Aerobic fitness after JDM—a long-term follow-up study

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Abstract

Objectives. It has previously been shown that patients with active JDM have decreased aerobic fitness; however, it is not known whether these patients regain their physical fitness after recovery. The objective of this study was to investigate the long-term outcome of aerobic fitness in patients with JDM. We hypothesized that fitness (VO2max) is reduced compared with healthy controls in the years after active JDM.

Methods. A maximal exercise test was performed using a cycle ergometer. Results were compared with those of sex- and age-matched healthy controls.

Results. A total of 36 patients with JDM in remission were included, 2–36 years after disease onset. Twelve patients (33%) had normal VO2max and 24 patients (67%) had decreased VO2max. Mean VO2max was higher in the healthy controls vs patients (P < 0.001, 95% CI −10.7, −4.4). A significant difference between patients with JDM and controls was observed for women (P = 0.001), men (P = 0.04), children < 18 years (P = 0.002) and adults > 18 years (P = 0.01). The decreased VO2max was independent of the duration of remission, but it was associated with the duration of active disease. By linear regression, it was revealed that for every year of active disease, VO2max was reduced by 0.85 ml/min/kg on average (P < 0.001).

Conclusion. This long-term follow-up study demonstrates that patients who have had JDM have persistently impaired fitness. This impairment is directly related to the duration of active disease.

Key words: JDM, follow-up, fitness, VO2max, myositis.

Introduction

JDM is the most common inflammatory muscle disease in childhood, often causing decreased functional ability and physical inactivity [1]. Patients with active JDM have decreased fitness and decreased aerobic capacity compared with healthy children [1–4]. Decreased aerobic capacity has also been demonstrated in adults with dermatomyositis/polymyositis [5]. Testing of aerobic exercise capacity has been validated in patients with JDM [6], and it has been suggested that maximal oxygen uptake (VO2max) could be an indicator of muscle function in patients with JDM [2].

A recent study of patients with JDM with impaired exercise capacity during active disease demonstrated an increased exercise capacity in periods of disease remission [7]. However, it is not known whether the patients with JDM fully regain their physical fitness in the years after recovery, as no long-term follow-up studies on inflammatory muscle diseases and physical exercise exist.

Chronic inflammatory disorders are associated with increased risk of cardiovascular mortality [8], and predictors of cardiovascular disease and metabolic abnormalities have recently been demonstrated to be common in children with severe JDM [9]. Furthermore, an association between decreased fitness and cardiovascular disease risk factors has been described—also in children...
[10–12]. Thus, further exploration of this area is of clinical relevance for patients with JDM, who have periods in their childhood with a combination of high levels of chronic inflammation and physical inactivity.

This study was part of a clinical follow-up study of Danish patients with JDM that describes the long-term outcome of patients with JDM [13]. In the present study we investigated the long-term outcome of aerobic fitness in the same patients. We hypothesized that VO$_{2\text{max}}$, although improved after active JDM, is still reduced compared with healthy subjects in the years after active JDM.

**Patients and methods**

A maximal exercise test was performed using a cycle ergometer in 36 patients with JDM, 2–36 years after disease onset. Results were compared with those of sex- and age-matched healthy subjects. The exercise test was carried out at the Neuromuscular Research Unit, Rigshospitalet, Copenhagen, Denmark.

The primary end point was to describe fitness (VO$_{2\text{max}}$) in patients who have suffered from JDM, but who are now in remission.

**Patients**

Patients were identified from the Danish National Register of Patients (1976–2007). Patients who fulfilled the Peter and Bohan criteria of definite and probable JDM [14] for at least 2 years and who were <18 years of age at disease onset were included. Patients were classified into four groups: (i) active disease; (ii) remission, still on treatment; (iii) remission, without medical treatment <1 year or (iv) remission, without medical treatment ≥1 year. Patients with active disease were not included in the final analysis. The study was approved by the Regional Committee on Health Research Ethics, Zealand, and the Danish Data Protection Agency. Informed written consent was given by all patients/parents.

