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## Correlation between physical activity, respiratory muscle strength and heart rate indexes in spinal cord injured wheel chair users

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Abstract --- Objective: To find out the correlation between physical activity, respiratory muscle strength, heart rate indexes and heart rate variability in spinal cord injured manual wheelchair users. Also compare the physical activity, respiratory muscle strength, heart rate indexes and heart rate variability of spinal cord injured manual wheelchair users with the normal healthy controls. Patients and Methods: A convenient sample that included 50 SCI and 50 normal healthy controls with age 22-35 years was recruited. Individuals with chronic traumatic SCI of C6 to T12 (AIS A or B)4 and are trained with basic wheelchair skills4 . While those on medication, having any comorbidity other than SCI and current smokers were excluded. The SCI propelled their wheelchair for 5 mins at a self-selected and comfortable pace around a 41m circular track. Static mouth pressures and physical activity was recorded. Healthy individuals performed the 6-minute walk test. Results: A significant correlation between the respiratory muscle strength, heart rate indexes and heart rate variability was seen. PCCI was the most correlated followed by THBI and PCI did not showed any correlation. Also a significant difference was seen within the SCI group and also between the healthy controls of the same age, sex and body mass index. Conclusions: There is a significant correlation between the respiratory muscle strength, heart rate indexes and heart rate variability. But physical activity was not significantly correlated.

*Keywords*--- spinal cord injury, heart rate indexes, maximum inspiratory pressure, maximum expiratory pressure, physical activity.

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## Introduction

Spinal cord injury (SCI) involves devastating damage to the nervous system resulting in varying degrees of sensory and motor loss along with alteration in cardiovascular control and respiratory disturbances. As per the Asian data incidence of SCI accounts for 12.06 to 61.6 per million.<sup>1</sup> The amount of respiratory insufficiency due to paralysis depends on the injury level. High cervical injury results in complete paralysis of both inspiratory and expiratory muscles therefore greater complications. Autonomic imbalance results in altered cardiovascular control. In cervical and high thoracic injuries i.e. above T6 lesions, disruption of the sympathetic pathways and reduced supraspinal control over preganglionic sympathetic neurons results in bradycardia, autonomic dysreflexia, and cardiovascular deconditioning<sup>2</sup>. The autonomic modulation can be recorded by measuring the beat to beat variation through Heart Rate Variability (HRV) parameters. Physical capacity and energy expenditure in SCI is reduced due to direct loss of motor control of sympathetic alteration as per the lesion level.<sup>3</sup> All these complications poses SCI at a greater risk of cardiovascular risk factors thus the study aimed to:

- To find out the correlation between physical activity, respiratory muscle strength, heart rate indexes and heart rate variability in spinal cord injured manual wheelchair users
- To compare the physical activity, respiratory muscle strength, heart rate indexes and heart rate variability of spinal cord injured manual wheelchair users with the normal healthy controls of the same age, gender and body mass index.

## Methods

## Research design and ethics

The study is a correlational research. Research ethics approval was granted by the institutional research ethics committee of the hospitals. All institutional regulations concerning the ethical use of human volunteers were followed during this research. Written consent was obtained prior to participation in the study.

## Participant's Eligibility criteria

A total of 100 participants were included; 50 adults with Spinal Cord Injury (mean age= $27.22\pm0.5$ ) and time since injury was (11.22±1.5 months); 50 normal healthy controls (mean age= $27.2\pm1.5$ ). Inclusion criteria for SCI included:

- Individuals with chronic traumatic SCI (>3 month duration)
- Injury level of C6 to T12 (AIS A or B)<sup>4</sup>
- Individuals who are trained with basic wheelchair skills and could propel the wheelchair for at least 5 min at self-selected pace.<sup>4</sup>

Exclusion criteria for SCI

• Subjects taking medication that could affect heart rate e.g. beta blockers,

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Ca++ channel blockers.

- Any diagnosed cardiac, pulmonary, neurological other than spinal cord injury, physiological or psychiatric medical condition
- Current smokers.

Inclusion criteria for normal healthy controls were individuals aged 22 to 35 years. Exclusion criteria was 1) Any diagnosed acute or chronic morbidity 2) Individuals taking medication affecting heart rate e.g. Antibiotics.

## Protocol

A duly signed consent form was obtained from those willing to participate. Demographic data was collected from the subjects. All subjects were interviewed about their medical history and after complete physical examination, explanation about the testing procedure, maximal respiratory mouth pressures and wheel chair propulsion was done. They were as well explained about the benefits of the study. For performing maximal respiratory mouth pressures Capsule Sensing Pressure Gauge was used (CSPG-V) and demonstration of the correct manoeuvre was done. All participants were requested to refrain from eating 3 hours prior to test. Polar heart rate monitor RS 800 CX electrode was tied around the chest and watch was tied at wrist. For SCI individuals, 5 minutes rest followed by wheelchair propulsion was instructed at their own comfortable pace around the set circular track of 41mts for a duration of 5 minutes. The normal healthy individuals were asked to perform the 6 minute walk test along the 30 meter long pathway at their self-selected pace according to American Thoracic Society guidelines. At last the Leisure Time Physical Activity Questionnaire - SCI was filled by the patient.

## Assessment procedure

For SCI, Continuous heart rate (HR) was recorded using Polar heart rate monitor RS 800 CX. Average values were obtained during last 3 min of rest and exercise. At end of each test, Total distance travelled, propulsion speed and heart indexes were calculated. Signal processing was performed using Kubios HRV Analysis software (Version 2.2) in the time and frequency domains. In the HRV time domain, measures included the mean normal-to-normal intervals, the standard deviation of the N-N interval (SDNN) and the square root of the mean squared differences of successive N-N intervals. SDNN reflects overall HRV and square root of the mean squared differences of successive N-N intervals reflects vagal (parasympathetic) outflow.<sup>5</sup> The frequency domain of HRV methods uses the power spectral density that measures how power (or variance) distributes as a function of frequency.<sup>5</sup> In the frequency domain, low frequency (LF) and high frequency (HF) mostly reflect sympathetic and vagal modulations of HRV respectively.<sup>5,6</sup> Leisure Time Physical Activity Questionnaire for people with Spinal cord injury (LTPAO-SCI) a standardized structure interview to recall rate the intensity of all the physical activity performed by the respondent over the previous 7days in terms of minutes of mild, moderate and heavy intensity performed leisure time physical activity.<sup>7</sup>

## Statistical methods

The SCI were divided into 3 groups; cervical (C<sub>6</sub>-C<sub>8</sub>), upper thoracic (T<sub>1</sub>-T<sub>5</sub>) and lower thoracic (T<sub>7</sub>-T<sub>12</sub>). Analysis was done using SPSS Statistics 21. Variables were correlated using Karl Pearson's correlation with a level of significance of  $\leq$  0.005. For between the group analyses One Way ANOVA (Analysis of variance) was used and for specific variables comparison Post Hoc Tukey's test was done.

