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# PHYSICAL PERFORMANCE IN INDIVIDUALS WITH LATE EFFECTS OF POLIO

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**ABSTRACT. The aim of this study was to evaluate physical performance in individuals with late effects of polio; specifically, to evaluate the effects of reduced muscle strength in the lower limbs. Thirty-two individuals seen at the polio clinic at Sahlgrenska University Hospital, Göteborg, Sweden, participated in the study. Each subject performed a bicycle exercise test in which peak oxygen uptake and anaerobic threshold were determined. Muscle strength in the quadriceps and the hamstrings were measured on an isokinetic dynamometer. Reductions in peak workload, peak oxygen uptake and predicted heart rate were seen. The anaerobic threshold was within or slightly lower than normal limits in relation to predicted maximal oxygen uptake, indicating that the cardio-respiratory system was not limiting performance. The muscle testing demonstrated a significantly lower ability to perform muscle actions compared with individuals from a reference group, and strong correlations were found between muscle strength peak $VO_2$ and peak workload, respectively. Adjusted peripheral muscle endurance training might improve the work capacity in those individuals with weak leg muscles and low oxygen uptake, while individuals with relatively good muscle strength would improve their aerobic fitness in a general fitness program.**

*Key words:* post-polio; physical performance; bicycle test; muscle performance.

## INTRODUCTION

Individuals with late effects of polio often complain of fatigue, and this symptom is one of the most common seen at polio clinics (2, 16, 27). In a study by Packer et al. (20), it was found that post-polio individuals experienced twice as much fatigue as control subjects. Fatigue is a complex phenomenon and it can have a variety of possible explanations and can also mean different things to different individuals (4). In post-polio individuals it is probably a combination of different aspects (1). In a study by Berly et al., (7), individuals with late effects of polio described fatigue as "increasing physical weakness", a sensation of loss of strength during exercise and "heavy sensations of the muscles". Degeneration of damaged activating centra in the brain has been demonstrated to be caused by the disease and may be one, although a rare, explanation for severe fatigue among some individuals with late effects of polio (10). A reason for a decline in function leading to fatigue is the loss of motor units and increased muscle weakness, which can also be effected by disuse or overuse (14, 21). Cardio-respiratory deconditioning leading to fatigue can be a result of a lower level of physical activity. In the musculature this may result in lower than normal levels of oxidative enzymes and capillarization (8).

Physical performance in individuals with late effects of polio was evaluated in two studies using a bicycle/arm ergometer. Owen (19) found on testing 21 individuals that they were extremely deconditioned. On testing 68 individuals with late effects of polio, Stanghelle et al. (22) reported a pronounced reduction in maximal oxygen uptake, especially in women. They also suggested that one-third of the individuals tested were forced to stop the test owing to muscle factors. However, no data on muscle strength are available. In studies in individuals with other muscle diseases, weakness and reduced muscle mass have been found to be associated with a markedly reduced maximal oxygen uptake (13).

The aim of the present study was to evaluate physical performance in individuals with late effects of polio and, specifically, to evaluate the effects of reduced muscle strength in the lower limbs.

## METHODS

### *Subject*

Thirty-two consecutive individuals with late effects of polio seen at the polio clinic at Sahlgrenska University Hospital were asked to participate in the study (Table I); all accepted. Inclusion criteria were: experience of late effects of polio; ability to cycle an ergometer bicycle; no clinically known cardio-respiratory disease; and age 65 years or below. The mean age of the group was 50 years (range 22–65 years). All were walkers with or without devices. The mean age at onset of polio was four years, for both women and men, and the average stable phase lasted for approximately 30 years. Twenty-seven individuals fulfilled the criterion for PPS (post-polio-syndrome) (15) being: a prior history of polio; typical findings on EMG; neurological recovery followed by an extended period of stability of at least 20 years; onset of new or increased muscle weakness; and other symptoms, such as fatigue muscle pain and joint pain, and exclusion of other conditions that might have caused the new health problems. The remaining individuals had late effects of polio, but did not fulfil the criteria for PPS. The polio effect was determined according to the individual's own clinical history together with EMG results in relevant muscle groups. None of the individuals had any clinically known cardio-respiratory disease. Six were on anti-hypertensive drugs, three on diuretics and three on $\beta$-blocking agents. Only one individual smoked regularly. All individuals were given information about the study, which was approved by the Ethics Committee at the Faculty of Medicine, Göteborg University.

