

ORIGINAL RESEARCH ARTICLE

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Efficacy of physical activities on children with juvenile idiopathic arthritis: a randomized controlled trial

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Abstract

Background: Juvenile idiopathic arthritis (JIA) is one of the serious chronic rheumatic disorders in children and adolescents which results in less physical activities and restlessness hours than their peer. The study aims to assess the efficacy of physical fitness training exercises on aerobic capacity and muscular strength of children with JIA. Sixty-five children with JIA were included in the study, out of a total of 70 children who were screened for eligibility. Children were randomized to a control group ($n = 32$) who received hot packs, transcutaneous electrical nerve stimulation (TENS), and strengthening exercises, or a study group ($n = 33$) who received a physical fitness training program (hydrotherapy pool exercises, bicycle ergometer, and treadmill apparatus) in addition to what had been given to the control group. Both groups were engaged in a training program for 12 consecutive weeks for three times per week. Evaluation was done pre- and post-interventions included: peak oxygen uptake (Vo_2 peak) during an incremental treadmill test and muscle strength assessed by isokinetic dynamometer.

Results: The current study showed that there were significant differences between pre- and post-interventions in both groups ($P < 0.05$). Comparing the two groups, there were statistically significant differences between children in both groups in favor of the study group ($P < 0.05$).

Conclusions: Physical fitness exercise training resulted in improved aerobic capacity and muscle strength of children with JIA. The obtained results suggested that children with arthritis could participate in formal exercise testing and structural physical fitness program.

Trial registration: PACTR, PACTR201907504136763. Registered on May 21, 2019. Retrospectively registered, <https://pactr.samrc.ac.za/TrialDisplay.aspx?TrialID = 8150>.

Keywords: Juvenile idiopathic arthritis, Fitness testing, Peak oxygen consumption, Isokinetic testing

Background

Juvenile idiopathic arthritis (JIA) is one of the common childhood disorders that affects around one in 1000 children [1]. It is diagnosed early under the age of 16 with arthritis in one or more joints and persists for at least 6 weeks [2]. The main clinical presentations are lack of joint movement, pain, and swelling of the involved

joints. The course of JIA may become more intense and continues throughout adulthood increasing cardiovascular risk, osteoporosis, and obesity in this period of lifespan [3, 4]. Physical deconditioning is seen in children with JIA as a consequence of weak musculature, joint pain, contracture, and lower peak oxygen uptake (Vo_2 peak) [5, 6].

Abdul-Sattar et al. [7] conducted a study on Egyptian children and adolescent patients of JIA with age more than 7 years and duration of disease exceeds 1 year to explore the factors that may contribute to increase the rate of absenteeism and lack of functioning at school.

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They found that these factors are the amount of inflammation present, the level of functional disability, and psychological deconditioning.

Physical therapy was instituted for patients with JIA to promote lifetime physical activity through controlling pain and inflammation, maintaining range of motion (ROM), and muscle strength that play important role in increasing joint stability [8].

It was found that patients got more improvements in their functional abilities than those who live a standard life care if they joined exercises in a form of aerobic conditioning, strengthening, and sport activities [9]. No previous studies investigated the effect of a physical fitness training program using validated measures on adolescents suffering from JIA. Therefore, this study was conducted to assess the efficacy of physical activities on the aerobic capacity and muscle strength of children with JIA.

Methods

Subjects

Seventy children with JIA were recruited from a pediatric outpatient clinic and assessed for their eligibility to participate in the study. All participants' ages ranged from 8 to 12 years. By using a number generating table, children were randomly allocated to a study or a control group ($n = 35$ in each group). Three children from the study group and two from the control group did not continue the exercise program and withdrew from the study. All participants were involved in a training program for 12 consecutive weeks for three times per week. The study extended from January 2019 to April 2019. The JIA children were enrolled according to the following:

A- Inclusion criteria:

- 1) Medical diagnosis of JIA was conducted by a pediatric rheumatologist in agreement of the criteria of International League Against Rheumatology [10].
- 2) Children were able to communicate verbally and obey commands and instructions and cooperate with testing and training protocols.

