How to Cite:
Arora, S., & Mitra, S. (2022). Correlation between physical activity, respiratory muscle strength and heart rate indexes in spinal cord injured wheel chair users . *International Journal of Health Sciences*, *6*(S3), 10951–10964.
https://doi.org/10.53730/ijhs.v6nS3.9606

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.

Manuscript submitted: 18 Feb 2022, Manuscript revised: 27 April 2022, Accepted for publication: 9 June 2022

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.[1] 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[2]. 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.[3] 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±0.5) and time since injury was (11.22±1.5 months); 50 normal healthy controls (mean age=27.2±1.5). Inclusion criteria for SCI included:

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

Exclusion criteria for SCI

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

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.[5] The frequency domain of HRV methods uses the power spectral density that measures how power (or variance) distributes as a function of frequency.[5] In the frequency domain, low frequency (LF) and high frequency (HF) mostly reflect sympathetic and vagal modulations of HRV respectively.[5,6] Leisure Time Physical Activity Questionnaire for people with Spinal cord injury (LTPAQ-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.[7]

Statistical methods

The SCI were divided into 3 groups; cervical (C_6-C_8), upper thoracic (T_1-T_5) and lower thoracic (T_7-T_{12}). Analysis was done using SPSS Statistics 21. Variables were correlated using Karl Pearson's correlation with a level of significance of ≤ 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 ± 0.5. Of the 50 SCI, 14 cervical, 15 upper thoracic and 21 were lower thoracic. The mean duration of chronicity was 11.22 ± 1.5 months. The control group was 50 normal healthy individuals with mean age ranging from 27.22 ± 1.5 years, Body mass index (BMI) of 23.48 ±1.91 kg/m^2

SPINAL CORD INJURY (N=50)	Mean	Standard deviation
Age (years)	27.22	0.5
Chronicity (months)	11.22	1.5
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^2)	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 correlation 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 2
Correlation analysis of Cervical cord injury of the respiratory muscle strength, heart rate indexes, physical activity and heart rate variability

	CHRONICITY	PIMAX	PEMAX	HR	PCI	PCCI	THBI	LTPAQSCI	MEAN RR	SDNN	MEAN HR	SDHR	RMSSD	NN50	PNN50	VLF	LF	HF	T.PWR
PIMAX	Pearson Correlation	.514																	
	Sig. (2-tailed)		.050																
PEMAX	Pearson Correlation	.454																	
	Sig. (2-tailed)	.089																	
HR	Pearson Correlation																		
	Sig. (2-tailed)	.976																	
PCI	Pearson Correlation				.812**														
	Sig. (2-tailed)	.818				.000													
PCCI	Pearson Correlation				.698**	.773**													
	Sig. (2-tailed)	.126				.004		.001											

THEI	Pearson Correlation				-.076													
	Sig. (2-tailed)		.050		.026													
LTPAQSCI	Pearson Correlation	.425			.351			-.328										
	Sig. (2-tailed)	.114			.028				.223									
MEANRR	Pearson Correlation				.405			-.217	.112									
	Sig. (2-tailed)	.971			.135			.426	.691									
SDNN	Pearson Correlation	.265			.622*			-.415	.252									
	Sig. (2-tailed)	.175				.011			.124	.195								
MEANHR	Pearson Correlation				-.426			.272	-.120									
	Sig. (2-tailed)	.980			.114			.227	.644		.000							
SDHR	Pearson Correlation	.222			.265			-.120	.197									
	Sig. (2-tailed)	.241			.157		.025		.644	.461			.000					
RMSSD	Pearson Correlation	.079			.517**			-.055	.226									
	Sig. (2-tailed)	.780				.000		.021		.005	.845	.216		.016		.021		.019

NN50	Pearson Correlation				.841**			-.094	.225																					
	Sig. (2-tailed)	.826				.000		.029		.012	.726	.226		.042		.023		.020			.000									
PNN50	Pearson Correlation				.911**			.010	.275																					
	Sig. (2-tailed)	.955				.000		.003		.001	.970	.221		.055		.024		.054			.000		.000							
VLF	Pearson Correlation	.057			.794**			-.245	.218																					
	Sig. (2-tailed)	.840				.000		.015		.027	.280	.247			.000			.016		.001		.002		.000						
LF	Pearson Correlation	.207			.745**			-.116	.460																					
	Sig. (2-tailed)	.459				.001		.049		.023	.679	.084			.022		.060			.000		.000		.000		.002				
HF	Pearson Correlation	.150			.620**		.649**	-.067	.409																					
	Sig. (2-tailed)	.595			.052		.000		.017		.009	.812	.130		.043		.022		.046			.000		.000		.000		.001		.000
T.PWR	Pearson Correlation	.126			.840**			-.197	.403		.776*																			
	Sig. (2-tailed)	.656				.000		.012		.015	.461	.126			.001			.025		.000		.000		.000		.000		.000		.000

