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The effects of 8-week water-running program on exercise capacity in children with juvenile idiopathic arthritis: a controlled trial

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Abstract

Exercise capacity has been reported to be lower in children with Juvenile Idiopathic Arthritis (JIA). Therefore, the aim was to investigate the effects of an 8-week water-based exercise program on exercise capacity in children with JIA. Forty-two children with JIA were divided into two groups as: exercise group [$n=21$, water-running, moderate-intensity exercise (60–70%), two times/week], and control group ($n=21$, no additional treatment other than the prescribed medication). All children were assessed at baseline and post-intervention in terms of physical and disease-related characteristics, pain at rest and in activity (visual analog scale), range of motion (Escola Paulista de Medicina Range of Motion Scale), aerobic exercise capacity (cycle ergometer), and anaerobic exercise capacity (Wingate Test). Anaerobic exercise capacity was found to be improved in the exercise group [baseline: 5.54 W/kg (IQR 25/75: 4.07/6.88 W/kg) vs. post-intervention: 6.0 W/kg (IQR 25/75: 4.8/7.4 W/kg), $p=0.002$], while no improvements were observed in the control group [baseline: 5.29 W/kg (IQR 25/75: 4.75/5.85 W/kg) vs. post-intervention: 5.5 watts/kg (IQR 25/75: 5.0/6.1 W/kg), $p=0.076$]. The amount of the changes related to anaerobic exercise capacity were higher in the exercise group [exercise group: 0.6 W/kg (IQR 25/75: 0.3/1.3 W/kg) vs. control group: 0.2 W/kg (IQR 25/75: −0.1/0.5 W/kg), $p=0.024$]. No changes were detected related to aerobic exercise capacity in any of the groups ($p>0.05$). An 8-week water-running program might be beneficial to improve anaerobic exercise capacity, but it is not enough to improve the aerobic exercise capacity in children with JIA.

Keywords Arthritis · Child · Exercise

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Introduction

Juvenile idiopathic arthritis (JIA) is an umbrella term which contains at least seven different childhood arthritis with specific disease characteristics. For an accurate JIA diagnosis, the symptoms should start before the age of 16, should continue for at least 6 weeks, and all the other diseases which mimic the JIA related symptoms should be excluded [1]. Pain, fatigue, and joint-related deformities might be present in children with JIA and these symptoms might influence the physical activity levels [2]. All these symptoms might lead to impairments in exercise capacity.

Exercise capacity can be defined as the ability to continue the current physical work and consists of two components as aerobic and anaerobic exercise capacity. While aerobic exercise capacity represents the capability of continuum of slow and sustained physical work such as walking and swimming, anaerobic exercise capacity defines the ability to perform physical work which requires quick and explosive power, such as stair climbing and jumping. Both types of exercise capacities were found to be diminished in children with JIA when compared to healthy peers [3–5].

Exercise is the main management approach for improving the exercise capacity. Moreover, exercise therapy is reported as safe, well-tolerated, and beneficial for improving muscle strength, bone mineral density, and functional capacity in children with JIA in recent systematic reviews [6, 7]. However, both reviews conclude that the evidence regarding exercise therapy in children with JIA is derived from low-quality studies, and more research is needed [6, 7]. Moreover, the effects of exercise therapy on exercise capacity are not well understood in these patients. Still, in the Canadian physical activity and management guideline about JIA, Pilates, cardio-karate, home and water-based exercises were recommended for management of JIA [8].

Water-based exercises are commonly employed for patients with rheumatic diseases due to unique physical, mechanical, and thermal characteristics of the water. Buoyancy, viscosity, and hydrostatic pressure are some of the important properties of the water which are used in the water-based exercises. Buoyancy helps unloading painful joints, while viscosity provides resistance during water-based exercises. Moreover, water-based exercises might provide an enjoyable environment for children.

As best to our knowledge, there is no controlled study that is investigating the effects of a water-based exercise program on anaerobic exercise capacity. Therefore, the aim of the present study was to investigate the effects of an 8-week water-based exercise program, which was performed at the weekends on aerobic and anaerobic exercise capacity in children with JIA.

