"EFFECTS OF CIRCUIT RESISTANCE TRAINING (CRT) FOR CARDIORESPIRATORY HEALTH & FITNESS IN PERSONS WITH PARAPLEGIA DUE TO HIGH THORACIC SPINAL CORD INJURY

CERTIFICATE BY THE HEAD OF INSTITUTION

Dr. V.Manivannan, ***M.P.T(Ortho).,M.I.A.P***

Principal/Head of the Institution

Nandha College of Physiotherapy

This is to certify that the work embodied in this dissertation entitled**"Effects of Circuit Resistance Training (CRT) for Cardiorespiratory health & fitness in persons with Paraplegia due to high thoracic spinal cord injury"**submitted to the TamilnaduDr.M.G.R University, Chennai, is a bonafiedcompiled work, carried out by Register Number:27102007, Nandha College of Physiotherapy, Erode- 638 052 in partial fulfillment for the award of degree in MASTER OF PHYSIOTHERAPYunder the guidanceof Mr.**R. SARAVANAKUMAR,M.P.T.** (cardio Resp.)

SIGNATURE

PRINCIPAL

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SIGNATURE

GUIDE

CHAPTER I

INTRODUCTION

Within the past - two decades, cardiopulmonary disease has emerged as the major cause of death and an important source of morbidity for persons aging with spinal cord injuries (SCI).One possible cause for this disease susceptibility is sedentary life-style, which is strongly associated with, and considered an independent risk factor for, heart disease. Profound physical inactivity is common among persons with paraplegia, with reports placing survivors of the paraplegia at the lowest end of the human fitness spectrum.

Regular participation in physical conditioning improves the fitness of persons with SCI, although their choices of exercise mode are more restricted than those available to persons without disability. The training modes commonly used by persons with paraplegia-arm ergometry (AE) and wheelchair ergometry (WE) often cause upper extremity injuries that compromise their ability to perform necessary daily activities. Such training may also hasten the early onset of pain and musculo skeletal decline of the shoulders and arms reported among young persons with SCI. These concerns challenge the suitability of arm and wheelchair ergometry as primary training mode to enhance fitness and health of individuals with paraplegia.

Circuit resistance training (CRT) consisting of several resistance exercises performed in succession, with one set directly followed by a different resistance maneuver. Rest periods between these maneuvers are usually kept to a minimum, which keeps the HR elevated throughout the entire training session. A prescribed number of circuits are then

completed for each training session. The benefits of CRT in persons without disabilities are well established and include greater muscular strength, cardiorespiratory endurance and aerobic capacity than achieved when performing resistance training and/or aerobic training alone.

The cardiorespiratory benefits of CRT have been related to resistance intensity, total training volume, and the duration and type of rest/recovery periods. The present study utilized a commercially available weight training system that permits independent use by persons with paraplegia from their wheelchairs and allows resistance training using concentric and eccentric contractions of key muscles of the arms and shoulder complex.

Purpose of the study

To examine the safety and effects of CRT program using mixed resistance training and arm ergometry on measures of muscle strength and cardiorespiratory endurance in persons with paraplegia secondary to SCI.

Significance of the study

- Understanding the potential health benefits of physical activity for people with SCI.
- Finding out the significant effects of Circuit Resistance Training for people with SCI.

Operational definitions

Arm Ergometer (AE)

It is targeted to meet the fitness needs of individuals who cannot use their legs for physical activity. It offers a great cardio workout that uses the upper body instead. Intensity can be altered by resistance & speed.

Circuit Resistance Training (CRT)

It is a form of conditioning program combining resistance training and high-intensity aerobics. It is an effective way to develop both strength & cardiorespiratory fitness simultaneously. A ‘circuit’ is the completion of all prescribed exercises in the program with minimal rest inbetween.

Maximal Oxygen Uptake (VO_{2max})

It refers to the amount of oxygen our body is capable of utilizing in one minute. It is measured as milliliters of oxygen per kilogram of body weight per minute. It is a commonly accepted measure of cardiorespiratory fitness.

