Exercise Prescription in Subjects With Spinal Cord Injuries

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ABSTRACT. Bizzarini E, Saccavini M, Lipanje F, Magrin P, Malisan C, Zampa A. Exercise prescription in subjects with spinal cord injuries. Arch Phys Med Rehabil 2005;86:1170-5.

Objective: To evaluate the effect of training with ergometers on subjects with spinal cord injury (SCI) in the postacute phase.

Design: Cohort study.

Setting: A spinal unit at a physical medicine and rehabilitation institute.

Participants: Twenty-one subjects with SCI in the postacute phase as a consecutive sample were chosen on a strict first-come, first-chosen basis. All patients completed the study.

Interventions: A 6-week (5d/wk, 90min/d) program consisting of exercises with the ergometers formulated (as intensity and duration) for each patient on the basis of the results obtained in specific cardiovascular tests.

Main Outcome Measures: Parameters of workload levels, as well as hematologic and hormonal parameters, recorded during the first 6 weeks of training.

Results: The workload performed during the training showed an initial increase, but it reached a plateau in week 4. No statistically meaningful variations in the workload emerged between the fourth and the sixth weeks of monitoring. There were no hematologic or hormonal signs of overtraining.

Conclusions: Strengthening and aerobic rehabilitation programs for patients with subacute SCI should be limited to 4 weeks, followed by an independent maintenance exercise program. The strengthening program is safe for these patients.

Key Words: Ergometry; Exercise; Hematology; Rehabilitation; Spinal cord injuries.

IT IS HIGHLY DESIRABLE THAT spinal cord injury (SCI) patients begin active physical therapy programs as soon after injury as possible. However, 2 important problems should be addressed when dealing with SCI patients in the subacute phase—namely, the reduction in cardiovascular fitness and in work capacity, by loss of sympathetic control and functional muscle mass. The sympathetic innervation of the heart derives from the spinal cord segments between T1 and T4, so a lesion above T1-4 could seriously compromise an increase in heart rate at the beginning of the exercise, as well as heart output, final diastolic volume, and stroke volume. However, in subjects with higher levels of injury, the primary mechanism for heart rate increase during exercise is withdrawal of vagal inhibition, in the absence of sympathetic innervation.[1] Sympathetic nervous system impairment limits control of regional blood flow and cardiac output, and maximal heart rate may be reduced to 110 to 130 beats/min. It should be remembered that, often in the recovery phase, subjects with SCI are candidates for immediate and serious hypotension.[2] Issues of concern in an exercise program for people with SCI in the subacute phase include the inability to respond to the training program (bedrest syndrome), because the heart, lung, and muscles above the lesion are not conditioned to exercise. After spinal cord trauma, muscles beneath the lesion are affected by morphologic, metabolic, and contractile alterations. Nevertheless, what is known is that a rise in mechanical power is also caused by a correct recruitment of the paretic muscles. To assess the effect of exercise on muscle, the first step is to measure the increase in workload. To be able to quantify the workout, the mechanical energy produced by the human body could be applied to instruments capable of measuring the amount of work exerted: the ergometers.

No other studies have examined the amount of increase attainable in muscle strength and the appropriate duration of training in subjects with SCI in the subacute phase. In addition, no other studies monitored the rehabilitation program effect on hormonal and metabolic parameters used to signal an overtraining syndrome.[3] Moreover, no consensus about a specific training program has been reached for the SCI population.[4]

The aim of our study was to assess the effectiveness of an "enhanced" 6-week rehabilitation program in newly injured paraplegic and tetraplegic patients.

Various combinations of training intensity, duration, and frequency are often proposed to people with SCI in order to improve fitness. We devised a rehabilitation program based on stress arm crank tests. Metabolic parameters (lactate, testosterone, cortisol, creatine phosphokinase [CPK], luteinizing hormone [LH], urea, blood iron, transferrin, ferritin, blood glucose) were used as reliable indicators of the conditioning levels of exercise.[3]

METHODS

Participants

Twenty-one subjects (mean age, 33.81±14.83y) were examined. We enrolled the first 21 patients admitted to the Spinal Unit of the Institute of Physical Medicine and Rehabilitation of Udine. They all had SCI in the postacute phase (6 cervical lesions, 15 thoracic and lumbar lesions). The demographic data referring to the SCI and the American Spinal Injury Association (ASIA) motor score are shown in table 1. The level of SCI for each participant was determined by a physician through myotomal and dermatomal testing. The ASIA system for classification of SCI was used, and each individual was categorized as being either tetraplegic (with an injury to the spinal cord between the levels of C4 and C8) or paraplegic (injury at T1 or below). Eight patients had ASIA Impairment Scale (AIS) score B, and 13 patients had AIS score C. Patients were divided into

