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Original Article

Effects of Upper Limb Exercises on Physical Capacity and Heart Function in Quadriplegics

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Introduction: Wheelchairs are the prime mobility aid of persons with spinal cord injuries. Manual wheelchair propulsion puts a lot of demand on the cardiopulmonary as well as the skeletal system. The main purpose of the study was to compare the effects of both arm ergometry training and progressive resistance exercise training of upper limbs on resting heart rate and distance covered during wheelchair propulsion in paraplegics.

Method: A convenience sample of 30 male subjects took were randomly assigned to two groups. Participants were spinal cord injured patients recruited from the Indian Spinal Injuries Centre, New Delhi. Each group consisted of 15 subjects. Group 1 received arm ergometry training and group 2 received progressive resistance exercise training. The resting heart rate and distance covered during wheelchair propulsion in a 3 minutes task of the wheelchair circuit was measured before and after 4 weeks of training.

Results: The post intervention resting heart rate and distance covered during wheelchair propulsion after 4 weeks between the two groups showed significant differences. In group 1, resting heart rate was 77.53±3.52 beats/min and in group 2 resting heart rate was 82.33±3.69 beats/min (mean±SD). In group 1, the distance covered during wheelchair propulsion was 305.19±17.21 meters and in group 2 it was 250.71+20.59 meters.

Conclusion: The arm ergometry training may be a better choice of exercise for improving the cardiovascular and functional aspect of spinal cord injury patients who are dependent on wheelchairs for mobility.

Keywords: Paraplegia, wheelchair, endurance, ergometry, functional independence.

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Introduction

Wheelchairs are important in achieving independent mobility as approximately 82% of persons with spinal cord injury (SCI) depend on the wheelchair for their mobility purposes [1]. Manual wheelchair propulsion is a straining form of ambulation, both for the cardiopulmonary as well as the skeletal system. Manual wheelchair propulsion is based on the use of upper extremities which are usually capable of producing less force than the lower limbs with less mechanical efficiency [2].

The normal daily locomotor patterns of wheelchair dependent individuals are insufficient to maintain or improve fitness levels. The lack of adequate fitness levels is a major concern in individuals who have lower body disablement. Therefore an upper limb exercise is important to maintain adequate levels of fitness in spinal cord injured persons using a wheelchair. Moreover, it is important to attempt to establish training models that serve the needs of persons confined to the wheelchair [3]. The concept of exercise specificity however suggests that use of an exercise mode which resembles wheelchair activity may be advantageous. So recently arm ergometry and wheelchair ergometry have shown to simulate actual wheelchair locomotion and are used as the bases of exercise tests to evaluate fitness for wheelchair activity [4]. It's been reported that resting heart rate is generally higher in those with lesions below T5 than in the uninjured population [5].

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Arm ergometry is an electronic arm bicycle used for exercises of the upper limbs. It is similar to the leg bicycle with two pedals which can be propelled by subjects while in a seated position. It is the most reliable and valid exercise mode for clinical and functional evaluation of exercise performance and for optimal prescription of individualized exercise training programs in SCI individuals [4, 6]. Progressive resistance exercises in physical therapy (PRE) provide a practical application of the overload principle and form the basis of most resistance training programs [7].

Dicarlo documented the effects of arm ergometry training on wheelchair propulsion in individuals with quadriplegia [8]. S.Nilsson and P.H Staff have shown a significant increase in the maximal oxygen uptake and maximal dynamic strength and endurance in 12 paraplegics who had undergone 7 weeks of intensive training [6]. Studies showing the physiological responses with an arm crank and wheelchair ergometry in SCI are well documented [9,10,11]. Studies have also shown the effects of strength training on wheelchair users [11,12].In this study there are not many studies that have compared the effects of arm ergometry training and strength training on resting heart rate and wheelchair propulsion in paraplegics.

Therefore, the main purpose of this study was to compare the effects of both arm ergometry training and progressive resistance exercise training of upper limbs on resting heart rate and distance covered during wheelchair propulsion in paraplegics.

Methods

A convenience sample of 30 male subjects was randomly assigned to two groups through the lottery method. The study was of pretest post-test experimental design. Participants were spinal cord injured patients recruited from a sub-specialty centre for treating spinal cord injuries in New Delhi. Each group consisted of 15 subjects. Group 1 received arm ergometry training. Group 2 received Progressive resistance exercise training. To avoid selection bias the following conditions were observed: the level of injury was T6-T12, patients were aged between 20-40 years, a minimum spinal cord independence measure score (SCIM) of 80, all participants should have been wheelchair users who could propel the wheelchair for at least 3 minutes, and patients should've been undergoing a regular rehabilitation program with no participation in any other endurance training program. The study was approved by the research and ethics committee of the institute affiliated with the hospital.

