Effect of Web-Based Brain Training Program on Cognitive and Academic Functions of Student Nurses with Sickle Cell Disease

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Abstract: Cognitive impairments associated with SCD are among the most devastating, and least studied complications. The use of web based brain training program as a remedial intervention was supposed to improve their cognitive and academic functions. This study aimed to evaluate the effect of web-based brain training program on cognitive and academic functions of student nurses with sickle cell disease. A quasi experimental double control design was utilized in this study. Two matched groups; experimental and control groups were recruited conveniently, thirty students for each. Their mean age was (19.8±0.9years), and (19.7±1.1years) respectively. The experimental group students utilized the brain training program while the control did not. Academic and cognitive evaluation was applied for the two groups. The results revealed a non-significant difference between the two groups before program implementation, but revealed a highly statistical significant difference between the two groups regarding their cognitive functions after program implementation. There was a significant change in cognitive function within the experimental group after the program implementation. Concerning academic functions there was a non significant difference between the two groups and non significant change within the experimental group. In conclusion: a web-based brain training program was effective in improving cognitive functions, and provide some evidence of transfer of this improvement into the SCD student academic life.

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1. Introduction

Sickle cell anemia is a genetic disorder characterized by irregularly shaped red blood cells due to an abnormal form of hemoglobin within the RBC's *(Campbell & Reece, 2005).* Central nervous system complications are among the most devastating manifestations of sickle cell disease, it includes overt stroke, silent cerebral infarction, and cognitive impairment *(Day and Chismark, 2006)*. Cognitive impairment have been proposed due to recurrent microinfarctions of the central nervous system; hypoxic damage to the brain secondary to chronic anemia; hypoxic damage exacerbated by acute events; and chronic nutritional deficiency associated with increased metabolic demand *(Brown et al., 2000)*. Strokes and silent infarcts differ in location and size. Both occur with roughly equal frequency in frontal, parietal, and temporal lobes of the brain *(Adams et al, 2001).*

In the past, SCD was considered a fatal disease, and many people died at young age. People with SCD can now live longer lives because of advances in medical care *(National Heart, Lung, and Blood Institute, 2007)*. Students with sickle cell disease have a genetically acquired blood disorder that makes their chronic illness invisible; they are usually mainstreamed into regular classroom within the school system, *(Javid, 1999)*. They had lower average scores for measures of processing speed, working memory, global cognitive functions, and most measures of executive functions. Difficulties with selective attention are illustrated by lower average scores for tests regarding visual scanning and attention. This may translate into challenges in academic life, difficulties with employment, financial management, medication adherence, use of community resources, and social functioning. The role of academic staff is critical to improve the academic status of students with SCD. They must have an accurate and comprehensive understanding of the academic and cognitive impact of SCD and be ready to implement specific remedial interventions to improve cognitive and academic functions *(Day and Chismark, 2006)*.

For centuries the human brain has been thought of as incapable of fundamental change. People suffering from neurological defects, brain damage or strokes were usually written-off as hopeless cases. But recent and continuing research into the human brain is radically changing the look at the potential for neurological recovery *(Sheerin, 2011)*. One of the most extraordinary discoveries of the twentieth century is neuroplasticity that refers to ability of the brain to alter its structure in response to experience. Neuroscience demonstrates that the brain is constantly forming new neural pathways, removing old ones, and altering the strength of existing connections at any age to compensate for an injury or illness and to adapt to new situations or changes in the environment *(Admin, 2009).*

Brain training is a system of highly targeted exercises used to change the brain's capacity to think and learn. Brain training exercises are designed to stimulate the neuroplasticity that leads to improved cognitive ability such as memory, attention and processing speed with appropriate training. Web-based cognitive training include repeated exercise on standardized tasks with an inherent problem or challenge that address specified cognitive domain aims to restore, maintain and optimize general cognitive functions *(Gats & Valenzuela, 2010)*.

Significance of the study:

In the Middle East an estimated 6000 children born annually with SCD, at least 50% of those in Saudi Arabia. Saudi Arabia has a high prevalence of the disorder, in Eastern (especially Al-hasa, and Al-Quatife) and Western provinces of the kingdom. The incidence of stroke in children with SCD is approximately 250-fold higher than in the general population, as 11% of them suffer clinical stroke before adulthood, and they suffer decline in performance overtime. Numerous studies have documented the academic and cognitive impact of SCD, yet, publications describing interventions are limited. Research is needed to identify effective preventive and remedial interventions that could be a useful non pharmacological manipulation of cognitive outcomes than the exploratory designs that have been used to date.

