ARTICLES

Effects of an Exercise Program on the Rehabilitation of Patients With Spinal Cord Injury

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ABSTRACT. Salinas Durán F, Lugo L, Ramírez L, Eusse E. Effects of an exercise program on the rehabilitation of patients with spinal cord injury. Arch Phys Med Rehabil 2001;82:1349-54.

Objectives: To evaluate the impact of directed physical exercise in patients with spinal cord injury (SCI) and to measure functional independence before and after an exercise program.

Design: Case series.

Setting: Tertiary care center.

Participants: Thirteen volunteers with thoracic SCI.

Intervention: Patients participated in a 16-week exercise program, consisting of 3 weekly 120-minute sessions. They performed mobility, strength, coordination, aerobic resistance, and relaxation activities.

Main Outcome Measures: The FIM™ instrument, arm crank exercise test, wheelchair skills, maximum strength, anthropometry (body composition measurements), and lipid levels. The results were processed by using nonparametric statistical tests.

Results: After comparing the values at the beginning and end of the program, patients showed a significant increase in the following parameters: average FIM score ($p < .001$) 113 $\pm$ 7.1; weight lifted in the bench press exercise (46%, $p < .0001$), military press (14%, $p < .0002$), and butterfly press exercise (23%, $p < .0001$), and number of repetitions for biceps (10%, $p < .0001$), triceps (18%, $p < .0001$), shoulder abductors (61%, $p < .0001$), abdominals (33%, $p < .009$), and curl back neck exercise (19%, $p < .0001$). The maximum resistance achieved during the arm crank exercise test increased ($p < .001$), and heart rate 6 minutes after the exercise test decreased ($p < .05$). The time required for the wheelchair skill tests significantly decreased in all the tasks. No statistically significant changes occurred in body weight ($p < .154$), percentage of body fat ($p < .156$), lean body weight ($p < .158$), cholesterol/high-density lipoprotein cholesterol ratio ($p < .076$), or maximum heart rate ($p < .20$). The only complication arose in a patient who developed transient sinus bradycardia and hypotension after the arm crank exercise test.

Conclusion: The directed exercise program had a positive impact for most of the variables of the study.

Key Words: Exercise; Exercise therapy; Rehabilitation; Spinal cord injuries.

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Accepted in revised form December 8, 2000.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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0003-9993/01/8210-6337$35.00/0
doi:10.1053/apmr.2001.26066

SPINAL CORD INJURY (SCI) causes sensory and motor alterations, and loss of sphincter control. SCI may lead to reactive depression, which can hinder the rehabilitation process and reduce the quality of life, as compared with that of the general population.

In the study by Yekutiel et al,[1] ischemic cardiac disease incidence in patients with SCI was found to be 16.9% compared with an incidence of 6.9% in the age-matched general population. Risk factors for coronary disease that are present in the general population are also found in patients with SCI: obesity, low levels of high-density lipoproteins (HDLs), high levels of serum cholesterol, glucose intolerance, sedentary style of life, smoking habits, and stress.[2-4]

Several factors affect the tolerance to exercise in patients with SCI, such as an inadequate rise in the heart rate in high SCIs, a diminished venous return from the lower limbs (which predispose to orthostatic hypotension), active exercise accomplished by the upper limbs that involves a small muscle mass (which fatigues more easily), loss of adrenal response to exercise that reduces the lipolysis and muscle glycogenolysis, and inadequate thermal regulation that predispose to the hyperthermia.[5] Despite alterations found in the physiologic responses to exercise in persons with SCI, many studies[6-10] have shown the benefits of a regular exercise program. In the psychologic aspect, it reduces anxiety and depression, and improves self-esteem and the feeling of independence.

The goals of this study were to evaluate physical capacity and skills of patients with SCI, and to measure functional independence before and after a directed exercise program. In addition, possible complications associated with the program were assessed.