In a national follow-up study, 53 patients were recruited [13]; 51 patients (96%) agreed to participate in the exercise test. In six patients, the JDM diagnosis was uncertain, three patients were excluded owing to pregnancy/lactation, one patient was too young (4 years) to cooperate, one patient could not perform the exercise test owing to contractures and muscular weakness and four patients had active disease. Hence 36 patients were included.

All patients with JDM were tested after the same protocol. The patients’ results were compared with those from 36 age- and sex-matched healthy subjects. The adult controls (≥18 years) were tested in the same lab, at the same cycle ergometer, and with the same protocol as the patients. Results from the children (<18 years) were matched with age-, sex- and height-matched healthy comparator cases from recent national school surveys with the same protocol for the children ≥8 years [15], whereas a treadmill was used in the surveys of children <8 years [16]. The exercise test on a treadmill gives a 6% higher VO$_{2\text{max}}$ [17], which we adjusted for in the calculations.

**Definitions**

To estimate disease activity, the Paediatric Rheumatology International Trials Organization JDM disease activity core set parameters [18] and nailfold capillaroscopy were used [19]. Active disease was defined as one of the following: JDM DAS > 0; Childhood Myositis Assessment Scale (CMAS) score < 48; physician’s global disease activity assessment > 0.5 cm, or creatine kinase > 150 U/l.

Disease-onset date was defined as the date of the first specific JDM symptoms, reported by the parents in the medical records. Diagnostic date was defined as the date when a physician used the definition dermatomyositis and initiated treatment. Remission date was defined as the date from which the patients demonstrated no clinical or biochemical evidence of disease activity and received no medical treatment for a minimum of 6 months. Disease duration was defined as the time from disease-onset date to remission date.

**Exercise capacity**

To determine VO$_{2\text{max}}$ and maximal workload (W$_{\text{max}}$), subjects performed an incremental exercise test to exhaustion on a cycle ergometer (Electronic Ergometer Bike 939E, Monark, Sports and Medical, Vansbro, Sweden). Gas exchanges were measured on a gas and airflow analyser (Quark b2; Cosmed, Rome, Italy). VO$_{2\text{max}}$ was expressed as ml/kg/min. Twelve patients felt uncomfortable wearing the mask for gas exchange measurements; in these patients, VO$_{2\text{max}}$ was calculated as follows:

\[
\text{VO}_{2\text{max}}(\text{l/min}) = 0.16 + 0.0117(\text{W}_{\text{max}}) \tag{20}
\]

Heart rate was monitored continuously. Three physiological criteria and one subjective criterion were used to determine whether the subjects reached a true maximal work capacity; the tests were considered maximal if the subjective criterion and at least one of the physiological criteria were met. The physiological criteria were as follows: heart rate; respiratory exchange ratio, RQ > 1.00; a plateau of VO$_{2\text{p}}$. In the subjects <18 years, a heart rate of > 195 beats/min was considered the maximum value, and the test was accepted if patients reached 90% of maximal. In adults, the satisfactory maximum value was calculated as HR$_{\text{max}}$ = (220 - age) × 90%. The test was stopped when the pedal rate per minute dropped from 70–80 to <50, and this was regarded as the patient’s maximal work capacity. For patients using the gas exchange mask, VO$_{2\text{max}}$ was measured directly, and VO$_{2\text{max}}$ was considered reached when oxygen consumption remained steady despite an increase in workload. The patients’ subjective perception of the test was estimated using the Borg Scale [21]. The work rate increment required to reach the peak workload during 10–15 min of exercise was estimated. Exercise time was 15 ± 5 min.

**Functional ability and disease damage**

Validated tools were used to measure functional ability and disease damage. Muscle function was tested using the Manual Muscle Strength Test (MMT) [22] and the CMAS [23]. The CMAS is a 14-item tool assessing
proximal, distal and axial muscle strength and endurance. It has been validated in children as young as 4 years [23]. The MMT assesses muscle strength on a 10-point scale and has been validated in JDM and other myositis conditions [22]. All muscular assessments were performed by the primary investigator experienced in evaluating myositis patients. A standardized order and set of commands were used.