Materials and methods

Patients

Patients were children (8–18 years) who were diagnosed with JIA according to International League of Associations for Rheumatology criteria by a pediatric rheumatologist and were followed by the Dokuz Eylul University Faculty of Medicine Department of Pediatrics, Division of Pediatric Rheumatology [9]. As the exercise capacity assessments in the present study were performed using a cycle ergometer, having an involvement related to lower extremities (hip and/or knee and/or ankle) was also determined as the inclusion criteria. Patients were excluded in following cases: a recent surgery/intraarticular injection, an ongoing exercise program, any cardiovascular and/or pulmonary pathologies, and/or unwillingness of the patient and/or the family in participating to the study. Children and the families were informed, and their informed consents were obtained prior to the study. The ethical approval was obtained at 30.06.2016 under the protocol number of 1958-GOA, with the decision number of 2016/18–32 from Dokuz Eylul University Non-invasive Research Ethics Board. Helsinki Declaration was conformed during the study.

The sample size was determined as 16 patients for each group using the GPower program with 95% power and 95% confidence interval (effect size 1.37, allocation ratio 1/1). The change in the anaerobic exercise capacity was the primary interest of the present study; however, as there was no similar study in the literature, the data from the first 20 patients served as a pilot study. A post-hoc power analysis was performed after obtaining this data and the results of this analysis indicated that the effect size was lesser than we estimated, and therefore, at least 21 patients were needed in each group for achieving at least 80% power. Therefore, 47 children were invited to the study. Children were divided into two groups according to their availability for participating in the water-based exercise sessions. Our center is providing care for children with rheumatic diseases in a very big area (the only center in the west part of the country). Therefore, many patients live in distances such as 300 km, and it was impossible to include these children in water-based exercise sessions, because the sessions were performed in one center. Thus, a true randomization could not be performed primarily due to this fact. The children, who could participate regularly in the exercise sessions, formed the experimental group. Other children who could not participate in the exercise sessions mainly due to living in another city or having difficulties (time, transportation) in attending water-based exercise sessions composed the control group.

Interventions

Water-running program

The patients in this group performed water-running exercises in weekends for 8 weeks. Due to the busy school/work schedule of the patients and the parents, weekends were chosen for the exercise sessions. Exercises were performed in groups (maximum four patients at once), in a therapy pool which was 140 cm deep and 33 °C. Floating devices were used for assisting the patients to stand in an upright position in water. A wearable heart rate-tracking system (Polar FT4, Finland) was used for tracing the exercise intensity during the exercises. The exercise intensity was set as according to the formula below [10]:

Target heart rate : (220-age-resting heart rate) × desired exercise intensity + resting heart rate.

As reported in the previous studies, the heart-tracking systems show 10 beats less than the actual hear rate in the water; thus, target heart rate was set 10 beats less than the formula [11].

Exercise intensity level was set as 60% at the beginning and increased to 70% at the fifth week. Water-running exercise duration was started at 15 min, was increased at every 2 weeks by 5 min, and finished at 30 min in last 2 weeks. Warm-up (10 min) and cool-down (5 min) were performed prior to and following the water-running. During the water-running phase, the patients were told to track their heart rates via a clock on their wrists which was connected wirelessly to the heart rate-tracking system. During water-running, the patients were warned about not falling below the target heart rate that was calculated for each patient prior to the exercise sessions. Patients were encouraged to run in an upright position in the water.

Control group

The patients in this group did not receive any special exercise recommendations and were only followed with the most appropriate pharmacological treatment.

Outcome measures

All the patients in both groups were assessed at baseline and following 8 weeks. Physical characteristics including age, height, weight, body-mass index [body-mass index (BMI), weight divided by height squared (kg/m^2)] and disease-related features as disease duration, JIA subtype, and medications were recorded at baseline.

Primary outcomes

The primary outcome was the exercise capacity which was measured in the exercise physiology laboratory of Dokuz Eylul University Faculty of Medicine Department of Physiology. Aerobic exercise capacity and anaerobic exercise capacity were measured to assess the exercise capacity [4, 5].

Aerobic exercise capacity

Aerobic exercise capacity was measured with an electronically braked cycle ergometer (Ergomedic 839 E, Monark, Sweden) and a metabolic gas analyzer system (Fitmate Pro, Cosmed, Italy) [4]. Exercise test was initiated at 50 W and increased 25 W every minute [12]. Peak aerobic power was recorded as VO_{2max}.

