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Energy Expenditure in Performance of the Basic Activities of Daily Living: A Comparison between Patients with Spinal Cord Injury and Normal Subjects

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A B S T R A C T

INTRODUCTION: Spinal cord injury is a catastrophic event that immeasurably alters activity and health. Depending on the level and severity of injury, functional and homeostatic decline of many body systems can be anticipated in a large segment of the paralyzed population. The level of physical inactivity and deconditioning imposed by SCI profoundly contrasts the pre injury state in which most individuals are relatively young and physically active. OBJECTIVE:- To quantify the difference in energy expenditure of patients with spinal cord injury with normal subjects during basic activities of daily living.

HYPOTHESIS:

•The total energy expenditure would be lower in patients with spinal cord injury than in normal subjects during basic activities of daily living.

•Energy expenditure during basic activities of daily living in patients with spinal cord injury and normal subjects is same.

DESIGN:- Observational study.

PARTICIPANTS:- 60 subjects divided into two groups of 30 patients with spinal cord injury (SCI) and 30 normal subjects. (Both male and female) between ages of 20-45 years.

MAIN OUTCOME MEASURES: -

- Oxygen uptake (VO2 max)
- Energy expenditure (EE)

RESULTS: The result of the study shows statistically significant result in both the groups which says that there is vast difference in Energy expenditure, $P<0.012$ and VO2max, $P<0.032$ in normal able body and SCI respectively.

CONCLUSIONS:. In an effort to combat many of the secondary conditions that occur after spinal cord injury, regular exercise and active lifestyles should be encouraged for all people with spinal cord injuries. The options for activity and types of exercise available vary depending on local resources, interests, and accessibility. In addition to the physical and metabolic benefits of exercise, persons with spinal cord injury who exercised reported less stress, less depression, and an improved quality of life.

Keywords: Spinal cord injury, Energy expenditure, Oxygen uptake (VO2 max) activities of daily living, dressing, grooming, COSMED K4b[2]

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1. Introduction

Spinal cord injury (SCI) is one of the most devastating injuries an individual can sustain. Of paramount concern to patients and their families, they expect the general recovery of motor function as well as recovery of ambulation and other activities of daily living following a spinal cord injury.(1-7)

Recovery of a specific functional task is dependent upon the neurological recovery that an individual attains. Individuals with incomplete spinal injuries can have a wide range of sensory and motor function despite having the same neurological level of injury. For example, a patient with a C5 incomplete injury may have decreased motor function in the lower cervical myotomes but may have lower extremity muscles that are all present, although weak.(8-13) This patient would have a more favorable prognosis for ambulation and other activities of daily living than another patient with an identical neurological level of C5 incomplete who had only spared sensation but no motor function. Because of this variance in function it is difficult to predict function based on level of injury in incomplete injuries.(7-9)

Individuals with spinal cord injury undergo numerous changes in body composition as a result of their injury. These changes include muscle paralysis, a reduction in lean tissue mass and bone mineral density, and an increase in fat mass (14, 15). Because of the extreme inactivity imposed by acute spinal cord injury and subsequent wheelchair confinement, this population is at increased risk for developing obesity-related disorders such as diabetes (16–18) and cardiovascular disease (19).A reduction in energy expenditure caused by a loss of lean tissue and bone mass may predispose SCI persons to weight gain and obesity in the event that energy intake exceeds daily energy expenditure (15, 20).

The level of spinal injury may be an important determinant of energy balance in this population, such that subjects with higher injury levels (i.e., those with cervical injuries) would experience the greatest reduction in body mass and daily energy expenditure. In addition, sympathetic nervous system (SNS) activity has been shown to be lower in persons with spinal cord injury than in control subjects (21). All of these factors would be expected to cause reductions in energy expenditure in SCI persons.

Total daily energy expenditure (TDEE) 1 and/or physical activity are inversely associated with body fat, weight gain, and/or weight regains(22-26). Despite the identified need for prevention of obesity in persons with physical disabilities (27-29), there is currently a dearth of information on energy expenditure (EE) and intakes in populations such as people with spinal cord injury (SCI).This is concerning because persons with SCI, largely dependent on wheelchairs for mobility, are at increased risk for obesity and other cardiovascular disease risk factors such as glucose intolerance and insulin insensitivity (30-32).