Table 3
Correlation analysis of Upper Thoracic spinal cord injury of the respiratory muscle strength, heart rate indexes, physical activity and heart rate variability

HR	PCI	PCCI	THBI	LTPAQSCI	MEANRR	SDNN	MEANHR	SDHR	RMSSD	NN50	PNN50	VLF	LF
.033													
-.239													
.296													
-.224	.727**												
.329		.000											
.141	.080	.221											
.542	.729	.337											
.066	-.129	-.094	.645**										
.402	.776	.579	.684		.002								
-.136	.078	-.054	-.011	-.347									
.557	.737	.818	.963	.123									
.160	-.097	-.611**	-.241	-.100	.124								
.489	.676		.003	.292	.666	.592							
-.297	.751**	.468*	.191	.184	-.122	.068							
.483	.191		.000		.032	.408	.425	.599	.771				
-.165	.080	.646**	.311	.127	-.129	-.976**	-.081						
.474	.731		.002	.170	.582	.577		.000	.728				
-.392	.290	.462*	.238	.136	.022	-.380	.277	.420					
.079	.203		.035	.299	.555	.926	.089	.224	.058				
-.100	.621**	.369	.107	-.213	.013	.362	.561**	-.289	.357				
.665		.003	.100	.643	.353	.954	.107		.008	.204	.112		
-.141	.801**	.624**	-.224	-.394	.137	.113	.463*	-.090	.213	.707**			
.543		.000		.002	.328	.078	.554	.627		.034	.697	.354	
-.103	.389	.105	-.140	-.263	.159	.641**	.482*	-.548*	.010	.771**	.643**		
.658	.081	.651	.545	.250	.490	.002	.027	.010	.966	.000	.002		
-.199	.794**	.740**	.108	-.032	-.131	-.090	.708**	.127	.247	.682**	.795**	.553**	
.860	.387		.000		.000	.642	.891	.571	.699		.000	.583	.280
-.086	.308	.017	-.162	-.289	.207	.173	.237	-.212	-.093	.193	.276	.205	.232
.711	.175	.943	.484	.204	.367	.453	.301	.356	.690	.401	.225	.372	.312

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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

Dependent Variable		(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
pimax	Tukey HSD	1.00	2.00	41.50755*	2.38844	.000	35.2627	47.7524
			3.00	39.70897*	2.32541	.000	33.6289	45.7890
			4.00	37.31945*	2.05404	.000	31.9489	42.6900
		2.00	1.00	-41.50755*	2.38844	.000	-47.7524	-35.2627
			3.00	-1.79857	2.93537	.928	-9.4734	5.8763
			4.00	-4.18810	2.72543	.420	-11.3140	2.9378
		3.00	1.00	-39.70897*	2.32541	.000	-45.7890	-33.6289
			2.00	1.79857	2.93537	.928	-5.8763	9.4734
			4.00	-2.38952	2.67036	.808	-9.3715	4.5924
		4.00	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
pemax	Tukey HSD	1.00	2.00	35.24983*	2.42110	.000	28.9196	41.5800
			3.00	35.67433*	2.35721	.000	29.5112	41.8375
			4.00	34.66288*	2.08212	.000	29.2190	40.1068
		2.00	1.00	-35.24983*	2.42110	.000	-41.5800	-28.9196
			3.00	.42450	2.97550	.999	-7.3553	8.2043
			4.00	-.58695	2.76269	.997	-7.8103	6.6364
		3.00	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	1.00	-34.66288*	2.08212	.000	-40.1068	-29.2190
			2.00	.58695	2.76269	.997	-6.6364	7.8103
			3.00	1.01145	2.70687	.982	-6.0659	8.0889
hr_change	Tukey HSD	1.00	2.00	-.45033	.19205	.095	-.9525	.0518
			3.00	-.36354	.18698	.217	-.8524	.1253
			4.00	-.13510	.16516	.846	-.5669	.2967
		2.00	1.00	.45033	.19205	.095	-.0518	.9525
			3.00	.08679	.23602	.983	-.5303	.7039
			4.00	.31523	.21914	.479	-.2577	.8882
		3.00	1.00	.36354	.18698	.217	-.1253	.8524
			2.00	-.08679	.23602	.983	-.7039	.5303
			4.00	.22844	.21471	.712	-.3330	.7898
		4.00	1.00	.13510	.16516	.846	-.2967	.5669
			2.00	-.31523	.21914	.479	-.8882	.2577
			3.00	-.22844	.21471	.712	-.7898	.3330
PCI	Tukey HSD	1.00	2.00	-146.64859*	10.29660	.000	-173.5702	-119.7270
			3.00	-152.84095*	10.02487	.000	-179.0521	-126.6299
			4.00	-141.89852*	8.85498	.000	-165.0508	-118.7462
		2.00	1.00	146.64859*	10.29660	.000	119.7270	173.5702
			3.00	-6.19236	12.65442	.961	-39.2787	26.8940
			4.00	4.75007	11.74933	.978	-25.9698	35.4700
		3.00	1.00	152.84095*	10.02487	.000	126.6299	179.0521
			2.00	6.19236	12.65442	.961	-26.8940	39.2787
			4.00	10.94243	11.51195	.778	-19.1568	41.0416
		4.00	1.00	141.89852*	8.85498	.000	118.7462	165.0508
			2.00	-4.75007	11.74933	.978	-35.4700	25.9698
			3.00	-10.94243	11.51195	.778	-41.0416	19.1568
THBI	Tukey HSD	1.00	2.00	-.87221*	.08117	.000	-1.0845	-.6600
			3.00	-.45800*	.07903	.000	-.6646	-.2514
			4.00	-.25643*	.06981	.002	-.4390	-.0739
		2.00	1.00	.87221*	.08117	.000	.6600	1.0845
			3.00	.41421*	.09976	.000	.1534	.6751
			4.00	.61579*	.09263	.000	.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 significant difference 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