*Assessments*

*The peak oxygen uptake and anaerobic threshold* were tested on a bicycle ergometer (CCE 2000 Medical Graphic Corporation, St Paul, MN, USA). The exercise started at zero and continued with a 10 Watt stepless increase every minute. Before each test, the individual familiarized him- or herself with the equipment and was asked to breathe through the mask for three minutes. This was followed by a three-minute period of pedalling without friction resistance before the exercise test started at 0 Watt. The test was supervised by a physiotherapist and a physician was present in the laboratory. Each individual performed a maximum test, i.e. was verbally encouraged to continue as far as he or she could. Perceived effort was rated on the Borg Category Ratio Scale (Borg CR-scale) with increments from 0 to 10 (9). In some cases, the individual had to wear a brace and/ or to be strapped around the foot to be able to perform the exercise test. Gas exchange was recorded during bicycle exercise by measuring the expired gas flow and expiratory oxygen and carbon dioxide concentrations with gas meters, which were calibrated against gas mixtures of known concentrations before each test. Oxygen consumption and carbon dioxide production were measured continuously at standard temperature and pressure. Heart rate was recorded from a three-lead ECG tracing, and blood pressure was measured with a sphygmomanometer once each minute during the test.

The anaerobic threshold was defined as the point at which the rise in $CO_2$ production was higher than the rise in oxygen consumption and was determined by the V-slope method (the point at which the change in the difference between the slopes for $VCO_2$ and $VO_2$ are $>0.1$) (5) . This point was determined by a computer programme (Med Graphic Co-operation, St Paul, MN, USA), and the method is reliable and found to be more exact than visual inspection of graphical plots (5). All parameters in the bicycle ergometer test were compared with reference values from a normal population (26).

*Force vital capacity (FVC)* was measured by spirometry (Micro Medical, Rochester, Kent, UK) and the values were compared with reference values for healthy persons (6).

*Muscle strength* in the quadriceps and hamstrings was measured using an isokinetic dynamometer (KINetic-COMmunicator, Chattex, Chattanooga, USA). The individual was seated with his or her back against the seat. A seat belt was strapped around the waist and the thigh to avoid unwanted movements. Prior to the test, the patient warmed up for five minutes on a bicycle ergometer. Peak isometric strength was measured at a 60° knee angle in extension and flexion. Maximal isokinetic strength was measured at a velocity of 60°/second and 180°/ second for concentric muscle actions. All measurements were performed by both legs if possible and compared with reference values from a random population (K. Stibrant Sunnerhagen, unpublished observation).

Self-chosen and maximal walking speed for 30 m walking were measured (3). The test started with the self-chosen speed. The values from the test were compared with those from references from a random population (K. Stibrant Sunnerhagen, unpublished observation).

*Physical activity level* was determined by means of PASE (Physical Activity Scale for the Elderly). The instrument is comprised of self-reported items concerning occupational, household and leisure activities over a one-week period. The maximal score is 360 points (24). The activity level was compared with values for age and sex from a random population (K. Stibrant Sunnerhagen, unpublished observation).

Table I. *Characteristics of 32 individuals with late effects of polio. Values in mean ± SD*

| | Women ($n = 16$) | Men ($n = 16$) |
|---|---|---|
| Age (years) | 51 ± 11 | 48 ± 8 |
| Body length (cm) | 163 ± 6 | 176 ± 7 |
| Body weight (kg) | 63 ± 9 | 76 ± 21 |
| BMI* | 24 ± 3 | 26 ± 2 |
| Age at onset of disease (years) | 4 ± 3 | 4 ± 3 |
| Stable phase (years) | 28 ± 13 | 30 ± 10 |
| Time since new symptoms (years) | 16 ± 13 | 8 ± 6 |

* Reference value 19–25.

*Statistical methods*

Conventional formulae were used for calculations of mean, median, standard deviations and 95% confidence intervals. The strength of the correlation between variables was assessed by Spearman's rank correlation test. The Mann–Whitney U test was used to test differences between groups, and the Wilcoxon signed-rank test was used for testing differences within groups. Multiple correlation analysis was adjusted using the Bonferoni–Holm method (17).

