

# Aerobic and Anaerobic Exercise Capacity in Adolescents With Juvenile Idiopathic Arthritis

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**Objective.** To examine the aerobic and anaerobic exercise capacity in adolescents with juvenile idiopathic arthritis (JIA) compared with age- and sex-matched healthy individuals, and to assess associations between disease-related variables and aerobic and anaerobic exercise capacity.

**Methods.** Of 25 patients enrolled in a JIA transition outpatient clinic, 22 patients with JIA were included in this study (mean  $\pm$  SD age 17.1  $\pm$  0.7 years, range 16–18 years). Aerobic capacity was examined using a Symptom Limited Bicycle Ergometry test. Anaerobic capacity was assessed with the Wingate Anaerobic Test. Functional ability was assessed with the Childhood Health Assessment Questionnaire. Pain and overall well-being were measured using a visual analog scale. Disease duration and disease activity were also assessed.

**Results.** Absolute and relative maximal oxygen consumption in the JIA group were significantly impaired (85% and 83% for boys, respectively; 81% and 78% for girls, respectively) compared with healthy controls. Mean power was also significantly impaired (88% for boys and 74% for girls), whereas peak power was significantly impaired for girls and just failed significance for boys (67% for girls and 92% for boys). A post hoc analysis correcting for underweight and overweight demonstrated that body composition did not influence the results substantially.

**Conclusion.** This study demonstrated that adolescents with JIA have an impaired aerobic and anaerobic exercise capacity compared with healthy age- and sex-matched peers. The likely cause for this significant impairment is multifactorial and needs to be revealed to improve treatment strategies.

**KEY WORDS.** Aerobic exercise capacity; Anaerobic exercise capacity; Juvenile idiopathic arthritis; Maximal oxygen uptake; Exercise.

## INTRODUCTION

Although the outcome of juvenile idiopathic arthritis (JIA) is generally considered as good, with many children experiencing a spontaneous remission, long-term outcome studies show that between 39% and 65% of children with JIA have active disease into adulthood (1–4). Adolescents with JIA and their parents call for developmentally appropriate care that addresses physical, social, psychological, and vocational issues (5). One of the issues that needs to be addressed is the physical fitness of the adolescents with JIA. It is now widely accepted that regular vigorous phys-

ical activity for children and youths has beneficial effects on growth and development and on achieving optimal adult health (6). Physical activity guidelines for children and youths primarily advocate the accumulation of 1 hour of at least moderate-intensity physical activity per day. Secondly, children must take part in activities that help develop and maintain physical fitness on at least 2 occasions per week (7). There is growing evidence that children with JIA have moderate to severe impairment in physical fitness as represented by maximal oxygen consumption ( $VO_{2peak}$ ) and perform less daily physical activities as compared with healthy children (8,9). In the short term, decreased physical fitness and activity levels can lead to further functional deterioration (10). In the longer term, decreased physical fitness and activity levels can lead to an increased risk for cardiovascular disease (11–13).

Physical fitness is most often described in terms of cardiorespiratory or aerobic fitness, muscular endurance and strength, flexibility, and body composition (14). However, physical fitness should also include anaerobic fitness because there is indication of a strong association between

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anaerobic physical fitness and daily functional ability (15). The causality of impaired physical fitness in children and adolescents with JIA is unknown. Klepper et al (16) suggested that physical fitness levels are less related to the degree of disease activity than often thought. Also, pain and disease activity are less related than often presumed. Malleson et al (17) demonstrated in a large cohort of patients with JIA that disease activity accounted for only 6.5% of the variance in pain scores and stressed the importance of investigating the role of other factors, including psychosocial factors. It is likely that impaired physical fitness levels in adolescents with JIA are also caused by a variety of factors. The goal of this study was to examine the aerobic and anaerobic exercise capacity in adolescents with JIA compared with age- and sex-matched healthy individuals, and to assess associations between disease-related variables and aerobic and anaerobic exercise capacity.