Patients’ quality of life was measured using the Danish Childhood Health Assessment Questionnaire (CHAQ) or Health Assessment Questionnaire (HAQ) [24, 25]. Disease damage was measured using the Myositis Damage Index (MDI) and the Myositis Disease Damage by visual analogue scale (MYODAM VAS) [26].

Physical activity was measured by the ActiGraph GT1M Accelerometer (Actigraph Inc., Pensacola, FL, USA) [27]. The accelerometers recorded information in 5-s intervals (epochs). Patients wore an accelerometer for 7 consecutive days and were instructed to wear it during waking hours, but remove it during water activities and sleep. A patient needed at least 2 days of monitoring to be included. A period with >10 min of zero counts was defined as time when the accelerometer was not worn. Data were compared with recent studies using an identical protocol. Reference values for the children (<18 years) were from Danish school cohort studies [15, 16]; the adult reference values were from a Norwegian study [28].

Additional investigations

Height and weight were measured using the same electronic weight and measuring stick. Fat and muscle composition was measured by dual energy X-ray absorptiometry (DEXA) scan (Lunar Prodigy Advance; GE Healthcare, Amersham, UK). Blood pressure was measured automatically using a cuff size as recommended by the manufacturer (Spot Vital Signs LX; Welch Allyn, Skaneateles Falls, NY, USA). Three measurements were performed at rest, and the mean value was calculated. Recommended reference values for children were used in patients <18 years [29]. Before exercise, ECG (12-lead) and pulmonary function test (conventional spirometry; Jäger GmbH, Würzburg, Germany) were performed in accordance with guidelines [30].

After an overnight fast, all patients were screened for metabolic syndrome (MS) defined as central obesity plus two of four additional factors: raised triglycerides ≥ 1.7 mmol/l; reduced HDL cholesterol < 1.03 mmol/l in males, 1.29 mmol/l in females; raised blood pressure, systolic ≥ 130 mmHg, diastolic ≥ 85 mmHg; fasting plasma glucose ≥ 5.6 mmol/l or previously diagnosed type 2 diabetes [31]. In children 10–16 years, adult values were used, except that central obesity was defined as >90% percentile for age; in children <10 years, the MS was not diagnosed, but patients were classified according to their risk factors [32].

Lactate dehydrogenase, creatine kinase, liver transaminases, aldolase, ESR and ANA were measured in all patients, and myositis-specific/-associated autoantibodies were analysed (EJ, JO-1, Ku, Mi-2, OJ, PL-12, PL-7, PM-Scl75, PM-Scl100, Ro-52 and SRP) (Euroline Myositis Profile 3 immuno line-blot; Euroimmun, Lübeck, Germany).

Statistics

Data are presented as the mean and s.d. Paired sample t-test was used when comparing data against reference values [forced expiratory volume at 1.0 s (FEV1), forced vital capacity (FVC), physical activity counts]. Wilcoxon signed-rank test was used to compare data with matched controls (VO2max, absolute VO2max, age, Wmax, heart rate). The Kruskal-Wallis (KW) test for unpaired data was used when comparing the three groups (disease stage, remission time). If this KW test was significant, comparisons between each group were performed using the Mann–Whitney test with Bonferroni correction for multiple comparisons (Fig. 1).

The controls were matched for (i) date of birth, (ii) sex and (iii) height, in that order, and blinded for fitness. With nearly 500 controls in each age group, the matching was almost perfect (same sex, a few days difference in age, a few centimetres difference in height). As there is high biological variation within the same age group, this method ensured the highest degree of comparability.

Correlations between VO2max and muscle scores, disease damage, body composition and quality-of-life scores were calculated using the non-parametric Spearman’s test adjusted for sex and age (Table 1).

Predictors of VO2max were determined by linear regression analysis; the independent variables in the regression model were age, sex, age at disease onset, disease duration and time in remission. Backward selection was used for the final model. The level of significance was 5%. SPSS statistics software, version 17.0, was used for the statistical calculations.

