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

Fabio Salinas Durán, MD, Luz Lugo, MD, Lina Ramírez, MD, Edgar Eusse, Lic


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 ± 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 < .0009), 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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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,\(^{22}\) 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 200mg/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, 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:

\[
\text{Reserve of heart rate} = \frac{\text{maximal heart rate} - \text{rest heart rate}}{\% \text{ of desirable intensity}} + \text{rest heart rate}.
\]

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.\(^{13}\) Furthermore, this scale correlates well with the peak oxygen uptake, the mechanical work, and the maximal heart rate.\(^{16}\)

**Data Analysis**

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<th>Increase (%)</th>
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<tr>
<td>Abdominals in 1'</td>
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<td>.0009</td>
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<tr>
<td>Curl back neck</td>
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### 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. 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.

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 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, 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. 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

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### Table 3: Results of Selected Wheelchair Skills

<table>
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<tr>
<th>Skill</th>
<th>Initial Average [s]</th>
<th>Final Average [s]</th>
<th>Decrease (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Forward propulsion</td>
<td>12.08 ± 6.5</td>
<td>9.02 ± 3.0</td>
<td>25</td>
<td>&lt;.003</td>
</tr>
<tr>
<td>2. Backward propulsion</td>
<td>13.38 ± 5.5</td>
<td>8.81 ± 1.8</td>
<td>34</td>
<td>&lt;.0006</td>
</tr>
<tr>
<td>3. Forward propulsion with a right turn</td>
<td>11.23 ± 7.5</td>
<td>7.14 ± 1.3</td>
<td>36</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>4. Backward propulsion with a turn</td>
<td>14.54 ± 6.8</td>
<td>11.17 ± 2.5</td>
<td>23</td>
<td>&lt;.04</td>
</tr>
<tr>
<td>5. Forward propulsion with a left turn</td>
<td>10.62 ± 3.4</td>
<td>6.41 ± 0.8</td>
<td>40</td>
<td>&lt;.0009</td>
</tr>
<tr>
<td>6. Backward propulsion with a left turn</td>
<td>15.31 ± 4.3</td>
<td>10.97 ± 2.5</td>
<td>28</td>
<td>&lt;.002</td>
</tr>
<tr>
<td>7. Advancing with obstacles</td>
<td>21.77 ± 6.7</td>
<td>17.86 ± 2.1</td>
<td>18</td>
<td>&lt;.0006</td>
</tr>
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<td>8. Going backward through obstacles</td>
<td>36.08 ± 11.0</td>
<td>31.41 ± 7.9</td>
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<td>9. Advancing to pick up an object</td>
<td>35.08 ± 12.3</td>
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NOTE. Data are mean ± SD.

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study by Midha et al.,\textsuperscript{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\textsuperscript{28} because lower limb tissues that will have more significant changes after a SCI\textsuperscript{29} are not taken into consideration. A future study should estimate the fat percentage by using the method by Steinkamp et al.,\textsuperscript{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 condition. A future study should estimate the fat percentage by using the method by Steinkamp et al.,\textsuperscript{30} which uses multiple skinfold measurements including the perimeter of the thigh.

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\textsuperscript{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.

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.

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* 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 infraspinous trapezius, the lattisimus 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.

Supplier
a. Centers for Disease Control and Prevention, Epidemiology Program Office, Div of Public Health Surveillance and Informatics, 1600 Clifton Rd, Atlanta, GA 30333.