METHODS

Participants

Two hundred eighteen patients with SCI (men, 83.5%; women, 16.5%) were examined at the Physical Medicine and Rehabilitation Department of the San Vicente de Paul University Hospital (Medellín, Colombia) between 1995 and 1996. Patients' average age $\pm$ standard deviation (SD) was 29 $\pm$ 13.3 years. The cause of injury was trauma in 88.5% of the cases, and 51.4% resulted from gunshot wounds. Thirty-three percent of the injuries were cervical and 52.9% thoracic. A total of 58.7% of the patients were classified with American Spinal Injury Association[11] (ASIA) class A injuries.

Our study included 13 patients with SCI (12 men, 1 woman; average age, 26.3 $\pm$ 8.3yr), acquired in most cases by gunshot wound. Subject characteristics are reported in table 1. The following selection criteria were used: (1) patients had been in a primary rehabilitation program; (2) patients were from the metropolitan area of Medellín, Colombia; (3) patients had thoracic-level lesions; (4) none was suffering from major medical problems; (5) none was taking medications for hyperlipidemia or cardiovascular disease; and (6) subjects were outpatient volunteers. Their education background was as follows: 4 had primary school education only; 5 had some high school education; and 4 had completed high school. The median time

Table 1: Subject Characteristics

Patient	Age (yr)	Gender	Weight (kg)	Injury Level	Time With Injury (mo)
1	17	M	55	T11	2
2	35	M	51.5	T10	10
3	21	M	47	T11	6
4	33	M	46.5	T11	10
5	19	M	54.7	T7	6
6	15	F	59	T7	6
7	33	M	56.2	T12	16
8	19	M	51.2	T3	39
9	23	M	50.5	T10	67
10	36	M	57	T12	5
11	19	M	74	T3	7
12	38	M	51.2	T4	120
13	33	M	73.5	T6	31

Abbreviations: M, male; F, female.

between injury and the start of the study was 10 months (range, 2–120mo). According to the injury level, 4 patients presented with high thoracic lesions (T6 and higher) and 9 with low thoracic lesions (below T6). Eleven patients had complete ASIA class A injuries, 1 had ASIA class B, and 1 had ASIA class C. On average, attendance at the physical exercise program was 85%.

Procedures

Patients were initially evaluated to classify their SCI type and level according to the ASIA classification system; during this evaluation, we also sought to determine the presence of risk factors, concomitant diseases, or limitations to perform the programmed exercises. The FIM™ instrument was used to evaluate each patient.[12] The percentage of muscular mass and body fat tissue were determined by anthropometry[13] and weight, and blood samples were drawn to determine serum lipid profiles. These tests were repeated at the end of the study. Additionally, each patient performed a progressive resistive arm crank exercise test at the beginning and end of the program.[14] The test started with a 3-minute warm-up at 0 watts. During the test, resistance was increased by increments of 12.5 watts every 2 minutes. The criteria to interrupt the exercise test were any of the following: personal decision, symptoms of cardiopulmonary abnormality, electrocardiogram alterations, or attaining the maximum expected level of proficiency. Wheelchair skills were evaluated by using a test adapted by the investigators (appendix 1).

The maximum strength of the upper limbs was determined by measuring the maximum weight mobilized in a single trial or the number of repetitions accomplished in 30 seconds; the measurement was conducted at the beginning of the program, and subsequently after 8 and 16 weeks.

Training Program

The program lasted 16 weeks, with a frequency of 3 sessions (120min) per week. Mobility activities, aerobic resistance, strength, coordination, recreation, and relaxation were combined (appendix 2). Some sessions included exercise in water. The specific aerobic program lasted 11 weeks, which included a 4-week adaptation and 1-week enhancement period. The program took into account the distance traveled and the time spent accomplishing activities that involved advancing movements, circuit training with light weights, repetition, and activities that increased heart rate to the desired level. Initially, sessions lasted for 15 minutes; subsequently, depending on individual tolerance, the length of the sessions was progressively increased to 40 minutes of aerobic training, and the target heart rate was increased gradually from 40% to 80% of the maximal heart rate. The heart rate was determined from the stress test by using the following formulas:

Reserve of heart rate = maximal heart rate − rest heart rate.