The Standard active wheelchair and its dimensions are of: 16 inches length, 16 inches seat width, 16 inches height, standard measuring tape, standardized weighing machine for wheel chair dependent, pulse oximeter, Reck Motomed arm cycle ergometer and free weights of different kilograms were the instruments used. An informed consent was taken from all the subjects and detailed explanation of the procedure was given. The patient's Demographic data and neurological details were collected. Preliminary measurements were taken prior to the beginning of the study which included body weight and spinal cord independence measure score.

The resting heart rate was measured using pulse oximeter in the morning in fasting state. The subjects were asked to relax for five minutes. The pulse oximeter probe was then attached to the patient's middle finger. The graphical display of the heart rate was noted. The pre-training distance covered during wheelchair propulsion in the 3 minutes task of the wheelchair circuit was measured. Subjects were seated on a standard wheelchair and were instructed to propel the wheelchair from the starting position marked on the 200 meter track with markings of 100 and 200 meters for 3 minutes [1]. Subjects were instructed to begin on a signal and to continue wheeling on a track until the stop sign was given. Subjects were free to determine their individual strategy for optimal performance. A 4-week protocol was carried out for both groups. Interval arm ergometer training program was carried out for group 1 subjects and Delorm's & Watkins protocol was followed for group 2 subjects [13].

The training mode was arm pedaling on an ergometer on a schedule of 3 times a week with 2 sets for 4 weeks. Training was closely supervised and daily logs were maintained for both workload and training heart rate. The starting phase of the exercise session included 5 minutes of warm up which provided stretching or arm pedaling on an ergometer. The arm pedaling was done on the ergometer at 50 rpm during the first week; at 50 rpm for 15 minutes plus an additional 5 minutes at 60 rpm in the second week, then at 50 rpm for 15 minutes at 60 rpm in the third week, then at 60 rpm with an additional 15 minutes at 60 rpm in the fourth week. The resistance load was kept constant at 0.5 kg. A rest period of 5 minutes in-between sets was given. At the end of each session 5 minutes of cool down was also included for group 1. Group 2 subjects were made to relax and were well positioned according to the muscle group to be tested against gravity. 10 Repetition maximum (10 RM) was calculated for each muscle individually. Subjects were given different weights for particular muscles to be tested. So the maximum weight which was lifted for a complete range of motion for 10 times was considered as the 10 RM. Rest period was provided in-between [7]. Caution was taken to begin the training session on the following day of calculating the 10 RM. The muscles which were tested and trained included anterior and posterior deltoid, infraspinatus, pectoralis major, middle trapezius, biceps, triceps and wrist extensors. All these muscles were trained in their standardized position against gravity. Training sessions included 3 sets of exercises for multiple muscle groups; each set consisting of 10 repetitions with 3 minute rests in-between. The first set required one half of 10 RM, the second set used 3/4th the 10 RM, and the final set used 10 RM of maximum weight. The training sessions were held 3 times a week. After the end of each week, 10 RM was again calculated and the same training procedure was followed for each muscle with the new 10 RM.

After 4 weeks of training, the resting heart rate (beats per minute) and distance covered during wheelchair propulsion (meters) were recorded. Post-training resting heart rate was measured in the morning after 4 weeks using pulse oximeter for both the groups. The distance covered during 3 minutes of wheelchair propulsion was measured using the wheelchair circuit test on a 200 meter track.

Data Analysis_The data was managed on an Excel spread sheet and was analyzed using SPSS software. A significance level of P≤0.05 was used. T-tests were used to find the differences between the effects of arm ergometry training and progressive resistance exercise training of upper limbs on resting heart rate and distance covered during wheelchair propulsion in paraplegics. Paired t-test was used for analysis within the group.

Results

Group 1 consisted of paraplegic patients with the following particulars; age: 30.6±5.31 years (mean±SD); duration of injury: 329.80±54.82 days; weight: 60.33±4.95 kg; SCIM score: 85.20±1.65. The patients in group 2 had the following particulars; age: 30.46±4.79 years; duration of injury: 329.26±55.94 days; weight: 60.66±4.77 kg; SCIM score: 85.

Analysis of data indicates that there were no significant differences in pre-test values of resting heart rate and distance covered during wheelchair propulsion between the two groups. The pre-test value of heart rate in group 1 was 84.13±2.87 beats/min and in group 2 was 84.53±3.50 beats/min. Pre-test values for distance covered during wheelchair propulsion in group 1 and group 2 were 238.41±16.19 and 238.02±19.85 meters. Comparison of post-intervention resting heart rate between the two groups showed significant differences; being 77.53±3.52 beats/min in group 1 and 82.33±3.69 beats/min in group 2. Comparison of post-test distance covered during wheelchair propulsion between the two groups showed a significant difference; being 305.19±17.21 meters in group 1 and 250.71+20.59 meters in group 2 table (1).