Studies suggest that those with SCI have significantly lower levels of physical activity than those in the able-bodied population. In fact, individuals living with SCI have been placed in the low end of the physical fitness spectrum. As expected, individuals with tetraplegia have lower levels of daily energy expenditure and aerobic power than those with paraplegia.

Those with paraplegia, despite their increased upper extremity mobility and options for exercise, have been found to be only marginally more fit than those with tetraplegia. Noreau and colleagueshas shown that approximately 25% of young people with paraplegia were able to achieve peak oxygen consumption levels that were only marginally sufficient to maintain independent living.

Earlier studies of energy expenditure in SCI persons used the heart rate method to estimate 24-h EE, which is based on the relation between heart rate and oxygen consumption (33). However, more reliable and valid measurements are needed to determine energy expenditure in this population because the heart rate response is abnormal in SCI individuals with lesions above T6 (because of a lack of normal innervations of the heart), particularly during exertion (34, 35). Previous studies were performed to measure resting metabolic rate (RMR) in SCI subjects with an indirect calorimetry system (36, 37).

The level of daily physical activity has a great effect on a person’s health. The assessment of energy expenditure can play a role in promoting healthy life style. Thus the measurement of energy expenditure in basic ADL activities will be helpful for evaluating current physical status and planning the treatment programme. However, no comparison was made with non injured control subjects; thus, the information regarding the effect of spinal injury on daily energy expenditure in performing basic activities of daily living is unknown.

The purpose of this study is to quantify the energy expenditure during basic activities of daily living in patients with spinal cord injury and compare with normal subjects in a rehabilitation setting.

2. Aims and Objectives

Aim: To quantify the difference in energy expenditure of patients with spinal cord injury with normal subjects during basic activities of daily living.

Objectives: To find out whether there is any difference in energy expenditure while performing basic activities of daily living between male and female spinal cord injury patient.

3. Hypothesis

EXPERIMENTAL HYPOTHESIS: - The total energy expenditure would be lower in patients with spinal cord injury than in normal subjects during basic activities of daily living.

NULL HYPOTHESIS: - Energy expenditure during basic activities of daily living in patients with spinal cord injury and normal subjects is same.

4. Methodology

STUDY AREA: Dept. of Occupational Therapy, NIOH, Patients with spinal cord injury between ages of 20-45 years.

STUDY POPULATION: 60 subjects divided into two groups of 30 patients with spinal cord injury (SCI) and 30 normal subjects. (Both male and female)

STUDY DESIGN: Observational study

PARAMETERS (outcome measures):-

- Oxygen uptake (VO_2 max)
- Energy expenditure (EE)

VO_2max is the maximum amount of oxygen in milliliters, one can use in one minute per kilogram of body weight.

Energy expenditure refers to the amount of energy (calories), that a person uses to breathe, circulate blood, digest food, and be physically active. To prevent weight gain, energy intake (caloric intake) must be balanced with energy expenditure.

STUDY TOOLS: -COSMED K4b^2

Fig 1 COSMED K4b^2

The K4 b2 is the first COSMED portable system for intrapulmonary gas exchange analysis on true breath by breath basis. Sport Medicine, Research, Human Performance, Gait Lab, Occupational health, Cardiology, Cardiac Rehabilitation, Clinical Nutrition and any application that requires the measurement of the cardio-respiratory response either in the field or in the lab. COSMED is the only manufacturer having more than 20 years of experience in mobile metabolic testing. The O2 and CO2 analyzers are maintained at a constant temperature. Sampling flow and pressure are continuously monitored. A barometer along with a temperature and pressure sensor allows instantaneous correction for any change in the environmental conditions.

INCLUSION CRITERIA:-

1. Patients with spinal cord injury of D-10 to L-1 level.
2. Age group of 20-45 years (both male and female)
3. Patients with spinal cord injury who could perform their own transfers independently.
4. Patients with spinal cord injury having independence in basic activities of daily living.
5. No other associated orthopedic/neurologic complications diagnosed during assessment.

EXCLUSION CRITERIA:-

1. Acute case of SCI patients.
2. Patients coming to therapy after 2 years of SCI.
3. Patients with orthostatic hypotension.

5. Protocol and Procedure

A total number of 60 subjects will be taken and convenient sampling method will be used for allocating subjects to SCI patients and normal subject groups of 30 each.Both groups will be evaluated for the energy expenditure, and oxygen uptake during following basic activities of daily living using K4b2.