## Results

Spinal cord injury is a devastating injury taking into account the respiratory musculoskeletal and cardiovascular impairments along with decreased physical activity and energy expenditure. The present study thus brings out a correlation between the respiratory muscle strength, physical activity levels, heart rate indexes and heart rate variability in spinal cord injured individuals.

## Demographic details of the data( Table 1)

In the present study a total of 100 individuals were enrolled out of which 50 were SCI, all male with mean age of  $27.22 \pm 0.5$ . Of the 50 SCI, 14 cervical, 15 upper thoracic and 21 were lower thoracic. The mean duration of chronicity was  $11.22 \pm 1.5$  months. The control group was 50 normal healthy individuals with mean age ranging from  $27.22 \pm 1.5$  years, Body mass index (BMI) of  $23.48 \pm 1.91 \text{ kg/m}^2$ 

SPINAL CORD	Mean	Standard
INJURY (N=50)		deviation
Age (years)	27.22	0.5
Chronicity	11.22	1.5
(months)		
Gender	Males =50	
	, females	
	=0	
Cervical		
(N=14)		
Age	27.85	6.84
Chronicity	8.14	2.16
Upper		
Thoracic(N=15)		
Age	27.73	7.44
Chronicity	10.06	4.61
Lower		
Thoracic(N=21)		
Age	26.42	6.21
Chronicity	14.09	5.17
NORMAL		
HEALTHY(N= 50)		
Gender	Males =50,	
	females	
	=0	

Age	27.2	1.5
BMI (kg/m <sup>2</sup> )	23.48	1.91

## Correlation between physical activity, respiratory muscle strength, heart rate indexes and heart rate variability in SCI group (Table 2, 3,4)

On comparing the energy indexes with respiratory muscle strength, heart rate variability and physical activity the following results were found. In cervical spinal cord injury group, significant positive correlation was found for PCCI with chronicity and Heart rate change. A negative significant correlation between PCCI and PI max was observed. PCI and PCCI was significantly correlated with LF, HF, VLF and total power. In upper thoracic group, a significant positive correlation was found for PCCI with PE Max and Heart Rate change. LTPAQ-SCI and PE Max showed a positive significant correlation. PCI and PCCI obtained a positive significant correlated with VLF, LF and HF. In lower thoracic, THBI negatively correlated with chronicity. PCI was positively correlated with HR, VLF AND total power; negative weak correlation between VLF and chronicity.

Table 2Correlation analysis of Cervical cord injury of the respiratory muscle strength,<br/>heart rate indexes, physical activity and heart rate variability

r 1	CHRO	FIMAX	FEMA	H	FCI	FCCI	THEI	LTPA	MEAN	SDMM	MEAN	SDHR	RMBS	373750	FMNSO	VLF	L	HF	T.PWR	[	 
	NICITY		х	R				QBCI	RR		HR		в				F				
	Peor	.514	<u> </u>				<u> </u>					<u> </u>			<u> </u>		<u> </u>				
PIMA	son																				
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	Bear		<u> </u>	<u> </u>	812**	<u> </u>	<u> </u>	<u> </u>		<u> </u>		<u> </u>		<u> </u>							
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## Table 3 Correlation analysis of Upper Thoracic spinal cord injury of the respiratory muscle strength, heart rate indexes, physical activity and heart rate variability

IR	PCI	PCCI	ГНВІ	LTPAQSCI	MEANRR	SDNN		MEANHR	SDHR		RMSSD		NN50	PNN50	VLF	LF
033																
.239																
296																
.224	.727**															
329		.000														
141	.080	.221														
542	.729	.337	T													
066	129	094	.645**													
.402	.776	.579	.684	4	.002											
.136	.078	054	011	1347												
557	.737	.818	.963	3.123												
160	097	611**	241	l100	.124											
489	.676	5	.003	.292	2.666	.592										
.297	.751**	.468*	.19	1.184	122		.068									
.483	.191		.000		.032		.408	.425	.599			.771				
.165	.080	.646**	.31	1.127	129		.976**	081								
474	.731	L	.002	.170	0.582	.577			.000			728				
.392	.290	.462*	.238	8.136	.022		380	.277	.420							
079	.203	3	.035	.29	9.555	.926		.089	9	.224	.058					
.100	.621**	.369	.10	7213	.013		.362	.561**	289		.357					
665		.003	.100	.64	3.353	.954		.107	7		.008		.204	.112		
.141	.801**	.624**	224	1394	.137		.113	.463*	090		.213		.707**			
543		.000		.002	.32	8.078		.554		.627			.034	.697	.354	
.103	.389	.105	140	)263	.159		.641**	.482*	548*		.010		.771**	.643**		
658	.081	.651	.545	5.250	.490		.002	.027	.010		.966		.000	.002		
.199	.794**	.740**	.108	8032	131		090	.708**	.127		.247		.682**	.795**	.553**	
.860	.387		.000		.000		.642	.891	.571			.699		.000	.583	.280
.086	.308	.017	162	2289	.207		.173	.237	212		093		.193	.276	.205	.23
711	.175	.943	.484	4.204	.367	1	.453	.301	.356		.690		.401	.225	.372	.31
		1	I	1		1			1							

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019	.582**	.337	178	352	.092	.351	.314	308	.037	.713**	.850**	.689**	.679**
936		.006	.135	.439	.118	.693	.119	.166	.174	.875		.000	
.182	.796**	.661**	.035	129	054	.004	.678**	.024	.191	.694**	.823**	.587**	.964**
430		.000		.001	.881	.576	.815	.986		.001	.917	.408	

### Table 4

# Correlation analysis of Lower Thoracic spinal cord injury of the respiratory muscle strength, heart rate indexes, physical activity and heart rate variability