One Repetition Maximum (1RM)

Resistive load for isoinertial resistance exercise during 12-week circuit resistance training.

HYPOTHESIS

Null Hypothesis

The null hypothesis states that there is no significant increase in cardiorespiratory endurance and muscle strength with circuit resistance training in persons with paraplegia due to SCI.

Alternate Hypothesis

The alternate hypothesis states that there is a significant increase in cardiorespiratory endurance and muscle strength with circuit resistance training in persons with paraplegia due to SCI.

CHAPTER II

REVIEW OF LITERATURE

G.M. Davis MA,P.R. Kofsky M.sc, J.C. Kelsey BPHE, 1981.

Muscle strength and endurance are important aspects of the disabled person's ability to function. Exercise with arm ergometer and with pulleys and participation in vigorous wheelchair sports can improve physical condition.

Hoffman MD, 1986.

With the growing interest in exercise and the significance of cardiovascular disease in the spinal cord injured population, the role of endurance training in improving cardiovascular health is of particular interest. Cardiorespiratory training studies revealed average improvements in VO_{2max}. and in physical work capacity after 4-20 weeks of training.

Flandrosis R, Grandmontague M, Gerin H, 1986.

Adaptation to prolonged exercise in paraplegics_ maximal O2 uptake (VO2max) and lactate threshold were elevated during an arm cranking exercise. VO_{2max}. was found to be directly related to the level of spinal injury : the higher the lesion the lower the uptake.

Ellenberg M, MacRitchie M, Franklin B, 1989.

Both strength and endurance contribute to overall functional capacity. In the rehabilitation of individuals with paraplegia, cardiorespiratory responses to progressive multi-stage arm ergometry were measured using open- circuit spirometry.

Bar-On ZH, Nene AV, 1990.

In persons with paraplegics monitoring heart rate alone becomes unreliable because of damage to their sympathetic systems. Those persons were put through an arm cranking exercise routine with increasing power levels. Almost linear relation was found between the heart rate and oxygen uptake in all subjects.

A.J.Mendez PhD, Ronald B.Goldberg MD,2000.

Results of graded arm exercise testing showed a improvements in peak O2 consumption, a increase in peak power output. These findings support the beneficial effects of circuit exercise resistance training on fitness & atherogenic lipid profiles in persons with chronic paraplegia.

Edward T.Mahoney MA, Mark S.Nash PhD, B.A.Green MD,2000.

The metabolic and heart rate responses to a single session of circuit resistance training in subjects with complete paraplegia determining the caloric cost of the exercise. Despite the modest absolute VO2 during exercise, CRT satisfies operational criteria developed for cardiorespiratory exercise prescriptions in persons without disability.

Hicks AL, Martin KA, Ditor Ds, 2003.

Determining the effects of 9 months of twice-weekly exercise training on strength,arm ergometry performance & indices of psychological well-being and quality of life. Following training, the experimental group had significant increase in sub maximal arm ergometry power output and significant increase in upper body muscle strength ; no significant change occurred in control group.

Gotshalk LA, Berger RA, Kraemer WJ, 2004.

Determining the level of cardiovascular stress elicited by continuous & prolonged CRT. Heart rate in CRT was higher than the heart rate of 150 found during treadmill running, which may help individuals develop enhanced toleration of physiological environments where high cardiovascular demands & higher lactate concentrations are present.

Nash MS,Van de ven I, Van ELK.N, Johnson BM, 2006.

With 4-month CRT program using alternating resistance maneuvers and high-speed, low-resistance arm exercise increases strength, VO2 peak, anaerobic power of middle-aged men with paraplegia while significantly reducing their shoulder pain.

Myers J, Lee M, kiratli J,2007.

For long-term SCI, morbidity and mortality from cardiovascular causes now exceeds that caused by other conditions. Thus screening, recognition and treatment of cardiovascular disease should be an essential component of managing individuals with SCI, and judicious treatment of risk factors can play an important role in minimizing the incidence of cardiovascular disease in these individuals.

Waller, Mike MA, Miller, Jason MS, 2011.

