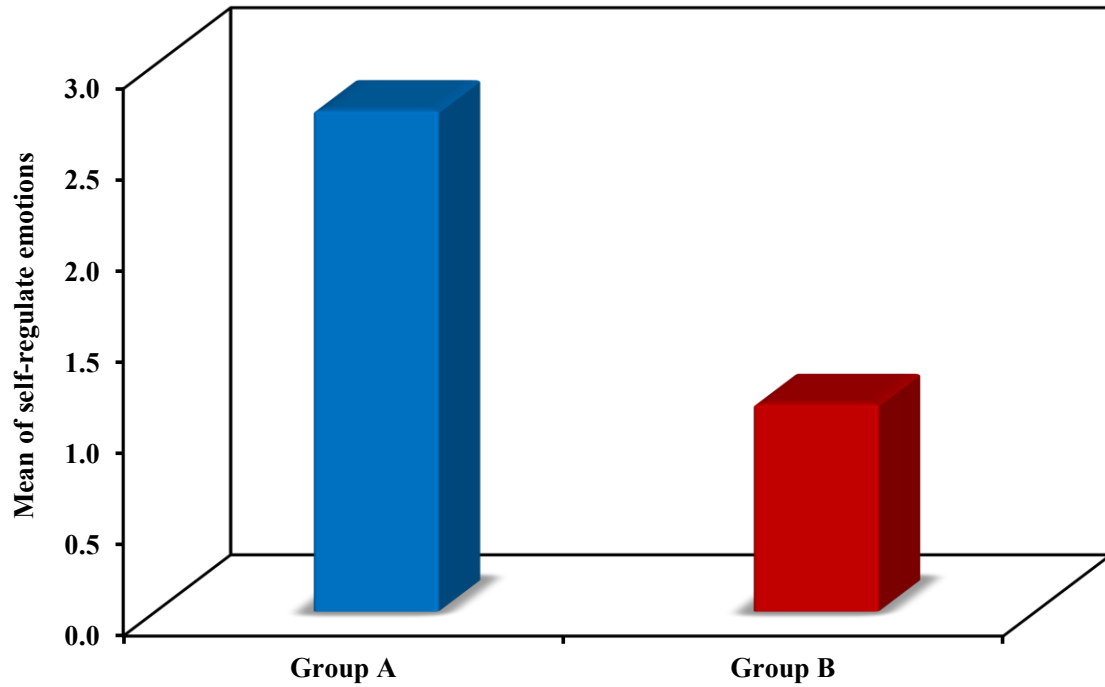


Figure (15): Comparison between the two studied groups according to degree of improvement in Self regulation of emotions

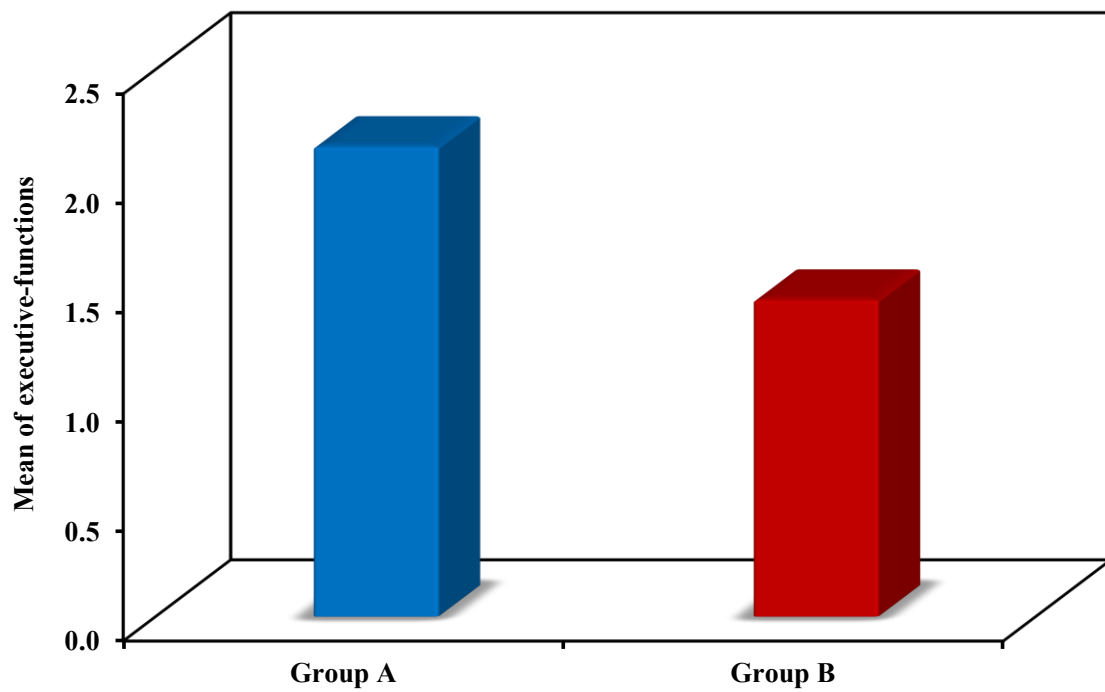


Figure (16): Comparison between the two studied groups according to degree of improvement in Executive functions summary score

Table 40 shows that group A showed a statistically significant improvement over group B in the degree of improvement in self management to time parameter.

Table (40): Comparison between the two studied groups according to number of children who improved and degree of improvement in Self management to time (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Self-management to time						
Not Improved	6	30.0	9	40.9	$\chi^2=$ 0.543	0.461
Improved	14	70.0	13	59.1		
Normal To Normal	2	14.3	1	7.7	$\chi^2=$ 6.037	^{MC} p= 0.451
Mild to Normal	4	28.6	4	30.8		
Mild to Mild	0	0.0	3	23.1		
Moderate to Normal	3	21.4	1	7.7		
Moderate To Mild	4	28.6	3	23.1		
Moderate to Moderate	0	0.0	1	7.7		
Severe To Mild	1	7.1	0	0.0		
Min. – Max.	1.0 – 7.0		1.0 – 8.0		U= 50.500*	0.048*
Mean ± SD.	3.50 ± 1.51		2.62 ± 1.80			
Median (IQR)	4.0 (2.0 – 4.0)		2.0 (2.0 – 3.0)			

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

MC: **Monte Carlotest**

p: p value for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

Table 41 shows that although group A showed more improvement than group B in self organize parameter, the difference between the two groups was not statistically significant.