pipendent variable         (i) GROUP         (i) GROUP         (ii) GROUP         (iii) GROUP         (iiii) GROUP         (iiiii) GROUP         (iiiii) GROUP         (iiiii) GROUP         (iiiii) GROUP         (iiiii) GROUP         (iiiii) GROUP         (iiiiii) GROUP         (iiiiiii) GROUP         (iiiiiiiii) GROUP	D 1 /	x7 · 11	(I) ODOUD		14	0.1 5	0.	05% 0 51	T / 1
Prime         Dimensional of the periodic of t	Dependent	Variable	(I) GROUP	(J) GROUP	Mean Difference (I	Std. Error	Sig.	95% Confiden	ce Interval
pimax         1.00         2.00         41.50755         2.38844         000         35.6287         47.7524           9.00         3070897         2.32541         000         31.9489         42.6900           2.00         3.00         1.79877         2.33541         000         47.7524         -35.2627           2.00         3.00         1.79857         2.93377         9.28         -9.47341         5.8763           3.00         1.79857         2.93537         9.28         -9.47341         5.8763         9.4734           4.00         -4.18810         2.72543         4.20         -4.5763         9.4734           4.00         -37.31945         2.05404         000         -45.7863         9.4734           4.00         2.03522         2.67036         8.08         -9.3715         4.5924           1.00         -37.31945         2.05404         000         -2.9378         11.3140           3.00         2.38952         2.67036         8.08         4.5924         9.3715           4.00         3.00         35.67433         2.35721         000         28.9194         1.5800           2.00         3.506289         2.76269         997         7.81					Difference (I-			Lower Bound	Upper Bound
pimax         1.00         2.00         39.70807         2.32541         000         33.6269         1.5800           pimax         1.00         4.00         37.31945         2.05640         000         31.9489         42.6900           1.00         41.50755         2.38844         000         47.7524         -35.2627           2.00         3.00         -1.79857         2.93537         9.28         9.4734         5.8763           4.00         4.81810         2.72543         4.20         -45780         -33.6289           3.00         2.00857         2.93537         9.28         -5.8763         9.4734           4.00         -2.38952         2.67036         808         9.3715         4.5924           4.00         2.004         35.24983         2.42110         000         28.9196         41.8800           3.00         3.67433         2.35721         000         29.5112         41.8375         -29.8112           4.00         -36695         2.7629         997         -7.8153         6.6364           4.00         -366483         2.0212         000         40.1068         -29.2190           4.00         -10145         2.76269         997				2.00	41 50755*	2 38844	000	35.2627	47 7524
pimax         1.00         40.00         37.31945''         2.05404         000         31.9489         42.6000           2.00         3.00         -1.79857         2.93537         928         9.477524         35.2627           2.00         3.00         -1.79857         2.93537         928         9.477524         35.2627           3.00         2.00         1.00         53.70897         2.32541         000         -45.7890         -33.6289           3.00         2.00         1.79857         2.93537         9.28         -5.8763         9.4734           4.00         -2.0852         2.67036         8.08         9.3713         4.5924           4.00         2.00         4.1810         2.72434         4.20         2.9378         11.3140           3.00         2.38952         2.67036         8.08         4.5924         9.3715           3.00         3.567433         2.35711         0.00         2.89196         4.15800         -28.9196           2.00         3.567433         2.35721         0.00         41.8375         -29.5112         41.8375           4.00         -58695         2.76269         997         -7.8103         6.6549           3.			1.00	3.00	39 70897*	2.32541	000	33 6289	45 7890
pimax         1.00         41.50755         2.38844         000         47.7524         35.2627           2.00         3.00         -1.79857         2.93537         9.92         -4.77524         5.8763           4.00         -4.18810         2.72543         420         -11.3140         2.9378           3.00         2.00         1.79857         2.93537         9.28         5.8763         9.4734           4.00         -2.38952         2.67036         808         -9.3715         4.5924         9.3715           4.00         -3.731945         2.05404         000         -4.59274         9.3715         4.5924         9.3715           4.00         -3.531945         2.67036         808         -4.59274         9.3715           4.00         3.00         4.267437         2.35721         000         29.5112         41.830           1.00         34.66288'         2.08212         000         -41.5800         -28.9196           2.00         -42450         2.97550         999         -7.3553         8.2043           1.00         -35.67433'         2.35721         000         41.8375         -29.5112           1.00         -36.67433'         2.35726			1.00	4 00	37 31945*	2.02011	000	31 9489	42 6900
pimax         Tukey HSD         3.00         1.79857         2.93537         9.28         9.4734         5.8763           1.00         -39.70897         2.32541         400         4.1810         2.72543         420         -11.3140         2.9378           3.00         2.00         1.79857         2.32541         400         4.5890         -3.36289           4.00         2.38952         2.67036         808         -9.3715         4.5924           4.00         2.38952         2.67036         808         -9.3715         4.5924           4.00         3.00         35.67433         2.35721         000         28.5924         9.3715           3.00         3.00         35.67433         2.35721         000         29.5112         41.8375           4.00         -4.66288         2.42110         000         42.59149         9.3715         4.9043           2.00         -35.67433         2.35721         000         29.5112         41.8375         4.934           4.00         -4.66288         2.42110         000         41.8375         -29.5112           3.00         3.67433         2.35721         000         41.8375         -29.512           2.0			-	1.00	-41 50755*	2.38844	000	-47 7524	-35 2627
Tukey HSD         A00         4 18810         272543         420         11.3140         2.0375           1.00         39.70897         2.32511         000         45.7890         -33.6289           3.00         2.00         1.79857         2.32537         528         5.8753         9.4734           4.00         -2.38952         2.67036         808         -9.3715         4.5924           4.00         -2.38952         2.67036         808         -4.5924         9.3715           4.00         -2.003         5.249837         2.42110         000         41.5800         -2.8978         11.3140           2.00         35.249837         2.42110         000         28.9196         41.5800         -2.89196           4.00         -35.67433         2.35721         000         40.1580         -2.89196           2.00         3.00         42450         2.97550         999         -7.3553         8.2043           1.00         -35.67433         2.35721         000         -40.1668         -2.92190           4.00         -1.0145         2.70687         982         -6.0659         8.2043           1.00         -35.67433         2.35721         000         <			2.00	3.00	-1 79857	2 93537	928	-9 4734	5 8763
pimax         Tukey HSD         1.00         39.70897         2.32541         000         45.7890         33.6289           2.00         1.70957         2.32541         000         45.7590         33.6289           4.00         -2.38952         2.67036         308         -9.3715         4.5924           4.00         -2.004         4.1810         2.72543         4.20         -2.9378         11.3140           3.00         2.200         4.18810         2.72543         4.20         -2.9378         11.3140           3.00         2.30952         2.67036         808         -5.9244         9.3715         4.5024           3.00         3.00         35.67433'         2.35721         000         29.2190         40.1068           4.00         -35.24983'         2.42110         000         41.5800         2.89196           2.00         -30.042450         2.97550         999         -7.3553         8.2043           1.00         -35.67433'         2.35721         000         41.18375         -29.9112           3.00         1.00         -36.67433'         2.36721         000         41.375         -29.9112           2.00         -3.00         1.0145			2.00	4 00	-4 18810	2 72543	420	-11 3140	2 9378