Training heart rate = (reserve of heart rate × % of desirable intensity) + resting heart rate.

Additionally, patients rated their subjective perception of effort on the Borg 10-point scale, which is recommended when subjects have nervous system disorders that can interfere with an increase of the heart rate.[15] Furthermore, this scale correlates well with the peak oxygen uptake, the mechanical work, and the maximal heart rate.[16]

Data Analysis

The nonparametric Wilcoxon signed-rank test was used to compare the numeric variables obtained during the exercise intervention. We considered p less than .05 statistically significant. Epi-Info, version 6.02,[a] was used for data processing.

RESULTS

FIM Instrument

At the beginning of the program, FIM scores ± SD averaged 106 ± 6.8; at the end of the program, the average score was 113 ± 7.1 ($p < .001$). In patients with injuries at a high thoracic level, FIM score increased an average of 5.3 points whereas at low thoracic levels it increased by 7.6 points. The largest increased in FIM scores occurred in mobility, which contributed 55% to the total improvement observed in functional independence.

Physical Capacity

The exercise program produced a significant percentage increase in the weight lifted during the different tests (table 2) and in the number of repetitions completed during the exercises (table 2). Regarding wheelchair skills, a decrease in the time required to accomplish each of the tests was observed (table 3), indicating improved ability and coordination after the training program. Also the ability to go up or down stairs improved after the training program (table 4).

Anthropometry (body composition measurements). Patients' initial mean weight was 55.9 ± 8.7kg, whereas their final mean weight was 56.4 ± 9.1kg ($p < .154$). The percentage of body fat did not change ($p < .158$).

Lipid profile. Cholesterol level was greater than 200-mg/dL in 2 patients at the beginning of the program, whereas the other patients had normal cholesterol levels. Low-density lipoproteins (LDL) levels ranged from 40 to 196mg/dL, with an average of 94 ± 39.8mg/dL at the beginning of the program; LDL levels did not change at the end of the exercise program ($p < .25$). HDL levels ranged from 19 to 58mg/dL, with an average of 38 ± 11.6mg/dL at the beginning of the program; HDL levels did not significantly change at the end of the program ($p < .08$). The average total cholesterol/HDL cholesterol ratio at the beginning was 4.75 ± 2.15, and this ratio did not change significantly at the end of the program ($p < .076$).

Arm Crank Exercise Test. Average resting heart rate was 83 ± 19.7bpm at the beginning and 81 ± 14.6bpm at the end of the study. The maximal heart rate achieved during the test did not change (mean before and after the exercise program,

Table 2: Changes in Weight Lifted and Repetitions Before and After Exercises

Exercise	Initial	Final	Increase (%)	*p*
Weight (kg)				
Bench press	42.7 ± 17.3	62.5 ± 20	46	.0001
Military press	60 ± 18.2	68.3 ± 17.8	14	.0002
Butterfly press	52.3 ± 12.6	64.2 ± 12.8	23	.0001
Repetitions				
Dumbbell: biceps	26.7 ± 7.5	29.4 ± 7.6	10	.0001
Dumbbell: triceps	35.8 ± 14	42.4 ± 16	18	.0001
Shoulder abductors	8.8 ± 2.1	14.2 ± 4	61	.0001
Abdominals in 1′	47 ± 9.9	62.4 ± 6.4	33	.009
Curl back neck	112.3 ± 30.9	134 ± 30.7	19	.0001

NOTE. Data are mean ± SD.

161bpm). However, the maximum resistance achieved during the arm exercise test increased from 90 ± 24 watts at the beginning of the program to 110 ± 26.1 watts at the end ($p < .001$). Heart rate at 6 minutes after the exercise test was 115 ± 18.9bpm after the initial test and 108 ± 18.6bpm at the end ($p < .05$).