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Table 1: Demographic Data

Patient	Sex	Age (y)	Lesion Type	Lesion Level	AIS Score	ASIA Motor Score	Lesion From t0 (d)
Tm1	M	19	Dislocation	C4	C	24	153
Tm2	M	65	Ependymoma	C5	C	53	49
Tm3	M	33	Frac-dis	C5	C	13	96
Tm4	M	25	Contusion	C4	C	44	50
Tm5	M	25	Fracture	C6	C	18	183
Tm6	M	29	Fracture	C7	B	40	38
PHm1	M	54	Frac-dis	T2	C	50	158
PHm2	M	29	Fracture	T4	C	50	65
PHm3	M	22	Frac-dis	T3	C	50	59
PHm4	M	16	Frac-dis	T5	B	50	94
PHm5	M	31	Fracture	T6	B	50	63
PHm6	M	66	Fracture	T6	B	50	91
PLm1	M	24	Fracture	T11	B	50	24
PLm2	M	49	Fracture	T12	B	54	213
PLm3	M	22	Frac-dis	T10	C	57	91
PLm4	M	32	Fracture	T7	B	50	103
PLm5	M	22	Fracture	L2	C	68	23
PLm6	M	38	Ependymoma	T8	C	85	18
PLf1	F	21	Fracture	L1	C	50	225
PLf2	F	51	Fracture	T7	B	50	41
PLf3	F	37	Fracture	T8	C	50	110

Abbreviations: AIS, ASIA Impairment Scale; f, female; F, female; Frac-dis, fracture-dislocation; m, male; M, male; PH, high paraplegic lesion; PL, low paraplegic lesion; T, tetraplegic lesion.

subgroups according to sex (male, female) and level of lesion (tetraplegic lesion level C4-8, high paraplegic lesion level T1-6, low paraplegic lesion level T7-L2). None of these subjects was affected by significant cardiovascular and respiratory diseases. The training began, on average, 92.71±14.83 days after the day of the spinal cord lesion and lasted 60 days at the most. Informed consent was obtained from all participants before the study.

Training Sessions

Patients were monitored every 2 weeks for 42 days. The first rehabilitation session was performed in our gym. Each patient undertook and completed a daily training session for approximately 90min/d, including during the recovery periods. The exercise program covered 5d/wk. The training consisted of exercises on the ergometers (cranking ergometer, wheelchair ergometer) based on discontinuous protocols and formulated for each patient on the basis of the results obtained in specific cardiovascular tests performed every 2 weeks. Each test was preceded by a 1-minute warm-up. During the test, resistance was increased by 12.5W every 2 minutes. The test could be interrupted for any of the following reasons: personal decision, symptoms of cardiopulmonary abnormality, electrocardiogram alterations, or attaining of the maximum expected level of proficiency. Because of the difficulty in achieving small enough workload grades for tetraplegic participants, the protocol was modified so that workload increments would be more gradual. Initially, this was accomplished by increasing only the rate at which the subjects were working, as opposed to the resistance on the flywheel. The training was then modulated with the aim of maintaining the target heart rate between 70% and 80% of the maximal heart rate. The heart rate was determined by using the following formulas: reserve of heart rate = maximal heart rate (reached at the stress test) – heart rate at rest; training heart rate = (reserve of heart rate × % of desirable intensity) + heart rate at rest. Additionally, patients rated their subjectively perceived effort on the Borg 20-point scale, which during the training session was maintained between score 12 and 16.

Training to improve upper-limb strength was performed by using pulley machines and with exercises concentrating on the main muscle groups (latissimus dorsi, deltiformis, pectoralis, triceps brachii, biceps brachii). A pyramidal protocol based on maximal tests (single maximal repetition reached during an increasing number of pounds lifted), repeated every 10 training sessions, was drawn up for this purpose. The exercises were then performed 8 times for 3 sets at an intensity of 40% to 60% of the single maximal repetition.

The workout with the ergometers and pulley machines was evaluated every 2 weeks, and a new training program was then proposed. The average value of the total workout at t0 (first day of training in our gym), t14, t28, and t42, by every group of subjects, was recorded. The average value was calculated as the total workout in newtons done in 2 weeks divided by 10 training sessions, the number of training sessions performed in 2 weeks.

Patients with AIS score C also undertook exercises to increase lower-limb strength (leg press). These exercises were also performed on a single maximal repetition basis (which was reached during an increasing number of pounds lifted). For these patients, a specific resistance workout was devised by using bicycle ergometers for the lower limbs and modulating the intensity and the duration of the training on previous cardiovascular tests.

Body mass index (BMI) was calculated for each individual by using the formula: BMI = weight (in kilograms)/height^2 (in meters). The body composition of the patients was estimated from measurements of skinfold thickness. The skinfold was estimated, by the same operator, entirely from the nondominant side of the body, taking the average of 3 measurements. A Harpenden caliper was used for the evaluation. The percentage of total body fat (table 2) was calculated on the basis of the sum of skinfold thickness from 4 locations (biceps, triceps, subscap-