Permax         3.00         2.00         1.79857         2.93337         928         -5.8763         0.4734           4.00         -2.38952         2.67036         808         -9.3715         4.5924           4.00         -2.38952         2.67036         808         -9.3715         4.5924           3.00         2.38952         2.67036         808         4.5924         9.3715           3.00         2.38952         2.47010         000         42.6900         31.9489           1.00         -35.24983'         2.42110         000         28.9196         41.5800           2.00         3.00         4.6288'         2.08212         000         42.89096         40.1068           2.00         -3.060         4.2697550         997         -7.3133         6.2636           4.00         -5.6695         2.76269         997         -7.8103         6.659           4.00         -1.01145         2.70687         982         +8.0489         6.0659           4.00         -1.01145         2.70687         982         +6.0659         8.089           4.00         -1.031510         1.6616         8.669         2.967         -6.6659         8.0889	pimax	Tukey HSD		1.00	-39.70897*	2.32541	.000	-45.7890	-33.6289
Permax         4.00         -2.38952         2.67036         808         -9.3715         4.5924           4.00         -37.31945'         2.05404         000         -42.6900         31.9499           2.00         4.18810         2.72543         .420         -2.9378         11.3140           3.00         2.38952         2.67036         .808         -4.5924         9.3715           3.00         2.38952         2.67036         .808         -4.5924         9.3715           4.00         3.66288'         2.08212         000         29.5112         41.8300           2.00         3.00         42450         2.97550         999         -7.3553         8.2043           3.00         2.00         -36695         2.76269         997         -7.8103         6.6364           4.00         -10145         2.07627         999         -8.2043         7.3553         2.003           3.00         2.00         -36695         2.76269         997         -7.8103         6.6659         0.0889           4.00         -10145         2.70687         982         -6.634         7.8103         6.059         0.0889         2.001         4.06283'         1.0816         4.0882 <td></td> <td></td> <td>3.00</td> <td>2.00</td> <td>1.79857</td> <td>2.93537</td> <td>.928</td> <td>-5.8763</td> <td>9.4734</td>			3.00	2.00	1.79857	2.93537	.928	-5.8763	9.4734
hr_change         1.00         -37.31945'         2.05404         000         -42.6900         -31.9489           2.00         4.18810         2.72543         420         -2.9378         11.3140           3.00         2.38952         2.67036         808         4.5924         9.3715           3.00         35.24983'         2.42110         000         28.9196         41.5800           4.00         34.66288'         2.08212         000         42.89196         40.1068           2.00         3.00         4.25695         2.42110         000         41.5800         28.9196           2.00         3.00         4.26592         2.97550         997         -7.3513         6.6364           4.00         -1.0145         2.70629         997         -7.8103         6.6659           3.00         1.01145         2.70687         982         -8.043         7.3553           3.00         1.01145         2.70687         982         -6.0659         8.0889           4.00         -3.0533         1.9205         .952         .0518         9525           2.00         -36591         2.3062         983         -5303         7039           4.00				4.00	-2.38952	2.67036	.808	-9.3715	4.5924
hr_change         4.00         2.00         4.1810         2.72543         4.20         -2.9378         11.3140           3.00         2.38952         2.67036         808         4.2024         9.3715           2.00         35.24983"         2.42110         000         28.9196         41.5800           3.00         35.67433         2.35721         000         29.5112         41.8375           4.00         3.466288"         2.08212         000         29.5112         41.8375           3.00         4.2450         2.97550         999         -7.3553         8.2043           4.00        58695         2.76269         997         -7.8103         6.6364           3.00         2.00        44650         2.97550         999         -8.2043         7.3553           4.00        44650         2.97550         999         -8.2043         7.3553         -6.0659           3.00         1.0145         2.70687         982         -6.6364         7.8103         -6.6364         7.8103           3.00         1.01145         2.70687         982         -6.6364         7.8103         -6.6364         7.8103         -6.6364         7.8103         -6.6364         <				1.00	-37.31945*	2.05404	.000	-42.6900	-31.9489
network         3.00         2.38952         2.67036         808         -4.5924         9.3715           Permax         1.00         35.24983'         2.42110         000         28.9196         41.5800           1.00         35.67433'         2.35721         000         29.5112         41.8375           4.00         35.62483'         2.08212         000         29.190         40.1068           2.00         3.00         .42450         2.97550         999         -7.3553         8.2043           4.00         -1.86295         2.76269         997         -7.3533         8.2043         7.3553           4.00         -1.01145         2.97550         999         8.2043         7.3553           4.00         -1.01145         2.70687         982         -8.0889         6.0659           3.00         1.01145         2.70687         982         -6.0659         8.0889           1.00         -36354         18698         2.17         -8524         1253           3.00         1.0145         2.70687         982         -6.0659         8.0889           1.00         -36354         18698         2.17         -8524         1253			4.00	2.00	4.18810	2.72543	.420	-2.9378	11.3140
Permax         1.00         35.24983'         2.42110         000         28.9196         41.5800           1.00         30.00         35.67433'         2.35721         000         29.112         41.8375           4.00         34.66288'         2.08212         000         29.1190         40.1068           2.00         3.00         4.2450         2.97550         999         -7.3553         8.2043           4.00         -42450         2.97550         999         -7.3553         8.2043         -7.3553           3.00         -42450         2.97550         999         -7.8103         6.6364           4.00         -101145         2.70687         982         -8.0889         6.0659           4.00         -101145         2.70687         982         -8.0889         6.0659           4.00         -13510         1.006         -45033         19205         .095         -9525         .0518           1.00         -45033         19205         .095         -0518         .9525         .0518           1.00         .31523         .21914         .479         -2577         .8824           2.00         3.00         .02679         .23602         .983<				3.00	2.38952	2.67036	.808	-4.5924	9.3715
Permax         1.00         3.00         35.67433'         2.35721         000         29.5112         41.8375           4.00         34.66288'         2.08212         000         29.190         40.1068           2.00         3.00         .42450         2.9750         .999         -7.3553         8.2043           4.00         .58695         2.76269         .997         -7.8103         6.6364           1.00         .35.67433'         2.35721         .000         41.8375         -29.5112           3.00         1.00         -34.66284'         2.97550         .999         -8.2043         7.3553           4.00         -1.01145         2.70687         .982         -8.0889         6.0659           4.00         2.00         .436628'         2.08212         000         -40.1068         -29.2190           3.00         1.01145         2.70687         .982         -6.0659         8.0889           1.00         .300         1.01145         2.70687         .982         -6.0659         8.0889           1.00         .45033         .19205         .995        9525         .0518         .9525           1.00         .45033         .19205         .995 </td <td></td> <td></td> <td></td> <td>2.00</td> <td>35.24983*</td> <td>2.42110</td> <td><mark>.000</mark></td> <td>28.9196</td> <td>41.5800</td>				2.00	35.24983*	2.42110	<mark>.000</mark>	28.9196	41.5800