## RESULTS

The average peak workload in bicycling exercise was 61% of the predicted value for men and 77% of the predicted value for women (Table II). Ten individuals, five men and five women, had a value for peak oxygen uptake of 90% of that predicted. Seven individuals had less than 50% of the predicted maximal oxygen uptake.

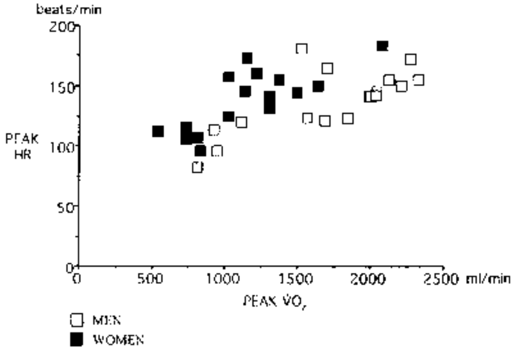


*Fig. 1.* Peak heart rate and oxygen uptake among 32 individuals with late effects of polio.

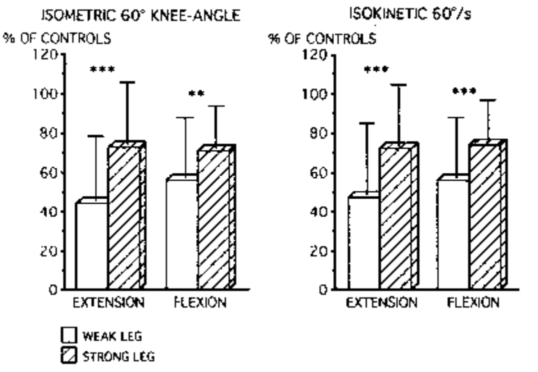


*Fig. 2.* Relative peak torque values for isokinetic and isometric flexion and extension compared with reference values in the weak and strong legs. ***$p < 0.001$. **$p < 0.01$ for the difference between the strong and weak leg.

Characteristic for these seven individuals, with one exception, was strongly reduced muscle strength; four were one-leg cyclers, and none performed above 50 W on the exercise test. The peak heart rate was somewhat lower in most subjects than the predicted. This was above 170 beats/minute in only four individuals and 160–170 beats/minute in an additional two. None of the subjects with a peak maximal oxygen uptake below 1l/minute had a peak heart rate above 120 beats/minute (Fig. 1).

The anaerobic threshold was found to be at an average of 47% of predicted maximal $V0_2$ among the women and at 34% among the men (Table II). Totally nine individuals could not perform the work necessary to reach the anaerobic threshold and had an average peak workload of 33% of predicted values. All except eight individuals reached a peak RER (respiratory exchange ratio) $\geq$1.00. These eight were all among the group that did not reach the anaerobic threshold. The average perceived effort marked on the Borg scale was 6 (verbally between strong and very strong) for the women and 8 (verbally greater than very strong) for the men (Table II).

The values for FVC were 92% of predicted value (SD = 14) for the men and 97% (SD = 16) of predicted value for the women.

The results of the muscle testing demonstrated a significantly lower muscle strength among the individuals with late effects of polio than among individuals from the reference group (Fig. 2). The mean peak torque in the individuals' weak legs was 50–60% of control values and the mean peak torque in the stronger legs was just under 75–80% of that of the reference group. In knee extension at 60°/second, all except three men and five women were outside the 95% confidence interval of the reference group (Fig. 3). The difference between the strength in the strong and the weak legs in each individual showed considerable variation.

The average maximal walking speed for the women

Table II. *Results of the exercise test on bicycle ergometer in 32 individuals with late effects of polio. Values in mean* $\pm$ *SD*

| | Women ($n = 16$) | Men ($n = 16$) |
|---|---|---|
| Peak Watt | 71 ± 43 | 110 ± 51* |
| Peak Watt % of pred. (26) | 77 ± 44 | 61 ± 29 |
| Peak $VO_2$ ml/kg/minute | 19 ± 7 | 22 ± 7 |
| Peak $VO_2$ % of predicted max. (26) | 79 ± 24 | 69 ± 22 |
| Peak HR beats/min | 138 ± 26 | 137 ± 27 |
| AT % of max VO (26) | 47 ± 15 | 34 ± 9* |
| RER (respiratory exchange ratio) | 1.12 ± 0.10 | 1.13 ± 0.15 |
| Borg (0–10) | 6 ± 2 | 8 ± 2 |

* $p \leq 0.05$ denotes difference between women and men.