Aim of the study:

This study aimed at:

Evaluation of the effect of web-based brain training program on cognitive and academic functions of student nurses with sickle cell disease.

Research Hypotheses:

1. After exposure to web-based brain training program, studied students will have better cognitive functions, compared to control group ……subjects.

After exposure to web-based brain training program, studied students will have better cognitive functions, compared to pre studied level.

2. After exposure to web-based brain training program, studied students will have better academic functions, compared to control group or to pre studied levels.

-After exposure to web-based brain training program, studied students will have better academic functions, compared to pre studied level.

2. Subjects and Methods:

Research design:

A quasi-experimental (double-control) research design has been utilized in this study.

Research setting:

Health Science Collage for Girls in Dammam (Eastern Region), Kingdom of Saudi Arabia.

Subjects:

All sickle cell disease students were recruited in this study. Sixty female nursing students were recruited into this study. The Students were recorded in a list, and then systematically randomly assigned to one of two experimental, and control groups, thirty students each. The experimental group was subjected to the web based brain training program, while the control group was not. Their mean age was (19.8±0.9 years), and (19.7±1.1years) for both experimental and control groups consecutively.

The inclusion criteria were student diagnosed with sickle cell disease, have no history of overt stroke (no focal signs, seizures, headache, visual loss), had sufficient vision acuity to discern the stimuli involved in the testing, had no identified hearing problem, no currently prescribed medication that can alter cognitive functions (such as anxiolytic, psychotropic, opiod, and sedatives). Exclusion criteria were carrier state, having psychiatric treatment, overt stroke (focal findings), history of head injury, any long term disorder that result in neurocognitive or brain dysfunction (systemic lupus erythmatosis, diabetes mellitus, history of long term transfusion, morbid obesity, active hepatitis), and has adequate knowledge with basic computer skills.

Tools of the study:

The following tools utilized to collect data related to this study.

Personal information questionnaire:

It was designed to elicit the student's personal information. It composed of two parts. Part one included personal information regarding age, income, marital status, student's state of whether she is fresh or repeater (current or previous) student, carrying subject(s) or had recite exam(s), and the student's GPA (before and after program implementation). Part two consisted of a medical record review to obtain data related to clinical symptoms of sickle cell disease, associated co-morbid conditions, drug used, medication prescribed, using of corrective lenses, eyeglasses, hearing aids.

Cognitive functions measurement tests

It was designed to assess the three aspects of learning (attention, working memory, learning and memory) through the following clinical tools:

Necker Cube pattern Control Test (NCPCT)

It was developed as a direct test of attentional capacity i.e., the capacity to inhibit a competing pattern stimulus *(Brewer & Therrien, 2000))*, by using a drawing of a cube with a width and length of 2 centimeters each and a depth of 1 centimeter. Subjects may see the cube pattern in two different views, one when looking at the foreground and the other when reversing to the background of the cube. To maintain one pattern, subjects have to mentally inhibit the alternative pattern. There are two assessment components to the NCPCT, for: 1) establishing a baseline of passive attention; and, 2) measurement of controlling, or effortful, attention.

In the first component, the subject is tested in two 30-second sessions (T1 and T2). The subject is asked to passively look at the cube. Each time the cube reverses or flips, the subject make a sign with a pencil on the test paper. The researcher counts the number of flips that occur.

In the second component, the subject is tested in the two more 30-second sessions (T3 and T4). The subject is asked to try to keep the cube from flipping. Whenever, the cube reverses or flips, the subject also make a sign with a pencil on the test paper. The numbers of flips that occur are counted for each trial. The values obtained from session T1 and session T4 are discarded. The value obtained in session T2 is subtracted from the value obtained in session T3, with the results being divided by the value obtained in session T2. This results is then multiplied by 100 for a percentage score [(T3-T2)/T2 x100]. The result was defined as the person's attentional capacity. Subjects who had a significantly higher mean NCPCT score than their matched control were determined to have distractibility.

Trail Making Test (TMT)

i- Trail Making (A) Test

Trail making (A) test was developed to provide a measure of attention and concentration abilities involving visual-motor, conceptual tracking, and sequencing skills *(Demakis, 2004)*. It is a timed (minutes) paper and pencil test, which consists of 25 encircled numbers randomly scattered over a paper sheet, the circles are numbered from 1-25, and the students are asked to connect, in ascending order, the series of numbers without lifting the pen or pencil from the paper. Students, who spent significantly more time to complete the test than their matched control, were determined to have poorer attention and concentration abilities.

ii- Trail Making (B) Test

Similar to trail making (A) test, trail making (B) test's circles include both numbers from (1-13) and letters from (A-L), the student should draw the lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc) *(Lezak, Howieson, and Loring, 2004)*.