Perfam         4.00         34.66288'         2.08212         000         29.2190         40.1068           3.00         .42450         2.97550         999         -7.3553         8.2043           4.00         .58695         2.76269         997         -7.8103         6.6364           1.00         .35.67433'         2.35750         999         -8.2043         7.3553         8.2043           3.00         .42450         2.97550         999         -8.2043         7.3553         2.92190           3.00         .400         -1.01145         2.70647         982         -8.0493         7.3553           4.00         .101145         2.70647         982         -8.0899         6.0659           3.00         1.01145         2.70647         982         -6.0659         8.0889           3.00         1.01145         2.70647         982         -6.0659         8.0889           3.00         1.010         .56133         19205         .9518         3.00         3.00         -2.067         .8254         .2057         .8518         .9525         .5518         .9525         .5018         .9525         .5018         .9525         .5033         .7039         .5303			1.00	3.00	35.67433*	2.35721	<mark>.000</mark>	29.5112	41.8375
pemax         Image relation         Image relation <thimage relation<="" t<="" td=""><td></td><td></td><td></td><td>4.00</td><td>34.66288*</td><td>2.08212</td><td><mark>.000</mark></td><td>29.2190</td><td>40.1068</td></thimage>				4.00	34.66288*	2.08212	<mark>.000</mark>	29.2190	40.1068
pemax         Tukey HSD         3.00         4.2450         2.97550         999         -7.3553         8.2043           1.00         -58695         2.76269         997         -7.8103         6.6364           3.00         4.2450         2.35721         000         -41.8375         -29.5112           3.00         -1.01145         2.70687         982         -8.0889         6.0659           4.00         -1.01145         2.70687         982         -8.0889         6.0659           4.00         -1.01145         2.70687         997         -6.6364         7.8103           3.00         1.01145         2.70687         982         -6.0659         8.0889           4.00         -3.05354         1.8698         .217         -8524         .1253           4.00         -3.13510         1.16516         .846         -5669         .2967           1.00         3.0304         1.905         .993         -5303         .7039           2.00         -30854         1.8698         .217         .1253         .8524           2.00         -31523         .21914         .479        2877         .8882           2.00         -31523         .21914<				1.00	-35.24983*	2.42110	<mark>.000</mark>	-41.5800	-28.9196
Pemax         Tukey HSD         4.00         -58695         2.76269         997         -7.8103         6.6364           1.00         -35.67433'         2.35721         000         -41.8375         -29.5112           2.00         -42450         2.97550         999         -8.2043         7.3553           4.00         -1.01145         2.70687         982         -8.0889         6.0659           4.00         -34.66288'         2.08212         000         -40.1068         -29.2190           4.00         -34.66233         19205         .982         -6.0659         8.0889           3.00         1.01145         2.70687         .982         -6.0659         8.0889           4.00         -13510         1.6516         .846        5669         .2967           4.00         -13510         1.6516         .846        5669         .2967           4.00         .3523         .21914         .479        5824         .1253           .00         .35523         .21914         .479        5303         .7039           .00         .35132         .21914         .479        5882         .2577           .00         .200         .68			2.00	3.00	.42450	2.97550	.999	-7.3553	8.2043
Primax         Haky HSD         1.00         -35.67433"         2.35721         000         -41.8375         -29.5112           3.00         2.00        42450         2.97550         .999         -8.2043         7.3553           4.00         -1.01145         2.70687         .982         -8.0889         6.0659           4.00         2.00         -58695         2.76269         .997         -6.6364         7.8103           3.00         1.01145         2.70687         .982         -6.0659         8.0889           3.00         1.01145         2.70687         .982         -6.0659         8.0889           4.00         -36354         .18698         .217        8524         .1253           4.00        13510         .16516         .846        5669         .2967           3.00         .08679         .23602         .983        7039         .5303         .7039           4.00         .31523         .21914         .479        2877         .8882         .2577           3.00        22844         .21471         .712         .3330         .7898         .3330           4.00         .300         -125.34095'         1.029660	nemax	Tulzev HSD		4.00	58695	2.76269	.997	-7.8103	6.6364
PCI         3.00         2.00         -42450         2.97550         .999         -8.2043         7.3553           4.00         -1.01145         2.70687         .982         -8.0889         6.0659           2.00         .58695         2.76269         .997         -6.6364         7.8103           3.00         1.01145         2.70687         .982         -6.0867         .8889           3.00         1.01145         2.70687         .982         -6.0867         .8889           4.00        36354         .18698         .217        8524         .1253           4.00        31520         .10516         .846        5669         .2967           2.00         4.00         .31523         .21914         .479        28577         .8882           2.00         4.00         .31523         .21914         .479        2309         .5303         .7039           3.00         .2804         .21471         .712         .3330         .7888         .2577         .8882         .2577           3.00         -22844         .21471         .712         .7898         .3330         .71970           4.00         .200         -31523         <	pennax	Tukey IISD		1.00	-35.67433*	2.35721	<mark>.000</mark>	-41.8375	-29.5112
PCI         Fukey HSD         4.00         -1.01145         2.70687         .982         -8.0889         6.0659           1.00         -34.66288'         2.08212         000         -40.1068         -29.2190           3.00         1.01145         2.706269         .997         -6.6364         7.8103           3.00         1.01145         2.70687         .982         -6.0659         8.0889           4.00         -1.3510         .16516         .846         .5569         .2067           1.00         4.5033         .19205         .955         .0518         .9525           2.00         3.00         .08679         .23602         .983        5303         .7039           2.00         3.00         .08679         .23602         .983        7039         .5303           3.00         2.00        08679         .23602         .983        7039         .5303           3.00        22844         .21471         .712         .3330         .7898           4.00         .231523         .21914         .479         .8882         .2577           3.00        22844         .21471         .712         .7135702         .119.7270			3.00	2.00	42450	2.97550	.999	-8.2043	7.3553
