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Gymnastics Training Improves Executive and Sensorimotor Functions in Children with Developmental Coordination Disorder

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Abstract

Developmental Coordination Disorders occurs when development of motor skills has delay, or coordinated movement problems appears. Performance of children with impaired daily activities that require motor coordination is lower than expected by age and intelligence level, and that is not due to physical and psychological illness. The aim of this study was to investigate the possible effects of gymnastics trainings on executive and sensory - motor functions in children with Developmental Coordination Disorder from 8 to 10 years old in Tehran.

Materials and Methods: This research was a quasi-experimental study. Among all patients, 34 children 8-10 years old with Developmental Coordination Disorder in Tehran, that was visited by occupational therapy and rehabilitation clinic in Tehran, available and targeted to selected and randomly divided in two experimental (n=19) and control (n=15) groups. Research tools for screening were Raven intelligence test and the Developmental Coordination Disorder questionnaire. Also, Conner nerves - psychological questionnaire was used to assess dependent variables. Then, the experimental group received an eight-week program for gymnastics locomotor intervention. Statistical analysis was performed by using MANCOVA at significance level $P \leq 0.05$ by the SPSS16 software help.

Findings: Significant differences observed between control and experimental groups in all executive variables ($F = 492.454^a$, $P < = 0.05$) and sensory - motor ($F = 285.683^a$, $P < = 0.05$) functions.

Conclusions: The results showed that gymnastics trainings can improve executive and sensory - motor functions in children with Developmental Coordination Disorder. Therefore, it's recommended that nurseries and schools using gymnastic trainings can help to reduce the Developmental Coordination Disorder in children.

Keywords: Developmental Coordination Disorder, Executive functions, Sensory - motor functions, Gymnastics

Introduction

Motor development defined as "changes in motor behavior over the lifetime and the process of making these changes". People had been passed various periods of developmental with different rates, that depending on multiple effects of internal factors (biological, motivational, cognitive, and social and ...) and external factors. Children have some movement milestones during its growth like first crawl, sit and walk. Motor coordination is one of the abilities that people earn that by simultaneously interaction with multiple factors. Defect in one of these factors may be the reasons of retardation or delay in the normal process of coordination growth. Although, some children that had a natural appearance was weaker, when their performance of motor skills compared with other children in their age were. These children often suffer from lack of necessary motor skills to perform daily physical activities [1]. According to the latest edition of Diagnostic and Statistical Manual of America Psychiatric, this problem was known as developmental coordination disorder (DCD), which is defined as: Developmental Coordination Disorder occurs when motor skills development has delay, or occurred coordinated movement problems that resulted in performing tasks with error everyday [2]. These people have not problems only in movement, but secondary effects caused by these disorders are the reasons to appearance behavioral and social consequences of being uncomfortable. Hence, in recent years, these abnormalities lead to further investigates in the nature known of it and those handled of more effective

intervention in these cases. Due to the problems of children with developmental coordination, disorder has been suggested that locomotor activity may improve cognitive and motor functions of these babies [3]. Thus, motor and exercise interventions can improve a large proportion of motor deficits in these children, early treatment can prevent the next consequences of this disorder, and the public expenditure; these children as well as other peers can easily deal with routine life and schooling.

Executive function is a term generally holds all complex cognitive processes that are necessary in performing new or difficult goal – directed homework [4] and includes ability to recess (delay) or inhibition of specific responses and subsequently planned action sequences and maintained a mental representation of the working memory tasks [5]. Executive functions are very important in purposeful motion, in other words in motion control [6]. Thus, existence of substantial difficulties in motor coordination, writing, fine motor, gross motor and existence of failure in perception of time raises the possibility that maybe children with developmental coordination disorder, as well as children with attention deficit disorder/ hyperactivity disorder (combined type) have problems in executive functions. Sensory tasks are depended on sensory systems that weight uses them as sources for getting information from the environment and provide appropriate response and successful adaptation to environmental demands. Human sensory system provides Passage for the brain to receive and interpret stimuli and offering an answer [7]. According to these findings, many areas of developmental disorders in children are associated with Developmental Coordination Disorder in other domains [4,8]. According to some research results, abnormal sensory processing may limit participating in targeted activities such as playing with other people and participating in social activities [9,10]. Comparison Children with movement disorders with normal children indicated that they are more inclined to participate in less diverse activities and motor activities without the fuss and less likely to participate in social activities, especially spontaneous activities [11,12].