Time was counted for trail making (A) test and trail making (B) test separately, if the patient make errors, it was pointed out immediately and the student was allowed to correct it. Errors affect the patient's score only in that the correction of the errors is included in the completion time of the task. Results for both TMT (A) and (B) are reported as the number of seconds required to complete the task; therefore, higher the score reveal greater impairment (poorer attention).

Digit Span Forward Test (DSFT)

It examined verbal recall; attention capacity and working memory by having subjects retain a verbally stated series of numbers, and then repeated back in the correct order *(Lezak, 2004)*. The number of digits in the sequence increases, with each successful repetition, until 9 digits are successfully repeated, or until the person fails, at a given sequence after two attempts. The score is the highest number of digits successfully completed. Scoring is expressed in the form of a digit. Each item is scored 0, 1, or 2, with: 2 = passes both trials; 1 = passes only one trial; and, 0 = fails both trials. The students who had significantly lower mean scores, than their matched control were considered to have attention impairment and distraction.

Digit Span Backward Test (DSBT)

This test measured more effortful activity in working memory, which involves both the storage and manipulation of information *(Wechsler, 1997)*. Students were asked to repeat digits backwards after they are verbally stated by the researcher. The number of digits, in a sequence, increased with each successful repetition, until 9 digits are successfully repeated, or until the student fails at a given sequence, after two attempts. The score is the highest number of digits completed. Scoring is expressed in the form of a digit. Each item is scored 0, 1, or 2, with 2=passes both trial; 1= one trial is passed; and 0= both trials are failed. The students who had significantly lower mean scores, than their matched control were considered to have working memory impairment.

In both cases, Digit Span also provides a performance measure of resistance to distraction.

Digit Symbol Substitution Test (DSST)

It was developed as a specific tool to identify cognitive and cerebral dysfunction, it measures perceptual skills, short term memory, decision making and motor component, in addition to measure associative flexibility when faced with a new learning *(Lezak, 1995)*. This test requires complex visual scanning and tracking perception, motor speed and memory. It consists of rows containing small blank squares, each paired with randomly assigned number from one to nine. Above the rows is a printed key that pairs each number with a different symbol. The student is required to scan the number and must fill in blank space with the symbols corresponding to each number, as rapidly as possible, within 90 seconds. The sequence of numbers is random, with no cues to spatial location contained in the key. Scoring of the test through recording the number of correct matches within a 90 seconds interval. About five minutes were required for the entire test. The test maximum score was 133 points, with the lower the score the most working memory deficit.

Hopkins Verbal Learning Test-R (HVLT-R)

Learning and Memory, the third component of cognitive performance, was assessed using the Hopkins Verbal Learning Test-R (HVLT-R) (*Charoenkitkarn, et al., 2009)*. This test examines three aspects of learning and memory: total recall, retention and recognition. The (HVLT-R) consists of a 12 item words listed in three consecutive trials. The word list is composed of three semantic categories with four words in each. The HVLT-R tasks include three learning trials (T1, T2 & T3), one 20-25 minute delayed recall trial (T4), and one yes/no delayed recognition trial (T5). The latter trial (T5) consists of a randomized list that includes the 12 target words and 12 non-target words, six of which are drawn from the same semantic categories as the target words. Raw scores are derived for total recall, delayed recall, retention (% retained), and a recognition discrimination index. The scores are measured as follow: 1) Total Recall = Trial 1 + Trial 2 + Trial 3; 2) Percent retained = (Trial 4 /Trial 3) x 100; and 3) Recognition = number of hits of the T5 recognition trial / 12. The students who had significantly lower scores, than their matched control, were considered to have learning and memory deficits.

Academic Function Assessment sheet

It was developed by the researcher to record the student's academic performance in their studied subjects through (theoretical, practical, and clinical courses) by recording their scores regarding class participation, attendance, semester requirements (reports, clinical training score), midterm exams, final theoretical exam, final practical exam in each subject, GPA before and after program implementation.

The Web-Based Brain (cognitive) Training Program:

Web-based brain training is an online system of highly targeted exercises designed to improve cognitive functions through the regular use of computerized tests *(Hardy & Scanlon, 2009)*. Computerized based cognitive training include repeated exercises (that require different mental and cognitive abilities) on standardized tasks with an inherent problem or challenge that addresses specified cognitive domains aims to restore, maintain and optimize general cognitive functions.