Table (41): Comparison between the two studied groups according to number of children who improved and degree of improvement in Self-organize (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Self-organize						
Not Improved	4	20.0	8	36.4	$\chi^2=$ 1.375	0.241
Improved	16	80.0	14	63.6		
Normal To Normal	1	6.3	1	7.1	$\chi^2=$ 4.918	^{MC} p= 0.505
Mild to Normal	5	31.3	2	14.3		
Moderate to Normal	1	6.3	0	0.0		
Moderate To Mild	8	50.0	9	64.3		
Moderate to Moderate	0	0.0	2	14.3		
Severe To Mild	1	6.3	0	0.0		
Min. – Max.	2.0 – 5.0		1.0 – 5.0		U= 67.000	0.064
Mean ± SD.	3.06 ± 0.85		2.43 ± 1.28			
Median (IQR)	3.0(2.50 –3.50)		2.0 (2.0 – 3.0)			

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

MC: **Monte Carlotest**

p: p value for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

Table 42 shows that there was no statistically significant difference between the two groups in the degree of improvement in self-restraint parameter.

Table (42): Comparison between the two studied groups according to number of children who improved and degree of improvement in Self-restraint (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Self-restraint						
Not Improved	6	30.0	6	27.3	$\chi^2=$ 0.038	0.845
Improved	14	70.0	16	72.7		
Mild to Normal	4	28.6	3	18.8	$\chi^2=$ 3.842	^{MC} p= 0.808
Mild to Mild	1	7.1	3	18.8		
Moderate to Normal	0	0.0	1	6.3		
Moderate To Mild	8	57.1	8	50.0		
Moderate to Moderate	0	0.0	1	6.3		
Severe to Moderate	1	7.1	0	0.0		
Min. – Max.	2.0 – 4.0		1.0 – 5.0		U= 84.000	0.257
Mean ± SD.	2.86 ± 0.77		2.50 ± 1.03			
Median (IQR)	3.0 (2.0 – 3.0)		2.0 (2.0 – 3.0)			

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

MC: **Monte Carlotest**

p: p value for comparing between the two studied groups

Table 43 shows that although group A showed more improvement than group B in self-motivate parameter, the difference between the two groups was not statistically significant.

Table (43): Comparison between the two studied groups according to according to number of children who improved and degree of improvement in Self motivate (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Self-motivate						
Not Improved	4	20.0	8	36.4	$\chi^2=$ 1.375	0.241
Improved	16	80.0	14	63.6		
Normal To Normal	0	0.0	1	7.1	$\chi^2=$ 9.317	^{MC} p= 0.054
Mild to Normal	8	50.0	4	28.6		
Mild to Mild	1	6.3	5	35.7		
Moderate to Normal	4	25.0	0	0.0		
Moderate To Mild	3	18.8	3	21.4		
Severe To Mild	0	0.0	1	7.1		
Min. – Max.	1.0 – 5.0		1.0 – 5.0		U= 72.000	0.101
Mean ± SD.	3.13 ± 1.15		2.43 ± 1.28			
Median (IQR)	3.0 (2.0 – 4.0)		2.0 (2.0 – 3.0)			

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

MC: **Monte Carlotest**

p: p value for comparing between the two studied groups

Table 44 demonstrates that group A showed a statistically significant improvement over group B in the degree of improvement of self regulation of emotions parameter.

Table (44): Comparison between the two studied groups according to number of children who improved and degree of improvement in Self regulation of emotions (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Self regulation of emotions						
Not Improved	5	25.0	7	31.8	$\chi^2=$ 0.239	0.625
Improved	15	75.0	15	68.2		
Normal To Normal	1	6.7	0	0.0	$\chi^2=$ 13.725*	^{MC} p= 0.007*
Mild to Normal	3	20.0	5	33.3		
Mild to Mild	1	6.7	0	0.0		
Moderate to Normal	1	6.7	0	0.0		
Moderate To Mild	8	53.3	3	20.0		
Moderate to Moderate	0	0.0	7	46.7		
Severe to Moderate	1	6.7	0	0.0		
Min. – Max.	2.0 – 5.0		1.0 – 4.0		U= 84.000	0.250
Mean ± SD.	2.73 ± 1.10		2.27 ± 1.03			
Median (IQR)	2.0 (2.0 – 3.0)		2.0 (2.0 – 2.50)			

IQR: Inter quartile range

SD: Standard deviation

U: Mann Whitney test

χ^2 : Chi square test

MC: Monte Carlo test

p: p value for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

Table 45 shows that although group A showed more improvement than group B in executive functions summary score parameter, the difference between the two groups was not statistically significant.

Table (45): Comparison between the two studied groups according to number of children who improved and degree of improvement in Executive functions summary score (qualitative comparison)

	Group A (n = 20)		Group B (n = 22)		Test of Sig.	p
	No.	%	No.	%		
Executive functions summary score						
Not Improved	5	25.0	8	36.4	$\chi^2=$ 0.633	0.426
Improved	15	75.0	14	63.6		
Mild to Normal	1	6.7	1	7.1	$\chi^2=$ 2.812	^{MC} p= 0.927
Mild to Mild	0	0.0	1	7.1		
Moderate to Normal	3	20.0	2	14.3		
Moderate To Mild	10	66.7	8	57.1		
Moderate to Moderate	1	6.7	1	7.1		
Severe to Moderate	0	0.0	1	7.1		
Min. – Max.	1.0 – 5.0		1.0 – 6.0		U= 73.500	0.172
Mean ± SD.	2.87 ± 1.06		2.36 ± 1.50			
Median (IQR)	3.0 (2.0 – 3.50)		2.00 (1.0 – 3.0)			

IQR: **Inter quartile range**

SD: **Standard deviation**

U: **Mann Whitney test**

χ^2 : **Chi square test**

MC: **Monte Carlotest**

p: p value for comparing between the two studied groups

5) Post intervention regression analysis

Table 46 shows a linear regression analysis for the parameters affecting Self management to time in total sample, this revealed that none of the parameters was a predictor for the severity of self management to time scores.

