Comparison between Sports and Non-Sports Paraplegics

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ABSTRACT

Ten sports-active male paraplegics were compared with ten non-sports paraplegic subjects. Oxygen consumption, heart rate and rate of perceived exertion were investigated during both seated and upright (frame-supported) arm crank ergometry, at work rates up to 40 watts. The results of tests on 10 sports-active paraplegics were therefore compared with the data of the ten non-sports paraplegic who were not members of the basketball team but who volunteered to perform seated and upright arm crank ergometry. The means of heart rate and perceived exertion (i.e." mean of all 3 work rates for both seated and upright arm crank ergometry) were respectively 6.5% and 20% lower in non-sports than in sports-active paraplegics, whereas the training effect of sports participation would have led one to expect that they would be lower in the sports group. Since the non-sports paraplegics had incomplete lesions, it may be suggested that the effect of regular physical activities has an important effect an physiological responses to exercises.
Key words: *Arm Crank Ergometry, Energy Expenditure, Heart Rate, Oxygen Consumption, Paraplegics.*

INTRODUCTION

Persons with spinal cord injury (SCI) represent a significant portion of the population[18]. Current estimates show the prevalence of spinal cord injury in the United States to be from 250,000 to 300,000 people, with approximately 10,000 new injuries each year[8]. Due to the confinement to wheelchairs, SCI often has a devastating effect on the lives of the injured persons[15].

The life expectancy for SCI patients was significantly lowered than the rest of the population due to cardiovascular and respiratory disease which the SCI's were especially susceptible[3]. Nearly half of the deaths of SCI patients are due to one of the reasons for the increased risk of cardiovascular diseases with little or no exercise involved[3,8,10,15,18].

The benefits of exercise for the ambulatory population are well known and documented[19]. Exercise may be even more crucial for a SCI patient because of the psychological benefits as well as the physiological benefits. Jochheim and Strokhendl[10] point out "The incentive of physical exercises toward activity promises a stabilization of the personality and social integrative effects by enabling experiences of success and mutual participation".

The benefits of cardiovascular exercise and training can be easily noted by comparing trained SCI athletes with untrained SCI patients. A study by Bhambhani et al[1] investigated physiological responses during wheelchair racing comparing quadriplegics to paraplegics. They found the peak values of VO_2, heart rate, and VE which were obtained during incremental velocity wheelchair exercises to be significantly higher in paraplegics than quadriplegics. No significant differences were found between these groups for O_2 pulse (which is the oxygen utilization per heart beat).

Eriksson et al.,[7] also investigated the aerobic power during a maximal exercise by comparing trained versus untrained quad and paraplegics. They found peak VO_2 differences to be as high as a 38% increase for trained athletes versus nontrained. They noted that a well trained quadriplegic individual is physiologically comparable to an untrained paraplegic with a low level injury; therefore, physical training can largely reduce the differences between quadriplegics and paraplegics. Also by comparing the trained paraplegic athletes to non trained able bodied persons, the able bodied persons achieved only a slightly higher VO_2 peak, again pointing out the benefits of training.

Eriksson et al.,[7] as well as Coutts, Rhodes, and McKenzie[5] attempt to provide reasons for the differences between quad and paraplegic performances. One difference they point out is that quadriplegics were traditionally not allowed to do any hard physical training. It was not until 1982 that quadriplegics were able to compete in distance events over 200 meters. The most probable explanation for the differences is likely due to the smaller amount of functional muscle and loss of sympathetic activity for high level quadriplegic injuries. Paraplegics have more working muscle mass as well as trunk stability which is important. The loss of sympathetic nervous innervations affects cardiac performance. Quadriplegics will have a significantly lower peak heart rate (123 average) compared to paraplegics (184 average). The low peak heart rate results in a lower maximal cardiac output.

Each year research is performed in conjunction with the Oita International wheelchair marathon in Japan. Studies related to the differences between highly trained and untrained athletes have been a primary focus of Okuma, et al.,[13] and Ide et al.,[9].

Okuma et al.,[13] focused mainly on oxygen consumption for well trained versus non athletic racers. The well trained group had a 38% higher value of oxygen consumption than the non athletic racers. This study also tested racers over successive years and found that each athlete who was tested repeatedly increased their personal oxygen consumption from year to year. Finally this study tested during the off season as well and found the physical fitness had decreased for both groups however the fitness of the well trained group was still significantly higher in the off season than the non athletes.