## PATIENTS AND METHODS

**Patients.** Patients attending the adolescent JIA transition outpatient clinic were eligible for the study. Patients were diagnosed by a pediatric rheumatologist according to the International League of Associations for Rheumatology (ILAR) criteria (18). The adolescent JIA transition clinic is a combined outpatient clinic of the Beatrix Children Clinic and the adult rheumatology clinic of the University Medical Center Groningen with the aim of transferring children ages 16–18 with JIA from pediatric to adult care. This outpatient clinic was started in 2001 to improve transitional care with an approach that is adolescent focused and evidence based. One of the issues in transitional care that needs to be addressed is the physical fitness of the adolescents with JIA, and therefore a protocol was designed to measure their aerobic and anaerobic exercise capacity. All tests were performed on the same day with sufficient resting time in between the aerobic and anaerobic tests. In this study, the included patients were referred to as the JIA group. Reference data for aerobic exercise capacity collected from healthy Dutch controls were published by Binkhorst et al (19). In the Binkhorst et al study, the same aerobic test protocol as in our study was used. Reference data for aerobic exercise capacity were matched for age and sex. Reference data for anaerobic exercise capacity were collected from healthy Dutch children attending a secondary school in the city of Assen, The Netherlands, because no published reference data for adolescents were available. Their anaerobic capacity was assessed with the same test protocol as in our study. These data were also matched for age and sex. This group was referred to as the Wingate group. Patients were fully informed about the test procedures and the possible risks involved and informed consent was obtained.

**Anthropometry.** Body mass and height were determined using an electronic scale and a stadiometer. Body mass index (BMI) was calculated as body mass/height<sup>2</sup>. The BMI of the JIA group and Wingate group was compared with reference values of healthy Dutch children

(20), with international cutoff points for overweight and obesity (21), and with Dutch cutoff points for underweight (22).

**Wingate Anaerobic Test.** Anaerobic capacity was assessed with the Wingate Anaerobic Test (WAnT) as described by Bar-Or (23). The test was performed on a calibrated electromagnetic braked cycle ergometer (Lode Examiner; Lode BV, Groningen, The Netherlands), which was upgraded by the manufacturer to a maximal resistance of 800W instead of the standard 400W. The external resistance was controlled and the power output was measured using the Lode Wingate software package (24). The seat height was adjusted to the patient's leg length (comfortable cycling height). The external load (torque, in Nm) was determined at 0.6 times body weight according to the user manual (24). The patient's feet were securely tied to the pedals. Patients were asked to exercise for 5 minutes with an external load of 50W at 60 revolutions per minute after the sprint protocol started. The patients were instructed to cycle as fast as possible for 30 seconds and were strongly verbally encouraged ("Go," "Come on," "Keep on going," "Faster"). Patients were informed about how much time was left. Measured variables were mean and peak power. Mean power represents the average power output during the 30-second sprint. Peak power is the highest recorded power output achieved during the 30-second sprint.

**Symptom Limited Bicycle Ergometry test.** Aerobic capacity was assessed using a Symptom Limited Bicycle Ergometry test (SLBE). SLBE was performed on an electronically braked cycle ergometer (Jaeger physis hc; Vi-sys, Bilthoven, The Netherlands). The seat height was adjusted to the patient's comfort. Patients rested until all measured variables were stable. Cycling started at a workload of 0W and the workload was increased by 20W every minute until the patient stopped due to volitional exhaustion, despite strong verbal encouragement from the investigators. Patients breathed through a mouthpiece that was connected to a calibrated metabolic cart (Oxycon pro, Jaeger, Bilthoven, The Netherlands). Expired gas was passed through a flow meter, oxygen analyzer, and a carbon dioxide analyzer. The flow meter and gas analyzer were connected to a computer, which calculated breath-by-breath minute ventilation, oxygen consumption ( $\text{VO}_2$ ), carbon dioxide production ( $\text{VCO}_2$ ), and respiratory exchange ratio ( $= \text{VCO}_2/\text{VO}_2$ ) from conventional equations. Heart rate was measured continuously during the maximal exercise test using an electrocardiogram.