Courses were developed to train five areas of cognitive functions: processing speed, attention, memory, flexibility, and problem solving. Courses were clusters of games set to prearranged schedules. These courses guide users through a training experience of 40 daily sessions of between 15 and 30 minutes. Once a course has been completed, others are suggested based on the user's profile of progress and performance. The difficulty of the training tasks increased as the participants improved to continuously challenge their cognitive performance and maximize the benefits of training.

Procedure:

The investigator went through literature review to establish the study tools. Administrative consent to collect data obtained. The study was conducted between September 2007 and December 2011. The study conducted on 4 successive academic years (started by the second year students) to collect as much numbers as could from sickle cell disease students. It started with base line assessment to their cognitive and academic functions. The studied subjects were met individually to complete the tool of cognitive assessment, and the academic assessment was recorded throughout the academic year during different type of courses (practical, theoretical, and clinical courses).

The current web based brain training program was selected on the following criteria (being used interactive multimedia software technology like that used in video games, being studied before and achieved published positive outcomes – in normal healthy adults, elderly, aphasic, cancer related learning difficulties, Attention Deficit Hyperactivity Disorder, mild traumatic brain injury, and Post Traumatic Stress Disorder-, being designed by neuroscientists).

All the selected students were passed successfully the computer course in their first academic year. Students then have given explanation on an illustrated print out of the training program before entering the web site. The first time to enter the web site was done in the presence of the researcher to help the student make her online account, and gave the student the necessary instructions, the student are then allowed to continue the remaining of the program at home. The students were asked to print out their scores pre and post training, only to make sure that the student practice adequately and to identify the progress resulting from training. These results are then dismissed.

3. Results:

Table (1) reveals non statistical significant differences between experimental and control group regarding their mean age, marital status, and income, and reveals that 63% of the students in both groups were either previously repeated, carrying subject(s), has succeeded after recite exam(s), or already repeater for the current grade (control group only) at the beginning of the study.

Results can be categorized into

Cognitive functions results

Table (2) shows a non statistical significant difference between experimental and control groups regarding all tested cognitive functions (attentional capacity, attention and concentration abilities, resistance to distraction, working memory, and learning and memory) before program implementation.

Hypothesis (1): After exposure to web-based brain training program, studied students will have better cognitive functions, compared to control group subjects.

Table (3): reveals a highly statistical significant difference in cognitive functions in the experimental group compared to the control group subjects regarding all tested cognitive functions (attentional capacity, attention and concentration abilities, resistance to distraction, working memory, and learning and memory).

Hypothesis (2): After exposure to web-based brain training program, studied students will have better cognitive functions, compared to pre-studied level.

Table (4) shows a highly statistical significant positive change in all aspects of the experimental groups' cognitive functions (attentional capacity, attention and concentration abilities, resistance to distraction, working memory, and learning and memory) after program implementation compared to the pre intervention level.

The academic functions results

Table (5) shows a non statistical significant difference between experimental and control groups regarding total score of theoretical, practical, clinical courses, and student GPA before program implementation.

Hypothesis (3): after exposure to web-based brain training program, studied students will have better academic functions, compared to control group subjects.

Table (6): reveals a non statistical significant difference between experimental and control groups regarding total scores of practical and clinical courses, while, a significant difference in midterm theoretical exams of the clinical course, and a highly statistical significant difference between the two groups regarding final theoretical exam, theoretical course total score, and GPA.

Hypothesis (4): after exposure to web-based brain training program, studied students will have better academic functions, compared to pre studied level.

Table (7): reveals a non statistical significant change regarding total score of practical and clinical courses, while reveals a significant change between students' score after the program compared to pre program levels in total score of theoretical course, and a highly significant change in student GPA.

4. Discussion:

The capacity of the human brain to make new associations and acquire new knowledge has been appreciated for hundreds of years. However, the brain's ability to fundamentally reorganize itself when confronted with new challenges is a relatively recent discovery. In response to these challenges, the brain will adapt and change. Given the right kind of exercise, it will reshape itself to become more efficient and effective *(Hardy and Scanlon, 2009)*, and the creative reuse of existing neural components may have played a significant role in the evolutionary development of cognition *(Anderson, 2007)*.