Resistance circuit training as a method of strength training for the adult population. Health-fitness adaptations gained from RCT include improved VO2max. in certain cases, an increase in time to exhaution, a decrease in resting blood pressure, increased muscular strength and changes in circulating cholestrol and hormone concentrations.

CHAPTER III

MATERIALS AND METHODOLOGY

Materials

- Open - circuit spirometer
- 12 - lead ECG
- Arm ergometer
- Hand held dynamometer
- Multi-station exercise system.

Study design

Quasi Experimental Design:

Single - Group Pretest - Posttest design.

(with in-group design)

Selection of samples

In this study, 15 patients with complete paraplegia were selected by convenient sampling technique.

Study setting

- Nandha Outpatient Department, Erode
- Government Head Quarters Hospital, Erode
- Best Physio Care, Tirupur
- Dhanvanthri Critical Care Centre, Erode

Study Duration

6 months

Variables

Independent variable : CRT with two levels: pre treatment and post treatment.

Dependent variables : VO_{2max}. and Heart rate

Inclusion criteria

- Persons with paraplegia due to complete spinal cord lesion
- Persons without arm & shoulder complex disability.
- Level of injury : T5 - T12
- Age : 25 - 50 years
- Body weight : 50 – 100 kgs.

Exclusion criteria

- Persons with paraplegia due to incomplete spinal cord lesion.
- Persons with shoulder joint dysfunction
- Level of injury : above T4 & below L1
- Dyspnoea at rest
- Presence of cardiac dysrhythmia or ischemia at rest.
- Stress during exercise.

Procedure

Subjects underwent 12 week of exercise training performed 3 times weekly on non-consecutive days. Each session lasted approximately 40-45 min and consisted of isoinertial

resisted exercise interspersed with periods of incomplete recovery(i.e heart rate not falling to baseline) with high-cadence, low resistance AE. Isoinertial resistance movements were performed on an Multi-Station Exercise System.

Following resistance exercises were performed by the subjects seated in their wheelchairs.

Pair 1: a) Military Press.

b) Horizontal rows.

Pair 2: a) Pec dec.

b) Preacher curls.

Pair 3: a) Wide grip latissimus pull-down.

b) Seated dips.

Each pair of resistance exercise was preceded by 2 min of warm-up using AE. Subjects then performed one set of 10 repetitions of the first resistance exercise (Military Press) each lasting 6 seconds (3 sec-concentric,3 sec-eccentric),followed immediately by 10 repetitions of horizontal rowing. Subjects then changed stations and performed 2 min of warm-up using AE. Subjects quickly wheeled to the next pair of maneuvers (pec dec and preacher curls) as previously described, followed by 2 more min of warm-up using AE. Subjects then completed the 3rd and final pair of resistance exercises followed by 2 more min of warm-up using AE.

These nine maneuvers comprised one full 'circuit'. Each CRT session consisted of three such circuits performed without interruption .The recovery periods between stations were minimal (15-20 sec) and were limited to the time needed for subjects to the next station.

Resistive loads were set between 50-60 percent of the one repetition maximum (1RM) strength and were recomputed every 4 weeks for each resistance exercise.

- 1RM strength was calculated with the Mayhew regression equation

$$\mathbf{1RM=wt/(0.533+0.419e^{-0.055*reps})}$$

CHAPTER IV

PROTOCOL OF DATA COLLECTION

Testing Personnel

Cardiorespiratory exercise testing :

- Using arm ergometry, performed before and after CRT.
- Metabolic and cardiac responses were measured during a single-test session of CRT.
- Subjects refrained from consuming food, cafine and nicotine for4 hours before testing and from ingestion of alcohol and the performance of strenuous activity for 24 hours before testing.
- Resistance settings were set at 60 percent of the 1RM.
- Metabolic activity for VO_{2max} during CRT was continuously monitored via open-circuit spirometry and Heart rate was continuously recorded with 12-lead ECG.

Isoinertial strength testing :

- Using multi – station exercise system, assessed before and after CRT.
- Before testing subjects were allowed several warm-up repetitions at each station.
- Start with minimum resistance and progressively increased in standard increments of all maneuvers.
- Complete 10 repetitions with incremental resistance increases until they were unable to complete more than 8 such repetitions.