**Functional ability.** Functional ability was assessed with the validated Dutch translation of the Childhood Health Assessment Questionnaire (C-HAQ) (25,26). Using a paper version of the C-HAQ, a number of questions were answered and scored (range 0–3; 0 = able to do with no difficulty, 1 = able to do with some difficulty, 2 = able to do with much difficulty, 3 = unable to do) in 8 domains (dressing/grooming, arising, eating, walking, hygiene, reach, grip, and activities). When assistance or aids were required for a domain, the score for that domain was

increased to a minimum of 2. The period for the self-assessment was a week. The mean of the 8 scores determined the C-HAQ score (range 0–3).

**Pain.** Pain was measured using a visual analog scale (VAS) that consisted of a 10-cm horizontal line with short vertical bars at each end. “No pain” was written at the left end (score 0) and “much pain” at the right (score 10). Patients were instructed to indicate their pain during the past week by drawing a vertical line. The higher the score, the higher the perceived pain.

**Overall well-being.** Overall well-being was measured using a VAS consisting of a 10-cm horizontal line with short vertical bars at each end. “Very well” was written at the left end (score 0) and “very bad” at the right (score 10). Patients were instructed to indicate their overall well-being during the past week with a vertical line. Higher values indicated worse overall well-being.

**Disease duration.** Disease onset was assessed by retrospective study of patients’ charts. Disease duration was defined as the period between time of onset and time of assessment (equal to time since diagnosis).

**Disease activity.** Disease activity was assessed by an adult rheumatologist and a pediatric rheumatologist using Pediatric Rheumatology International Trials Organization (PRINTO) core set criteria (27). Disease activity was accordingly classified as active disease, inactive disease, clinical remission on medication, and clinical remission off medication. Active disease was defined as active arthritis in  $\geq 1$  joint. Inactive disease was defined as no disease signs with medication. Six continuous months of inactive disease with medication was defined as clinical remission on medication, whereas 12 months off medication with inactive disease was defined as clinical remission off medication.

**Statistical analysis.** For statistical analysis, SPSS software, version 12 (SPSS, Chicago, IL) was used. Descriptive statistics were used for patient characteristics and for mean and peak power and  $VO_{2peak}$ . Independent sample *t*-tests were used to determine differences between the JIA group and the reference data. Analyses were performed for groups as a whole and for girls and boys separately. Pearson’s and Spearman’s correlation analyses were used to assess associations between disease-related variables and aerobic and anaerobic exercise capacity. Correlation coefficients between 0.26 and 0.49 reflect poor agreement, those between 0.50 and 0.69 reflect moderate agreement, and those  $\geq 0.70$  reflect high agreement (28). *P* values less than 0.05 were considered statistically significant.

## RESULTS

**Participants.** In 2004 and the beginning of 2005, 25 adolescents with JIA were enrolled in the transition outpatient clinic. Twenty-two patients were included in this cross-sectional study, 9 boys and 13 girls. One patient was

excluded because of Down syndrome and 2 patients refused participation. The population consisted of 5 patients with oligoarticular JIA, 2 patients with extended oligoarticular JIA, 8 patients with polyarticular rheumatoid factor (RF)–negative JIA, 3 patients with polyarticular RF-positive JIA, 2 patients with psoriatic arthritis, and 2 patients with enthesitis-related JIA. The mean  $\pm$  SD disease duration of the patients was  $8.3 \pm 4.8$  years. Five adolescents had active disease, 13 patients had inactive disease, and 4 patients were in clinical remission without medication. Eight patients were receiving only nonsteroidal anti-inflammatory drugs (NSAIDs); 1 patient was receiving only disease-modifying antirheumatic drugs (DMARDs); 7 patients were receiving both NSAIDs and DMARDs; 1 patient was receiving an NSAID, a DMARD, and a biologic agent; and 1 patient was receiving an NSAID and a biologic agent.