1. Dressing upper body
2. Dressing lower body
3. Grooming (combing)
4. Bed to w/c transfer

The four basic activities of daily living are selected based on their common mention in four standard ADL scales. These scales are as follows

a. Functional independence measure (FIM)
b. Barthel index of ADL
c. Spinal cord independence measure (SCIM)
d. Katz index for ADL evaluation

The basic activities of daily living used in these four ADL scales will be distributed among occupational therapy professionals and a consensus will be taken from them regarding the steps involved in each activities. The proposed steps will be circulated among occupational therapy professionals for the consensus regarding steps of basic activities of daily living as follows.

Dressing upper body (T-Shirt for Male, Kurta for Female)

a. Balance the body in high sitting position.
b. Open the T-shirt/Kurta on lap with collar towards chest.
c. Put arms into sleeves and pull over elbows.
d. Hold onto T-shirt/Kurta tails or back of the dress, pull it overhead and adjust.
e. Remove the T-shirt/Kurta by reversing the procedure.

Dressing lower body (Trouser for Male, Salwar for Female)

a. Balance the body in high sitting position and lean forward to feet and pull knee into cross legged position.
b. Holding top of Trouser/Salwar, flip it down to feet.
c. Put the dress over feet and pull up to hip.
d. In semi recline position; Rolls from hip to hip and pull it up.
e. Remove the dress by reversing the procedure.

Grooming (Combing)

a. Sit on the chair and reach forward to take the comb placed in front of him.
b. First comb his/her same side of hair.(e.g. right side for right handed person)
c. Then comb the opposite side of hair.
d. Finally comb the back side of hair and put back the comb in its original place.

Transfer from Bed to wheel chair

a. Sit on bed and place wheel chair in 900 positions to bed with locking.
b. Lean forward to put weight on both upper limb and shift body towards wheel chair.
c. Place both feet on foot rest of wheel chair.
d. Put weight on both upper limbs over arm rests and swing his/her trunk from bed to wheel chair.
e. Finally adjust his/her position on wheel chair.

Transfer from Wheel chair to Bed

a. Place the wheel chair in 900 positions to bed with locking.
b. Lean forward and take weight on both upper extremities to shift anteriorly towards the edge of the wheel chair.
c. Put weight over the bed through both upper extremity and swing his/her trunk from wheel chair to bed.
d. Finally adjust his/her position on the bed.

The maximum percentage of consensus for each single step of basic ADL activity will be included as the final step of that basic ADL activity.

After the consent is taken from each subject for the participation in the study, the subjects will be involved in the measurement of cardio respiratory responses (VO2 max, EE).The steps of each basic activities of daily living will be demonstrated to each subject and care giver. Privacy of each subject will be respected by using screen and presence of their respective attendant (male attendant for male subject and female attendant for female subject).K4b2 will be fitted correctly to each subject and their respective attendant will be instructed to monitor the subject while he/she performing the basic activities of daily living. The subject will carry out all the five basic activities of daily living (Dressing upper body, Dressing lower body, Grooming, Transfer from bed to wheel chair, Transfer from wheel chair to bed) and simultaneously the reading will be recorded in the K4b2 after completion of each basic activities of daily living.

A total number of 60 subjects will be taken and convenient sampling method will be used for allocating subjects to SCI patients and normal subject groups of 30 each.Both groups will be evaluated for the energy expenditure, and oxygen uptake during following basic activities of daily living using K4b2.

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a. Balance the body in high sitting position and lean forward to feet and pull knee into cross legged position.
b. Holding top of Trouser/Salwar, flip it down to feet.
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Transfer from Bed to wheel chair

a. Sit on bed and place wheel chair in 90^0 positions to bed with locking.
b. Lean forward to put weight on both upper limb and shift body towards wheel chair.
c. Place both feet on foot rest of wheel chair.
d. Put weight on both upper limbs over arm rests and swing his/her trunk from bed to wheel chair.
e. Finally adjust his/her position on wheel chair.

Transfer from Wheel chair to Bed

a. Place the wheel chair in 90^0 positions to bed with locking.
b. Lean forward and take weight on both upper extremities to shift anteriorly towards the edge of the wheel chair.
c. Put weight over the bed through both upper extremity and swing his/her trunk from wheel chair to bed.
d. Finally adjust his/her position on the bed.