According to studies, children with developmental coordination disorder have problems at some meta-cognitive functions, such as mental representation and visualization [2,13], purpose-based movements, setting the scroll speed [14] and new movements [15]. In general, previous studies focused fundamentally on identifying characteristics of children with developmental coordination disorder, and less emphasis on review of underlying mechanisms of etiological neuro-cognitive processes [16].

This Research has shown that cognitive and motor interventions are effective for improving cognitive- motion functions in children with Developmental Coordination Disorder [17].

Most children with DCD do not participate in physical activity. This will cause parents and educators believe mistakenly that these children do not have the ability to perform physical activity, while these children do not participate in activities just for the lack of motivation and laziness [18]. If these children do physical activity poorly than their peers, they become disillusioned very quickly and lose their motivation, which caused a retreat of more exercises. The retreat of activity may ultimately affect children's physical and mental health. Children with DCD are too weak to understand the rules and strategies of the game and in competitive games that need a lot of thinking and coordination. They suffer by movements that require eye and hand coordination, especially in situations where they must respond to moving objects in their environment. Many children with DCD are suffering from muscle stiffness. Due to lack of physical activity. For example, they tend to keep their bodies motionless to maintain posture and balance, instead of doing physical exercises and they keep their joint fixed, instead of moving the elbows, knees, hips and flexible joints. Keeping joints fixed is a cause of vibration in the muscles and the body of the child. This is what makes to show them so awkward. While organized sports activities causes the child to be troubled, there are many activities that children with DCD can have a successful performance, including moderate exercise, like swimming, skating, cycling and skiing. The main purpose of participate in physical activities among children with DCD is creating incentive for them and enhance their ability to participate in physical activity and prevent secondary consequences associated with childhood inactivity. It should be noted that children with DCD might need more time than other children of the same age to increase their skill level. Therefore, they require support and more trainings that are individual. Being exposed to enjoyable physical activities encourages younger children to be more involved, and will causes to increase health and fitness. Many useful activities for children with DCD at early ages perform to enhance body performance in flexibility, balance, strength and endurance. However, these activities encourage young children with DCD; these activities may cause lack of motivation in older children to DCD. Thus, older children with DCD need actions that are more difficult. Some Skills that required keeping balance should be taught to children at different stages. Examples of these types of activities are including martial arts, gymnastics and physio ball [18].

Gymnastics is a sport in which exhibit movements requiring strength, body flexibility, agility, organ balance and coordination. Gymnastics at recreational level is very popular, particularly as physical flexibility trainings. Gymnastics is a sport that will orchestrate the body's movements based on a harmony. In fact, gymnastics can be considered as an art. Due to the proportionality between the Physical and emotional needs for children with developmental coordination disorder and the effects of gymnastics training on individuals, it seems to perform these exercises to be effective in the field of executive and sensory motor functions. In recent years, Ministry of Education has special attention to perform gymnastics in primary schools, especially in the second grade of elementary. Therefore, a law is approved to implement this exercise at schools. However, in our country, according to research studies, research on the effects of gymnastic exercise on executive and sensory - motor functions have not been conducted in children with Developmental Coordination Disorder. Therefore, the purpose of this research is study the effects of gymnastics trainings on executive and sensory - motor functions in children with Developmental Coordination Disorder. Researcher is seeking answers the questions that whether do the executive trainings effect on executive functions in children with Developmental Coordination Disorder. Whether do the executive trainings effect on sensory - motor functions in children with Developmental Coordination Disorder?

Materials and Methods

This study was semi-experimental, cross-sectional and having the functional results on 34 boys with developmental coordination disorder aged 8 to 10 years of age. The sample was selected availability and purposively, from children with Developmental Coordination Disorder society in 2014 that were referred to some occupational therapy and rehabilitation clinics in Tehran (These numbers were maintained to end and was not observed drop test). For entry into the study, the children's IQ was measured by the Raven's IQ test and children in normal area were examined by using the Developmental Coordination Disorder Questionnaire and their scores below 47 and they had no history of heart disease or musculoskeletal injuries were selected for study. Then, they were assigned 19 children in the experimental group and 15 children in the control group randomly.

Measuring tools

Tools that used to measure various parameters in this study are including:

Raven's Colored Progressive Matrices IQ test

This test is one of the nonverbal intelligence assessment tools that used to measure fluid intelligence. The short form for this test consists of 36 questions that designed coloring for children 5 to 11 years and mentally or physically retarded people. The correlation coefficient of this test that was obtained by Stanford Binet and Wechsler's test is between 0.40 to 0.75 and its reliability is 0.70 to 0.90 for older ages and at for younger age is a little lower.

