Aerobic and Anaerobic Exercise Capacity in Children With Juvenile Idiopathic Arthritis

M. van Brussel,1 O. T. H. M. Lelieveld,2 J. van der Net,1 R. H. H. Engelbert,1 P. J. M. Helders,1 and T. Takken1

Objective. To compare the aerobic and anaerobic exercise capacity of children with juvenile idiopathic arthritis (JIA) with healthy controls, to determine if there were differences based on disease onset type, and to examine the relationship between aerobic and anaerobic exercise capacity in children with JIA.

Methods. Sixty-two patients with JIA (mean ± SD age 11.9 ± 2.2 years, range 6.7–15.9) participated in this study. Aerobic exercise capacity was measured using a cardiopulmonary exercise test. Anaerobic exercise capacity was measured using the Wingate Anaerobic Exercise Test (WAnT).

Results. All patients were able to perform the cardiopulmonary exercise test and WAnT without adverse events. On average, the maximal oxygen uptake (VO2peak) and VO2peak/kg were 69.8% and 74.8%, respectively, of that predicted compared with healthy controls. Mean ± SD power was 66.7% ± 37.2% of that predicted compared with healthy children. Mean ± SD peak power was 65.5% ± 43.1% of that predicted compared with healthy children. There were significant differences between subgroups of JIA; the oligoarticular-onset group values did not significantly differ from healthy control values; the polyarticular rheumatoid factor positive–onset subgroup had the greatest impairment in both aerobic and anaerobic exercise capacity. The correlations of mean power and peak power with VO2peak were r = 0.884 and r = 0.697, respectively (P < 0.05).

Conclusion. This study demonstrates that both the aerobic and anaerobic exercise capacity in children with JIA are significantly decreased. The WAnT might be a valuable adjunct to other assessment tools in the followup of patients with JIA.

KEY WORDS. Exercise tolerance; Aerobic fitness; Cardiovascular deconditioning; Physical fitness.

INTRODUCTION

Children with juvenile idiopathic arthritis (JIA) are believed to have a lower aerobic capacity, anaerobic capacity, and functional ability, which means that they have more problems in performing daily activities compared with healthy children (1). These lower parameters could lead to a more inactive lifestyle. Nonetheless, the manifestations of the disease such as chronic joint pain and stiffness, synovitis, and deformity are also thought to aggravate an inactive lifestyle (2,3). The aerobic capacity in children with JIA has been studied extensively in recent years (4–12). Most of these studies suggest that patients with JIA have impairment in aerobic fitness (13), but little is known about the anaerobic capacity of children with JIA (10,14–17). Anaerobic capacity is important because most daily activities performed by children are anaerobic in nature. In a study by Takken et al (15), a large association between anaerobic physical fitness and functional ability demonstrated the importance of anaerobic physical fitness for children with JIA. Malleson et al (10) compared anaerobic fitness of a group of children with chronic arthritis with that of healthy controls and found no significant differences between mean peak anaerobic power for patients and controls; however, the mean values for both controls and patients were significantly lower than reported values for healthy children (10). Fan et al (16) and Wessel et al (17) studied children with JIA during a 50-meter run and found reduced sprint ability compared with healthy peers.
Fisher et al (18) found that children with JIA could improve muscle strength significantly after an exercise training program, without increase in disease signs and symptoms.

The current evidence base for anaerobic exercise capacity is small and is derived from findings in small cohorts. In the current study, we aimed to increase the evidence basis for both aerobic and anaerobic exercise capacity and their interrelationship. We therefore studied 1) the aerobic and anaerobic exercise capacity of a large cohort of patients with JIA and compared these with healthy controls, 2) if there were differences in aerobic and anaerobic exercise capacity in children with JIA based on disease onset type, and 3) the relationship among aerobic and anaerobic exercise capacity in children with JIA.