Isokinetic strength testing

- Using hand held dynamometer.

- Following movements were tested on the dominant limb before and after CRT
    1) Seated elbow flexion & extention
    2) Seated shoulder external & internal rotation.
    3) Seated shoulder abduction & adduction
    4) Supine shoulder horizontal adduction & abduction
- Before testing subjects were allowed 3 min of exercise on an arm ergometer.
- Subjects executed three repetitions of both the concentric and eccentric actions for each isokinetic test maneuver.

Interventional program

Circuit Resistance Training is a form of exercise programming in which a series of exercise stations are sequentially performed-one set per station-for a prescribed number of circuits. Each circuit consists of the following six isoinertal resistance exercises

1. Military press : shoulder abduction with scapular elevation and upward rotation starting from the fully adducted and depressed position.
2. Horizontal rows : shoulder horizontal abduction with scapular adduction starting from a position of maximum forward reach.
3. Pec dec : shoulder horizontal adduction while in external rotation to the midline, from the maximum tolerated horizontal abduction in external rotation.
4. preacher curls : elbow flexion supported on an inclined pad from the fully extended position.
5. Wide grip latissimus pull-down : shoulder adduction with scapular downward rotation and depression starting from the maximal upward reaching position.

6. Seated dips : shoulder flexion, scapular depression and elbow extension while maintaining arms as near the body as possible, from the fullest allowed point of shoulder joint extension, scapular elevation and elbow flexion.

Statistical Analysis

Cardiorespiratory and HR data were expressed within intervals and across the entire exercise session as mean ± SD.

Statistical tool

Paired t-test used in this study. In all cases a p-value less than 0.05 was used as the criterion for statistical significance.

Formula: Paired t-test

$$S = \sqrt{\frac{\sum(d-\bar{d})^2}{n-1}}$$

$$t = \frac{\bar{d}}{S}\sqrt{n}$$

d = Difference between the pre traing and post training.

d = Mean difference

n = Total number of subjects.

S = Standard deviation

CHAPTER V

DATA PRESENTATION

Pre and post training values of VO_{2max}

S.no	$VO_{2\ max}$ (m1/kg/min)	
	Pre-training	**Post-training**
1	17.78	25.13
2	23013	26.72
3	19.45	25.26
4	21.26	24.57
5	16.91	22.35
6	15.18	23.48
7	18.35	2018
8	16.82	24.91
9	15.49	23.86
10	18.34	20.18
11	20.86	22.23
12	14.53	20.51
13	18.62	21.34
14	19.73	22.43
15	24.67	27.68
Mean	19.71	23.4
S.D	3.08	2.22

PRE AND POST TRAINING VALUES OF HEART RATE

S.no	Heart Rate (bpm)	
	Pre-training	Post-training
1	182	130
2	188	125
3	174	150
4	188	155
5	150	120
6	188	140
7	162	160
8	170	155
9	155	148
10	162	120
11	190	140
12	174	145
13	157	146
14	165	130
15	165	160
Mean	**171**	**142**
S.D	**13.3**	**13.13**

DATA ANALYSIS AND INTERPRETATION

The comparative mean values, mean difference, standard deviation and paired t-values of V02 max between pre and post training in persons with paraplegia

S.No	Variable VO_{2max}	Improvement			Paired t-value
		Mean (m1/kg/min)	Mean difference (m1/kg/min)	S.D (m1/kg/min)	
1	Pre-training	19.71	3.69	2.32	7.89
2	Post-training	23.4			