**Preliminary group analysis.** Independent-samples *t*-test for BMI demonstrated no significant difference between the JIA group and reference values of healthy Dutch children. Three of the 22 patients were overweight, 4 were underweight, and none were obese. A total of 27 adolescents were included in the Wingate control group, 14 boys and 13 girls. Two of these 27 were overweight, 3 were underweight, and none were obese. Independent-samples *t*-test for BMI demonstrated no significant difference between the Wingate group and reference values of healthy Dutch children. No significant differences between the JIA group and the Wingate control group were found with respect to age, weight, height, and BMI (Table 1).

**Preliminary aerobic exercise capacity.** Independent-samples *t*-test demonstrated a significant lower absolute and relative  $VO_{2peak}$  in the JIA group as compared with the reference group for both boys and girls. On average, absolute  $VO_{2peak}$  in the JIA group was 85% of that predicted for boys and 81% of that predicted for girls. Relative  $VO_{2peak}$  in the JIA group was on average 83% of that predicted for boys and 78% of that predicted for girls (Table 2).

**Preliminary anaerobic exercise capacity.** Independent-samples *t*-test showed a significant lower mean power in the JIA group compared with the reference group for boys and girls. On average, mean power in the JIA group was 88% of that predicted for boys and 74% of that predicted for girls. Girls in the JIA group showed a significant lower peak power compared with the reference group. No significant difference in peak power between the JIA group and reference group was found for boys ( $P = 0.14$ ). On average, peak power in the JIA group was 92% of that predicted for boys and 67% of that predicted for girls (Table 2).

**Correlations.** Pearson’s correlation coefficient demonstrated a significant and high association between aerobic and anaerobic parameters (Table 3). Spearman’s correlation coefficient demonstrated a significant and low negative association between VAS pain and absolute  $VO_{2peak}$  and a significant moderate association between VAS pain and VAS well-being and C-HAQ scores. Spearman’s correlation coefficient also showed a significant low to mod-

**Table 1. Characteristics of the patients with juvenile idiopathic arthritis (JIA) and the Wingate control group\***

Characteristic	JIA group (n = 22)	Wingate group (n = 27)	P†
Age, years	17.1 ± 0.7 (16.0–18.2)	17.0 ± 0.6 (16.1–18.2)	0.60
Height, cm	171 ± 8 (157–185)	176 ± 9 (159–189)	0.07
Weight, kg	61.6 ± 12.0 (42.0–86.0)	65.2 ± 9.0 (48.9–86.0)	0.25
BMI, kg/m <sup>2</sup>	20.8 ± 2.7 (16.4–26.8)	21.1 ± 2.3 (17.5–26.5)	0.75
C-HAQ score	0.5 ± 0.5 (0–1.8)		
VAS pain (0–10 cm)	2.8 ± 2.2 (0–6.9)		
VAS overall well-being (0–10 cm)	2.2 ± 1.9 (0–6.3)		
Disease duration, years	8.3 ± 4.8 (0.5–16.7)		

\* Values are the mean ± SD (range) unless otherwise indicated. BMI = body mass index; C-HAQ = Childhood Health Assessment Questionnaire; VAS = visual analog scale.  
 † Based on independent-samples *t*-tests.

erate negative association between VAS well-being and aerobic and anaerobic parameters. A significant low to moderate association was found between disease activity and aerobic parameters. There was a significant low negative association between C-HAQ scores and absolute VO<sub>2peak</sub> and a significant moderate negative association between C-HAQ scores and anaerobic parameters. There was no significant association between disease duration and any of the aerobic or anaerobic parameters, nor between disease duration, VAS pain, and VAS well-being scores. No significant association was found between disease activity and anaerobic parameters, VAS pain, and VAS well-being scores (Table 4).