Complications. Regarding pain,[17] the following data were found. One, musculoskeletal pain was reported by 4 patients during the initial evaluation. At the end of the program, pain persisted in 2 patients and the other 2 reported a neuropathic pain, 1 at the level of the injury and the other below it. Two, neuropathic pain below the injury level was reported by 4 patients during the initial evaluation. At the end, it persisted in 3. Three, neuropathic pain at the level of the injury was reported by 2 patients during the initial evaluation. At the end, it disappeared in 1 and in the other was replaced by a musculoskeletal pain. Four, of the 3 patients who began the program without pain, 1 finished with musculoskeletal pain.

At the beginning of the program, 4 patients had pressure ulcers; of these, 3 were sacral stages 2 or 3, and 1 gluteal stage 2.[18] At the end of the program, the gluteal sore and 1 of the sacral had healed. None of the patients who entered the program without ulcers developed this complication on termination.

A patient with a T8-level SCI presented with transient sinus bradycardia and hypotension 3 minutes after starting the recovery period of the arm crank exercise test. This alteration reverted spontaneously before the monitoring at 6 minutes.[19]

DISCUSSION

FIM score significantly improved in patients with paraplegia with both high- and low-thoracic level injuries. This is important because previous reports claim that FIM scores plateau after a suitable rehabilitation program approximately 6 months after the injury in paraplegics with lesions above T5, and at 3 months for those with injuries below T5.[20] The observation that FIM scores improved, despite the fact that in most patients injuries were more than 6 months old, suggests that this type of activity should be included in the rehabilitation program to achieve optimal performance of each individual. Furthermore, improvement in FIM scores was also shown by subjects who had their injury for several years.[21,22]

All scores on tests that evaluated changes in the physical capacity (ie, the weights lifted, exercise repetitions, wheelchair skills) showed significant improvement. In particular, the strength of the shoulder abductors increased, probably because conventional rehabilitation programs for individuals with SCI emphasize strengthening the shoulder depressors and adductors and elbow extensors because they are important for activities such as transfers. Therefore, this study is in agreement with others[23] that have shown how exercise can improve resistance and muscular strength in individuals with paraplegia.

Even though at the end of the program only 1 patient had cholesterol levels above the normal range, neither a significant decrease in LDL cholesterol nor an increase in HDL cholesterol was achieved with the training program. These results are similar to those of the study by Janssen et al,[24] which reported that the aerobic capacity is not a determining factor for the cholesterol levels in individuals with SCI; rather, Janssen found that body mass index and the fat tissue as well as consumption of alcohol or cigarettes were determining factors, factors that were not considered in our study. Furthermore, HDL levels have a tendency to return to preexercise values within 48 hours after exercising.[25,26] Our study did not find significant changes in total cholesterol levels nor in the percentage of lean body weight or adiposity, as reported in the

Table 3: Results of Selected Wheelchair Skills

Skill	Initial Average (s)	Final Average (s)	Decrease (%)	*p*
1. Forward propulsion	12.08 ± 6.5	9.02 ± 3.0	25	<.003
2. Backward propulsion	13.38 ± 5.5	8.81 ± 1.8	34	<.0006
3. Forward propulsion with a right turn	11.23 ± 7.5	7.14 ± 1.3	36	<.01
4. Backward propulsion with a right turn	14.54 ± 6.8	11.17 ± 2.5	23	<.04
5. Forward propulsion with a left turn	10.62 ± 3.4	6.41 ± 0.8	40	<.0009
6. Backward propulsion with a left turn	15.31 ± 4.3	10.97 ± 2.5	28	<.002
7. Advancing with obstacles	21.77 ± 6.7	17.86 ± 2.1	18	<.0006
8. Going backward through obstacles	36.08 ± 11.0	31.41 ± 7.9	13	<.006
9. Advancing to pick up an object	35.08 ± 12.3	25.19 ± 8.8	28	<.005

NOTE. Data are mean ± SD.