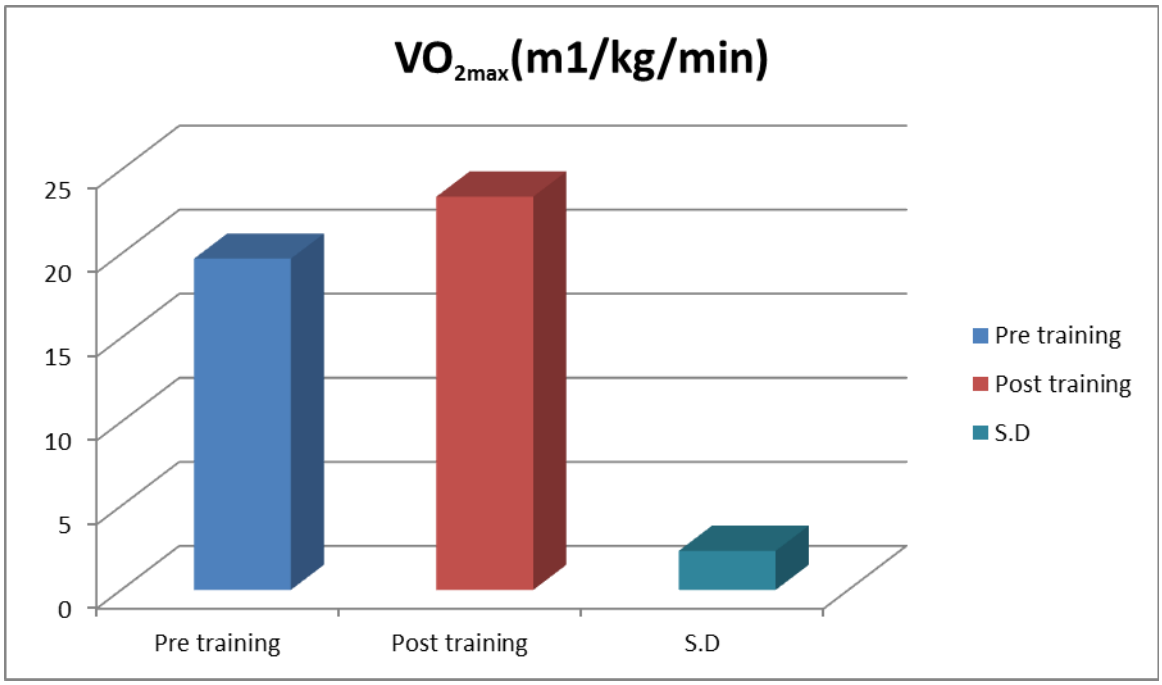
The paired t- value of 7.89 was greater than the tabulated t-value of 2.14, which showed a statistically significant difference at 0.05 level between Pre and Post training results of vo_2 max. The pre training mean was 19.71(m1/kg/min), post training mean was 23.4(m1/kg/min) and mean difference was 3.69(m1/kg/min). This showed an improvement in $\mathbf{VO_{2max}}$ in persons with paraplegia.

The comparative mean values, mean difference, standard deviation and paired t-values of Heart rate between Pre and Pose training in persons with paraplegia

