Rehabilitation of ADHD children by sport intervention: a Tunisian experience

Réhabilitation des enfants TDAH par le sport : une expérience Tunisienne

Soukaina Hattabi[1,4], Meher Bouallegue[3], Houda Ben Yahya[1,2], Asma Bouden[1,2]

1- Research *Unit UR 12SP20 Processus cognitifs dans la pathologie psychiatrique*
2- Departement of child psychiatry- Razi hospital/ Faculty of Medicine of Tunis- Tunisia
3- Research Unit, Sportive performence et physical rehabilitation (S2PR)- High institute of sport and physical education- Kef/ University of Jendouba- Tunisia
4- High institute of sports and physical education of Gafsa/ University of Gafsa- Tunisia

RÉSUMÉ

Introduction: Le trouble déficit de l'attention/hyperactivité (TDAH) est un trouble connu pour son retentissement important sur le vécu de l'enfant, et les cliniciens restent à ce jour en recherche d'approches thérapeutiques efficaces pour alléger les difficultés rencontrées par leurs patients.
But: Appliquer et évaluer l'efficacité d'une activité récréative en natation sur les fonctions cognitives auprès des enfants Tunisiens présentant un TDAH.
Méthodes : Les participants (N total = 40) âgés de 9-12 ans, enfants scolarisés, présentant un TDAH, ont été répartis en 2 groupes: un groupe d'enfants avec TDAH participant au programme de l'activité physique, un groupe d'enfants avec TDAH ne participant pas au programme de l'activité physique. Les deux groupes d'enfants sont évalués au niveau neuropsychologique avant et après l'intervention. Les tests d'évaluation des fonctions neuropsychologiques (la figure complexe de Rey (FCR), le Stroop test et le Hayling test dans leurs versions arabisées) ont été administrés à tous les enfants pour une évaluation détaillée des fonctions attentionnelles et exécutives.
Résultats: En post programme les enfants du groupe expérimental ont présenté un raccourcissement global des temps d'exécution des tâches (p=0.000) avec un nombre moindre d'erreurs d'omissions (p=0.000). Ils ont également commis moins d'erreurs dans les situations d'interférences (p=0.000) signalant ainsi un meilleur fonctionnement cognitif.
Conclusion: Ces résultats suggèrent qu'un programme de natation récréative pourrait avoir des répercussions positives sur les fonctions cognitives des enfants avec TDAH et pourrait fournir un soutien préliminaire à d'autres interventions thérapeutiques.

Mots-clés
Activité physique; programme de natation récréative; Fonctions cognitives; santé mentale.

SUMMARY

Introduction: Childhood attention-deficit/hyperactivity disorder is associated with impairment across multiple domains, including social, familial, emotional and academic functioning. Available therapies, and in particular medical treatment, fail to produce improvement in this impairment. In this context, interest has grown in physical activity and exercise as potential interventions for the treatment of children with ADHD.
Aim: The present study investigates the effect of a recreational swimming program on cognitives functions on Tunisian children with attention deficit hyperactivity disorder (ADHD).
Methods: The study recruited school children aged 9 to 12 years (n total = 40) with diagnosis of ADHD. They were randomly assigned into exercise or control groups. Neuropsychological tasks; the complex figure of Rey (ROCF), the stroop test and the Hayling test were assessed before and after the exercise program.
Results: The results indicates that there were significant improvements in memory accuracy (p=0,000), selective attention (p=0,000), and inhibition process (p=0,000), in experimental group compared with the control group after the intervention. In the post-program, children experienced an overall shortening of task execution times with fewer errors of omissions. They also made fewer errors in interference situations, signaling better cognitive functioning.
Conclusion These findings suggest that a recreational swimming program may have positive implications for cognitive function and may provide preliminary support for alternative therapeutic interventions that can be used by researchers, parents, educators, and clinicians and they support that reinforcement approved by recreational program can normalize cognitive deficiencies in children with ADHD

Key-words
Physical activity; recreational swimming program; Executive control; Cognitive function; mental health.