PATIENTS AND METHODS

Patients. Sixty-two patients with JIA participated in this study. The patients were recruited from the pediatric rheumatology outpatient clinic of the Wilhelmina Children’s Hospital and were diagnosed with JIA according to the International League of Associations for Rheumatology (ILAR) criteria (19). Thirty-six patients had polyarticular-onset JIA (29 rheumatoid factor negative and 7 rheumatoid factor positive), 11 patients had oligoarticular-onset JIA, 8 patients were classified as having extended oligoarticular-onset JIA, and 7 patients were classified as having systemic-onset JIA. Fifteen patients in the cohort were off medication. Of the remaining patients, 41 patients were receiving nonsteroidal antiinflammatory drugs, 28 were receiving disease-modifying antirheumatic drugs, 6 were receiving corticosteroids, and 7 were receiving biologic agents (biologic response modifiers). Disease onset and duration were assessed by retrospective analysis of patients’ files. During the tests, 35 patients had active disease, 12 patients were in clinical remission and taking medication, and 15 patients were in clinical remission and off medication, according to criteria developed by Ruperto and Martini (20). All tests and measurements of the patients were performed on the same day, with enough resting time between the aerobic and anaerobic exercise tests. Informed consent was obtained from the parents and/or from the children if they were >12 years of age. The Medical Ethics Committee of the University Medical Center Utrecht approved all study procedures.

Anthropometry. The children’s body mass and height were determined using an electronic scale and a stadiometer, respectively. Body mass index (BMI) was calculated as body mass (kg)/height (m2). The BMI of the included children was compared with reference values of healthy Dutch children (21) and with international cutoff points for BMI for overweight and obese children (22). Subcutaneous adiposity was determined from skinfold measurements using Harpenden skinfold calipers (British Indications, St. Albans, Hertfordshire, UK). Measurements were obtained in triplicate at 7 sites (at the right side of the body): triceps, biceps, subscapular, suprailliac, mid-abdominal, medial calf, and thigh in accordance with the American College of Sports Medicine guidelines (23). The sum of the 7 skin folds was used as an index for subcutaneous fat according to methods described by Pollack et al (24).

Joint status. Joint status was assessed by the number of tender and swollen joints. Tenderness and swelling were scored for the following joints: temporomandibular, sternoclavicular, shoulder, elbow, wrist, metacarpophalangeal and fingers, knee, ankle, metatarsophalangeal, and toes. Joint mobility was scored on the Pediatric Escola Paulista de Medicina Range of Motion Scale (pEPROM) (25). The pEPROM measures mobility in children with JIA based on the evaluation of joint range of motion. Ten joint movements (cervical spine [rotation], shoulder [abduction], wrist [flexion and extension], thumb [flexion metacarpophalangeal], hip [internal and external rotation], knee [extension], and ankle [dorsiflexion and plantar flexion]) were examined using a goniometer and were classified on a 4-point Likert scale ranging from 0 to 3 (0 = no limitation and 3 = severe limitation). The final score was calculated as the sum of the joint score of each movement divided by 10, providing a final range of scores for joint movement from 0 to 3.

Functional ability. The Childhood Health Assessment Questionnaire (C-HAQ) was adapted by Sing et al (26) from the Stanford Health Assessment Questionnaire for use in patients ages 1–19 years, and measures functional status. A Dutch version was translated and validated (27). The C-HAQ is a pediatric multidimensional questionnaire, which measures the child’s ability in performing functions included in 8 areas (dressing and grooming, arising, eating, walking, hygiene, reach, grip, and activities) for a total item number of 30. Respondents are directed to note only those difficulties caused by arthritis. Each question is scored from 0 to 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). The question with the highest score within each domain determined the score for that domain. Whenever aids or assistance were required, the score for that domain was increased to a minimum of 2. The mean of the scores on the 8 domains provided the C-HAQ disability scale (range 0–3, with 0 denoting no disability and 3 denoting severe disability). The C-HAQ also incorporates a double-anchored, horizontal, 10-cm visual analog scale for the assessment of the child’s overall well-being and a visual analog scale for the assessment of the intensity of the child’s pain.

Cardiopulmonary exercise test. The maximal oxygen uptake (Vo2peak) attained during a graded exercise test to volitional exhaustion is considered the single best indicator of aerobic physical fitness. Cardiopulmonary exercise test was performed on an electronically braked cycle ergometer (Lode examiner; Lode BV, Groningen, The Netherlands). The seat height was adjusted to the patient’s comfort. 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. Patients breathed through a mouth piece that was connected to a calibrated metabolic cart (Oxycon Champion; Jaeger, Viasys, Bilthoven, The Netherlands). Expired gas was passed through a flow meter, oxygen analyzer, and carbon dioxide analyzer. The flow meter and gas analyzer were connected to a computer, which calculated breath-by-breath minute ventilation, oxygen consumption, carbon dioxide production, and respiratory exchange ratio from conventional equations. Heart rate was measured continuously during the maximal exercise test with a 3 lead electrocardiogram.