Table (46): Univariate linear regression analysis for the parameters affecting Self management to time in total sample (n=42)

	Univariate	
	p	B (LL – UL 95%C.I)
Groups		
Group A	0.095	1.214 (-0.221 – 2.648)
Group B [®]		0.000
Sex [Male]	0.590	0.485 (-1.317 – 2.287)
Age (years)	0.098	0.844 (-0.162 – 1.850)
Family history [Positive consanguinity]	0.488	0.686 (-1.294 – 2.665)
Residency [Urban]	0.634	0.413 (-1.325 – 2.150)
Informant		
Mother	0.514	1.583 (-3.281 – 6.448)
Father	0.306	2.750 (-2.615 – 8.115)
Sister	0.240	4.000 (-2.786 – 10.786)
Grandma		0.000
IQ	0.575	0.073 (-0.189 – 0.336)

B: Unstandardized Coefficients

C.I: Confidence interval

LL: Lower limit

UL: Upper Limit

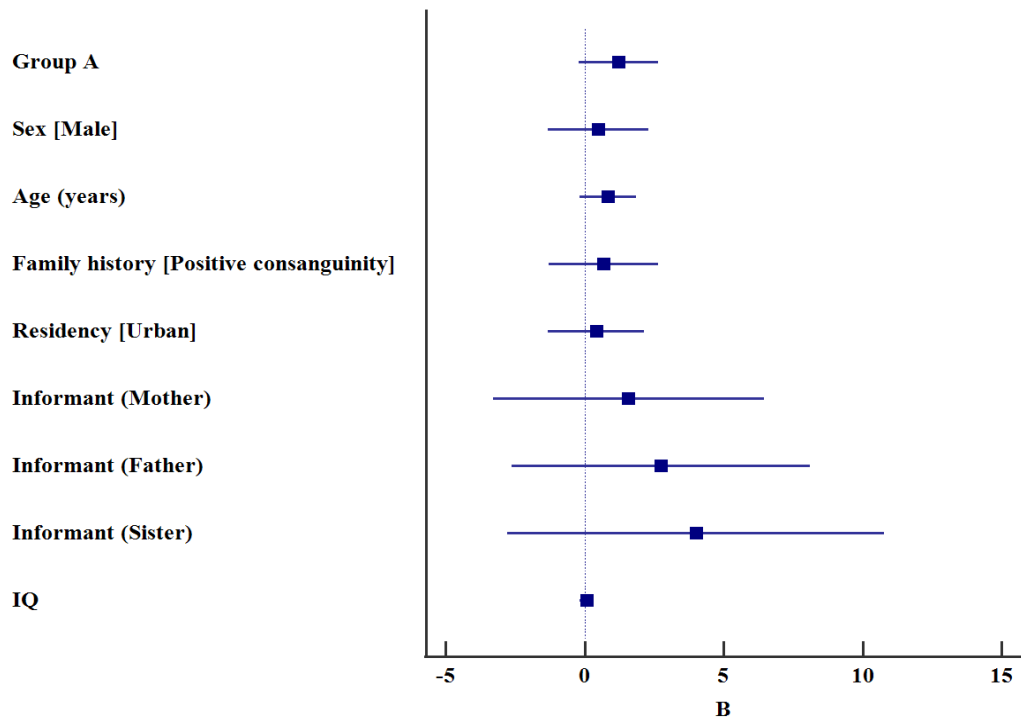


Figure (17): Univariate linear regression analysis for the parameters affecting Self-management to time in total sample (n=42)

Table 47 shows a linear regression analysis for the parameters affecting self regulation of emotions in total sample, this revealed that none of the parameters was a predictor for the severity of self regulation of emotions scores.

Table (47): Univariate linear regression analysis for the parameters affecting Self regulation of emotions in total sample (n=42)

	Univariate	
	p	B (LL – UL 95%C.I)
Groups		
Group A	0.226	-0.733 (-1.933 – 0.466)
Group B [®]	0.000	
Sex [Male]	0.561	0.375 (-0.910 – 1.660)
Age (years)	0.705	-0.162 (-1.018 – 0.693)
Family history [Positive consanguinity]	0.404	0.514 (-0.711 – 1.739)
Residency [Urban]	0.817	0.150 (-1.138 – 1.438)
Informant		
Mother	0.253	-2.740 (-7.497 – 2.017)
Father	0.234	-3.000 (-7.996 – 1.996)
Sister	0.765	-1.000 (-7.661 – 5.661)
Grandma	0.000	
IQ	0.862	-0.019 (-0.242 – 0.203)

B: Unstandardized Coefficients

C.I: Confidence interval

LL: Lower limit

UL: Upper Limit

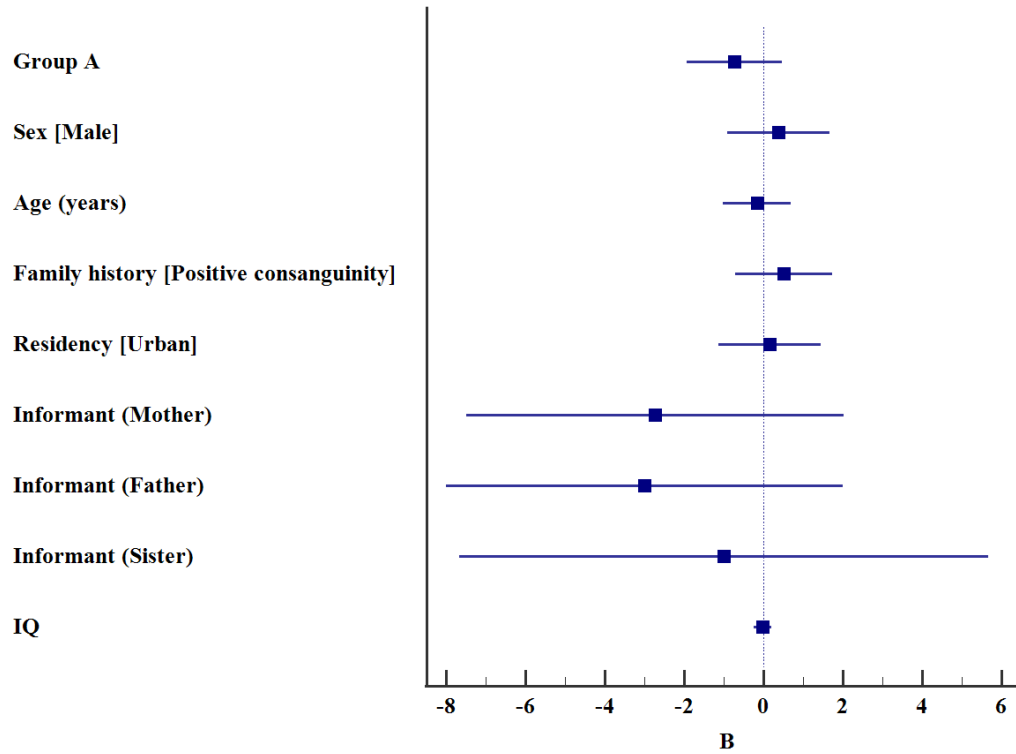


Figure (18): Univariate linear regression analysis for the parameters affecting Self regulation of emotions in total sample (n=42)

Table 48 shows a linear regression analysis for the parameters affecting self management to time in total sample, this revealed that female sex was a predictor for improvement in self management to time in group A (active group).