**Post hoc analysis.** Post hoc analysis was carried out to correct for abnormal body weight. In the JIA group and Wingate group, patients who were underweight or overweight were omitted in this analysis. In the JIA group 15 patients had normal body weight, 6 boys and 9 girls. In the Wingate group 22 patients had normal body weight, 12 boys and 10 girls.

**Post hoc aerobic exercise capacity.** Independent-samples *t*-test showed a significant lower relative VO<sub>2peak</sub> for girls in the JIA group. Absolute VO<sub>2peak</sub> for girls and abso-

lute and relative VO<sub>2peak</sub> for boys just failed significance. On average, absolute VO<sub>2peak</sub> in the JIA group was 85% of that predicted for boys and 88% of that predicted for girls. Relative VO<sub>2peak</sub> in the JIA group was on average 90% of that predicted for boys and 80% of that predicted for girls (Table 5).

**Post hoc anaerobic exercise capacity.** Independent-samples *t*-test showed a significant lower mean power in the JIA group compared with the reference group for boys and girls. On average, mean power in the JIA group was 86% of that predicted for boys and 76% of that predicted for girls. Girls in the JIA group showed a significant lower peak power compared with the reference group. No significant difference in peak power between the JIA group and reference group was found for boys (*P* = 0.09). Peak power in the JIA group was on average 93% of that predicted for boys and 71% of that predicted for girls (Table 5).

**DISCUSSION**

The goal of this study was to examine the aerobic and anaerobic exercise capacity in adolescents with JIA attending a transition outpatient clinic compared with healthy

**Table 2. Aerobic and anaerobic exercise capacity of patients with juvenile idiopathic arthritis (JIA) and controls\***

	JIA	Controls	% predicted	P†
VO <sub>2peak</sub> (liters × minute <sup>-1</sup> )	2.18 ± 0.68	2.62 ± 0.53	83 ± 19	< 0.05
Boys	2.77 ± 0.44	3.24 ± 0.05	85 ± 13	< 0.05
Girls	1.78 ± 0.49	2.20 ± 0.00	81 ± 22	< 0.01
VO <sub>2peak</sub> (ml × kg <sup>-1</sup> × minute <sup>-1</sup> )	35.36 ± 7.95	43.98 ± 5.85	80 ± 13	< 0.01
Boys	41.97 ± 7.18	50.84 ± 0.05	83 ± 14	< 0.01
Girls	30.78 ± 4.56	39.22 ± 0.07	78 ± 12	< 0.01
Mean power (watts)	410 ± 119	526 ± 92	80 ± 14	< 0.01
Boys	531 ± 68	602 ± 48	88 ± 11	< 0.05
Girls	327 ± 58	444 ± 44	74 ± 13	< 0.01
Peak power (watts)	605 ± 233	790 ± 180	80 ± 19	< 0.05
Boys	847 ± 135	921 ± 134	92 ± 15	0.14
Girls	437 ± 91	648 ± 92	67 ± 14	< 0.01

\* Values are the mean ± SD unless otherwise indicated. VO<sub>2peak</sub> = peak oxygen uptake.  
 † Based on independent-samples *t*-tests.

	<b>Absolute VO<sub>2peak</sub></b>	<b>Relative VO<sub>2peak</sub></b>	<b>WAnT mean power</b>	<b>WAnT peak power</b>
Absolute VO <sub>2peak</sub>		0.80†	0.92†	0.85†
Relative VO <sub>2peak</sub>			0.74†	0.75†
Mean power WAnT				0.96†
* VO <sub>2peak</sub> = peak oxygen uptake; WAnT = Wingate Anaerobic Test. † P < 0.01.				

individuals, and to assess associations between disease-related variables and aerobic and anaerobic exercise capacity. The results demonstrate a significant decrease in aerobic and in anaerobic fitness in adolescent boys and girls with JIA. This finding is worrying because fitness levels at the age of 18 are at their peak, tend to deteriorate during adulthood, and are a strong predictor of the work capacity of a person (29). It is unlikely that adolescents with JIA, entering adulthood with diminished fitness levels, are able to bridge this gap. Therefore, we must create new strategies to reverse or even prevent this unwanted trend.