B- Exclusion criteria:

- 1) Children do not take drugs regularly and complained from severe pain according to verbal pain intensity scale [11].
- 2) Children had cardiac, pulmonary, or metabolic disease.
- 3) Children had active features of systemic arthritis.
- 4) Children had fixed deformity (bony or soft tissue contracture) of both upper and lower limbs.
- 5) Children had previous surgical interventions which may include soft tissues release, synovectomies, or arthrodesis.

- 6) Children had visual or auditory defects.

Instrumentation

For evaluation

- 1- Weight and height scale: to calculate the body mass index were measured using an electronic scale (Human body Element Analyzer System, Seoul, Korea)
- 2- Tape measurement to assess the degree of effusion of the affected joints
- 3- Digital goniometer (model 12-1027, version 7-08, Fabrication Enterprises, Inc., White Plains, NY, USA) to measure the ROM of the shoulder, elbow, wrist, hip, knee, and ankle joints
- 4- Verbal rating scale for pain to assess pain intensity [11]
- 5- Cardiopulmonary function test via electrocardiograph (ECG) Nihon Kohden Cardiofax Engospirometry with integrated stress—ECG (Model: ISSOK, manufactured by Nihon-Kohden, Japan). Engospirometry is the most comprehensive test of cardiopulmonary analysis. The peak oxygen uptake (Vo_2 peak) was measured during instrumental treadmill exercise testing. The ECG was used first at rest and during activity to record heart rate and blood pressure.
- 6- Isoforce isokinetic dynamometer (TUR GmbH, Berlin, Germany): was used to assess the isokinetic muscular performance of the knee flexors and extensors

For intervention

- 1- Hydrotherapy pool, a large swimming pool at the outpatient clinic supplied with suspended chair and plinth, and sidebars. A single-use life jacket was utilized by each child to be safe in the pool.
- 2- Bicycle ergometer (TUV/GS:En 957-5, Class A, Taiwan). It is an electronically braked ergometer with a screen to check the child's heart rate and helps the therapist to control exercise intensity.
- 3- Treadmill apparatus (Biodex Gait Trainer 2TM, Biodex Medical Systems, Inc., Shirley, NY, USA) was used for fitness training.
- 4- Soft weight (exercise balls) and thera-band (elastic band) were used to provide resistance.

Interventions

Procedures for physical intervention for the control group

Moist heat Hot packs (40–45 °C) with suitable size to contour the affected joint were applied for 20 min to improve the circulation and decrease the inflammation [12].

Transcutaneous electrical nerve stimulation (TENS)

Gymna Uniphy (Pasweg 6A, 3740 Bilzen, Belgium) using a frequency of 100 Hz for 30 min on the affected joints was applied in the most relaxed position for each child aiming to relieve pain [13].

Strength exercises Strength training exercise involved progressive upper and lower limbs in a form of static and dynamic exercises using exercise balls, soft weights, thera-bands, and elastic bands. Exercises concentrated on the shoulder flexors, abductors, external rotators, elbow flexors and extensors, wrist flexors and extensors, hip flexors and extensors, abductors and adductors, knee flexors and extensors, ankle dorsi and plantar flexors, abdominal muscles, and back muscles. The intensity of exercise was determined during habituation testing session according to the maximum weight (a repetition maximum (1 RM)) that the child can lift through the available ROM just for one time. In weeks 1–6, the focus was on a 0.25 RM for 10 repetitions. In weeks 7–12, the focus was on a 0.5 RM for 20 repetitions [14].

Procedures for physical intervention for the study group

In addition to the treatment received by the control group, the following interventions were given to the study group:

Hydrotherapy session A well expert physical therapist performed the aquatic exercises. Before starting the program, the following factors were settled: water temperature (32–34 °C), room temperature (20–22 °C), and air temperature of the pool area was 25 °C.