Results

Subjects

A total of 36 patients (27 female, 9 male) were included. Characteristics of the patients are shown in Table 2. At the time of investigation, 21 patients were <18 years (of those 4 were ≤ 8 years), and 15 patients were ≥ 18 years. Three were in clinical remission but still receiving medical treatment; four had been in remission for less than 1 year and 29 for more than 1 year. All patients had normal levels of muscle enzymes, no signs of skin disease and normal nailfold capillaroscopy.

Maximal oxygen uptake, VO2max

VO2max was 18% lower for patients with JDM than for matched healthy controls (P < 0.001). The results from the exercise test are shown in Table 3. The decreased VO2max compared with healthy subjects was independent of the duration of achieved remission (Fig. 1).

The decreased VO2max showed a linear association with the duration of active disease, after controlling for the expected level of VO2max (computed on the basis of sex and age) (Fig. 2). By linear regression it was found that for every year of sickness, VO2max was reduced by
0.85 ml/min/kg on average ($P < 0.001$, 95% CI $-1.9$, $-0.2$). The regression analysis did not show a linear association between VO$_{2\text{max}}$ and time from remission or age at disease onset.

In a correlation analysis, adjusted for age, sex, height and weight, high muscle scores (MMT, CMAS) and total muscle mass were positively correlated with VO$_{2\text{max}}$ ($R > 0.6$). Damage scores (MDI, MYODAM) had a negative correlation ($R < -0.6$) with VO$_{2\text{max}}$ (Table 1).

### Cardiopulmonary status

All patients had a normal ECG, and most patients (28 of 36) had a normal pulmonary function test. No patients reported any pulmonary symptoms. Restrictive lung function was demonstrated in three patients (8%) and obstructive pattern in five patients (14%). The pulmonary variables are displayed in Table 3. Six patients had one or more positive autoantibodies (Mi-2, PM-Scl75, PM-Scl100 and Ro-52). There was no association between the presence of myositis-specific antibodies and an affected pulmonary function test or decreased aerobic fitness.

Patients’ total fat mass and fat percentage were negatively correlated with VO$_{2\text{max}}$ ($R = -0.7$), but not with BMI. There was no correlation between absolute VO$_{2\text{max}}$/free fat mass ratio and disease duration. Four women, 19–45 years, fulfilled the criteria of the MS.

### Daily activity

A majority of the patients (86%) wore an accelerometer that measured their physical activity. There were no significant differences between the patients and historical comparator cases ($P = 0.5$) or between VO$_{2\text{max}}$ and activity.
All patients had a CHAQ/HAQ score of <1.5. All adult patients had a full-time job or were in education. Four women had limitations on doing more strenuous housekeeping; no other functional limitations were reported.

Medical treatment

Previously we identified changes in treatment practice before and after 1990 [33], but there was no significant difference in VO\textsubscript{2max} in the patients treated before and after 1990 (P = 0.8).