Table 1: Comparison of pre-training and post-training resting heart rate and distance covered during wheelchair propulsion between the two groups

Variable	Group 1 N=15 (mean+SD)	Group 2 N=15 (mean+SD)	t	p
Pre-Training Resting Heart rate (beats/min)	84.13 + 2.8	84.53 +3.5	.342	0.735
Post-Training Resting Heart rate (beats/min)	77.53 + 3.52	82.33 + 3.69	3.64	0.001
Pre-Training Distance Covered in Wheelchair Propulsion (m)	238.41+ 16.19	238 +0.02 19.85	0.06	0.953
Post-Training Distance Covered in Wheelchair Propulsion (m)	305.19 + 17.21	250 + 20.59	7.86	0.001

comparison of pre and post intervention scores of resting heart rate and distance covered during wheelchair propulsion within the two groups showed significant differences too. In group 1, the resting heart rate was 84.13±2.87 beats/min (mean±SD) at day 0, and 77.53±3.52 beats/min at the end of the 4th

week. In group 2, the resting heart rate was 84.53±3.50 beats/min at day 0 and 82.33±3.69 beats/min at the end of the 4^{th} week. In group 1, the distance covered during wheelchair propulsion was 238.41±16.19 meters at day 0, and 305.19±17.21 meters at the end of the 4^{th} week. In group 2 the same measure was 238.02±19.85 meters at day 0, and 250.71±20.59 meters at the end of the 4^{th} week table (2).

Table 2: Comparison of pre-training and post-training resting heart rate and distance covered during wheelchair propulsion within the two groups

Variable	Group	Pre-training (mean+SD)	Post training (mean+SD)	t	p
Resting Heart rate (beats/min)	Group 1 N=15	84.13 + 2.8	77.53 + 3.52	21.60	0.001
	Group 2 N=15	84.53 +3.5	82.33 + 3.69	5.01	0.001
Distance Covered in Wheelchair Propulsion (m)	Group 1 N=15	238.41+ 16.19	250 + 20.59	16.73	0.001
	Group 2 N=15	238+.02 19.85	305.19 + 17.21	16.73	0.001

Discussion

Significant improvements were seen between the two groups in resting heart rate after 4 distances covered by the subjects in favor of group 1 subject. Possible explanations for the reduction in post-training heart rate values and increased distance covered by subjects can be central as well as peripheral adaptations of the body. Peripheral adaptations result in improvement of oxidative metabolic capacity, oxygen extraction and increased muscle blood flow, whereas central adaptation results in enhanced cardiac output and stroke volume with a compensatory decrease in sympathetic stimulation and alteration in the central nervous system and adaptation in the trained muscle. Central cardiac improvement after exercise results in increased volume loading and reduced heart rate because of a decreased sympathetic drive with decreased levels of epinephrine and nor epinephrine [14].

On comparing mean percentage decrease in resting heart rate after 4 weeks, there were significant differences between the two groups. Group 1 showed greater improvement with mean decreases in resting heart rate of 7.05%, versus group 2, where a mean decrease of 2.6% was observed after 4 weeks. There were also significant differences between the two groups on comparing the distance covered during wheelchair propulsion. Group 1 showed greater improvement with a mean increase of 28.00% in the distance covered, versus group 2, where a mean increase of 5.33% was observed after 4 weeks.

These results are in agreement with a previous study showing improvement in cardiopulmonary functions in parallel with an increase in wheelchair propulsion endurance in quadriplegics [8]. This study also reported that subjects exercising on an arm ergometer were able to work more efficiently. The changes in cardiovascular functional status might have contributed to the differences seen in group 1. Another factor might be the exercise specificity which helped improve the function. The arm ergometry training simulates more of a functional activity as compared to strength training that only consists of lifting and lowering of free weights. Moreover, wheel chair propulsion is an activity which demands cardiovascular endurance rather than muscle strength alone.

The results obtained from this study suggest that arm ergometry training may be used to improve functional independence in spinal cord injured subjects who are using wheelchairs. Future studies can be carried out to assess torque or force production ability during wheelchair propulsion. Furthermore, subjects should be tested for other wheelchair skills with arm ergometry training.

Conclusions

This study showed significant changes in heart rate and an increase in distance covered during wheelchair propulsion after 4 weeks of training with the arm ergometry protocol as compared to the progressive resistance training program. Thus, training programs well codified and adapted to each subject must be systematically considered in paraplegics' rehabilitation program to increase fitness and its components among these individuals.

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