Ide et al.,[9] study focused on comparing the anthropometric features of competitors who were deemed fine or poor racers based on the ability to finish the race. The study was conducted for a nine consecutive years. Large significant differences were found nearly each year for lung vital capacity and the muscle power of the upper arm of the fine racers compared to poor racers. For example average lung capacity for the fine racers was 4325 ml and the average for the poor racers was 3346 ml. An average muscle power was 42kg for the fine racers and 20.8 kg for the poor racers racers. The researchers expected to see significant differences due to age, weight, and body fat percentage, but few were seen. This shows that strength and aerobic training are much more important than age and weight for performance.

A spinal cord injury often severely impairs the immune system, and studies have shown that rehabilitation and exercise can have a significant impact in the return of near normal immune function. Kliesch, et al[12] studied immune function in 49 spinal cord injury patients. Compared to normal age-matched subjects, the natural killer (NK) cell function was reduced to only 21% of that in healthy individuals at two weeks post injury. T cell function decreased to 40.2% of normal, and T cell activation was also highly diminished. With rehabilitation therapy and exercise these values increased dramatically by 7 months post injury. By seven months post injury, the NK cell function was increased to 42% of the normal, and T cell function increased to 92% of the normal. Rehabilitation and exercise are one of the keys to returning the body's immune system function to normal, therefore making SCI patients less susceptible to deadly infectious diseases.

Another devastating metabolic consequence of spinal cord injury is the acute disruption of normal calcium balance. This contributes to a rapidly evolving osteopenia, or loss of bone mass, which can be a permanent consequence. The volume of cancellous bone in the body of a SCI patient can be reduced by as much as 33% within only 6 months of injury (Bloomfield, Mysiw, and Jackson)[2]. This reduction in bone mass makes SCI patients at extreme risk for fractures, especially later in life.

The purpose of this study was to investigate the different physiological responses to exercises between the sports and non-sports paraplegic subjects.

SUBJECTS AND METHODS

Subjects

Ten sports-active male paraplegics were compared with ten non-sports paraplegic subjects. Their characteristics are summarized in Table 1.

The sports paraplegic subjects were member of basketball team. The aims of the experiments were described to them and they were familiarized with the equipment to be used in the physiological testing. Agreed conditions for termination of exercise were; a) Requested by the subject to stop, b) Complaints of pain or discomfort by the subject and c) Apparent distress of the subject.

Table (1): Clinical details of paraplegic subjects

	Sports Paraplegics	Non-Sports Paraplegics
Age (years)	33.5 ± 3.2	32 ± 2.9
Mass (Kg.)	76 ±3.1	77 ± 3.5
Height (cm.)	168.7 ± 4.5	170 ± 5.1
Duration of lesion (years)	15 ± 2.9	13 ± 4.3

Procedure of Arm Crank Ergometry Experiment

(a) The arm crank ergometer used was a standard, friction-belt bicycle ergometer of the weight-load type (Monark), on which cylindrical handles had replaced the pedals. This ergometer was mounted on rigid frames with different heights {for seated and upright arm crank ergometry, separately}. A standard wheelchair was used, and its height was adjusted for each individual. In upright arm crank ergometry, the heights of the volunteers were also adjusted relative to the ergometer. The criterion for this adjustment (in the vertical plane) in both seated and upright arm crank ergometry was to set the ergometer crankshaft level with the subject's shoulder joint. The ergometer's internal dynamic friction at 50 rpm was evaluated. For upright arm crank ergometry, the paraplegics used their own calipers and were supported by a frame using straps around the knee and waist. The frame was built in such a way that would not hinder the movement of the arms during arm cranking.

(b) Oxygen consumption was measured by the Douglas bag technique. Collected volumes were measured by Parkinson Cowan gas meter; %02 was measured by a paramagnetic oxygen analyzers (Servomax type 570A) and %C02 by infrared absorption (Beckman L3-2). The calibration of both gas analyzers and the ergometer was checked before and after every session. The volume meter was regularly calibrated against a Tissot spirometer. PE 3000 Sports Tester measured heart rates with 15 seconds sampling rate and perceived exertion was evaluated by standard 6-20 Borg scale.