**Wingate Anaerobic Exercise Test.** The Wingate Anaerobic Test (WAnT), as described by Bar-Or (28), was performed on a calibrated electromagnetic braked cycle ergometer (Lode Examiner; Lode BV). The ergometer was upgraded and calibrated by the manufacturer to a maximum resistance of 800W instead of the standard 400W. External resistance was controlled, the power output was measured, and mean power and peak power were calculated from the exercise results using the Lode Wingate software package (Lode BV, Groningen, The Netherlands). The seat height was adjusted to patients’ leg length (comfortable cycling height). The external load (torque; in Nm) was determined by body weight (at 0.53 × body weight and 0.55 × body weight for girls and boys, respectively, <14 years of age and 0.67 × body weight and 0.7 × body weight for older girls and boys, respectively) according to the user manual. The patients’ feet were placed in the Velcro toe straps and the exercise protocol was explained. The patients were instructed to exercise for 1 minute with the cycle ergometer with an external load of 15W at 50–60 revolutions per minute. Thereafter the sprint protocol started. The patients were instructed to cycle as fast as possible for 30 seconds. Power output during the WAnT was corrected for the inertia of the mass of the flywheel (23.11 kg/m²). Measured variables were mean power and peak power. Mean power represents the average power output over the 30-second sprint. Peak power is the highest recorded power output achieved during the 30-second sprint and represents the explosive characteristics of a person’s muscle power. Recent data indicated that the WAnT could be reliably assessed in children with JIA (29). The anaerobic exercise capacity of the patients with JIA was compared with age-, weight-, and sex-matched reference values obtained from 50 healthy Dutch children and adolescents as has been reported previously (30). The subjects were recruited from family members of staff at our hospital or were living in the neighborhood of our hospital. All controls were tested following the same protocol as the patients.

**Statistical analysis.** Statistical analyses were performed using the statistical Package for the Social Sciences for Windows (version 12.0; SPSS, Chicago, IL). Variables were expressed as the mean ± SD and range; statistical comparisons between measurements were made using the Student’s t-test. The data were also expressed as the percentage of impairment compared with reference values, because of the large ranges in age. Spearman’s correlations were used to calculate possible correlations between the aerobic and anaerobic capacity. The level of statistical significance was set at \( P < 0.05 \).

**RESULTS**

Fifteen boys and 47 girls were included in this study. The mean ± SD age of the patients was 11.9 ± 2.2 years with a range of 6.7–15.9 years. Mean ± SD age at disease onset and duration were 6.6 ± 3.6 years (range 0.5–15.3 years) and 4.7 ± 3.2 years (range 0.4–11.8 years), respectively. The anthropometric values are shown in Table 1. The mean body mass of the patients was 44.5 ± 14.4 kg (range 22.2–81.0 kg), the mean height was 1.53 ± 0.14 meters (range 1.24–1.83 meters), and mean BMI was 18.7 ± 3.7 kg/m² (range 13.2–28.2 kg/m²). The mean sum of the 7 skinfold measurements was 103.2 ± 46.5 mm (range 41.33–240.3 mm). The sum of the 7 skinfold measurements of the children with JIA was significantly higher \( (P < 0.0001) \) compared with healthy controls. The anthropometric parameters of the patients indicated that none of the patients were obese and 10 patients were overweight, although mean BMI and weight values did not differ from reference values. The results of joint status, joint mobility, and functional ability are shown in Table 1. The patients had a mean ± SD of 3.0 ± 4.6 tender and swollen joints (range 0.0–24.0) and a mean pEPMROM score of 0.3 ± 0.3.

| Table 1. Characteristics of patients with juvenile idiopathic arthritis and controls* |
|---------------------------------|----------|----------|-----|
| **Characteristic**             | **Patients** | **Controls** | **P** |
| Age, years                      | 11.9 ± 2.2 (6.7–15.9) | 12.3 ± 2.5 (7.9–16.8) | 0.469 |
| Body mass, kg                   | 44.5 ± 14.4 (22.0–81.0) | 45.1 ± 13.4 (24.1–81.7) | 0.748 |
| Height, meters                  | 1.53 ± 0.14 (1.24–1.83) | 1.57 ± 0.14 (1.29–1.91) | 0.278 |
| BMI, kg/m²                      | 18.7 ± 3.7 (13.2–28.2) | 18.0 ± 2.6 (13.8–26.5) | 0.613 |
| \( \Sigma 7SF \), mm            | 103.2 ± 46.5 (41.3–240.3) | 85.3 ± 35.0 (44.2–175.0) | < 0.0001 |
| pEPMROM                         | 0.3 ± 0.3 (0.0–1.3) |           |     |
| Swollen joints                  | 3.0 ± 4.6 (0.0–24.0) |           |     |
| C-HAQ                           | 0.7 ± 0.7 (0.0–2.5) |           |     |
| Disease onset, years            | 6.6 ± 3.6 (0.5–15.3) |           |     |
| Disease duration, years         | 4.7 ± 3.2 (0.4–11.8) |           |     |