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is one of the most common childhoods, psychological disorders (1). It persists until adolescence and adulthood in the majority of diagnosed patients (2). ADHD is characterized by three core symptoms: inattention, hyperactivity and impulsivity (3–6). These symptoms usually appear before the age of seven and can create problems in different social settings such as school, home or recreational activities (7) .The calculated prevalence from a systematic review of the literature(8) included 102 epidemiological studies from all continents is 5.29%. ADHD affects about one child per class and it is a real public health problem regarding its financial cost, family life and academic performance (9).

Emerging literature has proposed that children with ADHD often exhibit deficiencies in cognitive function, particularly in executive function(9).

The management of ADHD's cognitive impairment includes different areas of intervention and multiple therapeutic modalities and it is not limited to the question of drug treatment(10). Despite the pharmacological treatment that demonstrated an effectiveness for many years, it is not suggested at the first-line therapy (10). Complementary or alternative to chemical treatments, many non-medicinal therapies of various inspirations have emerged to support ADHD children and their families. The benefits of physical exercise have been widely recognized both in the literature (11) and the media (12,13). It reported positive effects that can be broadly classified into physical health (14) behavioral (15) cognitive (16) and psychosocial health or functioning (17).The effects of physical activities in the field of mental health are so strong that some authors even consider it as a psychotherapeutic process in general (18)

In order to minimize ADHD impairment, we have hypothesized that physical activity and particularly recreative one could enhance positively ADHD.

Here, we aimed to investigate the effect of a recreational swimming program on cognitive functions of Tunisian children with attention deficit hyperactivity disorder (ADHD), using recreational games to provide motivation for ADHD children. As Ryngaert in (19) says: **"***Playing is a learning tool in the same way as other educational tools and must become a simple and familiar tool that encourages motivation".*

METHODS

Participants

Participants were recruited from primary schools in the North West region of Tunisia (El kef city). There are young people aged 8 to 12 years (n total = 40) with DSM IV diagnosis of ADHD (20).

First, the information on the research project was sent to the Tunisian Ministry of Education where the responsible has communicated the list of schools interested in the project.

The research ethics committee of the Razi University Hospital Center (CHUR) approved this research. Parents signed a consent form.

We have distributed the abbreviated questionnaire of Conner (21) (parents and teachers) translated and validated in Arabic in the primary schools of El kef city. The data were collected using Conner's, self-administered and anonymous questionnaire. One version of the questionnaire was intended for teachers and the parents completed another version. Once filled by parents and teachers, these questionnaires are collected by the study researcher. From the collected data, a T-score is calculated. The average score being "50", the score is greater than or equal to two standard deviations above the score "70" are considered pathological. The subjects selected for the study passed a proof of development quotient Colored Progressive Matrix(QD) (22) and a clinical interview conducted by a psychiatrist. They received no chemotherapy, they were free from mental and physical retardation and they have dominance of right hand writings.

Study Design

Selected participants were subdivided in two groups (for each group n = 20). The experimental group is composed of children with ADHD who participate in training programs (age = 9,95±1,31 years; height =1,40±1,00 m; weight = 34,95±8,95 kg; BMI = 17,56±2,91 kg/m^2). The control group is composed of children with ADHD not participating in exercise programs (age =9,75±1,33 years; height =1,40±0,73 m; weight =34,70±6,60 kg; BMI = 17,54±2,31 kg/m^2). All children are assessed before the start of the physical activity program at the Sports Performance and Physical Rehabilitation Research Unit at the Higher Institute of Physical Education and Sports of El Kef.

In terms of physical condition, the measures taken are the weight, the height, the resting heart rate, the max heart rate and a maximal effort test (measurement of the maximum VO2 peak oxygen consumption). Tests evaluating cognitive level are numerous, and there is no consensus regarding the relevance of a specific instrument and the executive processes recruited by each test (23) .

We therefore chose to assess working memory, selective attention and inhibition relying on tasks of Rey Complex Figure (ROCF) (24) which measures working memory, the Stroop test which evaluates the susceptibility to interference, and the Hayling test (25,26), which requires the deletion of dominant responses.