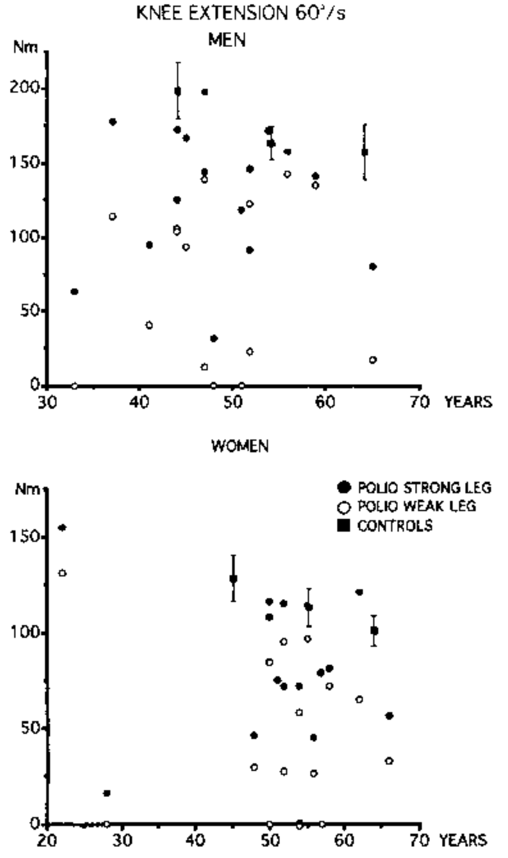


*Fig. 3.* Individual peak torque values for knee extension 60°/second in the strong and weak leg in each individual. The 95% confidence interval for the reference values is shown by vertical lines.

was 1.3 m/second (SD = 0.38) and for the men 1.5 m/second (SD = 0.17). Compared with reference values, maximal walking speed was strongly reduced. The difference between the self chosen and maximal walking speeds was only half of that in the reference individuals, among both woman and men ($p < 0.001$) (Fig. 4). The average physical activity level measured by PASE was 134 points (SD = 76) for women and 146 (SD = 96) for men. This was 78% of the reference values for women and 83% for men.

Strong positive correlations were found between muscle strength, peak $VO_2$ uptake and peak workload (Table III). The isokinetic strength in the strong leg explains 50% of the variation in peak workload, whereas the strength in the weak leg explains 49%. There was also a correlation, although somewhat weaker, between muscle strength and maximal walking speed.

## DISCUSSION

This study demonstrates a reduced capacity for exercise among individuals with late effects of polio. The work capacity on the bicycle ergometer is, as expected, influenced by muscle strength in the lower limbs. The perceived general fatigue in the exercise test, measured by the Borg scale (verbally strong to more than very strong), showed an acceptably high level of effort. While the activity level among the individuals in the study measured by PASE was lower than reference values, an examination of each single activity in the test show that all except one scored maximum points in housework activities and half of the individuals scored points from paid work that includes walking and/or handling materials. This, together with the fact that there was a small difference between self-chosen and maximal walking speed among the individuals, demonstrates a high relative level of physical activity in daily activities.

The anaerobic threshold in relation to predicted maximal oxygen uptake was within normal limits for the women and slightly below the predicted limit for the men, in spite of reduced maximal oxygen uptake. This is

Table III. *Correlation between knee muscle strength and peak $VO_2$ peak watt and maximal walking speed*

| | Peak $VO_2$ | | Peak Watt | | Max. walking speed | |
|---|---|---|---|---|---|---|
| | Weak leg *r* | Strong leg *r* | Weak leg *r* | Strong leg *r* | Weak leg *r* | Strong leg *r* |
| Isometric | | | | | | |
| Extention 60° | 0.654** | 0.704** | 0.700** | 0.747** | | |
| Flexion 60° | 0.636** | 0.479* | 0.520* | 0.542** | | |
| Isokinetic | | | | | | |
| Extension 60°/s | 0.649** | 0.819** | 0.624** | 0.770** | 0.444* | 0.505* |
| Flexion 60°/s | 0.664** | 0.497* | 0.458* | 0.598** | | |