Developmental Coordination Disorder Questionnaire

Growth coordinate questionnaire is a scale of parental awareness that helps to detect irregularities and Child Development Coordination Disorder. In the Questionnaire, parents want to compare their child's motor function than their peers by using a five-point Likert scale. This standard way is to measure child's coordination activities in daily practices. As reported in 2001, a high level of reliability and validity of this questionnaire have been reported. This new version is suitable for children ages 15-5 years. The questionnaire consists of 15 groups that each group is divided into three distinct factors. The first factor includes items related to motor control and used at the time of the child movement or any other object. The second factor contains quantities of handwriting and great movement, and the third factor is related to the overall organization.

Canners's neuropsychological test

This test was made by Canners in 2004 to assess neuropsychological skills for 5 to 12 years old children such as executive functions (problem solving functions, planning and behavior – emotional organizing), attention, memory and learning, sensory – motor functions, visual- Spatial processing and academic performance in four spectra (don't observer to Severe). Validity of Canners's forms is achieved by using factor analysis method; and discriminant validity of them is endorsed with statistical analysis of the ability of the questionnaire to distinguish them from ordinary people suffering from ADHD and other clinical groups strongly [19].

Research performing method

Doctor ordered allowing exercise, after collecting demographic data (age, height and weight) and examination by him. Before the performing of training program, explained trials to the parents and obtained written consent. Then the children were divided into control and experimental groups by random. Later, Canners's neuropsychological questionnaire provided for their parents to completion. After pretesting from trials, the test group began to doing gymnastic exercises for eight weeks (three one-hour sessions per week). Exercises directed under the guidance of a coach gymnastics in the morning. All used exercises in this study were selected from the gymnast design of the second-grade students of elementary that the suitability of these exercises had confirmed by physical and emotional state doctor of children with Developmental Coordination Disorder. All training programs were performed on the mat, and were taken necessary measures to protect the health of children.

Each session was divided into three parts. The first step was to warm up about 15 - 10 (min) with a variety of walking, running, jumping, hopping, the imitation – similes movements and stretching and flexibility movements of the upper to the lower, stretch upward, sides, front, low on right foot, left foot, middle, legs inner muscles stretching, posterior muscles or back of the feet, ankles and knees warm and spinning, blades spinning and push them back and forth. The second step of gymnastic exercises was performed about 40-35 min. Exercises divided into 15 parts. The instructor shows each exercise and then repeats verbally by the help of a child's learning to ensure the accuracy and then he/she monitors the implementation of the children and gives them the necessary guidance. In addition, all movements were taught to slow children and controlled to improve coordination and facilitating the children learning process. Trainings were selected in order to children acquaintance with the basics of gymnastics from simple gestures exercises initially. Intensity and complexity of movements were increased with the passage of time and advancement of children in early trainings and reform movements. The forward process of movements was a stand stationary exercise to jumping movements. In addition, a rest period of 30 seconds was considered between each exercise and next exercise (Tables 1 and 2).

The third session was performed at the end of each session about 10 min, which consists of low-intensity muscle stretching, holding each stretch for 10 seconds, then return the body to rest. Both groups were assessed by Canners's neuropsychological questionnaire for checking the effect of exercise training after the end of them.

Analysis of findings method

Kolmogorov-Smirnov test was used to check the data normality for statistical analysis. In addition, Levine test was investigated for variance homogeneity and then the multivariate covariance test was used to comparing them.

Findings

In this section, we first describe the physical characteristics and IQ, the average and criterion deviation between experimental and control groups about executive and sensorimotor functions; and then, the hypotheses test data analyzed by using MANCOVA

Table 1. Conducted exercises in the eight-week training period.

Exercise session	Activity
1st session	Skills (standing, walking and running properly, the hand muscle strengthening)
2nd session	Skills (sequential jump and longitudinal jump)
3th session	Skills (flexibility, rabbit jumping and angle sitting)
4th and 5th session	Skills (standing right, feet together cradle and cradle introduction)
6th session	Skills (integration of body and skating rink or fergon)
7th session	Skills (swimming, throwing legs back and forth and fish jumping)
8th session	Skills (angel on the knees, open leg pose and bend hand swimming
9th and 10th session	Skills (half away jump, leg throwing like scissors and rabbit jumps)
11th and 12th session	Skills (candle, open leg cradle and abdominal and back muscles strengthening)
13th session	Skills (arch back with legs open, balance preliminaries and shoulder flexible)
14th and 15th session	Skills (right foot cradle, arch back backwards and squat)
16th and 17th session	Skills (rotating body as rollback, open legs and angle sitting)
18th and 19th session	Skills (forward roll, bridge and walled balance)
20th and 21th and 22th session	Skills (balance preliminaries, legs throwing and carousels)
23th and 24th session	Skills (tripod balance and angel)

Table 2. Statistical indicators related to age, height and weight of the trials.