The study found distinctive sex differences in adolescents with JIA: girls were more impaired than boys in aerobic and anaerobic fitness. These findings are in line with the results found in the study by van Brussel et al in which 62 children with JIA ages 6–15 years were tested for aerobic and anaerobic exercise capacity (30). Van Brussel et al also found a considerable significant decrease in aerobic as well as anaerobic fitness with the same sex differences. Because body composition can influence outcome, we performed a post hoc analysis to study the possible confounding effect of overweight and underweight. Body composition did not influence the results substantially.

The decrease in aerobic fitness is in line with findings of earlier studies in preadolescent children with JIA (9). Several pathophysiologic factors specific to childhood JIA can limit aerobic capacity such as anemia, muscle atrophy and weakness, impaired lung function, and joint stiffness (31,32). This study demonstrates a significant low to moderate association between disease activity and aerobic exercise capacity. At the same time this study demonstrates a considerable decrease of aerobic capacity in adolescents

with JIA who are under disease control and are in remission. It is likely that factors other than disease activity are involved in reducing aerobic exercise capacity. This needs further exploration.

This study is the first to assess anaerobic exercise capacity in adolescents with JIA in comparison with a healthy population, and it demonstrates a dramatic decrease of anaerobic exercise capacity, particularly in adolescent girls. This can have serious consequences for these patients' daily functioning because children are normally engaged in very short bursts of intense physical activity that are anaerobic in nature (33). Anaerobic fitness is needed in more intensive daily activities such as climbing stairs, playing outside, and cycling against a strong wind. Anaerobic fitness is also needed in sports with short intensive bursts of activity such as soccer, volleyball, and athletics. Adolescents with such a decreased anaerobic exercise capacity are prone to drop out of physical education classes at school. Girls are more prone than boys to develop sedentary lifestyle patterns, and sedentary patterns developed in youth and adolescence are likely to persist over time, resulting in a sedentary lifestyle (34). Decreased anaerobic capacity can therefore be responsible for low physical activity levels, poor exercise behavior, and impairments in daily functioning. In our study, we found a significant inverse moderate association between C-HAQ scores and anaerobic parameters. This is an indication that low anaerobic fitness indeed impairs daily functioning and confirms findings of an earlier report by Takken et al (15).

The study demonstrated that disease duration (time since diagnosis) does not seem to be relevant for pain, well-being, and aerobic and anaerobic parameters. This study also demonstrated a low to moderate significant

	<b>Absolute VO<sub>2peak</sub></b>	<b>Relative VO<sub>2peak</sub></b>	<b>WAnT mean power</b>	<b>WAnT peak power</b>	<b>VAS pain</b>	<b>VAS well-being</b>
VAS pain	-0.47†	-0.30	-0.41	-0.38		
VAS well-being	-0.48†	-0.57‡	-0.45†	-0.50†	0.66‡	
Disease duration	0.37	0.21	0.37	0.35	0.06	-0.25
Disease activity	0.45†	0.58‡	0.33	0.30	-0.08	-0.036
C-HAQ	-0.48†	-0.42	-0.51†	-0.55‡	0.50†	0.51†
* VAS = visual analog scale; C-HAQ = Childhood Health Assessment Questionnaire; VO <sub>2peak</sub> = peak oxygen uptake; WAnT = Wingate Anaerobic Test. † P < 0.05. ‡ P < 0.01.						