* $p \leq 0.05$; ** $p \leq 0.01$

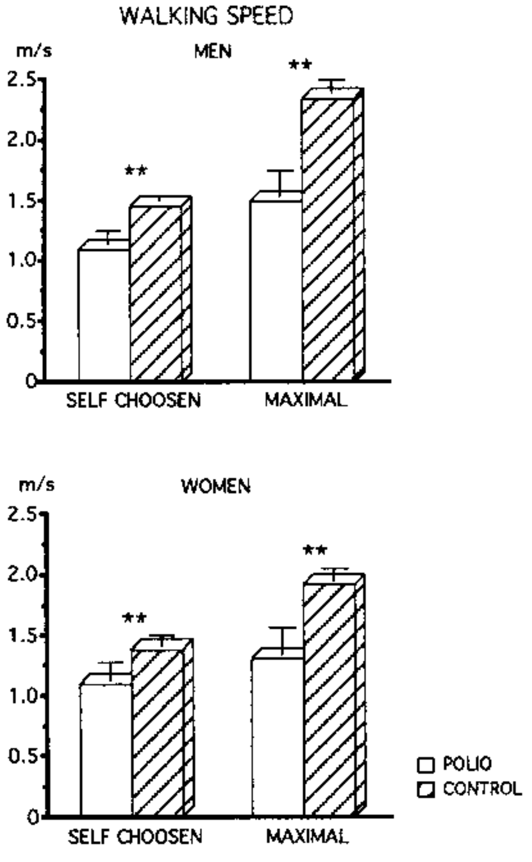


*Fig. 4.* The walking speed for self-chosen and maximal walking speed in individuals with late effects of polio and controls. $**p < 0.01$ for the difference between the individuals with late effects of polio compared with the reference group.

an indication that the cardio-respiratory system does not limit performance on the bicycle (25). A more probable explanation is that the reduced muscle function in essential muscle groups limits maximal performance at bicycle exercise. Nine individuals did not have a measurable anaerobic threshold. This may not be surprising, even though there is an increased lactate concentration in the polio-affected muscles, it is, however, not large enough to increase the total lactate level.

Stanghelle et al. (22) also found reduced work capacity at the bicycle exercise in individuals with late effects of polio. They presumed that the limiting factor for some individuals was related to muscle factors (muscle fatigue), but no data on local muscle performance were reported. The present study demonstrates a strong correlation between muscle strength and both peak work capacity and oxygen uptake. Some individuals did not have sufficient muscle strength to pedal the ergometer cycle optimally, and some could use only one leg for bicycling. The quadriceps muscle is one of the main muscles involved in cycling, and the velocity of 60°/sec was chosen for the analysis to be in accordance with the pedal velocity of the bicycle (11). The somewhat weak correlation between the maximal walking speed and the muscle strength for knee extension is not surprising, since other muscle groups than the knee extensors are of greater importance for walking (12).

Besides a reduction in muscle mass after polio, increased muscle fatigue can also be a result of inactivity with a decreased level of oxidative enzymes and reduced capillarization. Adapted training of the muscles in both the strong and the weak leg might improve work capacity, leading to better performance in activities of daily living (ADL). In individuals with weak leg muscles and low peak heart rate and oxygen uptake, muscle training focusing mainly on peripheral muscle endurance would be recommended. This is supported by the work by Tollbäck (23), who showed that, in polio muscles with reduced strength, the muscles favour strength at the cost of endurance when used excessively. In a study by Jones et al. (18), individuals with post-polio symptoms increased their aerobic fitness after exercising for 16 weeks. The exercise subjects also felt less fatigue and felt stronger in their leg muscles. In the present study, there were individuals with relatively good muscle strength, high peak heart rate and reduced maximal oxygen uptake. They would have the requirements to improve aerobic fitness in a general exercise program. Training using both models might lead to better performance in ADL.

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