Table 4: Patients Who Accomplished Wheelchair Activities

Skill	Beginning of Program (*n*)	End of Program (*n*)
12. Go up a step of 12cm	1	5
13. Go down a step of 12cm	1	11
14. Go up a step of 8 cm	2	8
15. Go Down a step of 8cm	4	12
16. Go up a step of 6 m	7	13
17. Go down a step of 6 m	7	13
18. Recline the wheelchair	4	13
19. Advance with a reclined wheelchair	4	13

study by Midha et al,[27] who found a decrease in total cholesterol and upper-arm fat area after an exercise program with the wheelchair aerobic fitness trainer.

The use of the Durning method for such measurement can underestimate the average percentage of fat according to Spungen et al[28] because lower limb tissues that will have more significant changes after a SCI[29] are not taken into consideration. A future study should estimate the fat percentage by using the method by Steinkamp et al,[30] which uses multiple skinfold measurements including the perimeter of the thigh.

Work capacity (in watts) for the arm crank exercise test, achieved at the end of the study, was significantly higher than that at the beginning, and the heart rate 6 minutes after the exercise test decreased. This suggests beneficial adaptation responses to the training program and confirms the fact that daily activities are insufficient to increase the physical conditioning levels.[31,32] The improvement observed in the exercise test can also be explained by better ventilatory mechanics because of the physical training.[33]

Only 2 patients developed a musculoskeletal pain that could be attributed to the program. This is one of the frequently described complications when physical activities of greater intensity than the ones required to propel the wheelchair are performed. The neuropathic pain showed almost no change, something that was expected because of the refractory aspect of this type of pain.

One of the concerns we had at the beginning of the exercise program was a possible lack of caution about skin complications while performing the routines. However, none of the patients who entered the study with healthy skin developed pressure ulcers; furthermore, 2 of the 4 patients who had sores healed during the study.

CONCLUSION

Our directed exercise program had a positive impact in most of the measures of physical function in the study, without causing any significant complications. Therefore, we recommend that this type of activity be included in conventional rehabilitation programs.

APPENDIX 1: WHEELCHAIR SKILLS

Skills evaluation in the wheelchair:

1. Forward propulsion, receiving and throwing a ball.
   The evaluated subject moves away from the instructor, who is 20 meters away. The instructor throws a volleyball when the subject has advanced 12 meters and then the subject throws back the ball while advancing the 8 remaining meters.
   Characteristics: flat ground, cement floor, straight line advancing movements. Catching the ball is made without stopping the wheelchair.
2. Backward propulsion receiving and throwing a ball.
   The evaluated subject begins backward propulsion of 10 meters. After advancing the first 5 meters, the instructor throws a volleyball and the subject will have to catch it and throw it back while advancing the 5 remaining meters.
   Characteristics: the instructor is positioned 5 meters in front of the subject when throwing the ball. The ground will be similar to that of the previous skill.
3. Forward propulsion doing a circle while turning right.
   The subject moves forward in 4 wheels along a circumference with a diameter of 1 meter.
   Characteristics: flat ground, cement surface, the inner wheel should not be within the line of the circumference.
4. Back propulsion doing a circle while turning right.
5. Forward propulsion doing a circle while turning left.
6. Backward propulsion doing a circle while turning left.
   Skills 4, 5, and 6 have similar characteristic to those of skill 3.
7. Forward propulsion between obstacles.
   The evaluated subject advances with zig-zag movements for 20 meters, between cones 22cm tall and 14cm in diameter, set each in a straight line, 1 meter apart. The track will be 1.5 meters wide.
8. Back propulsion between obstacles.*
   Similar to the previous test, but backward.
9. Propulsion while picking up objects from the floor.
   The evaluated subject picks up and gives the following objects to the instructor while advancing a distance of 10 meters: 2 coins, a cane, a wood chunk of $5cm^2$, a volleyball, and 2 balloons filled with 250mL of water.
   Characteristics: objects will be located in straight line 2m apart, in the established sequence and within a distance of 10 meters.
10. To open, to enter, and to close a door.
    The evaluated subject opens and enters a place through a door with the following characteristics: flat frame, 80cm wide, 198cm high, and a key lock.
11. To open, to leave, and to close a door.
    Similar characteristics to the previous skill.
12. To go up a step 12cm high.
13. To go down a step 12cm high.
14. To go up a step 8cm high.
15. To go down a step 8cm high.
16. To go up a step 6cm high.
17. To go down a step 6cm high.
    For tests 12 through 17, the subject will have to ascend or descend the step correctly, to go up facing the step, and descend backward.
18. To recline the wheelchair.
    The subject holds the wheelchair while balancing it on its 2 larger wheels.
    Characteristics: flat ground, cement surface.
19. Propulsion while reclining the wheelchair.
    The subject advances at least 2 meters with the wheelchair reclined and resting in its 2 larger wheels.
20. To descend a ramp.
    The subject descends while rolling the wheelchair onto a ramp with a given distance and slope.
21. To climb a ramp.†
    The subject climbs a ramp with similar characteristics to the one in the previous skill.