	Number	Minimum	Maximum	Mean	SD
Age	34	8	10	8.91	0.90
Stature	34	113	143	129.5	9.20
Weight	34	20	39	27.9	5.39

Table 3. Frequency distribution of IQ scores in the experimental group and control.

Groups	Intelligence	F	P
Experiment	90 To 100	8	0.42
	110 To 100	11	0.58
	Top 110	0	0.0
	Total	19	0100
Control	90 To 100	5	0.30
	100 To 110	9	0.60
	Top 110	1	0.10
	Total	15	0.100

test at significance level of α=0.05 and by help of SPSS 16 software (Tables 3 and 4).

Checking of descriptive indicators of executive functions shows the effect of movement gymnastic on the performance of the experimental group. Checks were made on the statistical variables after the test show the reducing deficits and problems during the testing, so that problem average relevant solving Posts / Planning / Organizing is reduced from 2.4857 to 1.3835 and the behavior - Emotional organization is dropped from 2.5524 to 1.2782. This implies the effectiveness of such movement on disorders. In addition, descriptive indicators of sensory – motor function show the effect of gymnastics movements on performance of the experimental group. Checks were made on the statistical variables after the test show the reducing deficits and problems during the testing, so that problem average relevant motor function is reduced from 2.4857 to 1.3835. Also, touch

Table 4. Statistical indicators related to executive and sensory - motor functions at pre-test and post-test.

Variable		Type of test	Mean	SD	N
Executive Function	Problem solving / planning / organizing	Pretest	2.4857	0.1693	19
		Posttest	1.3835	0.23354	19
		Pretest	2.5673	0.17024	15
		Posttest	2.6745	0.1781	15
	Organizational behavior - emotional	Pretest	2.5524	0.13087	19
		Posttest	1.2782	0.12126	19
		Pretest	2.5524	0.13165	15
		Posttest	2.4824	0.13278	15
Sensory functions - motion	Motor function	Pretest	2.9333	0.16275	19
		Posttest	1.7697	0.16803	19
		Pretest	2.8654	0.16342	15
		Posttest	2.8523	0.15981	15
	Tactile functions / sniff	Pretest	3.4833	0.31997	19
		Posttest	1.6974	0.11314	19
		Pretest	3.5121	0.32151	15
		Posttest	3.4972	0.31231	15
	Visual function	Pretest	2.5111	0.24774	19
		Posttest	1.2281	0.22368	19
		Pretest	2.6821	0.25432	15
		Posttest	2.6322	0.23241	15
	Performance Hearing	Pretest	2.6167	0.38807	19
		Posttest	1.4474	0.27104	19
		Pretest	2.7431	0.38911	15
		Posttest	2.6765	0.38642	15

Table 5. Results of multivariate covariance test (MANCOVA), the difference between the two groups in the domains of executive and sensory – motor functions tests

Statistical Indicators Source	Wilks lambda	F	Significance level	Eta 2
Group	0.029	492.454a	0.000	1.000

/ smell functions from 3.4833 to 1.6974, visual performance are dropped in the range of 2.5111 to 1.2281 and acoustic performance was in the range of 2.6167 to 1.4474. This implies the effectiveness of such movement on disorders.

The information of table 5 represents the results of multivariate covariance test (MANCOVA) and shows the difference between the two groups in the domains of executive and sensory – motor functions tests. Based on these results, there is a significant difference ($p < 0.05$) between these groups in the domain of executive functions. In other words, the differences between the two group scores express that early exercising interventions effect to executive function improving in children with Developmental Coordination Disorder. In view of the square of the beta, we can say that almost all of these changes or improvements are due to interference effects. Also based on these results, there is a significant difference ($p < 0.05$) between the groups in the domains of sensory – motor functions. In other words, the differences between the two group scores express that early exercising interventions effect to executive function improving in children with Developmental Coordination Disorder. In view of the square of the beta, we can say that almost all of these changes or improvements are due to interference effects.

According to pre-test scores as the same diffraction variables (auxiliary), the table 6 results show: the difference between the

Table 6. Results of multivariate covariance analytical test (MANCOVA), the difference between the two groups in the domains of executive and sensory – motor functions subtests.