The program included warming up activities consisted of ROM and light stretching exercises to relax stiff joints and get the children ready for further exercises. A structured pool program extended for 60 min in the form of jogging, marching, running, and swimming with floating foams for assistance [15, 16].

At the end of the pool session, the child got out the pool, took a neutral shower (25 °C), then waited for 15 min in the changing room (22 °C) and drunk a juice before participation in the land-based training program.

Bicycle ergometer training

- The child got explanation of the goals and procedures before pedaling.
- Any restricted clothes were removed to facilitate the performance of the exercise.
- The child was asked to sit erect on the seat of the bicycle grasping the bicycle handles and the feet strapped with the pedals.
- The bicycle was settled on a climb steady program in which the resistance increased gradually according to muscular force.

- The speed was settled on that of the habituation session then continued at 60–100 rpm.
- The child was asked to complete pedaling on the bicycle ergometer for 8 min in week 1, with the duration increases by 2 min each week until week 6. Then at the weeks 6–12, the program lasted for 20 min [17].

Treadmill training

- The goals of the exercise and the procedure were made clear to the child before starting the treadmill training.
- Any restricted clothes were removed to allow walking without difficulty. The child was asked to firmly grasp the treadmill bars of by both hands and keep looking forward.
- The initial speed and slope were determined at the habituation session. Then the speed kept between 1.5 and 3 km/h.
- The child was instructed to keep walking on the treadmill for 8 min in week 1, with the duration increased by 2 min each week until week 6. At the weeks 6 to 12, the program lasted for 20 min [18].

Outcome measures

- 1- Cardiopulmonary capacity testing was done using engospirometry with integrated stress—ECG. The test was carried on an anticipation of volitional fatigue regardless verbal encouragement [19]. This procedure has been established as a reliable test in previous studies [20, 21]. The O₂ uptake and Co₂ production were analyzed. The test room temperature was fixed at 20–28 °C and 40% relative humidity of air to decrease the thermal stress. The children were instructed to have a light breakfast for 2 h prior the exercise testing.
- 2- Isokinetic dynamometer
 - i-. Testing muscle performance of knee extension and flexion

Each subject was tested in an erect posture while sitting on the dynamometer with his/her hip and knee flexed 90°. The child was strapped to the seat by a wide belt that held to the pelvis, by chest straps, and by a horizontal strap over the middle third of the thigh just above the knee to prevent any extra movements or substitutions that would affect the measurements. All subjects performed a preliminary test to be familiarized with the equipment and testing protocol. The testing procedure consisted of 10 knee extension and flexion

repetitions for each lower extremity at slow regular speed (60°/s) and at angular speed (120°/s).

- ii-. Testing the muscular performance of wrist extension and flexion

Each child was tested with the back fully supported in the seated position. The child was strapped to the seat with a wide belt that held the pelvis and by a chest strap and a horizontal strap just below the elbow joint to prevent any substitutions that would affect the measurements. The child's forearm was pronated because a greater mean torque can be produced than in supination. All subjects performed preliminary tests to familiarize them with the equipment and testing protocol. Peak wrist extension and flexion torques were recorded [15]. The testing procedure consisted of 10 wrist extension and flexion repetitions for each hand at slow angular speed (60°/s) and at fast angular speed (120°/s) [22, 23].

Sample size calculation

The sample size was calculated using the G*Power software (version 3.1.9.4; University Kiel, Germany). Calculation of means and standard deviation were obtained from a pilot study included 10 patients with JIA who underwent similar intervention of the study ($n = 5$) and control ($n = 5$) groups for the same period using the mean (SD) of Vo_2 peak. Standardized mean difference effect size (d) of the difference in Vo_2 peak was calculated ($d = 0.95$); power of 95% and $\alpha = 0.05$ created a sample of 30 individuals for each group. Thus, the study required 35 individuals in each group to account for the dropout rates of 15%.