The maximum percentage of consensus for each single step of basic ADL activity will be included as the final step of that basic ADL activity.
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6. Statistical Analysis and Results

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 9.5 pt. Here follows further instructions for authors. All the data will be analyzed by using paired t test from the SPSS version 17. A probability level of $p<0.05$ was accepted as significant.Data were presented as arithmetic means +/- standard deviation(X+/-SD).

A total number of 60 subjects will be taken and convenient sampling method will be used for allocating subjects to SCI patients and normal subject groups of 30 each with age range from 20 to 45 years. There were 34 male and 26 female patients in the study. There was no drop out during the study.

(Demographic Data) shows the distribution of patients in both Groups.

SL NO	Baseline Characteristics	SCI GROUP	NORMAL SUBJECTS
1	No of Subjects	30	30
2	Age range(years)	20-45	20-45
3	Mean age(SD)	30.93(4.65)	31.03(4.39)

Table: 1 shows Energy expenditure in terms of kcal/hr in both the groups.

	SCI GROUP		NORMAL SUBJECTS		
	Mean (SD)	T value	Mean (SD)	T value	P
Dressing upper body	114.88(3.52)	13.59	64.88(7.52)	11.51	**0.012**
Dressing lower body	105.03(5.59)	17.43	55.03(9.49)	10.26	
Grooming (Combing)	94.05(7.52)	19.38	34.05(10.82)	10.59	
Transfer from Bed to wheel chair	124.88(11.42)	10.59	34.88(9.32)	14.56	
Transfer from Wheel chair to Bed	131.03(8.79)	11.89	35.03(11.29)	12.39	

Table: 2 show VO2max in terms of ml/kg/min in both the groups.

	SCI GROUP		NORMAL SUBJECTS		
	Mean (SD)	T value	Mean (SD)	T value	P
Dressing upper body	34.88(6.52)	13.59	54.88(8.58)	10.51	**0.032**
Dressing lower body	35.03(7.59)	17.43	55.03(7.69)	7.26	
Grooming (Combing)	24.05(10.52)	19.38	44.05(11.02)	9.59	
Transfer from Bed to wheel chair	39.88(11.12)	10.59	64.88(5.32)	12.56	
Transfer from Wheel chair to Bed	41.03(8.79)	11.89	65.03(10.29)	13.39	

Table: 3 Show EE in terms of kcal/hr in Male and Females in SCI groups.

	MALE GROUP		FEMALE GROUP		
	Mean (SD)	**T value**	**Mean (SD)**	**T value**	**P**
Dressing upper body	109.88(6.52)	11.59	114.88(9.52)	11.51	**0.037**
Dressing lower body	101.03(9.99)	17.48	117.03(8.49)	19.26	
Grooming (Combing)	96.05(8.52)	19.33	104.05(10.82)	15.59	
Transfer from Bed to wheel chair	114.88(10.12)	9.59	134.88(9.32)	14.56	
Transfer from Wheel chair to Bed	117.03(9.79)	10.89	135.03(10.29)	12.39	

Table: 4 Show VO2max in terms of ml/kg/min in Male and Females in SCI groups.

	MALE GROUP		FEMALE GROUP		
	Mean (SD)	**T value**	**Mean (SD)**	**T value**	**P**
Dressing upper body	32.88(6.52)	16.59	37.88(8.58)	10.51	**0.042**
Dressing lower body	33.03(7.59)	14.33	35.03(7.69)	12.26	
Grooming (Combing)	21.75(10.52)	20.39	34.05(11.02)	9.59	
Transfer from Bed to wheel chair	39.88(10.12)	12.89	60.88(7.92)	12.56	
Transfer from Wheel chair to Bed	40.03(9.79)	13.79	59.03(9.29)	13.39	

7. Discussion

The result of the study shows statistically significant result in both the groups which says that there is vast difference in energy expenditure and VO2max in normal abled body and SCI.

Physical activity accounts for 25% to 30% of the total daily energy expenditure. Not surprisingly, numerous studies suggest that individuals with SCI have significantly lower levels of regular physical activity than the able-bodied population. Studies suggest that those with SCI have significantly lower levels of physical activity than those in the able-bodied population. In fact, individuals living with SCI have been placed in the low end of the physical fitness spectrum. As expected, individuals with tetraplegia have lower levels of daily energy expenditure and aerobic power than those with paraplegia.