### Table 2

**Characteristics of 36 patients with JDM**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>s.d.</th>
<th>Min.-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>36</td>
<td>21.8</td>
<td>10.4</td>
<td>9.5–45.9</td>
</tr>
<tr>
<td>Age at disease onset, years</td>
<td>36</td>
<td>7.6</td>
<td>4.2</td>
<td>1.8–16.9</td>
</tr>
<tr>
<td>Diagnostic delay, years</td>
<td>36</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1–2.0</td>
</tr>
<tr>
<td>Disease duration, years</td>
<td>36</td>
<td>4.6</td>
<td>2.8</td>
<td>1.0–10.6</td>
</tr>
<tr>
<td>Time in remission, years</td>
<td>36</td>
<td>9.4</td>
<td>9.7</td>
<td>0.5–30.1</td>
</tr>
<tr>
<td>Follow-up time, years</td>
<td>36</td>
<td>14.1</td>
<td>9.9</td>
<td>2.1–35.1</td>
</tr>
<tr>
<td>CMAS score, 0–52</td>
<td>36</td>
<td>49.8</td>
<td>6.0</td>
<td>27–52</td>
</tr>
<tr>
<td>MDI, 0–40</td>
<td>36</td>
<td>2.0</td>
<td>2.3</td>
<td>0–7</td>
</tr>
<tr>
<td>MYODAM VAS score, 0–110</td>
<td>36</td>
<td>2.3</td>
<td>3.4</td>
<td>0–10.5</td>
</tr>
<tr>
<td>MMT8 score, 0–80</td>
<td>36</td>
<td>78.1</td>
<td>3.5</td>
<td>62–80</td>
</tr>
<tr>
<td>MMT24, 0–260</td>
<td>36</td>
<td>256</td>
<td>11.1</td>
<td>196–260</td>
</tr>
<tr>
<td>CHAQ score, 0–3</td>
<td>13</td>
<td>0.02</td>
<td>0.04</td>
<td>0–0.1</td>
</tr>
<tr>
<td>HAQ score, 0–3</td>
<td>23</td>
<td>0.24</td>
<td>0.54</td>
<td>0–1.9</td>
</tr>
</tbody>
</table>

**Daily activity**:  
- Children < 18 years (counts/min)  
- Adults ≥ 18 years (counts/min)  
- Fat mass, kg  
- Muscle mass, kg

*There are five missing values (three children and two adults); three patients wore the accelerometer for too short a time period, and three children refused to wear the accelerometer. MMT8: MMT, 8 muscle groups; MMT24: MMT, 24 muscle groups.

### Table 3

**Differences between patients with JDM and sex- and age-matched healthy comparator cases**

<table>
<thead>
<tr>
<th></th>
<th>Patients with JDM mean (s.d.) n = 36</th>
<th>Comparator cases mean (s.d.) n = 36</th>
<th>Mean difference (95% CI)</th>
<th>P\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.8 (10.4)</td>
<td>21.6 (9.8)</td>
<td>2.9 (–3.0, 8.8)</td>
<td>0.14</td>
</tr>
<tr>
<td>VO\textsubscript{2max} (l/min/kg)</td>
<td>33.8 (8.4)</td>
<td>41.3 (7.9)</td>
<td>–7.5 (–10.7, –4.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;18 years (n = 21)</td>
<td>35.1 (6.9)</td>
<td>42.9 (7.1)</td>
<td>–7.6 (–12.9, –2.3)</td>
<td>0.002</td>
</tr>
<tr>
<td>≥ 18 years (n = 15)</td>
<td>32.4 (9.5)</td>
<td>42.1 (7.9)</td>
<td>–9.8 (–15.5, –4.0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Female (n = 27)</td>
<td>32.2 (6.8)</td>
<td>40.1 (7.3)</td>
<td>–7.9 (–11.9, –4.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male (n = 9)</td>
<td>38.3 (10.8)</td>
<td>47.1 (5.1)</td>
<td>–8.8 (–17.2, –0.3)</td>
<td>0.04</td>
</tr>
<tr>
<td>Absolute VO\textsubscript{2max} (l/min)</td>
<td>1916.6 (758)</td>
<td>2506 (660.7)</td>
<td>588.4 (236.7, 942.1)</td>
<td>0.002</td>
</tr>
<tr>
<td>Wmax (watt)\textsuperscript{b}</td>
<td>127.8 (60.8)</td>
<td>1683 (44.6)</td>
<td>405 (3.2, 77.7)</td>
<td>0.04</td>
</tr>
<tr>
<td>Max. heart rate (beats/min)\textsuperscript{c}</td>
<td>198.35 (6.8)</td>
<td>186.8 (11.1)</td>
<td>11.6 (–18.3, 14.9)</td>
<td>0.76</td>
</tr>
<tr>
<td>BMI (kg/m\textsuperscript{2})</td>
<td>21.3 (4.1)</td>
<td>21.67 (3.6)</td>
<td>0.54 (–1.4, 2.5)</td>
<td>0.24</td>
</tr>
<tr>
<td>FEV\textsubscript{1} (l/s)</td>
<td>3.24 (1.0)</td>
<td>3.31 (1.4)</td>
<td>–0.07 (–0.2, 0.1)</td>
<td>0.4\textsuperscript{e}</td>
</tr>
<tr>
<td>FVC (l)</td>
<td>3.7 (1.2)</td>
<td>4.1 (1.8)</td>
<td>–0.4 (–0.6, –1.6)</td>
<td>0.002\textsuperscript{a}</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Wilcoxon signed-rank test unless otherwise stated, \textsuperscript{b}31 matched pairs, \textsuperscript{c}18 matched pairs, \textsuperscript{d}reference values, \textsuperscript{e}paired sample t-test.