Data analysis

Statistical analysis was computed using SPSS for Windows, version 20 (SPSS Inc., Chicago, IL, USA). Chi-square and independent t tests were utilized for data analysis of the participants' characteristics. Data were showed as mean \pm standard deviation (SD). Normality test of data using Shapiro-Wilk test was used. A one-way multivariate analysis of variance (MANOVA) was used to compare the tested variables between groups. The significant level was set at $P < 0.05$.

Results

The gathered data represent the statistical analysis of peak oxygen uptake, peak torque of knee extensors and flexors of both lower limbs, and peak torque of wrist extensors and flexors of both upper limbs during the concentric contraction mode.

Subjects' characteristics of both groups

Sixty-five children with JIA participated in the current study. The data collected from the study group ($n = 32$) and the control group ($n = 33$) pre- and post-interventions. Shapiro-Wilk test revealed normality of data collected ($P > 0.05$). No statistically significant differences were detected between both groups regarding mean values of age, height, weight, and body mass index (BMI) as shown in Table 1.

Cardiopulmonary capacity testing

Comparison of pre-intervention Vo_2 peak means of both groups revealed that there were no statistically significant differences between them ($P < 0.05$). A significant increase in the means of Vo_2 peak was found in the study and control groups posttreatment ($P = 0.001$, 0.01 respectively). Moreover, a significant difference was detected between both groups post-intervention with remarkable improvement in the study group ($P = 0.014$) as shown in Table 2.

Muscle performance testing using the isokinetic dynamometer

In comparison of pre-intervention values of peak torque of knee extensors and flexors, and peak torque of wrist extensors and flexors, there were no statistically significant differences of means between both groups ($P < 0.05$). However, the both groups showed improvement post-intervention ($P < 0.05$). The comparison between the mean values of the muscles' torques post-intervention revealed that there were significant differences ($P < 0.05$) between both groups in favor of the study group as seen in Tables 3 and 4.

Discussion

It was established that JIA leads to physical deconditioning and low quality of life experience [7, 17, 18]. This study attempted to test the hypothesis that it is acceptable for children with JIA to participate in physical training program and that the designed program might improve the physical fitness and life satisfaction of children with arthritis.

The pre-intervention Vo_2 peak mean values of participants indicated that those children had less cardiopulmonary exercise capacity compared to healthy peers [6, 24–26]. Also, the isokinetic muscle performance for the knee and wrist joints of the tested groups indicated that those children have musculoskeletal changes, as engaged joints are habitually kept in a comfort flexion position; these lead to delayed neuromuscular development, muscular weakness, ligamentous laxity, and generalized or localized growth disturbances [27].

According to the World Health Organization (WHO), activity limitations and participation restrictions in life

Table 1 Subjects' characteristics of both groups (placed after line 205)

General characteristics	Study group (n = 32)	Control group (n = 33)	P value
Sex ^a (M:F)	15:17	15:18	0.908
Age ^b (years)	10.13 (1.3)	9.5 (1.4)	0.069
Weight ^b (kg)	29.7 (2.4)	28.98 (2.3)	0.221
Height ^b (cm)	135.33 (4.53)	134.49 (3.74)	0.417
BMI ^b (kg/m ²)	16.21 (1.2)	15.82 (1.7)	0.29

Values indicated mean (standard deviation). Significant level was set at $P < 0.05$

^a χ^2 test

^bIndependent t test

situations are included in the definition of disability [28]. Previously, Jasso et al. [29] compared the physical work capacity of children with JIA as determined by measurement of maximal oxygen uptake with that of children without JIA. Children with JIA were found to be significantly less fit than their age-matched controls. They concluded that the amount of physical work that children with JIA are able to accomplish is related to the severity of their articular disease. This research also established that children with JIA have a problem in maintaining normal levels of physical fitness.

The post-intervention results of the treated groups revealed significant improvement in mean values of the measured outcomes including the following: peak oxygen uptake, peak torque of knee extensors and flexors of both lower limbs during the concentric contraction mode, and peak torque of wrist extensors and flexors of both upper limbs during the concentric contraction mode too. The application of hot packs and TENS before involving in the strengthening exercises helped the children to be more relaxed and not to fear from participating in the exercises as they both decrease the pain and the inflammation [12, 13].