Accordingly, this study aimed at evaluation of the effect of web-based brain training program on cognitive and academic functions of student nurses with sickle cell disease. The comparison between experimental and control groups in the current study revealed no statistical significant difference between them regarding their sociodemographic characteristics of age, marital status and income. The results of the present study revealed that about two third of the experimental and control groups suffering academic trouble, as they were either previously repeated a grade, carrying subject(s), succeeded after recite exam(s), or already repeaters for the current grade, which indicate to their troubled academic performance. This finding is similar to *Javid(1999)* study which reported that as many as fifty percent of students with SCD would fail at least one grade during their academic life. *Schatz and colleagues (2002)* reported suggestive evidence that the difference in IQ points increase as students aged. *Day and Chismark (2006)*, pointed to such poor academic performance of students with SCD, which is far below their matched comparison group by three year and below the national norms. This academic impairment can be translated to academic failure and consequently a life time of limited career options or total disability.

Table (1): Sociodemographic characteristics of the studied subjects

Characteristics	Experimental No.= 30	%	Control No.= 30	%	Test	P	Sig.
Age*(at the beginning of the stud)* Mean± SD	19.8±0.88		19.7±1.1		t= 0.27	>0.05	NS
Academic status at the beginning of the study:							
Fresh and never repeated	19	63	20	66			
Fresh but Previously repeated	9	30	6	20			
Fresh with suspended (carrying) subject(s) or have a recite exam(s)	10	33	10	33			
Repeater of the current grade	0	0	3	10	-	-	-
Marital status							
Married	23	76.7	23	76.7			
Single	7	23.3	7	23.3	X^2=0.00	>0.05	NS
income							
Adequate	2	6.7	4	13.3			
Fair	13	43.3	11	36.7			
Not adequate	15	50	15	50	X^2=0.83	>0.05	NS

Table (2): Comparison of cognitive functions between the experimental and control groups before implementation of the program

	Experimental Mean ±SD	Control Mean ±SD	Independent sample t test	P	Sig.
Attentional capacity (distractibility): (Necker cube pattern control test)	-37.3±24.06	-37.4±24.17	0.016	>0.05	NS
Attention and concentration abilities: visual-motor, conceptual tracking, and sequencing skills (Trail making A test)	52.5±7.48	51.8±6.85	0.378	>0.05	NS
(Trail making B test)	98.53±14.24	98.47±12.72	0.019	>0.05	NS
Resistance to Distraction: ***Efficiency of attention and immediate recall*** (Digit span forward test)	5.57±0.77	5.67±0.84	-0.478	>0.05	NS
Effortful activity of working memory to both store and manipulate information (Digit span backward test)	5.07±0.45	5.033±0.49	0.274	>0.05	NS
Working memory: ***Perceptual skills, short term memory, decision making, motor component, and associative flexibility when faced with a new learning.*** **(Digit symbol substitution test)**	26.83±4.61	25.57±4.26	1.106	>0.05	NS
Learning and Memory: (Hopkins verbal learning test)					
Total recall	13.93±1.48	13.40±1.30	1.479	>0.05	NS
Retention	104.73±6.55	105.30±7.73	-0.306	>0.05	NS
Recognition	0.78±0.18	0.80±0.17	0.569	>0.05	NS

Table (3): Comparison of cognitive functions of the experimental and control groups after implementation of the program

	Experimental	Control	Independent sample t test	P	Sig.
	Mean $\pm SD$	Mean $\pm SD$			
Attentional capacity (distractibility): (Necker cube pattern control test)	-32.30 $\pm$20.60	-36.17 $\pm$23.18	2.776	<0.001	HS
Attention and concentration abilities: visual-motor, conceptual tracking, and sequencing skills (Trail making A test)	47.60$\pm$9.05	51.73$\pm$6.83	-5.624	<0.001	HS
(Trail making B test)	90.87 $\pm$13.65	98.33 $\pm$12.05	-6.111	<0.001	HS
Resistance to Distraction: ***Efficiency of attention and immediate recall*** (Digit span forward test)	6.67$\pm$0.99	5.87$\pm$0.82	6.012	<0.001	HS
Effortful activity of working memory to both store and manipulate information (Digit span backward test)	6.00$\pm$0.59	5.20$\pm$0.55	5.647	<0.001	HS
Working memory: ***Perceptual skills, short term memory, decision making, motor component, and associative flexibility when faced with a new learning.*** **(Digit symbol substitution test)**	30.40$\pm$2.82	25.90$\pm$4.02	6.677	<0.001	HS
Learning and Memory: (Hopkins verbal learning test)					
Total recall	16.7$\pm$0.98	13.40$\pm$1.22	10.260	<0.001	HS
Retention	110.33 $\pm$6.46	105.20 $\pm$7.17	5.410	<0.001	HS
Recognition	0.98$\pm$0.07	0.83$\pm$0.15	5.320	<0.001	HS