Resource dependent variable Total Statistical Indicators		Squares	df	mean square	F	significantly	Eta
Hmprash variables	Problem solving / planning / organizing	0.013	1	0.013	0.339	0.565	0.087
	Organizational behavior - emotional	0.112	1	0.112	8.127	0.008	0.788
Group	Problem solving / planning / organizing	9.11	1	9.11	242.423	0	1
	Organizational behavior - emotional	13.348	1	13.348	970.98	0	1
Hmprash variables	Motor function	0.06	1	0.06	2.893	0.1	0.376
	Tactile functions / sniff	0.191	1	0.191	1.268	0.27	0.193
	Visual function	0.027	1	0.027	0.522	0.476	0.107
	Performance Hearing	0.004	1	0.004	0.045	0.834	0.055
	Motor function	11.033	1	11.033	528.471	0	1
	Tactile functions / sniff	25.984	1	25.984	172.628	0	1
	Visual function	12.744	1	12.744	250.516	0	1
Group	Performance Hearing	11.474	1	11.474	120.475	0	1

performance of intervention group and control group in the domains of executive functions subtests is at the $p < 0.05$ level. In other words, the differences between these two group scores express that early educational interventions effect to executive functions subtests, including solving Posts / Planning / Organizing (The sum of squares of 9.110, F. 242.423 and significant at the 0.00 means a significant difference between experimental groups.) and emotional- behavior organization Organizing (The sum of squares of 13.348, F. 970.980 and significant at the 0.00 means a significant difference between experimental and control groups.). Also the results of this table show, according to pre-test scores as same diffraction variables (auxiliary): the difference between the performance of intervention and control groups in the domains of sensory – motor functions subtests is less than 5 percent. In other words, the differences between the two group scores express that early educational interventions effect to sensory – motor functions subtests, including movement functions, touch / smell functions, visual performance and acoustic performance.

Discussion

Present study reviews the effects of gymnastics trainings on executive and Sensory - motor functions improving for children with Developmental Coordination Disorder. Analyzing the research findings revealed significant differences between experimental and control groups in measured variables after doing a period of gymnastic exercises. This difference reflects the effect of gymnastics training. Before we get into the discussion of research, it is essential to note that unfortunately, researching on exercise interventions and movement programs on children performance with Developmental Coordination Disorder is very limited and present study is one of the handful researches on movement interventions with gymnastic exercises, according to the research findings and the positive effects of them on cognitive and motor functions in children with Developmental Coordination Disorder, we hope that it will be suitable for future researches. So, explain and discuss about the research findings cite to limited similar researches. Among the problems that children with developmental coordination disorder face to them are defect in executive and sensory - motor functions (Ozuna, 1995). If these children can be helped by exercise can be hoped to treat at an early age and at the same time as are initial or reduce the severity of their disorder and encounter fewer problems in the future.

The first hypothesis of this study was the gymnastic exercises have influence in executive functions in children 8 to 10 years with developmental coordination disorder in Tehran. The results showed that the gymnastic trainings effect on executive functions in children with Developmental Coordination Disorder significantly. These research results are compatible with Tsai (2009) and Tesya et al. (2012). In addition, Tsya (2012) saw an improvement in executive function in children by practicing soccer skills. Note that in practice, people need to organize their own behavior, be able to reform the process for skills and decision to move, thus, it appears that exercise can regulate children's behavior, and improve their administrative functions.

The second hypothesis of this study was the gymnastic exercises have influence in sensory - motor functions in children 8 to 10 years with developmental coordination disorder in Tehran. As noted above, the results showed that 8 weeks gymnastics training on children with developmental coordination disorder was had on significant impact. The results of this study are compatible with the findings of Tsai (2009) and Rintala et al. (1998) [3,20]. As However, Tsai (2009) during a ping-pong practice was investigated the impact of these exercises on the extent of executive, cognitive and motor function in children with developmental coordination disorder. This study showed that exercise interventions can improve executive, cognitive and motor function in children with developmental coordination [20]. Also Rintala et al (1998) were examined the effects of motor-mental programs on movement skills in children with developmental coordination disorder; And concluded that physical-mental exercise improves movement skills, in particular controlled activities [3]. So we can conclude that although children with developmental coordination disorder are weak than normal children in sensory – motion functions, and also have problem in some movement skills than their peers like driving a tricycle, get off the ball, even daily tasks like taking a spoon and fork, close button dress [21], but what is significant and important is effect of exercise on sensory – motion functions that can help them to overcome learning problems partially.

Suggestions

Due to the variety of equipment in gymnastics, it is

recommended that future research should use other gymnastics equipment such as treadmills for more knowing of its effects. Participants in the study were selected from boys. Therefore, it can be used of the girl child in future studies. In addition, future studies should use larger samples to generalize the findings.

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