Table (48): Univariate linear regression analysis for the parameters affecting change in Self-management to time in group A (n = 20)

	Univariate	
	p	B (LL – UL 95%C.I)
Sex [Female]	0.012*	4.056 (0.991 – 7.120)
Age (years)	0.101	0.967 (-0.209 – 2.142)
Family history [Positive consanguinity]	0.605	0.765 (-2.290 – 3.820)
Residency [Urban]	0.989	-0.020 (-3.098 – 3.059)
Informant		
Mother	0.467	-1.813 (-6.956 – 3.331)
Father	0.632	-1.333 (-7.096 – 4.429)
Sister		0.000
IQ	0.947	0.013 (-0.388 – 0.414)

B: Unstandardized Coefficients

C.I: Confidence interval

LL: Lower limit

UL: Upper Limit

*: Statistically significant at $p \leq 0.05$

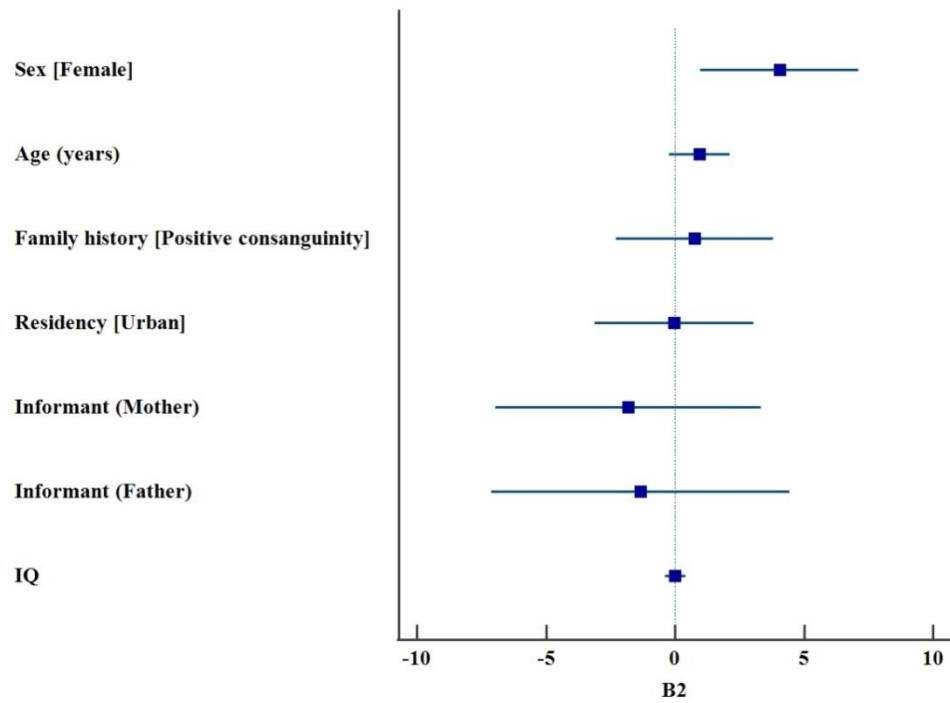


Figure (19): Univariate linear regression analysis for the parameters affecting change of Self-management to time in group A (n = 20)

Table 49 shows a linear regression analysis for the parameters affecting self regulation of emotions in total sample, this revealed that female sex was a predictor for improvement in self regulation of emotions in group A (active group).

Table (49): Univariate linear regression analysis for the parameters affecting change in Self regulation of emotions in group A (n = 20)

	Univariate	
	p	B (LL – UL 95%C.I)
Sex [Female]	0.002*	4.722 (2.020 – 7.425)
Age (years)	0.337	0.567 (-0.639 – 1.772)
Family history [Positive consanguinity]	0.374	-1.275 (-4.210 – 1.661)
Residency [Urban]	0.839	0.294 (-2.705 – 3.293)
Informant		
Mother	0.608	-1.250 (-6.300 – 3.800)
Father	0.542	-1.667 (-7.324 – 3.990)
Sister		0.000
IQ	0.979	0.005 (-0.386 – 0.396)

B: Unstandardized Coefficients

C.I: Confidence interval

LL: Lower limit

UL: Upper Limit

*: Statistically significant at $p \leq 0.05$

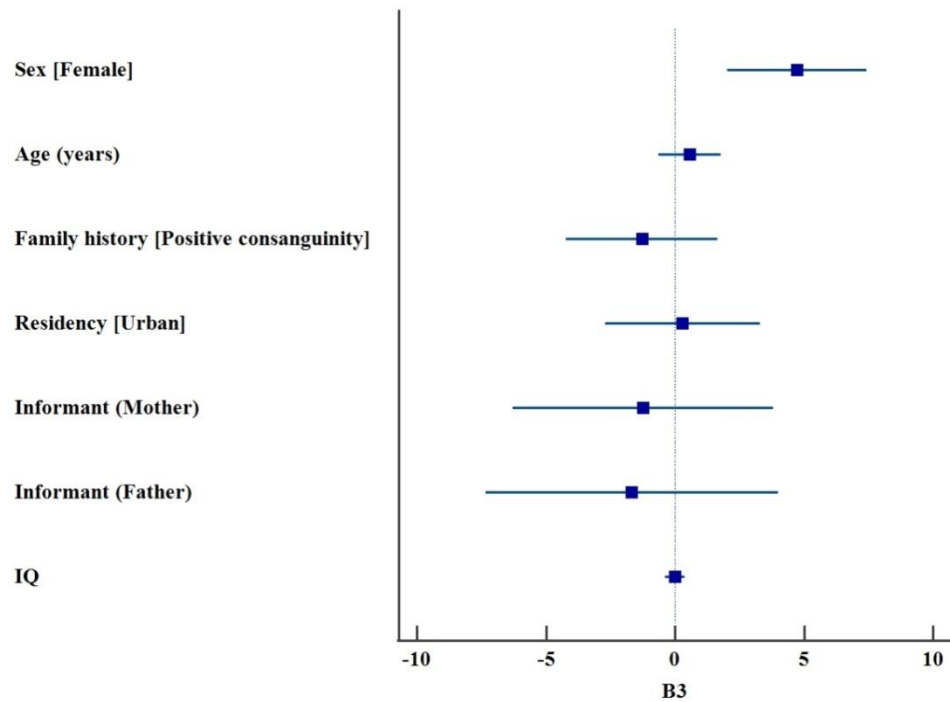


Figure (20): Univariate linear regression analysis for the parameters affecting change in Self regulation of emotions in group A (n = 20)