Table (4): Comparison of change in cognitive functions within the experimental group (after –before) implementation of the program

	Mean Diff*	Std. Dev.	Paired t test	p	Sig
Attentional capacity: (Necker cube pattern control test)	5.00	5.96	2.77	< 0.001	HS
Attention and concentration abilities: visual-motor, conceptual tracking, and sequencing skills (Trail making A tes	4.90	4.48	-6.57	< 0.001	HS
(Trail making B test)	7.67	6.34	-10.03	< 0.001	HS
Resistance to Distraction: ***Efficiency of attention and immediate recall*** (Digit span forward test)	1.10	0.66	0.85	< 0.001	HS
Effortful activity of working memory to both store and manipulate information (Digit span backward test)	0.93	0.64	0.69	< 0.001	HS
Working memory: ***Perceptual skills, short term memory, decision making, motor component, and associative flexibility when faced with a new learning.*** **(Digit symbol substitution test)**	3.57	2.58	2.60	< 0.001	HS
Learning and Memory: (Hopkins verbal learning test)					
Total recall	2.80	1.40	2.28	< 0.001	HS
Retention	5.60	5.36	3.60	< 0.001	HS
Recognition	0.20	0.17	0.14	< 0.001	HS

*Mean Diff= mean of the difference between student score (after minus before)

Table (5): Comparison of academic functions between the experimental and control groups before program implementation

	Experimental	Control	Independent sample t test	P	Sig.
	Mean±SD	Mean ±SD			
Theoretical course					
Attendance & class participation (5)*	4.83±0.2	4.78±0.26	0.79	>0.05	NS
Midterm theoretical exams (45)	28.75±5.12	29.2±7.17	-0.25	>0.05	NS
Final theoretical exam (50)	23.58±6.57	24.61±1.36	0.54	>0.05	NS
Total (100)	57.17±9.23	58.58±11.01	-0.48	>0.05	NS
Practical course					
Attendance & class participation (5)	4.93±0.13	4.95±0.10	-.0.48	>0.05	NS
Midterm practical exams (25)	19.94±3.37	19.81±3.35	0.12	>0.05	NS
Practical reports (30)	23.88±2.84	23.04±3.66	0.84	>0.05	NS
Final practical exam (40)	27.90±5.76	28.85±7.92	-0.45	>0.05	NS
Total (100)	76.64±7.92	76.65±8.76	0.00	>0.05	NS
Clinical course					
Attendance & class participation (5)	4.82±0.19	4.850±0.183	-0.58	>0.05	NS
Clinical practice (30)	20.64±2.58	20.56±2.83	0.12	>0.05	NS
Midterm theoretical exams (25)	14.74±3.27	14.41±3.25	0.38	>0.05	NS
Final theoretical exam (20)	11.26±2.79	11.07±2.63	0.27	>0.05	NS
Final practical exam (20)	13.77±3.71	13.57±4.73	0.18	>0.05	NS
Total (100)	65.22±8.7	64.46±7.58	0.36	>0.05	NS
GPA (5)	2.67±0.57	2.66±0.54	0.054	>0.05	NS

*Numbers between brackets is the marks distribution of the subjects

Table (6): Comparison of academic functions of the experimental and control group after program implementation

	Experimental	Control	Independent sample t test	P	Sig.
	Mean±SD	Mean ±SD			
Theoretical course					
Attendance & class participation (5)	3.6±0.9	4.7±0.3	-5.93	<0.001	HS
Midterm theoretical exams (45)	34.2±4.8	32.6±5.4	1.06	>0.05	NS
Final theoretical exam (50)	223.6±5.6	29.9±6.7	3.85	<0.001	HS
Total (100)	74.7±10.0	67.2±8.6	2.89	<0.001	HS
Practical course					
Attendance & class participation (5)	4.9±0.1	4.9±0.1	1.33	>0.05	NS
Midterm practical exams (25)	21.3±3.4	19.9±3.4	1.22	>0.05	NS
Practical reports (30)	24.5±2.5	23.9±2.8	-1.32	>0.05	NS
Final practical exam (40)	29.5±5.6	27.9± 5.8	0.47	>0.05	NS
Total (100)	80.3±7.2	76.7±7.9	0.48	>0.05	NS
Clinical course					
Attendance & class participation (5)	4.9±0.1	4.8±0.3	1.88	>0.05	NS
Clinical practice (30)	21.3±2.7	19.8±3.2	1.36	>0.05	NS
Midterm theoretical exams (25)	16.6±3.3	1.5±3.6	2.55	<0.05	S
Final theoretical exam (20)	11.7±2.8	11.2±3.2	-0.13	>0.05	NS
Final practical exam (20)	14.9±4.1	13.4±4.9	0.60	>0.05	NS