Training program

Three professional instructors conducted the training sessions with a background in water exercise. The program consisted of 12 consecutive weeks of 3 sessions per week (36 sessions in total) at the swimming pool of the High Institute of Sport and Physical Education of El Kef. Each session lasted 90 min and consisted of three stages: a 5-min warm-up period; moderate-intensity water aerobic exercise for 80 min based on aquatic games and a 5-min cool-down period. The moderate-intensity exercise program was used, based on an evidence that moderate intensity exercise may improve cardiovascular fitness, one of the potential mechanisms that are associated with exercise and cognition as well as the appropriateness of the intensity for children with ADHD (27). The perceptual-motor water exercise included games designed to incorporate coordination, balance, and power to reinforce different aspects of motor skills. The exercise program emphasized enjoyment and safety to maximize the children's motivation (9).

Instruments

The Rey Osterrieth Complex Figure

The Rey Osterrieth Complex Figure (ROCF), which was revised by Rey standardized by Osterrieth (24), to test visual perception and long-term visual memory function. It is used as a neurological evaluation tool for both children and adults for a diverse number of conditions from child developmental problems to dementia, trauma and infectious processes. The test requires the subject to copy the figure, and later reproduces from memory (28).

The Stroop test

The Stroop Test is a color-naming task developed by Stroop (29). Adleman et al. (30) suggests that executive processes such as sensitivity to interference and inhibition of responses can be examined using the test of Stroop. We used the Modern Standard Arabic version of the Stroop test (31) which requires the child to inhibit the automatic reading process in favor of a less automatic naming process.

Time to completion and the number of errors for each of the three conditions was used as the dependent variable (23).

An interference score was calculated using the formula : CW – C based on the assumption that color identification and word reading can be processed in parallel rather than sequentially, with word reading occurring faster than color identification (32,33).

The Junior Hayling Test

The Junior Hayling test (26) consists of two parts, "A" and "B" (23). Each part has 10 sentences in which the final word is omitted (23). In part "A" (initiation), the word completing the sentences has to fit appropriately. In part "B" (inhibition), the child has to complete the sentence by a word that has no sense within the context of the sentence (23).

In both parts, the response time (in seconds) and the produced word were recorded. For the response time, we calculated what Shallice (26) called the "Additional Thinking Time" (ATT) as the difference between the latencies in parts "A" and "B" (B − A). In part "B" the produced words was scored according to its semantic relatedness to its stimulus sentence and the error score could vary between a total of zero to thirty points. The sum is what Shallice (26)called the "error score". The Arabic version of the Junior Hayling test was not a simple translation of the items proposed by Burgess & Shallice (34), but was developed based on empirical local data (25). The individual phrases were randomly distributed over the two parts of the test so that the average frequency of missing words and the average length were equivalent in both parts of the test. Each of the two parts of the test included 10 sentences, and 4 more sentences were added to serve as a familiarization trial (23).

Statistical analysis

For this study, examination of the normal distribution by the Kolmogorov-Smirnov test revealed that the indices coming from the ROCF test, Stroop test and hayling

tasks are distributed normally. Independent t-tests and Student t for matched sample were performed to compare the demographic, physical variables and cognitive tasks between the aquatic exercise and control group and between the same group before and after the intervention. In addition to test exercise interaction manipulation, a mixed 2 (group: exercise vs. control) × 2 (time: pre, and post) analysis of variance (ANOVA) was completed. A ṅ (eta square) value for the ANOVAs was used as an index of the effect size. All statistical analyses were performed using SPSS (Version 20.0) for Windows (SPSS Inc., Chicago, IL, USA). A significance level of .05 was used prior to the adjustment.

RESULTS

Demographic and fitness Analysis.

Results showed that before the training period, there are no significant differences between the two groups in age, weight t=0,101(38), p =0.920, height t= -0,133(38), p= 0.895 and body mass index, t= -0,033(38), p= 0 .974 for all groups, suggesting homogeneity.

Analysis of Anthropometrical and Fitness Variables indicates that after the intervention only maximum oxygen consumption (F (1, 38) = 102,001, p=0.000, $\dot{\eta}^2$=0,729) and maximum heart rate are visibly ameliorating in the experimental group (F (1, 38) = 44,927, p=0.000, $\dot{\eta}^2$=0,542).

The demographic and fitness characteristics of participants in both groups are summarized in Table 1.