(c) Before each exercise test, subjects familiarized themselves with the equipment by arm cranking for two minutes against zero loads, in the body position in which the test was to be performed. Then, they rested for five minutes in the same position. Heart rate was recorded throughout this rest period and in the last two minutes expired air was collected for analysis.

(d) An incremental series of three work rates was then completed. The real work rates adopted were 16, 28 and 40 watts. These were achieved in the presence of the 4.7 watts internal friction load, by setting the adjustable belt load to 11-12, 23-24 and 35-36 watts, respectively. The chosen work rates were found in a pilot study to be within the capacity of all subjects. Cranking rate was standardized at 50 rpm, monitored by a counter, and the number of crank revolutions per minute was displayed continuously. Each work pout was maintained for five minutes. Heart rate was continuously measured. In the last two minutes of each exercise stage, expired air was again collected for analysis. At the end of each work load, subjects were also shown a standard 6-20 Borg scale and asked to state their perceived exertion.

RESULTS

The results of 10 sports-active paraplegics are compared with the data of the 10 non-sports paraplegics who participated for seated and upright arm crank ergometry. The non-sports paraplegic shows the unstable heart rate at last work rate of 40 watts during upright arm crank ergometry.

Although seated oxygen consumption and heart rates during exercise at 16 watts show no apparent differences between the two groups (Table 2), heart rates at 28& 40 watts and perceived exertion at all work rates. Heart rate in the upright non-sports paraplegic was within the range of the sport-active paraplegics. At the same power output, the percentage difference of heart rate was 6.5% lower in non-sports paraplegics than in the sports-active paraplegics in the mean of all exercise periods at all intensities in both seated and upright experiments.

Table (2): A comparison of variables between sports-active and non-sporting paraplegics during seated and upright arm crank ergometry

Type of Paraplegic	Arm Ergometry	Oxygen Consumption				Heart Rate				Perceived Exertion		
		Rest	16W	28W	40W	Rest	16W	28W	40W	16W	28W	40W
Non-Sport	Seated	0.24±0	0.58±0.001	0.78±0.009	0.91±0.002	71±4	84±2	93±2	98±5	7±0	7.5±0.5	10.5±0.5
Sport-Active	Seated	0.28±0.01	0.58±0.022	0.75±0.022	0.931±0.024	72±5	87±4	100±5	114±6	9±0.7	11.8±0.5	13.6±0.48
Non- Sport	Upright	0.27	0.52	0.71	0.86	85	92	105	123	8	11	11
Sport-Active	Upright	0.28±0.01	0.59±0.031	075±0.027	0.92±0.026	76±4	97±6	112±8	126±10	9.43±0.8	9.43±0.44	13.86±0.5

A similar analysis of perceived exertion shows the non- sports active paraplegics rated the work 20% easier to perform than did the sports active paraplegics. Clearly, these trends are counter to one's expectation on the basis of training. It should be considered that the physiological responses to exercise in paraplegics are related to several parameters e.g., nature, level and completeness of injury plus regularity and intensity of exercise.

DISCUSSION

Spinal Cord Injury patients represent a very specific population, whose physiological responses differ significantly from those of normal, able bodied persons. Since SCI often impairs many of the pulmonary muscles such as the diaphragm and intercostals, respiratory function is often significantly decreased in SCI patients[3].

Many tests of cardiac and lung function have focused on running or biking, thus the utilization of the lower limbs was necessary. Since SCI patients do not have the use of lower limbs, tests were developed to predict their cardiac and pulmonary fitness based on upper body exertion tests[14]. These tests produce differing results compared to lower extremity based tests, therefore a body research exists to test these subjects for physiological responses and establish peak values and norms for this population.

Coutts[4] found that the average heart rate elicited during a wheelchair basketball game was 148 bpm. This was the highest average heart rate. Other sports elicited lower rates, including volleyball (115), tennis (128), and racquetball (134). Although these heart rate values are slightly lower overall than the average able bodied population during these sports, the present study data is consistent with their findings. Since basketball requires a constant state of physical exertion compared to volleyball which involves more short anaerobic bursts, the average heart rates during basketball should likely be higher.

Rotstein et al.,[16] studied the aerobic capacity and anaerobic threshold of wheelchair basketball players. These tests were performed on a wheelchair treadmill in a graded exercise test, and also using an arm cycle ergometer. During each test, respiratory and oxygen uptake were measured to determine maximal aerobic capacity and anaerobic threshold. The tests performed by Rotstein, et al.,[16] were on a rather homogeneous group of athletes (male, same age range, basketball players).