PCI         4.00         1.00         -34.66288'         2.0212         000         -40.1068         -29.2190           1.00         .36695         2.76269         .997         -6.6364         7.8103           3.00         1.01145         2.70687         .982         -6.0659         8.0889           1.00         3.00        36354         .18698         .217        8524         .1253           4.00         .13510         .16516         .846         .5669         .2967           2.00         3.00         .08679         .23602         .983        5303         .7039           2.00         3.00         .08679         .23602         .983        7039         .5303           4.00         .31523         .21914         .479        2577         .8882         .2577           3.00         2.00        08679         .23602         .983        7039         .5303           4.00         .2087         .21914         .479        8822         .2577           3.00         -100         .13510         .16516         .846        2967         .5669           2.00        31523         .21914         .479         -				4.00	-1.01145	2.70687	.982	-8.0889	6.0659
PCI         4.00         2.00         .58695         2.76269         .997         -6.6364         7.8103           1.01145         2.70687         .982         -6.0659         8.0889           2.00         -4.5033         .19205         .095        9525         .0518           1.00         3.00        36354         .18698         .217        8524         .1253           4.00        13510         .16516         .846        5669         .2967           2.00         3.00         .08679         .23602         .983        5303         .7039           3.00         .36354         .18698         .217        1253         .8524           3.00         .200        08679         .23602         .983        7039         .5303           3.00         .2204         .2101         .1253         .8524         .2577         .8882         .2577           3.00         .2204         .2111         .712        3330         .7898         .200         .303         .2967         .5669           4.00         .13510         .16516         .846        2967         .5669         .2067         .5669         .2067         .5669				1.00	-34.66288*	2.08212	<mark>.000</mark>	-40.1068	-29.2190
PCI         3.00         1.01145         2.70687         .982         -6.0659         8.0889           hr_change         1.00         3.00        45033         .19205         .095        9525         .0518           hr_change         1.00         3.00        36354         .18698         .217        8524         .1253           2.00         .300         .05679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479        2577         .8882           3.00         .08679         .23602         .983         .7039         .5303           4.00         .31523         .21914         .479         .2577         .8882           3.00         .08679         .23602         .983         .7039         .5303           4.00         .22844         .21471         .712         .3330         .7898           3.00         .12844         .21471         .712         .3330         .7898           3.00         .1284095'         10.02467         .000         .173.5702         .119.7270           3.00         .128.4095'         10.02461         .000         .179.5512         .126.6			4.00	2.00	.58695	2.76269	.997	-6.6364	7.8103
PCI         1.00         2.00        45033         .19205         .095        9525         .0518           hr_change         1.00         3.00        36354         .18698         .217        8524         .1253           hr_change         1.00         .45033         .19205         .095        0518         .9525           2.00         3.00         .08679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479        2577         .8882         .200           3.00         2.00        08679         .23602         .983        7039         .5303           4.00         .31510         .16516         .846        2967         .5669           4.00         .22844         .21471         .712         .3330         .7898           1.00         .13510         .16516         .846        2967         .5669           2.00         -4.66.4859'         10.29660         .000         -173.5702         .1919.7270           1.00         1.46.64859'         10.29260         .000         .165.0508         .118.7462           2.00         4.00         -152.84095'				3.00	1.01145	2.70687	.982	-6.0659	8.0889
PCI         1.00         3.00        36354         .18698         .217        8524         .1253           hr_change         1.00         .45033         .19205         .995         .0518         .9525           2.00         3.00         .08679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479        2577         .8882           3.00         .28644         .1171         .712         .3303         .7039           3.00         .28644         .2171         .712         .3333         .7039           3.00         .28644         .21471         .712         .3333         .7898           4.00         .22844         .21914         .479         .8882         .2577           3.00        22844         .21914         .479         .8882         .2577           3.00        22844         .21914         .479         .8882         .2577           3.00         -152.84095         10.02487         .000         .179.0521         .126.6299           1.00         .146.64859'         10.02487         .000         .197.0521         .126.6299           2.00				2.00	45033	.19205	.095	9525	.0518
hr_change         4.00        13510         .16516         .846        5669         .2967           1.00         .45033         .19205         .095        0518         .9525           2.00         3.00         .08679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479        2577         .8882           1.00         .36354         .18698         .217        1253         .8524           3.00         .22844         .21471         .712        3330         .7898           4.00         .22844         .21471         .712        3330         .7898           3.00         .22844         .21914         .479        8882         .2577           3.00         .22844         .21914         .479        8882         .2577           3.00         .22844         .21914         .479        8882         .2577           3.00         .200         .31523         .21914         .479        8882         .2577           3.00         .100         146.64859'         10.29660         .000         .179.0521         .126.6299           1.00 <t< td=""><td></td><td></td><td>1.00</td><td>3.00</td><td>36354</td><td>.18698</td><td>.217</td><td>8524</td><td>.1253</td></t<>			1.00	3.00	36354	.18698	.217	8524	.1253
hr_change         Tukey HSD         1.00         .45033         .19205         .095        0518         .9525           3.00         .08679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479         .2577         .8882           3.00         .08679         .23602         .983         .7039         .5303           4.00         .28844         .2171         .1253         .8524           2.00         .08679         .23602         .983         .7039         .5303           4.00         .22844         .21471         .712         .3330         .7898           4.00         .21844         .21471         .712         .3330         .7898           3.00        22844         .21471         .712         .7898         .3330           2.00         -146.64859'         10.29660         000         .173.5702         .119.7270           1.00         1.00         146.64859'         10.29660         000         .179.521         .126.6299           2.00         .400         .1284095'         10.02487         000         .118.7462           2.01         .00         144.64				4.00	13510	.16516	.846	5669	.2967
hr_change         2.00         3.00         .08679         .23602         .983        5303         .7039           4.00         .31523         .21914         .479        2577         .8882           3.00         .26879         .23602         .983        7039         .8524           3.00         .200        08679         .23602         .983        7039         .5303           4.00         .22844         .21471         .712        3330         .7898           4.00         .22844         .21471         .712        3330         .7898           3.00        22844         .21471         .712        7898         .3330           .00         .200        31523         .21914         .479         .8882         .2577           3.00        22844         .21471         .712         .7898         .3330           .00         .152.84095*         10.02487         .000         .179.0521         .126.6299           1.00         146.64859*         10.29660         .000         .118.7462         .961         .39.2787         26.8940           2.00         3.00         -6.19236         12.65442         .961         .				1.00	.45033	.19205	.095	0518	.9525