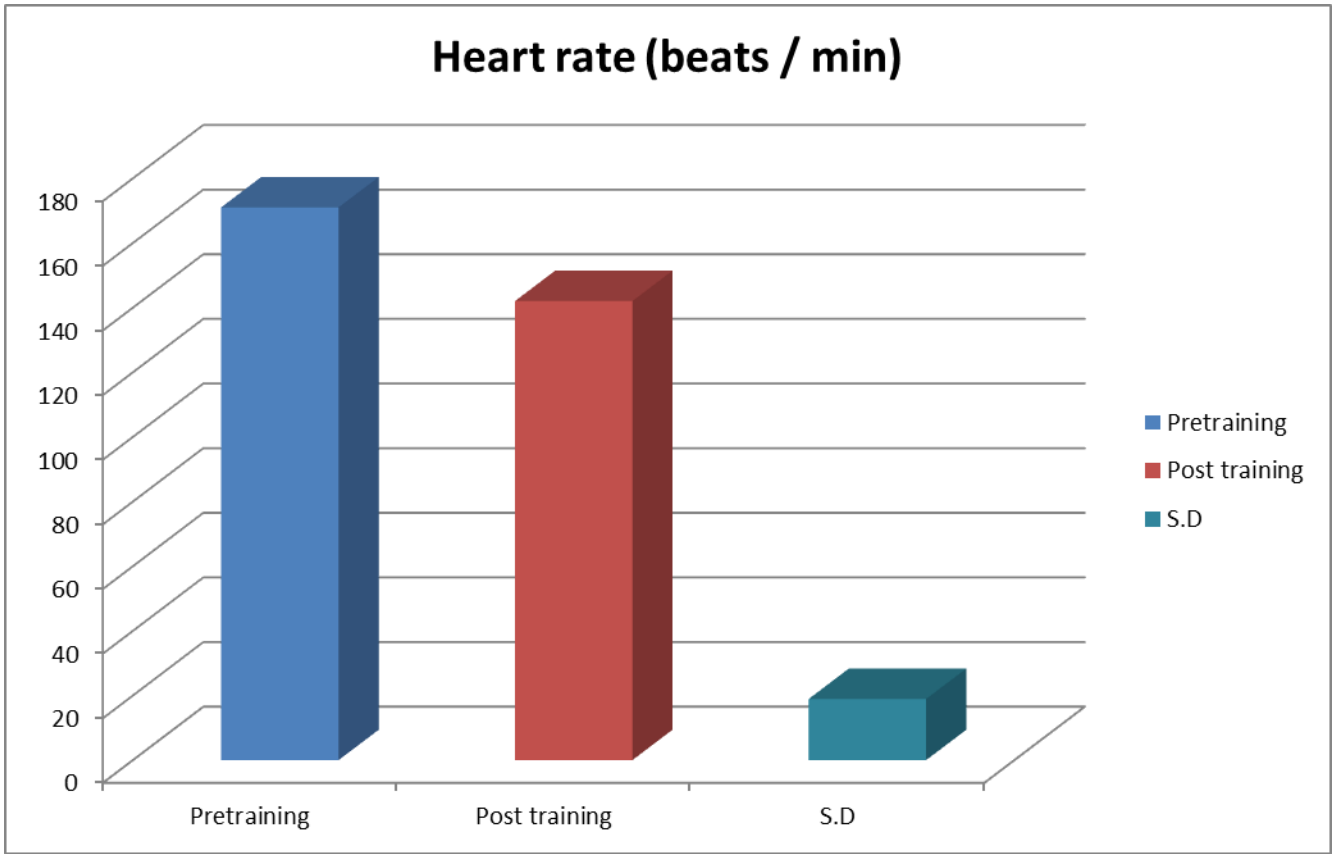
S.No	Variable Heart rate	Improvement			Paired t-value
		Mean (bpm)	Mean difference (bpm)	S.D (bpm)	
1	Pre training	171	29	18.9	5.8
2	Post training	142			

The paired t-value of 5.8was greater than the tabulated t-value of 2.14, which showed a statistically significant difference at 0.05 level between pre and post training results of heart rate. The pre training mean was 171bpm, post training mean was 142bpm and mean difference was 29bpm. This showed a significant improvement in Heart Rate control in persons with Paraplegia

Graphical Presentation of Pre and Post training values of VO_{2max}



Graphical Presentation of Pre and Post training values of heart rate



CHAPTER VI

RESULTS AND DISCUSSION

RESULTS

Calculated t- values are > table value of 2.02 at 5% level of significance ($p<0.05$), rejecting Null Hypothesis and the Alternate Hypothesis is accepted.

The results obtained from statistical analysis indicates that there was an improvement in vo2 max and Heart rate in persons with paraplegia due to SCI.

The increase in VO2 max and control in heart rate increase after training was observed in all subjects irrespective of their age.

By analyzing the mean values, the result showed that there is an significant increase in vo2 max and heart rate after circuit resistance training.

The student's t-test results showed that increase in vo2 max and control in heart rate increase with circuit resistance training.

DISCUSSION

The purpose of the study is to examine the safety and effects of CRT program on measures of cardiorespiratory endurance and muscle strength in persons with paraplegia secondary to SCI.

Base for the current study

Various research strategies have been used to define and redefine the exercise prescription used for endurance training of persons without disabilities. In most cases these studies have tested various combination of acute exercise intensities, durations and frequencies to examine whether they ultimately improved cardiorespiratory endurance.