### Discussion

This study aimed to describe fitness (VO\textsubscript{2max}) in patients that have suffered from JDM but now are in remission. The main finding was that VO\textsubscript{2max} was decreased in patients with previous JDM, although they had been in clinical remission for many years. Longer disease duration was correlated with a decreased VO\textsubscript{2max}, but there was no association between the duration of remission and the present level of VO\textsubscript{2max}, indicating that the patients did not recover over time.
Decreased VO$_{2\text{max}}$ in patients with JDM with active disease has been shown by other investigators [1, 2, 34]. An increase in VO$_{2\text{max}}$ shortly after remission has been demonstrated by Takken et al. [7], but this is the first study that describes a persistent decrease in fitness in patients with JDM, lasting many years after remission.

Several factors could determine this decrease in VO$_{2\text{max}}$. JDM is a disease that affects the muscles in several ways, resulting in decreased muscle strength and maximal muscular oxygen uptake. Histopathological changes in muscles include infiltrates of inflammatory cells with invasion of viable muscle cells; degenerating, regenerating and necrotic fibres; decreased type I muscle fibres [35] and capillary destruction [36, 37]. This angiopathy might lead to disturbed muscle perfusion, which may impair oxygen delivery and aerobic capacity [2]. However, angiopathy is reversed in patients in remission for years, and therefore low performance might be related to irreversible destruction of muscle tissue in the course of the active disease. Steroid treatment is also known to have a negative impact on muscle strength, which may play a role in decreased muscle performance, however, the corticosteroid effect is usually reversible and should have little effect in patients who have been in remission without treatment for a long time [38].

We found a significant correlation between decreased VO$_{2\text{max}}$ and reduced muscle scores (CMAS, MMT), indicating that a muscular component may account for a part of the decreased VO$_{2\text{max}}$. This corresponds with Takken et al. [2], who found a correlation between low fitness and low CMAS score, and decreased exercise time in children with JDM, indicating less peripheral muscle endurance.

Muscle atrophy may explain part of the muscle weakness in JDM, although muscle biopsies show only few signs of atrophy, even in severely weakened patients with JDM [39]. Furthermore, in chronic inflammatory rheumatic diseases, circulating inflammatory cytokines cause muscle atrophy and loss of skeletal muscle mass, which can create a vicious circle, with even more decreased physical activity and further muscle weakening, leading to an increasingly sedentary lifestyle [35].

In studies of healthy persons, a sedentary lifestyle plays an important role in decreased VO$_{2\text{max}}$ [40, 41]. In childhood, patients with JDM often experience periods where they are unable to participate in normal physical activities, and it could be hypothesized that incomplete recovery of muscle function might lead to a sedentary lifestyle in patients with JDM, explaining the decreased VO$_{2\text{max}}$. In healthy populations, a sedentary lifestyle causes 8–28% decrease in VO$_{2\text{max}}$ [40, 42]. Our population had 18% decrease in VO$_{2\text{max}}$, but as their measured activity level was comparable to that of healthy controls, we suspect that the decrease in VO$_{2\text{max}}$ is due to affected muscles.