DISCUSSION

ADHD is one of the most common neurodevelopmental disorders, its symptoms begin since childhood with inattention (inability to stay focused and being easily distracted), hyperactivity (excessive movement inappropriate to the context) and impulsivity (hasty actions that occur in the moment without forethought following a desire immediate rewards or an inability to delay gratification). ADHD affects mainly boys with prevalence of 8.4% of children and 2.5% of adults. It may also affect their academic achievement, causes problems in socializing with the surroundings and in the relation between the parents and their children.⁽¹⁷⁾

Children with ADHD often spend significant amounts of time playing video games. Research indicates that children suffering from ADHD are more likely to engage in excessive gaming compared to their peers.⁽¹⁸⁾

Digital therapeutic video games have emerged as a groundbreaking intervention for treating ADHD. These games offer a novel solution by providing an engaging platform that can enhance treatment adherence and efficacy while also being enjoyable for children and adolescents.⁽¹³⁾

In the current study, the efficacy of one of these new video games is being tested by Comparing between the efficacy of medications in addition to behavioral and parenting training combined with this digital therapeutic video game (Lumosity games) and the efficacy of medications in addition to behavioral and parenting training only in treating ADHD in a sample of 60 children and adolescents diagnosed with ADHD taken from the child and adolescent psychiatry clinic in ElHadra university hospital.

The children were recruited according to their order of presentation to the clinic and divided into 2 random groups (even numbers were assigned to group A and odd numbers were assigned to group B).

All the participants in both groups were assessed with Stanford Binet IQ test 4th edition Arabic version, Conners parents rating scale Arabic version and General Health Questionnaire Arabic version (GHQ-28) before treatment.

All the participants in both groups were assessed with Conners' continuous performance test 3rd edition (CPT 3) and Barkley Deficits in Executive Functioning Scale (BDEFS-CA) before treatment and at the end of treatment after 12 week.

Demographic characteristics of the study sample

As regard gender prevalence, forty children (66.7%) were boys and twenty children (33.3%) were girls as ADHD is more frequently diagnosed in males than females as proven by many studies like Danielson et al. (2024), this large-scale survey of U.S. children found that males (12.1%) were more likely than females (7.3%) to have ever received an ADHD diagnosis.⁽¹⁹⁾

Similarly, a study by Young et al. (2020) showed that females with ADHD are consistently under-identified and under-diagnosed. It details how their symptoms (e.g., internalizing problems, inattention) are less likely to prompt referral, leading to the male-skewed diagnostic statistics.⁽²⁰⁾

We recruited children and adolescents from 13 to 18 years old as the minimum age of approval for the game is 13 years old, 41.7% of children had positive family history of ADHD showing that ADHD runs in families. Research provides robust evidence that ADHD has a strong familial component. The largest

and most recent GWAS (Genome-wide analyses) meta-analysis of ADHD by Demontis et al. (2023) identified 27 independent genome-wide significant risk loci, confirming its highly polygenic nature. It showed that ADHD genetic risk is correlated across generations (parent-offspring) and that a polygenic risk score (PRS) based on these variants can predict ADHD diagnosis in independent samples.⁽²¹⁾

Similarly, a study by Uchida et al. (2023) evaluated children at risk for ADHD by virtue of having parents with ADHD and compared them with children of parents without ADHD and found that children of parents with ADHD are at a high risk for ADHD and its related psychiatric, cognitive, and educational impairments.⁽²²⁾

Children's mean IQ was 89.98 ± 2.75 and the main informant was the mother as 83.3% of all informants were the children's mothers, this shows that mothers are the main caregiver carrying the responsibility for managing their children's mental healthcare, this may be due to cultural reasons and due to fathers being always busy with their work. This was also proven in a study by ElMoaty et al. (2024), this study was to assess caregiving burden among caregivers of children with ADHD in Alexandria, Egypt and found that the main caregivers carrying the responsibility of the children were the mothers.⁽²³⁾

Most caregivers (71.7%) were highly educated (university education), this shows that the more educated the parents, the more they will seek outpatient psychiatric care for their children. This may be because educated caregivers are better at recognizing symptoms, navigating referral pathways, and persisting in seeking specialist care. A study by Mashayekhi et al. (2024) found that higher parental mental health literacy was associated with a greater probability of having a child

diagnosed with ADHD and using evidence based services. Parents with better knowledge of mental health disorders and treatments were more proactive in navigating the healthcare system.⁽²⁴⁾

Assessment of children pretreatment

All children were screened using the general health questionnaire (GHQ-28) and they underwent full psychiatric assessment, mental state and neurological examination to ensure the absence of any psychiatric comorbidities, all children with comorbid psychiatric illness were excluded from this study.

Conners parents rating scale was done and showed that most children suffered from combined ADHD (75%) as this type is the most common type among children, it was followed by the mainly inattentive type (15%) then the mainly hyperactive type (10%), this was proven by Danielson et al. (2018) in a U.S. population-based study, among children aged 2-17 with a current ADHD diagnosis combined type was the most common type (62.0%) followed by predominantly Inattentive Presentation (28.6%).⁽²⁵⁾

Baseline comparison between the two groups pretreatment according to CPT, Barkley deficits in executive functions scale and conners parent rating scale revealed no statistically significant difference between the two groups.

It was noted that during pretreatment assessment of children with CPT, most children did not show any overall impulsivity problems, this may be due to our study age group (13 to 18 years old) as the hyperactivity and impulsivity symptoms of ADHD decrease as children enter adolescence.