	CHRONICITY	PIMAX	PEMAX	HR	PCI	PCCI	THBI	LTPAQSCI	MEANRR	SDNN	MEANHR	SDHR	RMSSD	NN50	PNN50	VLF	LF	HF	T.PWR	
PIMAX	Pearson Correlation	.181																		
	Sig. (2-tailed)	.433																		
PEMAX	Pearson Correlation	.410	.467*																	
	Sig. (2-tailed)	.065		.033																
HR	Pearson Correlation		.012	-.239																
	Sig. (2-tailed)	.101	.959	.296																
PCI	Pearson Correlation		.159	-.224	.727**															
	Sig. (2-tailed)	.296	.490	.329		.000														
PCCI	Pearson Correlation		-.304	.141	.080	.221														
	Sig. (2-tailed)	.280	.180	.542	.729	.337														
THBI	Pearson Correlation		-.193	.066	-.129	-.094	.645**													
	Sig. (2-tailed)		.050	.402	.776	.579	.684		.002											
LTPAQSCI	Pearson Correlation	.113	-.081	-.136	.078	-.054	-.011	-.347												
	Sig. (2-tailed)	.626	.728	.557	.737	.818	.963	.123												
MEANRR	Pearson Correlation		-.241	.160	-.097	-.611**	-.241	-.100	.124											
	Sig. (2-tailed)	.894	.293	.489	.676		.003	.292	.666	.592										
SDNN	Pearson Correlation		-.162	-.297	.751**	.468*	.191	.184	-.122	.068										
	Sig. (2-tailed)		.006	.483	.191		.000		.032	.408	.425	.599	.771							
MEANHR	Pearson Correlation		.199	-.165	.080	.646**	.311	.127	-.129	-.976**	-.081									
	Sig. (2-tailed)	.862	.387	.474	.731		.002	.170	.582	.577		.000	.728							
SDHR	Pearson Correlation		-.301	-.392	.290	.462*	.238	.136	.022	-.380	.277	.420								
	Sig. (2-tailed)	.582	.185	.079	.203		.035	.299	.555	.926	.089	.224	.058							
RMSSD	Pearson Correlation		-.194	-.100	.621**	.369	.107	-.213	.013	.362	.561**	-.289	.357							
	Sig. (2-tailed)	.397	.400	.665		.003	.100	.643	.353	.954	.107		.008	.204	.112					
NN50	Pearson Correlation		.154	-.141	.801**	.624**	-.224	-.394	.137	.113	.463*	-.090	.213	.707**						
	Sig. (2-tailed)	.331	.504	.543		.000		.002	.328	.078	.554	.627		.034	.697	.354		.000		
PNN50	Pearson Correlation		-.180	-.103	.389	.105	-.140	-.263	.159	.641**	.482*	-.548*	.010	.771**	.643**					
	Sig. (2-tailed)	.114	.434	.658	.081	.651	.545	.250	.490	.002	.027	.010	.966	.000	.002					

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.

Table 6
Comparison of heart rate index (PCCI) between the spinal cord injury cord injury (cervical, upper thoracic and lower thoracic)

Multiple Comparisons				
Dependent Variable: pcci				
Tukey HSD				
(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
1.00	2.00	3.16524*	1.02329	.009
	3.00	4.50095*	.95010	.000
2.00	1.00	-3.16524*	1.02329	.009
	3.00	1.33571	.93090	.332
3.00	1.00	-4.50095*	.95010	.000
	2.00	-1.33571	.93090	.332
*. The mean difference is significant at the 0.05 level.				

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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