* The time and the number of obstacles that the subject has contact with will be considered.

† The wheelchairs used in the skills are conventional chairs owned by each of the individuals.

In skills 12 through 19, what must be assessed is whether the subject has the capacity to perform the task. The rest of the skills combine the ability to perform a task within the mean time required, as calculated based on skills performance times of a trained group of 18 people with paraplegia.

The conventions for the evaluations are as follows:

1. Cannot perform it.
2. Incomplete performance of the test.
3. Complete performance with a greater mean time.
4. Complete performance with a lesser mean time.

APPENDIX 2: PROGRAM DESCRIPTION

Description of the strength exercise program:

1. Bench press:
   Objective: To strengthen the pectoral muscles.
   Position: Supine decubitus, with passive flexion of knees and hips performed by the instructor. Shoulders in abduction of 90°, elbows in flexion of 80°. The bar is held with the respective weights and it is lifted until achieving a complete extension of the elbows.
2. Military press:
   Objective: To strengthen the middle portions of the deltoid muscles and superior portions of the trapezius.
   Position: Sitting, straight back. Shoulders in abduction of 45° and external rotation of 90°, elbows in flexion of 110°, and pronation of forearm. The bar is held with the respective weights and it is lifted until achieving a complete extension of the elbows.
3. Dumbbell (biceps):
   Objective: To strengthen the biceps.
   Position: Sitting, straight back, upper extremity (UE) in anatomic position. The dumbbell is held with a given weight and it is lifted until achieving a complete flexion of the elbow.
4. Dumbbell (triceps):
   Objective: To strengthen the triceps.
   Position: Sitting, straight back, complete flexion of the shoulder and the elbow. The dumbbell is held with a given weight and it is lifted until achieving a complete extension of the elbow.
5. Dumbbell (shoulder abductors):
   Objective: To strengthen the shoulder abductors.
   Position: Sitting, straight back, upper limbs in anatomic position. The dumbbell is held with a given weight and the UE is abducted until an angle of 90° is achieved with the elbow extended.
6. Butterfly press:
   Objective: To strengthen the pectorals.
   Position: Sitting in a multifunctional machine, straight back, shoulders in abduction and external rotation of 90°, elbows in flexion of 90°. Arms are displaced (moved) toward the machine against its resistance, until achieving a complete horizontal abduction of the shoulders.
7. Curl back neck:
   Objective: To strengthen the inferior trapezius, the latissimus dorsi, the subscapularis, and the teres major muscles.
   Position: Sitting, straight back, shoulders in flexion and elbows in complete extension. A bar tied to a pulley is held, with the hands at a distance equivalent to shoulder width, then the bar is pulled down until placing it in the posterior region of the neck.

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