Although the study group showed more improvement, these improved results may be attributed to the effect of water exercise as buoyancy of water makes it a favorable choice for patients with muscular and joint disease. This comes in agreement with Brawley and Culos-Reed [30] who reported that patients with arthritis benefited from aquatic exercises as the pain decreased, the muscle strength increased, the joint ROM improved, and the aerobic capacity is raised.

Table 2 Comparison of Vo_2 peak pre- and post-intervention within and between both groups (placed after line 211)

Vo_2 peak (ml/kg/min)	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	P value
Study group	29.41 (4.67)	34.98 (3.23)	0.001*
Control group	28.25 (3.72)	32.64 (4.22)	0.01*
P value	0.271	0.014*	

SD standard deviation, MD mean difference, P value probability level

*Significant

Table 3 Comparison of peak torque of knee extensors and flexors pre- and post-intervention within and between both groups (placed after line 218)

Peak torque (Nm)	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	P value
Knee extensors at 60°/s				
Right	Study	41.93 (2.88)	64.7 (4.16)	0.0001*
	Control	42.28 (3.41)	58.5 (5.45)	< 0.001*
P value		0.656	< 0.001*	
Left	Study	40.8 (2.26)	63.8 (4.5)	0.0001*
	Control	41.34 (3.38)	57.76 (5.84)	< 0.001*
P value		0.453	< 0.0001*	
Knee extensors at 120°/s				
Right	Study	35.7 (2.4)	48.9 (2.74)	0.0001*
	Control	34.84 (3.9)	45.76 (3.43)	< 0.001*
P value		0.29	0.0001*	
Left	Study	35.4 (2.3)	48.4 (2.9)	0.0001*
	Control	35.89 (3.14)	45.61 (3.27)	< 0.001*
P value		0.476	0.0006*	
Knee flexors at 60°/s				
Right	Study	19.26 (1.7)	36.83 (2.9)	0.0001*
	Control	20.18 (2.2)	34.52 (3.4)	< 0.0001*
P value		0.064	0.004*	
Left	Study	18.9 (1.6)	35.9 (2.6)	0.0001*
	Control	17.84 (2.74)	33.46 (3.2)	< 0.0001*
P value		0.062	0.001*	
Knee flexors at 120°/s				
Right	Study	16.5 (1.4)	31.7 (2.4)	0.0001*
	Control	16.27 (2.1)	29.63 (2.7)	< 0.0001*
P value		0.606	0.001*	
Left	Study	16.4 (1.2)	30.8 (2.1)	0.0001*
	Control	15.86 (1.7)	29.12 (2.0)	< 0.0001*
P value		0.145	0.001*	

Nm newton meter, SD standard deviation, MD mean difference, P value probability level

*Significant

Table 4 Comparison of peak torque of wrist extensors and flexors pre- and post-intervention within and between both groups (placed after Table 4)

Peak torque (Nm)	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	P value
Wrist extensors at 60°/s				
Right	Study	3.47 (0.7)	6.74 (1.2)	0.0001*
	Control	3.51 (0.64)	5.83 (1.7)	0.0001*
	P value	0.81	0.015*	
Left	Study	3.43 (0.6)	6.55 (1.1)	0.0001*
	Control	3.33 (0.9)	5.94 (4.3)	0.0001*
	P value	0.601	0.045*	
Wrist extensors at 120°/s				
Right	Study	2.86 (0.5)	5.17 (0.8)	0.0001*
	Control	2.62 (0.6)	4.57 (0.6)	0.001*
	P value	0.085	0.001*	
Left	Study	2.7 (0.4)	5.12 (0.7)	0.0001*
	Control	2.56 (0.32)	4.74 (0.54)	0.001*
	P value	0.123	0.016*	
Wrist flexors at 60°/s				
Right	Study	5.13 (1.1)	14.18 (2.6)	0.0001*
	Control	4.92 (1.2)	12.59 (2.4)	0.001*
	P value	0.465	0.012*	
Left	Study	4.9 (0.9)	14.3 (2.5)	0.0001*
	Control	4.5 (0.81)	12.67 (3.1)	0.0001*
	P value	0.078	0.023*	
Wrist flexors at 120°/s				
Right	Study	4.63 (0.8)	12.9 (1.9)	0.0001*
	Control	4.47 (0.74)	11.83 (1.76)	0.001*
	P value	0.405	0.021*	
Left	Study	4.1 (0.7)	12.3 (2.3)	0.0001*
	Control	4.26 (0.83)	11.18 (2.12)	0.001*
	P value	0.404	0.045*	