The current study was based on a different strategy similar to that previously reported, which examined the acute responses to an exercise conditioning program already shown successful at increasing the upper –limb endurance and muscle strength of persons with paraplegia.

Discussion on Heart Rate

In conventional resistance training protocols superior cardiorespiratory adaptations have been reported when endurance activities were used as either separate exercise stations or modes of active recovery periods as opposed to true rest periods.

In the current study these guidelines were employed to design a protocol that consists pairs of isoinertial resistance maneuver altered with high-cadence, low-resistance AE sufficient to maintain heart rate elevated above baseline, average ranging between 120-160 bpm throughout the circuit.

Discussion on VO2max. and muscle strength

Nilsson and colleagues were described a program consisting of interval AE followed by progressive resistance exercise. Their results showed increase in VO2max. and muscular strength, both of which are significantly less than the results reported in the current study.

Cooney and Walker trained subjects using hydraulic resistance equipment and multiple sets at two exercise stations with 40-100 sec of rest periods. Improvements in cardiorespiratory capacity and power output as assessed by arm ergometry testing were observed after the 9-week training program, although no strength-related outcomes were reported.

Davis and Shephard measured muscle strength in subjects training at high work intensities were observed large strength differences of muscles which are not the weakest muscle groups nor those most in need of strengthening to perform ADLS for persons with SCI.

I n the current study of CRT the individuals were able to dramatically increase their daily activities, and no longer described their lives as limited by discomfort.

This study finds that 12 weeks of CRT significantly increases both cardiorespiratory endurance and muscular strength in persons with chronic paraplegia. The average increase inVO2max. sustained by the subjects was greater than enhancements of aerobic capacity previously reported after many extended programs of endurance AE exercise conditions.

As individuals undergoing this training had varying degrees of residual trunk control, it is possible that increased VO2max. resulted, in part, from improved trunk stability acquired during training. Such stability would be beneficial for those requiring improved body stabilization during wheelchair locomotion and other daily activities.

Among the benefits of well-designed conditioning programs are enhancements in function and life-satisfaction. Several reported dramatic improvements in their ability to perform regular daily tasks that rely primarily on upper extremity strength and endurance.

The study result of **Jacobs P.L, M.S. Nash and J.W. Rusinowski** supported the present study result in which circuit resistance training cause significant increase in VO2max. and Heart rate in persons with paraplegia due to high thoracic SCI.

Therefore the present study was accepting the alternate hypothesis and was rejecting the null hypothesis.

LIMITATIONS

This study is a small sample study confined to a small number of patients which limits generalization.

This study is conducted over a short period of time. The duration of the study was only 6 months.

This study demonstrated a significant short-term effect on VO2 max and Heart rate. But longer term effect need to be established over time frames.

RECOMMENDATIONS

- Further research is needed to study the effects of complementary endurance training on the aerobic capacity as measured by VO2max. & Heart rate and to assess their value in the rehabilitation process.
- A similar circuit resistance training program study can be conducted to modify the exercise prescription for healthy normal subjects
- A similar circuit resistance training program study can be conducted to improve exercise performance in athletic subjects.

CHAPTER VII

SUMMARY AND CONCLUSION

SUMMARY

The purpose of this study was to prove the safety and effectiveness of circuit resistance training in persons with high thoracic SCI.

The total number of 15 subjects of age group 25-50 years diagnosed as paraplegia due to complete SCI were conveniently selected for this study.

Circuit resistance training is the interventional program for this study. Metabolic and cardiac responses to exercise were continuously monitored via open-circuit spirometry and 12-lead Electro cardio graphy.

The selected groups were given 12 weeks of circuit resistance training and examined for a period of 6 months. Before and after 12 weeks of CRT program, the pre and post training values of VO2max. and Hear rate were measured.

The Paired t-test was used to compare the pre and post training values of VO2max. and Heart rate.

Based on the statistical analysis the result of this study showed a significant increase in both VO2max. and Hear rate.