They found their subjects to have a lower aerobic capacity compared to previous studies such as Veeger et al.,[17] in which a more heterogenic group was used as subjects. Also the method of testing is important to accurately evaluate aerobic capacity and anaerobic threshold. The wheelchair ergometer (treadmill) was more difficult because of trying to keep the wheelchair on a straight course, and therefore may yield values of aerobic capacity which are higher than an arm cycle ergometer.

Pare, Noreau, and Simard[14] point out that a submaximal test is more appropriate than a maximal effort test to predict aerobic power for several reasons. Newly spinal cord injured patients usually have a very low fitness level following hospitalization which put them at risk for adverse reactions to maximal training including the risk of vertebral fractures. They stressed again the need for a standardized piece of equipment such as the wheelchair ergometer to most accurately predict that aerobic power and establish norms. Some of their significant findings included that maximal heart rate for paraplegic patients was only approximately 5 bpm lower than the predicted maximum (220 - Age).

Also, they pointed out that lean body mass contributed to an increased accuracy of the prediction of aerobic power. A larger upper body muscle mass allows a higher efficiency of physiological adaptation to wheelchair exercise, while a smaller muscle mass may induce inappropriate adaptations to exercise such as poor muscle blood flow, higher muscle tension, and rapid contribution of anaerobic metabolism.

Davis & Shephard[6] showed that cardiac output and stroke volume were 40% higher in active than in inactive paraplegics. This was explained by i) Greater use of middle and lower body movement by the active subjects for the generation of force (assisting venous return), ii) A reduced cardiac after load in these subjects due to upper body hypertrophy in the active paraplegics (i.e. greater activation of arm muscles, allowing a larger blood flow to the working tissues). The recognition of the importance of sports in the rehabilitation of patients with spinal cord injury has to lead to the investigations of the physiological benefits of training programs on spinal cord injured individuals. With regard to the results of the comparison of cardio-respiratory responses between sports and non-sports paraplegics during both seated and upright arm crank ergometry in the present study.

Kaprielian et al.[19] stated that "A lower heart rate and upward trend in stroke volume during sub-maximal exercise in paraplegics suggests that lower body positive pressure offers positive hemo-dynamic benefits with the untrained group showing stronger benefit than the trained group, suggesting a possible venous pooling".

Summary and Conclusion

This study has reviewed the scientific literature available as to the importance of exercise for a person with a spinal cord injury. A spinal cord injury is a profound life impacting event, which can lead to devastating consequences. Exercise and fitness, however, can greatly increase the quality of life of these individuals. Fitness can lead to greater independence as well as longer life expectancy and reduced risk of cardiovascular and pulmonary diseases. All of the literature studied points out the importance of continued research in this area. Being a relatively new field of study since wheelchair sports were not introduced until the 1950's, there is still much to be learned about exercise and SCI. All of the benefits are still unknown, but the benefits which have been documented cannot be ignored.

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الملخص العربى

مقارنة بين الناشطين رياضيًا وغير الناشطين رياضيًا فى مرضى الشلل السفلى للجسم

إن المشاركة فى التمارين الرياضية يمكن أن يكون لها تأثير عميق على نتيجة إعادة التأهيل. وكان غرض الدراسة بحث الردود القلبى – رئوية فى مرضى الشلل السفلى للجسم . وقد تم إختيار عشرة من الناشطين رياضيًا من أعضاء فريق كرة السلة، لمقارنتهم مع عشرة من غير الناشطين رياضيًا. وأخذت قياسات استهلاك الأوكسجين ومعدل نبضات القلب ونسبة العمل المحسوس أثناء الوضع جالس وقائم (مدعوم بإطار) مع جهاز التدوير بساعد الذراع، فى نسب العمل 16، 28، 40 وات. وأظهرت النتائج أن اختلاف النسبة المئوية فى معدل نبضات القلب كان 6.5% منخفض فى مرضى الشلل السفلى للجسم غير الناشطين رياضيًا. بينما كانت نسبة العمل المحسوس 20% منخفضة فى غير الناشطين رياضيًا. وفى الخلاصة فإن المشاركة لمرضى الشلل السفلى للجسم لها تأثير كبير على ردودهم الفسيولوجية فى التمارين الرياضية.