Nm newton meter, SD standard deviation, MD mean difference, P value probability level

*Significant

This was consistent with the findings of Nolte et al. [31] who revealed that land-based exercises if combined with water-based exercises resulted in a positive influence on the physical conditioning of joint diseased patients with the beneficiary of water-based exercises in reducing joint swelling. Improvement of the mean values of the peak torque of knee extensors and flexors of both lower limbs during concentric contraction mode of the study group may be due to treadmill training. The weight bearing training on the moving surface helped the children to spend more time with their feet on the surface during the walking cycle than when they walked

over ground [32]. This comes in agreement with Tulchin et al. [33] who disclosed that treadmill training increases walking endurance, muscle action, aerobic fitness, and balance.

The treadmill stimulates weight bearing on the lower extremities in upright posture through repetitive and rhythmic stepping which in turn improves gait pattern. Four weeks of treadmill training associated with muscle strength training are supposed to improve push-off power generation and speed of locomotion [34]. Moreover, the improved post-intervention values of the muscle strength of the study group in the current study may be attributed to cyclic ergometer exercises. Ergometer requires active contribution of muscles of the lower limbs [35]. Physiologically, the ergometer stimulates the gait generating circuitry in the spinal cord which facilitates affected leg muscles in a more nearly normal temporal rhythm [36]. Pedaling is considered as an aerobic exercise utilizes alternate agonist and antagonist muscles' contraction of the lower limbs in repetitive functional activity as that required for walking [37].

The increased muscle strength of the upper and lower limbs of the JIA group after physical therapy intervention program may be attributed to the effect of strength training exercises as strengthening exercises offer enough resistance or overload which result in increased recruitment of the muscle fibers [38].

Limitations

The long effect of the intervention program was not assessed due to time constraints, and the children were prepared to attend their final exams. Future studies are recommended to investigate the effect of practicing physical activities on subjects with JIA at different age groups.

Conclusions

Our results suggested that children with JIA should participate in moderate fitness, flexibility, and strengthening exercises to improve health, reduce secondary conditions, and enhance quality of life. It is hoped that children with JIA who incorporate regular exercises into their lifestyles will have a better chance of becoming adults who are happier and healthier with fewer secondary complications.

Abbreviations

BMI: Body mass index; ECG: Electrocardiograph; JIA: Juvenile idiopathic arthritis; MANOVA: One-way multivariate analysis of variance; RM: Repetition maximum; ROM: Range of motion; TENS: Transcutaneous electrical nerve stimulation; Vo₂ peak: Peak oxygen uptake; WHO: World Health Organization

Acknowledgements

Not applicable

Authors' contributions

MIB and HK designed and wrote the manuscript. ML and HK performed the procedures. WMB, ML, and HK analyzed and interpreted the patient data. All authors read and approved the final manuscript.

Funding

The work had accomplished without any sponsorship or funding support.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethics approval and consent to participate

The subject's parents signed a written consent form that was approved by the ethical committee for research studies, Cairo University (P.T.REC/012/002055). The study was registered on the Pan African Clinical Trial Registry database (PACTR201907504136763).

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Received: 1 May 2020 Accepted: 8 June 2020

Published online: 09 September 2020

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