Based on the data analysis and interpretation of VO2max. values the paired t-value of 7.89 was greater than the tabulated t-value of 2.14 at 0.05 level which showed a statistically significant difference between pre and post training values.

Based on the data analysis and interpretation of Hear rate values the paired t-value of 18.69 was greater than the tabulated t-value of 2.04 at 0.05 level which showed a statistically significant difference between pre and post training values.

CONCLUSION

The study showed that persons with paraplegia safely increased their endurance and muscular strength after 12 weeks of circuit resistance training.

The study showed a significant increase in VO2max. and Heart rate while performing sioinertial resistance exercises after circuit resistance training program.

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APPENDICES

APPENDIX I

PHYSICAL THERAPY ASSESSMENT CHART

NAME:

AGE:

SEX:

OCCUPATION:

P.M.R:

WEIGHT:

DATE:

CHIEF COMPLAINTS

ASSOCIATED PROBLEMS

SURGICAL NOTES/ PHYSICAL OBSERVATION (IF ANY):

MEDICAL HISTORY:

PAST HISTORY:

PRESENT HISTORY:

DRUG HISTORY:

FAMILY HISTORY:

SOCIAL HISTORY:

VITAL SIGNS:

TEMP: **PR:** **RR:** **BP:**

PAIN ASSESSMENT:

LOCATION:

NATURE:

AGGRAVATING FACTORS:

RELIVEVING FACTORS:

OTHERS IF ANY:

INFLAMMATORY SIGNS:

TENDERNESS:

WARMTH:

REDNESS:

OTHERS IF ANY:

PHYSICAL BUILT:

CARDIO THORACIC ASSESSMENT

EXTERNAL APPLIANCES:

CHEST DEFORMITIES:

CLUBBING:

CYANOSIS:

EDEMA:

- Pitting/non pitting
- Area

COUGH:

- Type:
- Frequency:

SPUTUM:

- Quantity:
- Color:
- Consistency:
- Odour:

WHEEZE:

CHEST PAIN:

- Character:
- Location:
- Duration:
- Behavior:

PERIPHERAL PULSES:

RESPIRATION:

- Type:
- Depth:
- Pattern:

VOCAL FREMITUS:

PERCUSSION NOTE:

- Hyper-resonanat/ normal/ dull/ stony-dull

AUSCULATION:

- Air entry
- Breath sounds
- Added sounds

- Heart sounds

THORACIC EXPANSION:

- Axilla
- Nipple
- Xiphoid

RANGE OF MOTION (OF RELEVANT JOINTS):

SPECIAL TESTS (IF ANY):

FUNCTIONAL ASSESSMENTS:

INVESTIGATIONS:

CLINICAL DIAGNOSIS:

TREATMENT PLAN:

APPENDIX II

TECHNIQUE

The 12 weeks of circuit resistance training performed 3 times weekly on non-consecutive days. The circuit consist of 8-10 strength exercises and have a cardiovascular component. Rest periods between stations should be kept little/no rest (HR should not fall below baseline during this time)

Exercise Recommendations as per ACSM guidelines:

FREQUENCY: 3 times per week

REPETITIONS: 10-15 repetitions per station

REST : 15-20 seconds

INTENSITY : Low- resistance/high-intensity. (60-80% HR max, 50-60% 1RM)

DURATION : 40- 45 minutes.

ACSM Guideline for Exercise intensity

Relative intensitry(%) **HR max**	**VO_{2max}**	**Description of intensity**
<35%	<30%	Very light
35-59%	30-49%	Light
60-79%	50-74%	Moderate
80-89%	75-84%	Heavy
>90%	>85%	Very heavy

WARM – UP (2 min) :

Using AE

RESISTANCE EXERCISES (3 Pairs) :

10 10 repetitions each

Lasting 6 seconds (3sec-concentric, 3 sec-eccentric)

Warm-up between each pair.

APPENDIX 3

DETERMINATIONS

Determination of VO2 max

VO2 max = 15.3 × (MHR/ RHR)

MHR - Maximum Heart Rate (beats/minute) = 208 – (0.7 × Age)

RHR - Resting Heart Rate = 20 second heart rate × 3

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