Anaerobic exercise capacity

Wingate Test (Ergomedic 894 E, Monark, Sweden) was employed to determine the anaerobic exercise capacity [5, 13]. The test was explained to the patient and the family at baseline. Five-minute warm-up was performed prior to the testing. The patient started the test with a minimal load, and when he/she reached the maximal speed, the load (7.5% of the body weight) was applied. The patient was instructed to continue pedaling as fast as he/she can for 30 s, and especially, during the last seconds, the patient was motivated to continue. Peak power and mean power were calculated.

Anaerobic/aerobic power ratio

The anaerobic/aerobic power ratio was calculated using the following formulas [14]:

Mean anaerobic/aerobic power ratio Mean anaerobic power/peak aerobic power.

Peak anaerobic/aerobic power ratio Peak anaerobic power/peak aerobic power.

Secondary outcomes

Pain level and range of motion was also evaluated to determine the safety of the exercise program.

Pain level

The pain level was evaluated using a 100-mm Visual Analog Scale (VAS) which anchors two different statements as 'No

Pain' and 'Unbearable Pain'. The patients were asked to mark their pain levels in rest and in activity [15].

Range of motion

The Paediatric Escola Paulista de Medicina Range of Motion Scale (pEPM-ROM) was used to evaluate the range of motion. Ten joint movements (cervical rotation, shoulder abduction, wrist flexion, wrist extension, metacarpophalangeal flexion, hip internal rotation, hip external rotation, knee extension, ankle dorsal flexion, and ankle plantar flexion) were graded in a four-point Likert scale (0 = no limitation, 3 = severe limitation). All the points were summed and divided to 10 and this result gave the general range of motion [16].

Adherence to the exercise sessions

The participation in the exercise sessions was recorded in a structured form for each patient. The adherence rate was calculated as the percentage.

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Science for Windows version 20.0. The normal distribution of the data was assessed with Shapiro–Wilk Test. Non-parametric tests were deemed more suitable for interpretation of the results due to relatively small sample size and heterogeneous distribution of the data. Mann–Whitney *U* test was employed for between group comparisons and Wilcoxon Signed Rank test was used for in-group comparisons. $p < 0.05$ was accepted as statistically significant.

Results

The study was completed with 21 patients in the exercise group (15 males and 6 females) and 21 patients in the control group (14 males and 7 females). No differences were determined between the groups regarding age, height, weight, BMI, time since diagnosis, pain level, and range of motion (Table 1). The groups also were similar in terms of subtype of the disease and medication. The most prevalent subtype was enthesitis-related arthritis (57%), followed by oligoarticular (24%), polyarticular (14%), and systemic juvenile idiopathic arthritis (5%) in both groups. The most commonly used medications were sulfasalazine, methotrexate, and non-steroidal anti-inflammatory drugs. 10 children from exercise group and eight children from control group was using biologics (anti-TNF, anti-IL-6).

Table 1 Comparison of the JIA patients in the groups at baseline

	Exercise group ($n = 21$) Median (IQR 25/75)	Control group ($n = 21$) Median (IQR 25/75)	p*
Age (years)	14 (12/15)	14 (11/16)	0.533
Time since diagnosis (months)	18 (6/51)	18 (5/36)	0.930
Height (cm)	164 (148/168)	158 (153/165)	0.546
Weight (kg)	49.6 (43.9/61.0)	50.0 (45.2/59.6)	0.990
Body-mass index (kg/m^2)	20.2 (18.1/23.2)	19.7 (18.2/21.6)	0.753
VAS rest (mm)	0 (0/0)	0 (0/0)	0.639
VAS Activity (mm)	27 (0/55)	0 (0/35)	0.119
pEPM-ROM (score)	0 (0/0.1)	0 (0/0)	0.283

*Mann–Whitney *U* Test, *cm* centimeter, *kg* kilogram, *m* meter, *mm* millimeter, *VAS* Visual Analog Scale, *pEPM-ROM* the Paediatric Escola Paulista de Medicina Range of Motion Scale, *IQR 25/75* interquartile range 25/75, $p < 0.05$