Similarly, a study by Sasser et al.(2016) found that hyperactivity and impulsivity symptoms show more decline with age than symptoms of inattention in ADHD.⁽²⁶⁾

Relation between demographic data and the pretreatment results of both CPT and barkley deficits in executive functions scale

There was no significant relation between the results of conners continuous performance test 3rd edition parameters and all the demographic data

This proves that these results are a robust clinical feature of ADHD, relatively independent of demographic backgrounds.

This was shown by a study examining the Conners Continuous Performance Test 3rd Edition (CPT-3) in relation to demographic variables in an ADHD population, this study found no significant correlations between key CPT-3 performance metrics and factors such as age, gender, or parental education level. The research, conducted by Conners et al. (2014) as part of the CPT-3's technical manual and subsequent validation, indicated that while the test is highly sensitive to the attentional deficits characteristic of ADHD, its scores are not systematically influenced by these demographic characteristics within the clinical age range for which it is normed.⁽²⁷⁾

Additionally, a systematic review and analysis by Hall et al. (2016) investigated the clinical utility of objective tests like the CPT-3 for ADHD. In their examination, the researchers performed analyses showing that specific CPT-3 scores remained strong and independent predictors of an ADHD diagnosis even after statistically controlling for the demographic variables of age, sex, and estimated IQ. This indicates that the relationship between CPT-3 performance and ADHD is not a confounding effect of these demographic differences; the test measures variance specifically related to the disorder.⁽²⁸⁾

In contrast to our study, a systemic review by Callan et al. (2024) revealed that CPT-3 as a single tool of assessment is a weak or poor predictor of ADHD and recommended using multiple measures for evaluating people with ADHD.⁽²⁹⁾

There was also no significant relation between the results of Barkley deficits in executive functions scale parameters and all the demographic data.

This also shows that these results are a robust clinical feature of ADHD, relatively independent of demographic backgrounds.

A study by Barkley (2011) in the scale's validation research, specifically examined this relationship. The analysis found that BDEFS scores showed no significant correlation with key demographic factors such as age, gender, education level, or socioeconomic status within the ADHD group. The manual states that after entering ADHD status into the regression model first, which accounted for 25-41% of the variance in scores, the subsequent block of demographic variables (age, sex, education, income) failed to add a statistically significant increment to the prediction of BDEFS total scores and most subscale scores.⁽³⁰⁾

Moreover, a study by Hamza et al (2023) on the Arabic version of the scale for children and adolescents used in this study found that the reliability of the scale domains was evident showing high internal consistency (Cronbach's alpha from 0.93 to 0.97 scores over the five domains). These values were close to the original English version which is 0.95 to 0.97.⁽³¹⁾

Analysis of dropouts

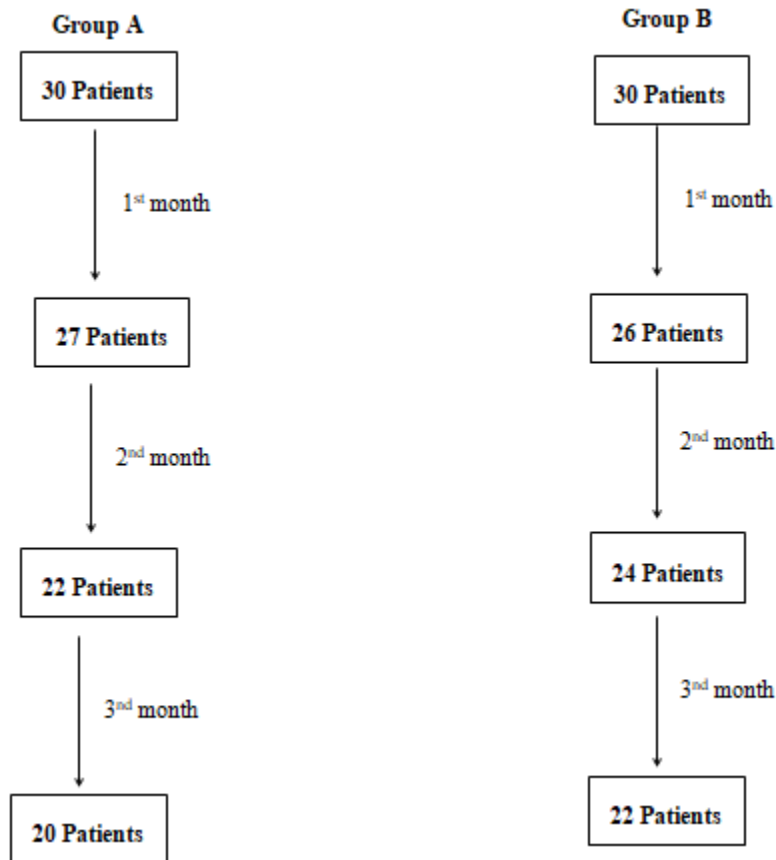


Figure (21): Dropouts during the study

During the 12 weeks period of the study, there was a dropout rate of 10 patients in group A and 8 patients in group B.

Some of the reasons of this dropout were adolescent rebellion and refusal of treatment (minimum children age of this study was 13 years old), absence of an arabic based game, economic burden of transport especially for those living in rural areas, absence of available networks to play the game in some areas and long duration of the study (12 weeks).

The remaining group (42 children) and dropout group (18 children) were compared according to demographic data and there was a statistically significant relation ($p=0.017$) between dropouts and the place of residence as children from rural areas made up 33.3% of the total sample and 55.6% of the dropouts.

This shows that the farther the distance between the place of residence and the hospital where the study is being conducted (which is in an urban area), the more the rate of dropouts.

This was demonstrated in a study by Pellerin et al. (2010), this study identified travel distance as one of several significant environmental and structural factors (alongside caregiver stress and perceived treatment relevance) associated with non-completion of treatment. Families living farther away were more likely to drop out.⁽³²⁾

There was also a trend towards significance ($p=0.053$) when we compared the 2 groups according to informant education, this shows that the less educated the caregiver, the more likely it is for the child to dropout, this may be due to communication barriers and lower mental health literacy.

Similarly, a meta-analysis of 65 studies by De Haan et al. (2013) identified lower parental education as one of the most consistent demographic predictors of treatment attrition. The analysis synthesized evidence showing that families where the primary caregiver had less formal education were significantly more likely to discontinue treatment prematurely.⁽³³⁾

Comparison between the two groups pre and post treatment

- **Comparison between the two groups according to CPT parameters**

When each group's pre and post treatment CPT parameters results were compared, there was a significant improvement in almost all of the parameters in both groups (except perseverations which showed significant difference only in group A)

This proves that non stimulants (Atomoxetine) in addition to behavioral and parenting modification are effective in improving ADHD symptoms

Several studies used Conners continuous performance test as an assessment tool and proved the efficacy of atomoxetine and behavioral and parenting modification in improving the symptoms of ADHD.