After the training period, statistical analysis showed that there was an improvement in the scores of cognitive function for Children in the exercise group (P< 0.05) while there was no significant changes (P>0.05) of cognitive functions in the control group who did not receive any exercise program. The descriptive data of the various cognitive measures for each of the different groups are summarized in Table 2. In what follows, we communicate the results analysis by process.

ROCF

There was a significant main effect on Latency of memory with (F (1, 38) =5, 361, p<0.05, $\dot{\eta}^2$=0,124). The interaction between experimental group and control group by time in the delayed memory accuracy showed a great effect of intervention in the post test of experimental group (F (1, 38) =82, 018, p<0.001, $\dot{\eta}^2$=0,683).

Table 1 : Anthropometrical and fitness characteristics of participants in the study and control groups

	GE (n= 20)		GC (n= 20)		Interaction	
	Pre	*post*	*Pre*	*Post*	*F(1,38)*	*Etat*
Weight	34,95±8,95	35,85±7,08	34,70±6,6	36,05±6,93[b]	0,417	0,011
Height	1,4±1	1,4±0,95	1,4±0,73	1,40±0,7[b]	1, 033	0,026
BMI	17,56±2,91	18,03±2,24	17,54±2,31	18,05±2,29[a]	0,019	0,000
VO2max	35,35±2,09	42,09±2,37***	35,79±2,16	36,84±2,08[a]	102,001†††	0,729
FC reset (bpm)	74,85±4,09	75,00±3,87	74,85±4,09	75,00±3,87	0,000	0,000
FC max (bpm)	143,15±3,34	154,50±4,26***	143,15±3,34	145,45±3,91[a]	44,927†††	0,542
ADHD type(N[%])						
ADHD-I	4(20)	--	--	5(25)	--	--
ADHD-HI	6(30)	--	--	4(20)	--	--
ADHD-C	10(50)	--	--	11(55)	--	--
Number (F/M)	3/17	--	--	2/18	--	--

Note. ***p<0,001 (pre vs. post test for each group) ; [a] **p<0,001 ; (comparison between the two study groups (GEX** vs. GC) ; ††† **p<0,001 (interaction** groups*evaluation **;** ES = effect size = proportion of observed variance attributed to differences between the groups.
BMI = body mass index; ADHD-I predominantly inattentive subtype; ADHD-HI predominantly hyperactive-impulsive subtype; ADHD-C combined hyperactive-impulsive and inattentive subtype.

STROOP test

The effect of the training program on Stroop test (Table 2)

The analysis revealed a significant effect of recreational swimming program on stroop tasks;

For Stroop word there was a significant effect of physical activity program. Significant improvements were found in 3 categories of the Stroop test, mainly in condition 3 inhibition (p > 0.001), total errors condition 3 (p > 0.001).

Interaction between groups and period for stroop test (Table 2.)

Repeated-measure analysis of variance (ANOVA) revealed that there was a significant main effect of time in word Stroop F (1, 38) = 20,487 with $\dot{\eta}^2$ = 0,350 where shorter times were recorded in the post-test for the experimental group.

In the category of Stroop Color there was a similar effect of period (F (1, 38) = 38, 929, p < 0.001, $\dot{\eta}^2$ = 0,506).

For Stroop Color-Word, a significant time effect was found for the exercise group and an interaction of group by time (F (1, 38) =30, 740, p< 0.001, $\dot{\eta}^2$ =0,447).

Table 2 Means, standard deviations, and ES for the ROCF, Stroop Test and the Hayling test.