hr_change         Tukey HSD         4.00         .31523         .21914         .479         .2577         .8882           3.00         1.00         .36354         .18698         .217         .1253         .8524           3.00         2.00         .08679         .23602         .983         .7039         .5303           4.00         .22844         .21471         .712        3300         .7898           4.00         .300         .22844         .21471         .712        3300         .7898           3.00         .22844         .21471         .712        7898         .3300         .2577           3.00         .22844         .21471         .712        7898         .3330         .2577           3.00         .200         .146.64859'         10.29660         .000         -173.5702         .119.7270           1.00         146.64859'         10.02487         .000         -165.0508         .118.7462           2.00         3.00         -6.19236         12.65442         .961         .39.2787         26.8940           3.00         1.00         152.84095'         10.02487         .000         126.6299         179.0521           3.00			2.00	3.00	.08679	.23602	.983	5303	.7039
PCI         Tukey HSD         1.00         .36354         .18698         .217         .1253         .8524           3.00         2.00        08679         .23602         .983        7039         .5303           4.00         .22844         .21471         .712        3330         .7898           4.00         .200        31523         .21914         .479        8882         .2577           3.00        22844         .21471         .712         .7398         .3330           2.00        31523         .21914         .479        8882         .2577           3.00         .22844         .21471         .712         .7898         .3330           1.00         3.00         -152.84095*         10.02487         000         -173.5702         -119.7270           1.00         146.64859*         10.02487         000         -165.0508         -118.7462           2.00         3.00         -6.19236         12.65442         .961         -39.2787         26.8940           2.00         3.00         -152.84095*         10.02487         .000         126.6299         179.0521           3.00         1.00         142.8495*         10.265442<	hr change	Tukev HSD		4.00	.31523	.21914	.479	2577	.8882
$ {\rm PCI} \  \   {\rm TukeyHSD} \  \  \   {\rm TukeyHSD} \  \  \  \   {\rm TukeyHSD} \  \  \   {\rm TukeyHSD} \  \  \  \  \  \   {\rm TukeyHSD} \  \  \  \  \  \  \  \  \  \  \  \  \ $	8			1.00	.36354	.18698	.217	1253	.8524
$ {\rm PCI} \  \   {\rm FukeyHSD} \  \  \   {\rm FukeyHSD} \  \  \   {\rm FukeyHSD} \ \   {\rm FukeyHSD} \  \   {\rm FukeyHSD} \  \   {\rm FukeyHSD} \  \   {\rm FukeyHSD} \ \  {\rm FukeyHSD} \ \   {\rm FukeyHSD} \ \   {\rm FukeyHSD} $			3.00	2.00	08679	.23602	.983	7039	.5303
PCI         Tukey HSD         1.00         .13510         .10516         .846        2967         .5069           PCI         2.00        31523         .21914         .479        8882         .2577           3.00        22844         .21471         .712        7898         .3330           1.00         146.64859*         10.29660         .000         -173.5702         -119.7270           3.00         -152.84095*         10.02487         .000         -165.0508         -118.7462           2.00         3.00         -6.19236         12.65442         .961         -39.2787         26.8940           4.00         4.75007         11.74933         .978         -25.9698         35.4700           3.00         2.00         6.19236         12.65442         .961         -39.2787         26.8940           4.00         1.52.84095*         10.02487         .000         126.6299         179.0521           3.00         2.00         6.19236         12.65442         .961         -39.2787         26.8940           4.00         1.094243         11.51195         .778         -19.1568         41.0416           4.00         2.00         -4.75007         11				4.00	.22844	.21471	.712	3330	.7898
$ {\rm PCI} \  \   {\rm TukeyHSD} \  \  \  \  \  \  \  \  \  \  \  \  \ $			1 00	1.00	.13510	.16516	.846	2967	.5669
PCI         Tukey HSD         1.00         1.00         1.46.64859*         10.29660         0.00         -173.5702         -119.7270           1.00         3.00         -146.64859*         10.02487         0.00         -173.5702         -119.7270           4.00         -141.89852*         8.85498         0.00         -165.0508         -118.7462           2.00         3.00         -6.19236         12.65442         .961         -39.2787         26.8940           2.00         3.00         -6.19236         12.65442         .961         -39.2787         26.8940           4.00         4.75007         11.74933         .978         -25.9698         35.4700           3.00         2.00         6.19236         12.65442         .961         -26.8940         39.2787           4.00         10.94243         11.51195         .778         -19.1568         41.0416           4.00         10.94243         11.51195         .778         -19.1568         41.0416           4.00         4.00         1.04852*         8.85498         000         118.7462         165.0508           2.00         -4.75007         11.74933         .978         -35.4700         25.9698           3.0			4.00	2.00	31523	.21914	.479	8882	.2577
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $				3.00	22844	.21471	.712	7898	.3330
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			1.00	2.00	-140.04859	10.29660	.000	-173.5702	-119.7270
$ \begin{array}{c} \mbox{PCI} \\ \mbox{Figure HSD} \\ \mbox{Tukey HSD} \end{array} \begin{array}{c} 1.00 & 146.00 & -141.89322 & 6.83436 & 1.000 & -1105.0308 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1165.0402 & -1055.0402$			1.00	3.00	-152.84095	10.02487	000	-179.0521	-120.0299
$ \begin{array}{c} \mbox{PCI} \\ \mbox{PCI} \\ \mbox{Tukey HSD} \end{array} \begin{array}{c} 1.00 & 1^{+0.0+039} & 10.29000 & 1000 & 119.7210 & 173.702 \\ \hline 3.00 & -6.19236 & 12.65442 & .961 & -39.2787 & 26.8940 \\ \hline 4.00 & 4.75007 & 11.74933 & .978 & -25.9698 & 35.4700 \\ \hline 1.00 & 152.84095^{*} & 10.02487 & .000 & 126.6299 & 179.0521 \\ \hline 3.00 & 2.00 & 6.19236 & 12.65442 & .961 & -26.8940 & 39.2787 \\ \hline 4.00 & 10.94243 & 11.51195 & .778 & -19.1568 & 41.0416 \\ \hline 4.00 & 2.00 & -4.75007 & 11.74933 & .978 & -35.4700 & 25.9698 \\ \hline 3.00 & -10.94243 & 11.51195 & .778 & -41.0416 & 19.1568 \\ \hline 4.00 & 2.00 &87221^{*} & .08117 & .000 & -1.0845 &6600 \\ \hline 3.00 &25643^{*} & .06981 & .002 &4390 &0739 \\ \hline 1.00 & .87221^{*} & .08117 & .000 & .6600 & 1.0845 \\ \hline 2.00 & .41421^{*} & .09976 & .000 & .1534 & .6751 \\ \hline 4.00 & .61579^{*} & .09263 & .000 & .3736 & .8580 \\ \hline \end{array}$				1.00	146 64950*	10.00490	000	110 7070	173 5700
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			2.00	3.00	-6 19226	12 65442	961	-39 2787	26 8940
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $			2.00	3.00	4 75007	11.03442	.901	-39.2787	20.8940
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	PCI	Tukey HSD		1.00	152 84095*	10.02487	000	126 6299	179.0521
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			3.00	2.00	6 19236	12 65442	961	-26 8940	39 2787
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$			0.00	4 00	10 94243	11 51195	778	-19 1568	41 0416
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$				1.00	141 89852*	8 85498	000	118 7462	165.0508
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			4 00	2.00	-4 75007	11 74933	978	-35 4700	25 9698
$ THBI \qquad Tukey HSD \qquad \begin{array}{ccccccccccccccccccccccccccccccccccc$			1.00	3.00	-10.94243	11.51195	.778	-41.0416	19.1568
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$			1	2.00	87221*	.08117	.000	-1.0845	6600
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		1	1.00	3.00	45800*	.07903	.000	6646	2514
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$			1	4.00	25643*	.06981	.002	4390	0739
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	THBI	Tukey HSD		1.00	.87221*	.08117	.000	.6600	1.0845
4.00 .61579 <sup>•</sup> .09263 .000 .3736 .8580			2.00	3.00	.41421*	.09976	.000	.1534	.6751
				4.00	.61579*	.09263	<mark>.000</mark>	.3736	.8580