One randomized, double-blind, placebo-controlled trial by Michelson et al. (2002) established the efficacy of atomoxetine in children and adolescents suffering from ADHD. The Conners' CPT was used as a primary objective measure of attention and impulse control. The study found that atomoxetine treatment resulted in statistically significant improvements on CPT scores compared to placebo.⁽³⁴⁾

Another study by Handenet al.(2015) tested both medication management primarily with atomoxetine and behavioral parent training in the treatment of ADHD. Children in this study showed great improvement.⁽³⁵⁾

There was a statistically significant improvement in perseverations only in group A, this improvement shows that digital therapeutic video games (Lumosity games) may be effective in improving ADHD symptoms.

When both groups were compared according to degree of improvement in different CPT parameters, it was noted that Group A showed more degree improvement in almost all of the parameters (except commission errors) including overall

inattention and sustained attention problems, however, this improvement was not statistically significant.

We could not compare the two groups according to overall impulsivity problems, as most children had no overall impulsivity problems according to CPT parameters in the pretreatment assessment

The absence of a difference in the improvement in commission errors may be because we needed to follow up on commission errors after a longer period of time to see the improvement (more than 3 months), it may also be because commission errors are a sign of impulsivity problems and most of the study sample did not show any overall impulsivity problems to begin with.

This suggests that digital therapeutic video games may have a role in improving ADHD symptoms.

The difference between the degree of improvement between group A and group B being not statistically significant even though group A showed more improvement in almost all of the parameters may be because treatment with atomoxetine alone shows an improvement in 50-60% of children as proved by Michelson et al. (2002), the addition of behavioral and parenting modification may increase the improvement rate to 60-70%, this may be the reason why the difference in the degree of improvement between group A and group B is not be statistically significant.⁽³⁴⁾

A randomized controlled trial by Kollins et al. (2020) on children aged 8-12 diagnosed with ADHD using EndeavorRx compared an active group using EndeavorRx to a control group using a word or a puzzle game (neither group received medications), the group using EndeavorRx showed a statistically significant improvement in attention compared to the control group.⁽³⁶⁾

Another study by Klingberg et al. (2005) used adaptive computerized working memory training in the treatment of children diagnosed with ADHD, this study compared an active group using the treatment computer program against a control group using a comparison program (neither group received medications), it showed that adaptive computerized working memory training could lead to generalized cognitive improvements and reduce ADHD symptoms, particularly inattention.⁽³⁷⁾

Again, a study by Kim et al. (2022) compared children receiving conventional drug treatment in addition to a similar game (NeuroWorldDTx digital therapy) with children receiving conventional drug therapy alone and found that when the game and the standard treatment were combined, a marked decrease in the CGI-S severity evaluation was observed, thereby suggesting the effectiveness of NeuroWorldDTx. NeuroWorldDTx was found to be effective as a digital therapy adjuvant therapy along with drug treatment.⁽³⁸⁾

Furthermore, a meta analysis of the efficacy of digital therapies in children with ADHD published in Frontiers in Psychiatry showed that digital interventions improved the symptoms of inattention with an effect value of -0.20 (95% confidence interval [CI] -0.36, -0.04) and decreased the continuous performance task (CPT) reaction time (effect, -0.40, 95% CI -0.73, -0.07) in ADHD patients.⁽³⁹⁾

However, some studies like Westwood et al. (2023) found no consistent evidence that computerized cognitive training (including video game formats) leads to meaningful, lasting improvements in daily functioning, academic achievement, or ADHD symptoms as rated by teachers or independent evaluators making the effect of therapeutic video games controversial.⁽⁴⁰⁾

- **Comparison between the two groups according to Barkley deficits in executive functions scale parameters**

When each group's pre and post treatment Barkley deficits in executive functions scale parameters results were compared, there was a significant improvement in all of the parameters in both groups.

This proves that non stimulants (Atomoxetine) in addition to behavioral and parenting modification are effective in improving executive functions in children diagnosed with ADHD.

A study by Adler et al. (2020) examined the relationship between maintenance of improved executive functioning in ADHD with long-term symptom improvement with atomoxetine and found that treatment with atomoxetine improved executive functions during the treatment phases and this improvement was sustained up to 6 months after stoppage of atomoxetine.⁽⁴¹⁾

A meta-analysis by Fabiano et al. (2009) found that behavioral and parental modification therapies have shown effectiveness in enhancing executive function. These behavioral interventions led to improved organization, task initiation, and working memory in children with ADHD.⁽⁴²⁾

When both groups were compared according to the degree of improvement in different Barkley deficits in executive functions scale parameters, it was noted that Group A showed more degree improvement in almost all of the parameters except self restraint, this may be due to self restraint being related to impulsivity and most of the study group did not show overall impulsivity problems when assessed with CPT to start with.

There was a statistically significant difference in the degree of improvement of two parameters which are self management to time and self regulation of emotions

($p=0.043$ and 0.012 respectively), this statistically significant difference was found when we compared the 2 groups quantitatively and qualitatively .

This shows that digital therapeutic video games (Lumosity game) have a role in improving executive functions

Improvement in self management to time may be because therapeutic video games typically present clear goals and deadlines, which can help users practice planning and prioritizing tasks within a timed framework and improvement in self regulation of emotions may be because these games allow players to experience various emotional scenarios in a low-risk environment, promoting practice in regulating emotional responses without real-world consequences and they typically provide immediate feedback on emotional reactions and decisions, helping players understand the consequences of their emotional responses.