		GE (n= 20)		GC (n= 20)			Statistically Signifiants Interactions (p < 0,05)
		Pre	***Post***	***Pre***	***Post***	***ES***	
ROCF	**Copy Time**	378,65± 121,3	262,04±68,83	315,05±71,08	318,2±82,38	0,346	S**
	Memory Time	314,4±112,37	222,45±50,74	346,8±103,3	309,5±79,18	0,124	S
	Copy accuracy	22,2±1,28	32,45±1,9	22,35±1,46	22,95±1,82	0,877	S**
	Delayed Memory accuracy	17,9±0,6	22,8±1,94	17,78±0,6	17,95±0,84	0,683	S**
Stroop	**Word**	146,75±28,44	90,3±20,88	156,5±18,89	145,65±21,28	0,506	S**
	Color	113,65±33,24	72,10±17,66	129,05±30,8	111,05±28,22	0,35	S**
	Color/ Word	228,05±36,57	159,65±44,15	234,4±19,3	216,2±20,99	0,447	S**
	Total errors color/word	13±4,34	7,1±1,55	16±7,73	14,20±3,61	0,141	S
	Int. Score	114,40±35,79	87,55±36,3	105,35±28,14	105,15±28,37	0,126	S
Hayling	**Time A**	**49,84±18,97**	**32,11±9,37**	**45,4±6,87**	**38,77±11,85**	**0,187**	**S**
	Time B	**97,69±41,14**	**53,61±18,03**	**88,56±27,72**	**77,03±17,9**	**0,336**	**S****
	Error Score A	**3,8±1,58**	**0,6±0,94**	**4,35±1,14**	**1±1,26**	**0,002**	**NS**
	Error Score B	**22,5±3,72**	**12,65±2,13**	**20,35±3,03**	**18,7±2,72**	**0,673**	**S****
	ATT	**47,83±28,13**	**21,5±12,89**	**43,52±17,45**	**38,25±12,89**	**0,3**	**S****

ROCF: Memory Time; copy time; copy accuracy; delayed Memory accuracy.
Stroop test: Word = response time for the card "Word"; Color = response time for the card "Color"; Color/Word = response time for the card "Color/Word"; Int. Score = interference score;
Hayling test: Time A = median response time for part A; Time B = median response time for part B of the Hayling test; ATT = additional thinking time.
S: Significant (p<0.05); S**: Highly significant (p<0.001); NS: Non Significant

In the total errors of the color-word condition, a significant effect of the period was observed (F (1, 38) =6,244 with $\dot{\eta}^2$ =0,141).

Hayling test

Analysis of the interaction revealed that the groups did not differ significantly in the response latency of automatic condition (*F* (1, 38) = 8,716 p= 0,005, $\dot{\eta}^2$ =0,187) but differed in the response latency of Inhibition condition (*F* (1, 38) = 19,205 p<0.001, $\dot{\eta}^2$ =0,336).

Concerning the error score, the control and experimental groups have significantly made equivalent score errors (*F* (1, 38) = 0,081 p>0.05, $\dot{\eta}^2$ =0,002) in the automatic condition but after exercise program the experimental group showed a lower score of errors (*F* (1, 38) = 78,114 p<0.0001, $\dot{\eta}^2$ =0,673) in the inhibition condition compared to control group.

In addition, Hayling ATT revealed a significant effect of training program in favor of experimental group (*F* (1, 38) =16,286 p<0.001, $\dot{\eta}^2$ =0,300).

DISCUSSION

In the present study, we have investigated the effects of recreational swimming exercise, on cognitive tasks assessing working memory, selective attention and inhibition in children diagnosed with ADHD. Analyses indicated positive enhancement in allocation of attentional resources, coupled with selective enhancement in stimulus classification , processing speed and in inhibitory control , following the swimming program (9). Further, acute exercise appears to have benefits for children with ADHD and induced facilitations on cognitive processes (35–38). Our results indicate that children with ADHD demonstrated an improvement in memory accuracy for the ROCF test.

It revealed the superiority of the experimental group in the cognitive elaboration of the ROCF after exercise.

At the end of the intervention, only the ROCF memory reproduction condition visibly differentiated in favor of the experimental group with a high level of delayed Memory accuracy (ES= 0.6) (39).

Significant effects were also revealed in the Hayling test specifically, children in the exercise group exhibited significant inhibition enhancement over time (ES = 0.3) whereas inhibition in children in the control group remained unchanged.

In the Stroop Test the exercise group presented better performance in Stroop Color-Word rather than Stroop Word and Stroop Color condition following recreational swimming program compared with controls. In general Stroop test appears as a measure of selective attention and cognitive inhibition or inhibition of a dominant response in favor of completing a required unusual task (39,40)information updating and monitoring ("Updating"; It is an appropriate neuropsychological task with moderate sensitivity to distinguish children with ADHD from normal children (35).