The figure shows that the difference in VO$_{2\text{max}}$ when compared with normal controls (PatientVO$_{2\text{max}}$ – ControlVO$_{2\text{max}}$) is predominantly negative, and thus the patients’ VO$_{2\text{max}}$ is lower than the matched control. A linear regression analysis showed a negative association with disease duration (P = 0.03).
In healthy populations, decreased physical activity is strongly related to risk factors that define the MS. Low cardio-respiratory fitness and decreased muscular strength and lower life expectancy are associated with MS [41–44] and MS is associated with lower life expectancy [11, 12]. In our study, four patients (11%) fulfilled the criteria of MS, and recently Coyle et al. [9] found that 25% of 17 severely affected patients with JDM fulfilled the criteria of MS. This indicates that future clinical awareness of the risk factors of the MS is of relevance in patients with JDM.

In this study, patients were recruited on the basis of medical records with large variations in the available information. It could be difficult to judge whether the diagnosis was correct, as the descriptions of the skin rash and muscle biopsies were not comprehensive. In consequence, only patients with a definite/probable diagnosis according to the diagnostic criteria [14] were included, which may lead to a bias towards including more severely affected patients and excluding milder cases. Thus VO\textsubscript{2max} in former patients with JDM could be underestimated.

Disease duration was associated with decreased VO\textsubscript{2max}. Previously, long disease duration has been associated with increased persistent damage in patients with JDM [45, 46]. The present study was not designed to identify the causes of prolonged disease, and we cannot distinguish between a protracted disease course owing to disease severity, insufficient treatment, diagnostic delay or other explanations.

The medical therapies were not standardized, making it impossible to validate the impact of therapeutic interventions on VO\textsubscript{2max}. Since 1990 immunosuppressants have been used in all patients, whereas only severely affected patients received immunosuppressants before 1990 [33]. Therefore it is surprising that there was no difference in fitness outcome when comparing patients treated before and after 1990, as the medical treatment has improved. In Denmark, the attitude towards more active physiotherapy and exercise during periods of active disease has changed within the last 10 years, so although patients recover earlier from their disease, there has only recently been a focus on regaining muscle strength and fitness after the disease, which might be an explanation for this finding.

Aerobic fitness is influenced by the level of physical activity, which was measured by accelerometer. A few methodological considerations should be noted. There are no reference values for Danish adults wearing accelerometers, therefore Norwegian controls were used. These populations have comparable exercise capacity [47]. The accelerometers were worn for 5–7 consecutive days, but a few patients wore them for a shorter period. To be included, it had to be worn for at least 2 consecutive days. The activity was measured as counts per observed minute. There was no association between counts per minute and number of valid days. Thus including subjects with few days of monitoring only introduces non-differential misclassification, not bias.

Another methodological consideration was that not all the patients wore a mask during the exercise test. However, a high correlation (R > 0.8) was observed between peak VO\textsubscript{2} and maximal power output, and peak VO\textsubscript{2} was therefore calculated from maximal power output in these patients [16, 48]. We did not measure diffusion capacity (DLCO), which is more sensitive to small airway damage and might have identified more patients with pulmonary affection, which then could explain the decreased fitness.

CMAS and MMT measured muscle strength before exercise, but CMAS has not been validated in adults. Thus a very well-trained person could have a maximum score on the CMAS, while a decrease in muscle strength compared with the patient’s expected level will not be caught. An inactive healthy person might have a lower CMAS score in spite of normal muscle function, which can make it difficult to distinguish between disease sequelae and inactivity.

Adults with myositis have incomplete recovery of muscle function after disease remission [49, 50], but a few studies indicate that a muscle training programme could improve VO\textsubscript{2max} in patients with active disease [34, 50]. Future studies are needed to investigate whether this is also the case for patients with JDM, in whom muscle damage affects the growth phase of the musculature. As even small improvements in fitness lead to lower mortality in a healthy population [10, 11], this could be of clinical relevance for patients with JDM. In conclusion, this long-term follow-up study demonstrates that patients previously affected by JDM have persistently impaired aerobic fitness, and that this impairment is directly related to the duration of active disease.

**Rheumatology key messages**

- Patients with JDM have significantly impaired aerobic fitness several years after remission.
- It is recommended that fitness be measured routinely in patients with JDM.

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