Table 2 Anaerobic exercise capacity parameters of the JIA patients in the groups

	Exercise group (*n*: 19)			Control group (*n*: 21)		
	Before median (IQR 25/75)	After median (IQR 25/75)	p*	Before median (IQR 25/75)	After median (IQR 25/75)	p*
Peak power (W)	354.73 (267.59/471.55)	441.3 (295.2/636.9)	**0.002**	355.57 (225.43/463.62)	366.7 (236.3/447.8)	0.259
Peak power (W/kg)	6.74 (5.44/8.94)	7.7 (6.4/9.7)	**0.001**	6.69 (5.80/7.83)	7.3 (6.1/8.1)	0.232
Mean power (W)	291.5 (188.78/359.61)	360.0 (220.4/446.4)	**0.001**	261.04 (181.68/351.27)	284.8 (187.8/373.0)	0.050
Mean power (W/kg)	5.54 (4.07/6.88)	6.0 (4.8/7.4)	**0.002**	5.29 (4.75/5.85)	5.5 (5.0/6.1)	0.076

The p values in bold means p<0.05

*Wilcoxon Signed Rank Test, *W* Watt, *W/kg* Watt/kg, *IQR 25/75* interquartile range 25/75, $p < 0.05$

Table 3 Comparison of the changes related to anaerobic exercise capacity of the JIA patients between the groups

	Exercise group ($n = 19$) median (IQR 25/75)	Control group ($n = 21$) median (IQR 25/75)	p*
ΔPeak power (W)	65.1 (23.8/107.1)	24.5 (−15.6/39.4)	**0.009**
ΔPeak power (W/kg)	0.9 (0.3/1.6)	0.3 (−0.3/0.6)	**0.007**
ΔMean power (W)	41.4 (9.9/78.7)	17.3 (5.0/31.3)	**0.019**
ΔMean power (W/kg)	0.6 (0.3/1.3)	0.2 (−0.1/0.5)	**0.024**

*Mann–Whitney *U* test, Δ Delta, *W* watt, *W/kg* watt/kilogram, *IQR 25/75* interquartile range 25/75, $p < 0.05$

Aerobic exercise capacity was assessed in 39 patients (exercise: 19, control: 20). Three patients (exercise group: 2, control group: 1) could not be assessed due to a temporary disorder of the oxygen analyzer. The groups were similar at the baseline regarding to VO_{2max} [exercise group: 31.5 ml/kg/min (IQR 25/75: 27.1/38.9 ml/kg/min) vs. control group: 35.35 ml/kg/min (IQR 25/75: 25.80/41.95 ml/kg/min), p: 0.888]. No improvements were observed neither in the exercise nor in the control group ($p > 0.05$). No differences were found in the amount of the changes between the groups [exercise group: 5.5 ml/kg/min (IQR 25/75: −2.5/7.4 ml/kg/min) vs. control group: 3.3 ml/kg/min (IQR 25/75: −2.2/8.5 ml/kg/min), p: 0.989].

Anaerobic exercise capacity was assessed in 40 patients (exercise = 19, control = 21). Two patients in the exercise group could not be assessed (one patient was too short for the saddle, and the other one had a serious hip limitation). Groups were similar at baseline regarding anaerobic exercise capacity parameters ($p > 0.05$). All the anaerobic exercise capacity parameters were found to be improved following the water-running program (Table 2). However, no improvements were observed in the control group (Table 2). Moreover, the amount of the changes between groups were higher in the exercise group (Table 3).

The mean anaerobic/aerobic power ratio was determined as 2/1 and peak anaerobic/aerobic power ratio was found as 2.5/1.

No differences were found related to pain level nor range of motion in neither of the groups ($p > 0.05$).

The adherence rate to the exercise sessions was determined as 85%. The most reported reasons for non-attendance were being out of the town (25%) and having flu-like symptoms (25%).

Discussion

The results of the present study showed that an 8-week water-based exercise program which was performed at weekends might be beneficial in improving the anaerobic exercise capacity, but is not adequate for improving aerobic capacity.

The main reason of the fail in the aerobic exercise improvement might be the inadequate exercise frequency. The current American College of Sports Medicine guideline and a recent review about exercise therapy in children with JIA recommends at least a 3-day exercise program in a week [6, 17]. Unfortunately, due to educational necessities or work-related limited time of the parents, it did not reach recommended levels in the present study. However, other authors also indicated that the time was a limitation for exercise interventions in children with chronic conditions, and the exercise interventions should be supported with home exercises [18]. Moreover, the exercise duration might be quite shorter than the recommended standards (at least 60 min and moderate–high intensity) in the present study. The water-running program was started with a 15-min loading phase with an intention not to load a sedentary child. Previous studies showed similar results. Takken et al. applied a 1 day in a week water-based exercise program for 20 weeks and detected no improvements in aerobic exercise capacity [19]. On the other hand, Doğru Apti et al. reported beneficial effects of a walking and range of motion exercise program which were performed 4 days a week on aerobic exercise capacity [20].