Our positive findings are in accordance with previous studies that demonstrated the beneficial effects of a physical activity program on response inhibition in children with ADHD (27,35,36). It suggest that motivating children with ADHD using swimming games may have positive effects on aspects of cognitive function and inhibitory control on ADHD children (41).

Many researchers have observed enhanced information processing, visual search and sustained attention in 10 children with ADHD compared with a similar-sized control group after participation in a 10-week physical exercise program (45 min, three times a week); For example Smith et al. (27) reported improved inhibitory control in 14 children at risk for ADHD after they engaged in an 8-week physical exercise program (30 min, five times a week). Hung et al. (42) and Piek et al. (43) find that improvement of motor skills have demonstrated an association with cognitive functions specially when the exercise sessions were designed to improve participant‘s attention and concentration.

In accordance with several previous research a recreational program based on games could provide harmonious development of body, intelligence and affectivity, it could be a real enhancer of the mental evolution of the child (44). Gaming could be an effective way to maximize performance in ADHD (7) and practitioners of a variety of theoretical persuasions use games in working with children. According to Koocher and D'Angelo (45), it was used in child therapy by a majority of clinicians, who stated that oriented games therapy remains the dominant and most enduring approach to child treatment (19).

At the end, if exercise may be essential in compensating cognitive function deficits especially inhibitory control observed in this clinical population (46), possible explanation may be proposed :

Firstly, the exercise benefit in inhibition may result in an individual's neuroelectric adjustment. Hillman et al. (47) results indicated larger P3 amplitude following acute exercise compared to baseline. Shorter P3 latency was observed during the baseline Eriksen flankers task for the neutral compared to the incompatible condition; an effect not found following the acute bout of exercise. These findings suggest that acute bouts of cardiovascular exercise affect neuroelectric processes underlying executive control through the increased allocation of neuroelectric resources and through changes in cognitive processing and stimulus classification speed.","DOI":"10.1016/S0167-8760(03 examined acute aerobic exercise on cognition using the Eriksen flanker task as well as event-related potential. Results indicated that following 30 min of treadmill exercise, college students showed a larger P3 amplitude and shorter P3 latency in incongruent stimulus compared with baseline and congruent stimulus. Because the amplitude and latency of P3 reflect the amounts of attention resources allocated and speed of stimulus evaluation and recognition processes, respectively, the results proposed that acute exercise that improves inhibition may be accompanied by changes in attention resource allocation and increased stimulus evaluation and recognition (35).

Secondly, exercise induced dopamine release as mentioned previously, and according to developpement dynamic theory (TDD) ADHD patients have revealed dysfunction in three cerebral zone and especially in dorsolateral prefrontal cortex and the orbitofrontal cortex of the prefrontal cortex (48) and these cortices have been linked to executive function, including the ability to maintain and set shifting (35).

Dysfunction of attention circuits in ADHD have been linked to dopamine activation (49). Dopamine is a type of neurotransmitter that regulates brain processes for movement. Tantillo et al. (50) determined that exercise was possibly beneficial for children with ADHD through changes in dopamine.

Limitations and Future Research

There are some limitations that should be addressed. First, our sample size is relatively small. In fact, sample recruitment and diagnosis is a main difficulty in this study. Sample size should be increased in future studies to have a more significant and generatively results in children with ADHD.

Second, this study includes only children with ADHD, it will be recommended to investigate the effect of the exercise intervention on normal children.

Finally, this study included males and females ADHD children, but the effect of the intervention on gender isn't examined. Previous studies were demonstrated that sex difference present a significant effect on cognitive tasks after exercise. Therefore, it will be so important to investigate sex difference effect on cognitive functions in ADHD children.

CONCLUSION

These findings demonstrate the positive enhancement of recreational swimming program on cognitive functions in Tunisian ADHD children after using adapted neuropsychological task and it appear promising for additional researches. The results suggested that exercise facilitate attention resource, memory and inhibitory control process. It can be used as alternative non-pharmacological treatment and a putative treatment for ADHD children and it can provide preliminary support for therapeutic interventions that can be used by researchers, parents, educators, and clinicians.

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