## Comparisons between physical activity, respiratory muscle strength, heart rate indexes and heart rate variability (Table5, 6)

For within the group analysis between the SCI group, cervical, upper thoracic and lower thoracic with age and gender matched normal individuals. PI Max was significantly different between the healthy controls and SCI group but no significant difference was observed within SCI group.PE Max was significantly different in the healthy with the SCI group but no difference was there within the SCI's group. Heart Rate change was significantly different for the healthy with the SCI group but not within the group. THBI was significantly different in healthy with the SCI group and significantly different with in the SCI group of upper and lower thoracic. The frequency parameter, LF was significantly different for the healthy group with cervical and lower thoracic. HF showed significantly different in results for healthy and the cervical group. PCCI was significantly different within the SCI, cervical and lower thoracic.

 Table 5

 Comparison of respiratory muscle strength, heart rate indexes, physical activity



and heart rate variability between the spinal cord injury cord injury (cervical, upper thoracic and lower thoracic) with the healthy normal controls of the same age , sex and Body mass index.

	Mu	ltiple Cor	npariso	ons				
Dependent Variable: pcci								
Tukey HSD								
(I)	(J)	Mean	Std.	Sig.				
VAR000	VAR000	Differen	Error					
02	02	ce(I-J)						
1.00	2.00	3.1652 4*	1.023 29	. <mark>009</mark>				
	3.00	4.5009 5*	.9501 0	. <mark>000</mark>				
2.00	1.00	- 3.1652 4*	1.023 29	. <mark>009</mark>				
	3.00	1.335 71	.9309 0	.332				
3.00	1.00	- 4.5009 5*	.9501 0	. <mark>000</mark>				
	2.00	- 1.3357 1	.9309 0	.332				
*. The mean difference is significant at the 0.05 level.								

1	`ab	le	6	

Comparison of heart rate index (PCCI) between the spinal cord injury cord injury (cervical, upper thoracic and lower thoracic)

## Discussion

Traumatic spinal cord injury is a devastating damage that dramatically alters the course of an individual's life affecting multiple body systems immediately and in long term. These includes but not only limit to the musculoskeletal system, urinary system, cardiovascular and the respiratory system leaving them with a number of complications. Physical deconditioning along with alteration in the cardiac control, respiratory dysfunction and continued inactivity poses a high risk of various complications. Wheelchair is a commonly used mode of locomotion which is a strenuous activity for a spinal cord injury person. Limited researches are done on assessing the energy expenditure in a SCI individuals that primarily focus on the heart rate indexes alone. Now a days a spinal cord injured is no longer restricted to wheelchair and are involved in more active lifestyle so the physiological diversity due to their injury can have a great impact on them.

The degree of respiratory impairment depends upon the level of injury. The higher level presents with greater respiratory disturbances and disturbed respiratory physiology. In high cervical injuries ( $C_1$ . $C_5$ ), complete paralysis of the inspiratory

and expiratory muscles take place whereas in  $C_5$  and below the diaphragm is spared but the strength is weak. Thoracic level injury has intact diaphragm and respiratory impairment is minimal. In cervical cord injury group, there is a positive correlation between Physiological Cost Index (PCI) and Heart Rate change, as the exercise intensity increases the oxygen consumption also increases and the cardiovascular changes occur presenting with the change in heart rate. Propulsion Cardiac Cost Index (PCCI) and chronicity are related positively as more the duration of injury the body undergoes deconditioning thus increasing the respiratory demands and heart rate so the amount of energy expenditure is increased. Heart Rate Indexes showed a negative correlation with PI Max, this is due to the reason that in cervical cord injury respiratory status is compromised and during wheelchair propulsion the respiratory demands as well the energy consumption increases. The frequency analysis of heart rate variability, showed a significant correlation with Heart Rate Indexes suggesting that both the sympathetic and parasympathetic modulation of heart takes place during wheelchair propulsion and increasing the energy expenditure.

In upper thoracic ( $T_1$ - $T_5$ ), a significant correlation is seen in PI Max and chronicity as more the duration of injury, rehabilitation and the body's adaptation thus increases the inspiratory muscle strength. Total Heart Beat Index (THBI) showed a negative correlation with PI Max, this is because in thoracic injury respiratory demands are compromised and during wheelchair propulsion the respiratory demands as well the energy consumption increases thus increasing the exertional level and decreasing the capacity of inspiratory muscles. A weak significant correlation between LTPAQ- SCI and PE Max is seen as the physical activity increases, the physical capacity also improves thus reflecting in increases strength of the expiratory muscles. The frequency analysis of heart rate variability, showed a significant correlation with Heart Rate Indexes suggesting that both the sympathetic and parasympathetic modulation of heart takes place during wheelchair propulsion and increasing the energy expenditure.

In case of Lower thoracic ( $T_{6}$ - $T_{12}$ ) group, a weak negative correlation was there between chronicity and Very Low Frequency (vLF) such that as the injury duration increases, the impact of autonomic modulation is decreased and in these groups there is less impact of the autonomic modulation as such. Also Physiological Cost Index (PCI) showed a significant correlation with Very Low Frequency (vLF) and Total Power suggestive of both the sympathetic and parasympathetic modulation of heart takes place at the time of wheel chair propulsion. In within the group analysis, PI Max and PE Max were significantly different between the healthy control and the SCI groups cervical, upper and lower thoracic because the injury has an impact on the normal respiratory mechanics. But no significant difference was observed within the SCI groups. Physiological Cost Index (PCI) was significantly different between the healthy control and the SCI groups cervical, upper and lower thoracic as the injury has decreased physical capacity and thus the energy consumed as compared with the normal healthy.

But no significant difference was observed within the SCI groups. Total Heart Beat Index (THBI) showed significantly different between the healthy control and the SCI groups cervical, upper and lower thoracic and a significant difference with in the SCI groups except for within the upper and lower thoracic no significant difference seen. Propulsion Cardiac Cost Index (PCCI) came out to be significantly different within the cervical, upper and lower thoracic group but upper thoracic and lower thoracic were not significantly different within group. The frequency analysis of heart rate variability, Low Frequency (LF) there was a significant difference between healthy group with cervical and lower thoracic but not upper thoracic. No difference was seen within the SCI group. High Frequency (HF) showed significant difference in results of healthy and the cervical group and no difference within the SCI group.

## Limitation

No female participant took part in the study due to the non-acceptance of tying the Polar Hear Rate Monitor electrode at the chest level.

## Conclusions

The study concluded that there is a significant correlation between the respiratory muscle strength, heart rate indexes and heart rate variability. But physical activity was not significantly correlated. Also a significant difference was seen in some of the parameters of respiratory muscle strength, heart rate indexes and heart rate variability within the spinal cord injury group and also between the healthy controls of the same age, sex and BMI.

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