On the contrary, anaerobic capacity was found enhanced following water-based exercise program in the present study. The improvements in the anaerobic exercise capacity might be contributed to the nature of performing the exercise in water. It was advocated that muscles work less in the water; however, recent studies showed that electromyography signals are greater in water than on land in movements with higher speeds and unsupported conditions [21]. The water-based exercise program consists of both conditions as the patients had to run in high speeds to reach the target heart rate, and floating devices created an "unsupported" environment. This might have resulted in a strengthening effect along with the resistance of the water and thus might have led to the improvements in the extremity strength and consequent improvement in anaerobic exercise capacity. In accordance with our results, Singh-Grewal et al. reported improvements following a 12-week circuit training program involving pool, stationary bicycle, treadmill, and Fitball for nine children with JIA [10].

The anaerobic/aerobic power ratios were first determined by Brussel et al. in children with JIA [14]. The authors reported the mean anaerobic/aerobic power ratio as 2/1 and peak anaerobic/aerobic power ratio as 3/1. In the present study, while the mean anaerobic/aerobic power ratio was found similar, the peak anaerobic/aerobic power ratio was found as 2.5/1. It might be interpreted that the anaerobic peak power of our sample was more diminished and thus more suitable to be improved.

The water-running program in the present study seems to be safe, as no differences were observed in pain level and range of motion during the study.

The attendance rate to the exercises is important to see the beneficial effects of the exercise approach, and it was found as high (85%) in the current study. The exercise attendance rates were reported between 55 and 100% in the previous studies [7]. Even though the level of fun was not assessed with structured tools in the present study, the patients in the exercise group reported verbally that they had fun during water-based exercises.

As the lower extremity involvement was set as the inclusion criteria, more than half of the patients had the enthesitis-related arthritis disease subtype, following oligoarticular and polyarticular JIA. In addition, as the enthesitis-related arthritis are more prevalent among boys; thus, more male patients were included in the present study. Demirkaya et al. reported that the most prevalent JIA subtypes were persisting oligoarticular (36.9%), polyarticular (20.3%), and enthesitis-related arthritis (18.9%) in Turkey [22]. Our sample seems reflecting the distribution of the JIA subtypes for our country.

As the exercise approach which was employed in the present study does not include special movements and techniques, it may be performed by the patients and families themselves in future applications and may help to achieve the desired exercise frequency. Wearable heart rate-tracking systems may allow parents to follow the safety of their children. A structured study would be needed for a self-exercise program in this regard.

Study limitations

The limitations of the present study were determined as the incompliance to the recommended exercise guidelines regarding to aerobic exercises, the absence of healthy controls for comparing the exercise capacity, lack of a true randomization, limited number of patients, and the lack of follow-up periods. In addition, the physical activity levels were not questioned during the study and possible differences in physical activity patterns between groups might influence our results.

Conclusions

The present study is the first controlled study, which investigates the effect of an exercise program on the anaerobic exercise capacity, in children with JIA. The water-running program performed in the present study was determined as a safe method and may be employed to improve the anaerobic exercise capacity; however, this weekend-based program is not adequate for improving the aerobic capacity. The present program seems suitable for children with JIA with lower extremity involvement as no adverse effects or increase in pain was detected. However, the optimal frequency for improving aerobic capacity and possible differences with land-based programs should be investigated in future studies.

Author contributions DB: study design, data management, analysis, interpretation, and writing. SS: study design, interpretation, and writing. OA-G: data management. EM: data management. BM: data management, and writing. NI: study design and interpretation. EU: study design, data management, and writing.

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Compliance with ethical standards

Ethical approval Children and the families were informed, and their informed consents were obtained prior to the study. The ethical approval was obtained at 30.06.2016 under the protocol number of 1958-GOA, with the decision number of 2016/18–32 from Dokuz Eylul University Noninvasive Research Ethics Board.

Conflict of interest The authors declare that they have no conflict of interest.

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