Total (100)	69.4±9.6	62.7 ±11.5	1.44	>0.05	NS
GPA (5)	3.17±0.46	2.66 ±0.47	8.343	<0.001	HS

Table (7): Comparison of change in academic functions within the experimental group (after –before) program implementation

	Mean Diff*	Std. Dev.	Paired t test	P	Sig.
Theoretical course					
Attendance & class participation (5)	0.050	0.350	0.68	> 0.05	NS
Midterm theoretical exams (45)	2.870	10.495	1.31	> 0.05	NS
Final theoretical exam (50)	3.217	8.398	1.84	> 0.05	NS
Total (100)	6.137	13.486	2.18	< 0.05	S
Practical course					
Attendance & class participation (5)	0.056	0.182	-1.28	> 0.05	NS
Midterm practical exams (25)	0.306	4.885	-0.26	> 0.05	NS
Practical reports (30)	1.706	3.412	2.06	> 0.05	NS
Final practical exam (40)	0.274	10.563	-0.11	> 0.05	NS
Total (100)	1.064	14.045	0.31	> 0.05	NS
Clinical course					
Attendance & class participation (5)	0.097	0.274	-1.94	> 0.05	NS
Clinical practice (30)	0.097	0.274	-1.94	> 0.05	NS
Midterm theoretical exams (25)	0.761	4.127	-1.01	> 0.05	NS
Final theoretical exam (20)	0.873	3.955	-1.21	> 0.05	NS
Final practical exam (20)	0.108	4.281	0.14	> 0.05	NS
Total (100)	0.175	8.209	-0.12	> 0.05	NS
GPA (5)	0.49	0.29	0.38	P < 0.001	HS

*Mean Diff= mean of the difference between student score after minus before

This academic impairment is understandable in the light of their exposure to the central nervous system complications which include overt stroke, silent cerebral infarction (ischemic changes with no clinical history of stroke). This is emphasized by *Schatz, et al. (2002)*, who explained that the cognitive impairment associated with SCD are due to cerebral vascular injury, which may include attention and executive skills, such as coding and digit span, matching familiar figures, verbal or language functions, and memory functions. *National heart, lung, and blood institute (2007)* documented such complications in children with SCD who were commonly have frontal lobe dysfunction syndrome, which is a brain disorder that can affect cognitive functioning in areas such as attention, concentration, information processing, and decision making.

Up to my knowledge, this was the first reported study of cognitive training-induced changes in cognitive and academic functions in students with sickle cell disease.

In terms of cognition, the results of the present study showed a similarity between experimental and control groups regarding cognitive functions before the program implementation, while showed a highly statistical significant difference between them regarding all aspects of tested cognitive functions (attentional capacity, attention and concentration abilities, resistance to distraction, working memory, and learning and memory). These findings were emphasized by a significant positive change in all aspects of cognitive functions within experimental group subjects. These findings were similar to *Ball et al. (2002)* who reported effectiveness and durability of the cognitive training interventions in improving targeted cognitive abilities in older adult. In a large, randomized controlled trial known as the ACTIVE study done on the elderly population, participants trained in memory, speed of processing, or reasoning showed significant improvements in the trained domains, and these improvements were maintained over a 5-year follow-up interval *(Willis et al., 2006)*. Such findings were reported by (*Mazoyer et al., 2009*; *Smith, etal., 2009)*, while, *Shatil et al. (2010)* reported similar findings on patient with multiple sclerosis.

This improvement may be attributed to exercising attentional processes, strengthening memory during the engagement in the program, which was designed to target the fife areas of cognitive functions (processing speed, attention, memory, flexibility, and problem solving). According to Brenner's model of vicious cycle, the attentional processes are considered the basic component of cognitive functions *(Brenner, 1992)*. Based on this model, the results of *Chan et al. (2009)* on schizophrenic patients explained that the improvement in terms of changes in basic cognitive functions may lead to changes of complex cognitive functions.