It is also noted that individuals with tetraplegia had lower levels of fitness versus those with paraplegia. The thermal effect of food accounts for approximately 10% of the total daily energy expenditure and is not felt to be significantly different in the able-bodied population versus the population with SCI. This decrease in RMR and decreased physical activity in individuals with SCI can lead to a positive energy balance.

Regular physical activity can increase exercise capacity, endurance, and muscle strength and has clearly been associated with decreased risk of cardiovascular disease. High levels of exercise have shown positive effects on lipoprotein profiles. Meta-analysis of 52 exercise trials of exercise training programs of 12 weeks' duration yielded significant increases of HDL-C and decreases in both LDL cholesterol (LDL-C) and triglycerides.

The American College of Sports Medicine (ACSM) and Centers for Disease Control (CDC) recommend that healthy adults participate in 30 minutes or more of moderate-intensity physical activity (ie, brisk walking) on most, and preferably all, days of the week. Moderate intensity exercises are classified as 40% to 60% of one's peak VO2 max or 4 to 6 metabolic equivalents (METs). One MET (3.5 mL O2/kg/min) is equivalent to one's energy expenditure at total rest. A brisk walk of about 3 miles per hour is roughly equivalent to 4 METs

Those with paraplegia, despite their increased upper extremity mobility and options for exercise, have been found to be only marginally more fit than those with tetraplegia. Noreau and colleagues has shown that approximately 25% of young people with paraplegia were able to achieve peak oxygen consumption levels that were only marginally sufficient to maintain independent living. After spinal cord injury, there is loss of voluntary motor function in the large muscle groups in the lower extremities. This loss generally limits exercise routines to the smaller muscle groups of the upper extremities and trunk. The overall availability of muscle mass is dependent on level and completeness of injury and varies between individuals.

An inverse relationship between level of injury and the peak oxygen consumption and cardiac output has been observed during exercise in those with spinal cord injury . Individuals with paraplegia have peak power output and cardiac output levels approximately half of those on able-bodied persons performing lower extremity exercise. The levels in tetraplegia are even further reduced from those seen with paraplegia.

As the level of injury increases, less muscle mass is available during exercise. During peak exercise, individuals with higher-level lesions may have more difficulty reaching levels of O2 consumption that stress the cardiovascular system appropriately before they reach peripheral fatigue. Persons with tetraplegia may also be less efficient during exercise because of the loss of trunk control and the need to stabilize themselves with the same muscle groups they are attempting to exercise.

In studies of persons with paraplegia with injury levels T1 through T4, sympathetic input and exercise response have shown inconclusive results. Approaching levels of T6 and below, there is generally sustained central control of sympathetic regulation. Individuals with mid-level thoracic lesions and below are able to maintain normotensive blood pressures and cardiac output levels similar to able-bodied controls at rest. The sympathetic cardiac response allows for these individuals to compensate for decreased stroke volume secondary to the venous pooling in the lower extremities by elevating the heart rate, which is not seen in tetraplegia.

Therefore, to maintain a similar cardiac output as able-bodied persons in the face of a lower stroke volume, resting heart rates are generally higher in those with lesions below T5 than in those in the uninjured population. Heart rates in paraplegia patients are also higher at similar workloads during exercise. The overall effect of heart rate on cardiac output is somewhat limited in paraplegia, and elevation of heart rate is unable to fully compensate adequately to increase the cardiac output to a level similar to able-bodied controls during more rigorous exercise using the upper extremities.

The need for exercise in the SCI population has been well recognized and does not vary dramatically from the general population. Generally, it is suggested that three to five exercise sessions should occur on a weekly basis. These sessions should be 20 to 60 minutes in duration with an intensity of 50% to 80% of the individual's peak heart rate . The American College of Sports medicine has published recommended exercise programming for individuals with SCI. The recommendations for these exercise programs are summarized as follows: different modes of cardiopulmonary training, which includes arm crank ergometry, wheelchair propulsion, swimming, vigorous wheelchair sports, ambulation with crutches or braces, seated aerobic exercise, and the use of electrically stimulated leg cycle activities. Important considerations in the prevention of overuse injuries are important components.

8. Conclusion

In an effort to combat many of the secondary conditions that occur after spinal cord injury, regular exercise and active lifestyles should be encouraged for all people with spinal cord injuries. The options for activity and types of exercise available vary depending on local resources, interests, and accessibility. In addition to the physical and metabolic benefits of exercise, persons with spinal cord injury who exercised reported less stress, less depression, and an improved quality of life.

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