**Table 5. Aerobic and anaerobic exercise capacity of patients with juvenile idiopathic arthritis (JIA) and controls corrected for underweight and overweight\***

	JIA	Controls	% predicted	P†
VO <sub>2peak</sub> (liters × minute <sup>-1</sup> )	2.28 ± 0.62	2.62 ± 0.53	87 ± 18	0.12
Boys	2.78 ± 0.51	3.25 ± 0.05	85 ± 15	0.08
Girls	1.95 ± 0.44	2.20 ± 0.00	88 ± 20	0.12
VO <sub>2peak</sub> (ml × kg <sup>-1</sup> × minute <sup>-1</sup> )	37.10 ± 8.42	43.88 ± 5.89	84 ± 11	< 0.05
Boys	45.77 ± 5.01	50.85 ± 0.05	90 ± 10	0.06
Girls	31.33 ± 3.80	39.23 ± 0.07	80 ± 10	< 0.01
Mean power (watts)	411 ± 105	530 ± 94	80 ± 12	< 0.05
Boys	519 ± 58	603 ± 48	86 ± 10	< 0.05
Girls	339 ± 51	443 ± 49	76 ± 12	< 0.01
Peak power (watts)	616 ± 217	792 ± 188	80 ± 16	0.05
Boys	855 ± 75	920 ± 143	93 ± 8	0.09
Girls	456 ± 86	639 ± 98	71 ± 13	< 0.01

\* Values are the mean ± SD unless otherwise indicated. VO<sub>2peak</sub> = peak oxygen uptake.  
† Based on independent-samples *t*-tests.

negative association between aerobic and anaerobic exercise capacity and VAS overall well-being scores. This finding indicates that adolescents with higher fitness levels feel better. In addition, a significant moderate association was found between VAS pain and VAS well-being scores. Pain and poor well-being are likely to reinforce each other.

This study also found a low to moderate significant association between VAS pain and well-being and C-HAQ scores, indicating that pain and poor well-being are likely to lower functional ability. The study demonstrated no association between pain and disease duration and disease activity. We found a low and nonsignificant association between well-being and disease duration and disease activity. This enforces the idea that nonpathophysiologic factors may be responsible for a substantial reduction of aerobic and anaerobic exercise capacity. According to Bar-Or (35), chronic illness, by means of overprotection, fear, social isolation, and ignorance, can lead to hypoactivity, which is the trigger for further detraining and functional deterioration.

The study further demonstrates a strong and significant association between aerobic and anaerobic parameters, especially between WAnT mean power and absolute VO<sub>2peak</sub>. Anaerobic exercise testing, which is safer and simpler than aerobic exercise testing, is therefore a possible valid instrument to test exercise capacity and fitness. Further research is necessary to conclude if anaerobic testing can replace aerobic testing.

This study has the limitation of including a small number of adolescents with JIA. It is therefore not possible to make strong assumptions over possible indicators of aerobic and anaerobic exercise capacity. A (multicenter) study with a larger sample size is needed.

In conclusion, we found that adolescents attending a transition outpatient clinic for patients with JIA have an impaired aerobic and anaerobic exercise capacity compared with healthy age- and sex-matched peers (girls more severely impaired than boys). The importance of improving aerobic and anaerobic exercise capacity in children and adolescents with JIA by means of exercise is widely accepted (32). How this improvement can be achieved is

still under debate. The likely cause for this significant impairment is multifactorial and needs to be revealed to improve treatment strategies.

#### AUTHOR CONTRIBUTIONS

Mr. Lelieveld had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Study design.** Lelieveld, van Brussel, Takken, van Weert, Armbrust.

**Acquisition of data.** Lelieveld, van Leeuwen, Armbrust.

**Analysis and interpretation of data.** Lelieveld, Takken, van Weert, Armbrust.

**Manuscript preparation.** Lelieveld, van Brussel, Takken, van Weert, van Leeuwen, Armbrust.

**Statistical analysis.** Lelieveld, Takken, van Weert, Armbrust.

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