Another explanation proved by *Mozolic, et al., (2011)* study results that proved significant increase in resting cerebral blood flow to the prefrontal cortex than the control after cognitive training program in healthy older adults. This increase in blood flow was associated with reduced susceptibility to distraction after training. Several interventional studies have capitalized on this plasticity to improve cognitive functions in older adults with training programs that target memory, attention, reasoning, and speed of processing (*Jennings et al., 2005 ; Mahncke et al., 2006 ; Erickson et al., 2007 ; Bherer et al., 2008 ;Buschkuehl et al., 2008 ; Dahlin et al., 2008 ; Mozolic et al., 2009).*

In context of the academic functions, this cognitive improvement did not transfer to equal improvement in academic functions related to practical and clinical courses, the core of nursing profession. This was evident in the present study by a non statistical significant difference between experimental and control groups after program implementation, and a non statistical significant change within the experimental group subjects. These findings were similar to *Ball et al. (2002)* who reported absence of transfer of cognitive improvement to real world outcomes in older adults. *Owen et al.(2010)*, reported results of six-week online study on 11,430 normal young adults trained several times each week on cognitive tasks designed to improve reasoning, memory, and planning, visuospatial skills and attention. Although improvements were observed in every one of the cognitive tasks that were trained, no evidence was found for transfer effects to untrained tasks, even when those task were cognitively closely related.

The lack of improvement in academic functions in the current study may be referred to short time of training. A similar explanation was provided by *Owen et al. (2010)* who pointed to the possibility that the amount of practice was insufficient to produce a measurable transfer effect of brain training. Another explanation might be related to the academic assessment done shortly after starting the cognitive training, with no follow up assessment after a reasonable period of training, which is supported by *Willis et al. (2006)* who reported modest evidence for transfer of the effects of cognitive training to function which was not observed until the 5-year follow-up. These delayed outcomes are explained by a temporal lag between onset of cognitive decline and subsequent impact on daily functions. However, the full extent of the interventional effects on daily functions would take longer than 5 years to observe in a population. On other hand, *Smith, et al. (2009)* discuss the likelihood of time effect that the computerized training method resulted in near transfer effects; however, it is unknown either there were long-lasting effects or if any existing far transfer effects on more global or everyday cognitive functions. In the same instance, *Vinogradov (2011)* mentioned that training-induced increases in brain activation patterns predict real-world functional improvement 6 months later. *Jennings et al. (2005) and ; van Hooren et al. (2007)* reported similar explanations.

A different suggested explanation is that brain training did not include a real life situations representing the skills and situations reflecting the real nursing world. *Rebook (2008)* provided evidence that training outcomes are highly specific to the cognitive ability being trained and are limited to tasks that are very similar to the training itself. There is frequently little transfer to other laboratory cognitive tasks or to analogues of the training tasks encountered in everyday situations.

In the current study, an academic improvement was observed regarding theoretical outcomes and GPA as shown by a statistical significant difference between the experimental and control groups in the essence of theoretical final exam, total of the theoretical course, midterm theoretical exam of the clinical course and student final GPA on one hand, and a significant change in total theoretical score, and GPA within the experimental group subjects on the other hand. Similar to these findings *Grealy et al. (1999)* reported significant improvement in learning performance after 4 weeks of training in persons with traumatic brain injury. The improvement in performance in learning may be due to enhancement in hippocampus function and the speed of information processing. In *Alloway (2009)* study on students with learning difficulties, the control group did not perform much better without intervention, and in some instances they performed worse, while, the study group demonstrated clear gains, not only in working memory tasks but also in learning outcomes. They represented the difference between the grades of C and B, or between B and A – after just eight weeks of training. These findings support the impact of cognitive training on the theoretical learning outcomes as shown in the present study.

Conclusion:

The result of the present study concluded that a web-based brain training program was effective in improving cognitive functions in terms of attention and concentration abilities, attentional capacity, resistance to distraction, working memory, and learning and memory in student nurses with SCD, however, it provides some evidences of transfer of this improvement into the SCD student academic life.

Recommendations:

Brain based assessment should proceed a tailored made cognitive remediation program. This program should be created to target the cognitive deficits in SCD, and provide virtual reality training that fit the skills needed on the academic nursing courses especially practical and clinical ones.

Design school intervention program including sickle cell educational literature, in terms of one hour in-service program to the school faculty and one hour peer program in the class room. Teacher printed guidelines that address the cognitive deficit.

Future researches are required to determine the most effective type of cognitive training for producing transfer to everyday life. One approach would be to train at the level of complex activities reflecting real-world tasks, measuring its effect on the academic attainment and long term academic outcomes.

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