* Values are the mean ± SD (range) unless otherwise indicated. BMI = body mass index; \( \Sigma 7SF \) = sum of 7 skinfold measurements; pEPMROM = Pediatric Escola Paulista de Medicinas Range of Motion Scale; C-HAQ = Childhood Health Assessment Questionnaire.
and 49.3% (n = 59) had an impaired aerobic exercise capacity and 94% (n = 58) had an impaired anaerobic capacity. The outcomes of the aerobic and anaerobic capacity for the different subtypes in this study are shown in Table 3 as additional findings. Table 4 shows that there were significant correlations between the impairments of the mean power, peak power, and \( \text{VO}_{2\text{peak}} \).

### DISCUSSION

The goal of this study was to compare the aerobic and anaerobic exercise capacity of children with JIA with that of age-, weight-, and sex-matched healthy controls; to determine if there were differences in aerobic and anaerobic exercise capacity in children with JIA based on disease onset type; and to examine the relationship among aerobic and anaerobic exercise capacity in children with JIA. The results show a significantly decreased aerobic as well as anaerobic capacity in children with JIA compared with healthy controls. The decreased aerobic capacity is in line with earlier findings by our group (5) and by others (4,13) and has been discussed extensively. In the current study, anaerobic capacity was expressed by means of peak power and mean power, which demonstrated that most of the children with JIA had a significantly lower anaerobic capacity compared with healthy children. Our study is the first to assess anaerobic exercise capacity in a large cohort of children with JIA compared with a healthy control group. Lower anaerobic capacity was also found in the

<table>
<thead>
<tr>
<th>Subgroup JIA</th>
<th>Mean power</th>
<th>Peak power</th>
<th>( \text{VO}_{2\text{peak}} )</th>
<th>( \text{VO}_{2\text{peak}}/\text{kg} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyarticular RF negative</td>
<td>64.4 ± 29.5†</td>
<td>64.7 ± 41.5†</td>
<td>65.2 ± 19.9†</td>
<td>70.2 ± 14.8†</td>
</tr>
<tr>
<td>Polyarticular RF positive</td>
<td>52.5 ± 38.2†</td>
<td>48.4 ± 41.1†</td>
<td>52.8 ± 22.3†</td>
<td>62.5 ± 8.4†</td>
</tr>
<tr>
<td>Oligoarticular</td>
<td>94.8 ± 55.5</td>
<td>94.4 ± 57.8</td>
<td>89.3 ± 32.6</td>
<td>78.8 ± 16.9†</td>
</tr>
<tr>
<td>Oligoarticular extended</td>
<td>57.2 ± 23.4†</td>
<td>52.7 ± 26.1†</td>
<td>68.3 ± 14.6†</td>
<td>75.7 ± 21.1†</td>
</tr>
<tr>
<td>Systemic</td>
<td>64.7 ± 27.9†</td>
<td>65.2 ± 30.7†</td>
<td>64.5 ± 19.7†</td>
<td>60.3 ± 1.8†</td>
</tr>
</tbody>
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* Values are the mean ± SD unless otherwise indicated. RF = rheumatoid factor; see Table 2 for additional definitions.
† Significantly different (\( P < 0.05 \)) from reference values.
Arthritis in childhood may result in significant muscular deficits (36–40). Localized muscle weakness and atrophy around inflamed joints, secondary to disuse, are common in children with joint disease, and may persist long after the resolution of the arthritis (11,38). Giannini and Protas (37) found significantly reduced isometric quadriiceps strength in children with JIA compared with healthy controls. Lindehammar et al (39,40) assumed that muscle weakness is in part caused by atrophy of the muscle, which is influenced by local arthritis. The presence and intensity of local arthritis is an important factor affecting muscle function in patients with JIA (40). Muscle weakness may result from disuse, because a smaller or deconditioned muscle has a lower cross-sectional area to generate force (41).