This was shown in a Systematic Literature Review by Lin et al (2025). This review gathered evidence from 35 studies on serious games as Digital therapeutics in children with ADHD. The results indicated that the potential of serious games as a digital therapeutic modality for children with ADHD offers benefits in attention, hyperactivity-impulsivity symptoms, social skills, and executive functions.⁽⁴³⁾

Moreover, the previously mentioned meta-analysis of the efficacy of digital therapies in children diagnosed with ADHD published in *Frontiers in Psychiatry* showed that executive functions were improved (effect, 0.71 , 95% CI 0.37 , 1.04) and the capability of working memory appeared to be increased (effect, 0.48 , 95% CI 0.21 , 0.76) between the two groups.⁽³⁹⁾

However, a randomized clinical trial by Chacko et al. (2014) tested Cogmed Working Memory Training, a widely used gamified digital intervention in school aged children diagnosed with ADHD. While the training group improved on **some**

of the trained working memory tasks, there were no significant differences compared to the control group on measures of academic achievement, complex reasoning, or teacher-rated executive functioning.⁽⁴⁴⁾

Post intervention regression analysis

Univariate Linear regression analysis for the parameters affecting change (improvement) of self regulation of emotions and self management to time in total sample didn't show any parameter to be a predictor for this change

However, univariate Linear regression analysis for the parameters affecting change (improvement) of self regulation of emotions and self management to time in Group A only (the active group) showed that female sex was a predictor of the improvement.

This indicates that girls with ADHD demonstrated greater improvement with digital therapeutic video games (Lumosity game) compared to boys.

A randomized controlled trial by Flannery et al. (2024) conducted secondary analyses of clinical outcomes by sex in three AKL-T01 (prototype of EndeavorRx) randomized clinical trials in ADHD and found that girls showed greater improvement in objective attention relative to boys following AKL-T01 (TOVA Attentional Composite Score; Cohen's $d = .36$ and Reaction Time Mean Half; Cohen's $d = .54$). This difference was mostly noted in childhood. However, in contrast to our study, this sex difference was not observed in adolescent or adults samples.⁽⁴⁵⁾

In conclusion, the present work found that digital therapeutic video games (Lumosity game) may be an effective treatment for ADHD in combination with medications and behavioral and parenting training as group A (active group)

showed more improvement than group B (controls) in almost all of the parameters of the CPT 3rd edition and the Barkley deficits in executive functions scale, however, most of this improvement was not statistically significant so more research is needed to establish the efficacy of these digital interventions.

CONCLUSIONS

From this study, it was concluded that:

1. Digital therapeutic video games are a promising emerging new treatment for ADHD.
2. These games may be effective in improving both ADHD core symptoms and executive functions.
3. These games can be used as an adjunctive therapy with medications and behavioral and parenting modifications.
4. Girls showed more improvement than boys in the parameters showing significant improvement.
5. The less educated the caregiver and the farther the distance between the place of residence and the hospital where the study is being conducted, the more the rate of dropouts.
6. Mothers are the main caregiver shouldering the responsibility for managing their children's mental healthcare.
7. The combination of non stimulants (Atomoxetine) and behavioral and parenting training is very effective in treating ADHD symptoms.

LIMITATIONS AND STRENGTHS

Limitations to our study were:

- 1- Absence of any digital therapeutic video games for ADHD in Arabic language at the time of the study
- 2- The need for follow up at longer durations (6 months –1 year)
- 3- The absence of a group receiving the game alone without medications or behavioral modifications which which didn't show the full potential of the game
- 4- The sample size is small
- 5- The need to test the game on different age groups (younger and older than our study sample)

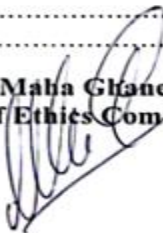
Strenghts of our study were:

- 1- It is the first study in Egypt assessing role of therapeutic video games in treating ADHD
- 2- It used both objective assessment methods (CPT 3rd edition) and subjective assessment methods (BDEFS-CA) reported by caregivers
- 3- It used improvement in skills of daily living (executive functions) as an assessment tool and this is important for functional implications.
- 4- No conflicts of interest

Declarations

Ethics approval and consent to participate

The study adhered to strict ethical guidelines and received approval from the Institutional Research Ethics Board (IREB) of the Alexandria Faculty of Medicine, Alexandria University, Egypt. An informed written consent was taken from patients and caregivers before conducting the study. Participation was entirely voluntary and the patients were free to decline without any consequences. (serial number 0108400)

 ETHICS COMMITTEE FACULTY OF MEDICINE ALEXANDRIA UNIVERSITY	Member of ICLAS http://iclas.org/members/member-list http://www.hhs.gov/ohrp/assurances/index.html IRB NO: 00012098(Expires 2025) - FWA NO: 00018699(Expires January 21 st , 2026)
<u>Review Report</u>	
Serial Number: 0108400	
Date of Monthly Meeting: 09 / 06 / 2024	
Name of the Researcher:	يوسف شادى عماد برسوم
Name of Department:	أمراض المخ والأعصاب
Type of Research:	MS ☒ MD ☐ Promotion Research ☐
Title of the Research: فاعلية لعبة الفيديو الرقمية فى علاج اضطراب فرط الحركة وتشتت الانتباه.	
Reviewer Report: Accepted According to Ethical Standards of Scientific Research ☒ Accepted After Correction ☐ Not Accepted ☐	
 Prof. Dr. Maha Ghanem Chairman of Ethics Committee	
Issue Date: 09 / 06 / 2024 Expire Date: 09 / 06 / 2025	
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الموافقة على الخضوع لبحث طبي

عنوان البحث:

فاعلية لعبة الفيديو العلاجية الرقمية (لوموزيتي) فى علاج اضطراب فرط الحركة و تشتت الانتباه

أسم الباحث الرئيسى: يوسف شادى عماد برسوم

أوافق على الآتى:

- ١- تم إيضاح الغرض وخطوات ومدة البحث .
- ٢- تم إخطارى بفوائد البحث لى و للآخرين.
- ٣- تم إخطارى بإحتمالات تغيير فى خطوات البحث عند الضرورة ولمصلحتى .
- ٤- لى حق ترك البحث فى أى وقت دون التعرض لأى مساءلة .
- ٥- سيتم مراعاة سرية معلومات البحث الخاصة بي و بطفلي .

توقيع ولى أمر الخاضع للبحث :

الرقم القومى لولى أمر الخاضع للبحث:

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Consent for publication

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The authors declare that they have no competing interests

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Authors' Contribution

HE conceived the study design, conducted the clinical data collection, performed statistical analysis, and drafted the initial manuscript. SA assisted in methodology development, data curation, literature review, and revised the manuscript draft. YB coordinated the clinical workflow, contributed to data interpretation, handled technical compliance, and critically revised the manuscript. AS provided overall study supervision, secured resources and institutional support, conceptualized the research framework, and finalized the manuscript. All authors read and approved the final manuscript.

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