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Fatigue resistance of the knee extensor muscles is not reduced in post-polio syndrome

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Abstract

The present study investigated whether intrinsic fatigability of the muscle fibers is reduced in patients with post-polio syndrome (PPS). This may contribute to the muscle fatigue complaints reported by patients with PPS. For this purpose, we assessed contractile properties and fatigue resistance of the knee extensor muscles using repeated isometric electrically evoked contractions in 38 patients with PPS and 19 age-matched healthy subjects. To determine whether any difference in fatigue resistance between both groups could be attributed to differences in aerobic capacity of the muscle fibers, 9 patients with PPS and 11 healthy subjects performed the same protocol under arterial occlusion. Results showed that fatigue resistance of patients with PPS was comparable to that in controls, both in the situation with intact circulation and with occluded blood flow. Together, our findings suggest that there are no differences in contractile properties and aerobic muscle capacity that may account for the increased muscle fatigue perceived in PPS.

Keywords: Postpoliomyelitis syndrome; Muscular fatigue; Skeletal muscle fibers; Muscle weakness; Electric stimulation

1. Introduction

Postpoliomyelitis syndrome (PPS) is a complex of late onset neuromuscular symptoms with new or increased muscle weakness and abnormal muscle fatigability as key symptoms [1,2]. Knowledge about the origin of the muscle fatigue perceived by patients with PPS is presently limited. The muscle fatigue may result from the motor unit reorganization and the altered pattern of activity and function of the remaining muscle fibers that occurred during recovery from the acute polio and the secondary decline [3].

Several adaptations have been described that may change the fatigue resistance of the muscle fibers in PPS [4–6]. Mean muscle fiber cross-sectional area was found to be about twice as large in patients with PPS compared to healthy subjects, probably due to excessive use of remaining fibers [6]. Secondary to this hypertrophy, a reduced capillary supply in relation to fiber area was observed, that might impair diffusion capacity, leading to shortage of substrate during muscle work. This assumption is supported by the low aerobic enzyme activity of the muscle fibers [5]. A low capillary density in combination with decreased aerobic enzyme capacity would reduce fatigue resistance of the muscle fibers. Furthermore, a muscle fiber transformation from type II fibers to type I fibers was reported, most likely also resulting from overuse of the reduced muscle mass. Contrary to the other adaptations, this would enhance fatigue resistance [4–6]. Therefore, it remains unclear whether the combination of these opposite adaptations will enhance or reduce the fatigue resistance of the muscle fibers in patients with PPS compared to healthy subjects [3].

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The few studies on fatigability of muscles in PPS reported contradictory results. Some have shown that muscles of patients with PPS are more fatigable than muscles of healthy subjects, irrespective of strength [7–9], while other studies reported no differences [10–13]. All these studies have in common that voluntary contractions were used to induce fatigue. Because fatigue is influenced by both central neural and peripheral muscle factors, the use of voluntary contractions complicates the search for the relative contribution of each of these factors. The use of electrically evoked contractions, an experimental situation that completely removes the volitional element, allows studying the intrinsic fatigability of the muscle fibers [14,15].

Our primary objective was to investigate fatigue resistance of the knee extensor muscles in patients with PPS during electrically evoked muscle contractions in comparison with healthy subjects. The knee extensor muscles were chosen, because muscle weakness in PPS often affects the lower limbs, and measurements can accurately be performed on this muscle group that is of major importance during locomotion-related activities [16]. The second objective was to determine whether differences in fatigability between both groups could be attributed to differences in blood flow or aerobic capacity of the muscle. Therefore, we compared fatigue with an intact circulation with fatigue under ischaemic conditions, during which the ability for aerobic energy regeneration was largely eliminated [17]. If differences in fatigue resistance between PPS and healthy subjects during the protocol with an intact circulation are attributed to differences in aerobic muscle capacity or blood flow then no differences will be evident when the blood supply is occluded.

2. Materials and methods

2.1. Subjects

A sample of 38 former polio patients who were diagnosed with PPS according to the criteria published by the March of Dimes participated in this study [1]. The criteria for PPS are as following: (1) prior paralytic poliomyelitis with evidence of motor neuron loss, as confirmed by history of the acute paralytic illness, signs of residual weakness, and atrophy of muscles on neurological examination, and signs of denervation on electromyography (EMG), (2) a period of partial or complete functional recovery after acute paralytic poliomyelitis, followed by an interval (usually 15 years or more) of stable neurologic function, (3) gradual or sudden onset of progressive and persistent muscle weakness or abnormal muscle fatigability (decreased endurance), with or without generalized fatigue, muscle atrophy, or muscle and joint pain, (4) symptoms persist for at least 1 year, and (5) exclusion of other neurologic, medical, and orthopedic problems as causes of symptoms. Patients were recruited from the Dutch expert center for polio survivors of the Academic Medical Center in Amsterdam. Twenty-eight of these patients performed the measurements as part of an ongoing clinical trial of the efficacy of exercise therapy and cognitive behavioral therapy to improve fatigue, daily activity performance, and quality of life in PPS [18]. The remaining 10 patients responded to an invitation after chart review for eligibility. All patients were capable of walking with or without walking aids and had minimum knee extensor strength of 30 Nm in at least one leg, assumed as minimal muscle strength for functional use. In addition, healthy individuals, matched for age and gender, who never had polio or any other neurological disease served as controls. The control subjects were recruited from employees of the university and others who had responded to a recruitment advertisement for the study. The study was approved by the medical ethics committee of the Academic Medical Center (University of Amsterdam, The Netherlands), and written informed consent was obtained from all participants.

2.2. Instrumentation

Isometric torque recordings were made of maximal voluntary and electrically evoked contractions of the knee extensor muscles. Subjects were seated in a specially designed dynamometer with a knee angle of 60° and a hip angle of 100°. The upper body and pelvis were restrained with adjustable belts to prevent the hip from extending when the knee extensor muscles contracted. The lower leg was tightly strapped to a lever arm, immediately proximal to the malleoli. The torque applied by the knee extensor muscles was displayed on a screen, digitized (1000 HZ), and stored on disk for off-line analysis.

Electrical stimulation of the knee extensor muscles was delivered through two self-adhesive surface electrodes (8×13 cm, Schwa-medico, Leusden, The Netherlands) placed over the proximal and distal part of the anterior thigh. A personal computer running custom-made software controlled the frequency and number of square-wave pulses (200 μs) delivered by a constant-current high voltage stimulator (model DS7H, Digitimer Ltd., Welwyn Garden City, UK).

2.3. Procedure

In patients with PPS measurements were performed on the leg which they felt was most limiting performance during activities in daily life. However, if maximum knee extensor strength in this leg was lower than 30 Nm, measurements were performed on the other leg. In healthy subjects, the leg on which measurements were performed was selected randomly. Subjects performed three maximal voluntary isometric knee extensions. They received visual feedback of the torque and were verbally