The sum of skinfold measurements was significantly higher in the JIA group than in controls. A lack in muscle activity due to arthritis and the resulting muscle wasting can contribute to a decreasing free fat mass composition (42) and an increasing sum of skinfold measurements.

The impairment in anaerobic exercise capacity might have strong clinical implications because many activities of daily living, such as play, leisure, and sport activities, are initially short term and high intensity (anaerobic) in nature (43). Impairment in anaerobic exercise capacity makes these activities difficult to perform or impossible to perform at all. Takken et al (15) found a significant relationship between anaerobic exercise capacity and functional ability in patients with JIA. This illustrates a possible physiologic basis for activities of daily living in pediatric rheumatology patients.

The study by Hebestreit et al (11) demonstrated that some patients with HLA-B27-positive juvenile spondylarthritis in whom disease is inactive or in remission had reduced aerobic fitness. In the current study, the children who were in remission (off medication) also showed a lower exercise capacity compared with healthy controls. The lower exercise capacity in the children in remission (off medication) did not differ significantly from the other patients. Therefore, we can say that children whose disease has been inactive for long periods still have deficits in aerobic and anaerobic capacity. Malleson et al (10) concluded that “disease severity may be related to fitness levels, but psychological factors may perhaps be more important determinants of fitness.” This could also be true for our 15 children who were off medication.

Children with JIA seem to have realistic perceptions of their own physical capabilities, and even those children who are less fit and perceive themselves as having less athletic competence do not appear to have lower self-esteem (10). Several studies have demonstrated that children with JIA can safely participate in physical activities (14,44–47). Exercise may prevent cardiovascular disease, osteoporosis, and the decline of functional ability. A training program might prevent deconditioning due to hypoactivity and break the vicious circle, thus improving functional ability. Hypoactivity is not only caused by detraining, but indirect links such as fear, overprotection, ignorance, and social isolation could also play a significant role. Aerobic exercise has been shown to have beneficial health effects for this patient group (36). It is yet to be determined if anaerobic exercise training should be performed in children with JIA. Because of the high impact on bones and cartilage, its safety should be studied carefully in patients with JIA before this training model can be recommended for use in the clinical setting. The relationship of anaerobic capacity with activities of daily living and functional outcome underlines the importance of further studies in the direction of exercise therapy in JIA. The different outcomes in (an)anaerobic capacity between subgroups of JIA that were found in this study underline that

### Table 4. Pearson’s correlations (r) between VO2peak, VO2peak/kg, mean power, and peak power

<table>
<thead>
<tr>
<th></th>
<th>VO2peak</th>
<th>VO2peak/kg</th>
<th>Mean power</th>
<th>Peak power</th>
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<tbody>
<tr>
<td>VO2peak</td>
<td>0.422†</td>
<td>0.884†</td>
<td>0.697†</td>
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<tr>
<td>VO2peak/kg</td>
<td>0.085</td>
<td>0.039</td>
<td>0.940†</td>
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<tr>
<td>Mean power</td>
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<td>Peak power</td>
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* See Table 2 for definitions.
† *P < 0.01.
exercise programs, to improve fitness, should be individualized or at least be modified according to different subgroups (4).

Bar-Or and Rowland (48) suggested that children, prepubescents in particular, are metabolic nonspecialists. This means that children are less specialized as anaerobic or aerobic performers. This is in accordance with our study in which children showed similar impairment in anaerobic and aerobic performance. Despite our finding of a moderate to large relationship between aerobic and anaerobic exercise capacity, we advise testing both, because they represent 2 different physiologic parameters. The WAnT might be a valuable adjunct next to other more commonly used assessment tools, such as the C-HAQ, the Juvenile Arthritis Functional Assessment Scale, hand-held myometry, and aerobic exercise tests.

In conclusion, we found that both aerobic and anaerobic exercise capacity were significantly decreased in a large cohort of patients with JIA under 16 years of age. Moreover, distinct differences were observed between sexes and disease subgroups. A moderate to large relationship was found between aerobic and anaerobic capacity measures.

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AUTHOR CONTRIBUTIONS

Dr. Takken 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. Takken, van Brussel, Lelieveld, van der Net, Engelbert, Helders.

Acquisition of data. Takken, van Brussel, van der Net, Engelbert.


Statistical analysis. Takken, van Brussel, Lelieveld, Engelbert.

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