Original Article

Longitudinal study of body composition in spinal cord injury patients

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ABSTRACT

Background: Bone mass loss and muscle atrophy are the frequent complications occurring after spinal cord injury (SCI). The potential risks involved with these changes in the body composition have implications for the health of the SCI individual. Thus, there is a need to quantitate and monitor body composition changes accurately in an individual with SCI. Very few longitudinal studies have been reported in the literature to assess body composition and most include relatively small number of patients. The present prospective study aimed to evaluate the body composition changes longitudinally by DEXA in patients with acute SCI.

Materials and Methods: Ninety five patients with acute SCI with neurological deficits were evaluated for bone mineral content (BMC), body composition [lean body mass (LBM) and fat mass] by dual-energy X-ray absorptiometry during the first year of SCI.

Results: There was a significant decrease in BMC ($P < 0.05$) and LBM ($P < 0.05$) and increase in total body fat mass (TBFM) and percentage fat at infra-lesional sites. The average decrease was 14.5% in BMC in lower extremities, 20.5% loss of LBM in legs and 15.1% loss of LBM in trunk, and increase of 0.2% in fat mass in legs and 17.3% increased fat in the lower limbs at 1 year. The tetraplegic patients had significant decrease in arm BMC ($P < 0.001$), arm LBM ($P < 0.01$) and fat percentage ($P < 0.01$) compared to paraplegics. Patients with complete motor injury had higher values of TBFM and fat percentage, but comparable values of BMC and LBM to patients with incomplete motor injury.

Conclusions: Our findings suggest that there is a marked decrease in BMC and LBM with increase in adiposity during the first year of SCI. Although these changes depend on the level and initial severity of lesions, they are also influenced by the neurological recovery after SCI.

Key words: Body composition, body mass index, dual-energy X-ray absorptiometry, paraplegia, spinal cord injuries, tetraplegia

INTRODUCTION

Bone mass loss and muscle atrophy are the frequent complications occurring after spinal cord injury (SCI).[1,2] Although unloading is an important factor in the pathogenesis of bone loss in SCI patients, neuronal lesion and hormonal changes also seem to be involved in this process.[3] Inactivation and extreme unloading in SCI patients result in marked atrophy of the leg and thigh skeletal muscles within a few months of the injury.[4] Accurate quantification of skeletal muscle is important in the assessment of nutritional status, disease risk, physical function and atrophic effects of aging and muscle wasting diseases.[5] The potential risks involved with these changes in the body composition have implications for the health of the SCI individual.[6] Thus, there is a need to quantitate and monitor body composition changes accurately in an individual with SCI.

Body mass is composed primarily of bone mineral, fat and fat free soft tissue [lean body mass (LBM)]. Skeletal muscle is the largest component of fat free mass, representing 50% of the non fat component in the body.[7] Although dual-energy X-ray absorptiometry (DEXA) was first developed to measure bone mineral content (BMC), it has been shown to be one of the most feasible, valid and reliable measures of body composition in people with disabilities.[8-10] Very few longitudinal studies have been reported in the literature to assess body composition and most include relatively small number of patients.[4,10,11] The present prospective study aimed to evaluate the body composition changes longitudinally by DEXA in patients with acute SCI.

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MATERIALS AND METHODS

This prospective, longitudinal study was carried out on 106 patients (79 males and 27 females) with acute SCI with neurological deficit who were admitted at our tertiary level health care institute. Only patients with grade A or B injury on the American Spinal Injury Association impairment scale (AIS)[12] at the time of presentation to the institute and those presenting within 72 h of injury were enrolled in the study. During the initial evaluation and final followup at 1 year, 11 patients expired; therefore, the final data analysis included 95 patients (71 males and 24 females). Table 1 shows the socio-demographic profile of the study population. The mean age of the patients was 33.3 years (range 19-60 years). Majority of patients were adults below 50 years and only nine patients were aged above 50 years.

Written consent was obtained from all patients. Complete general physical and neurological examination was done. Body mass index (BMI) was calculated. BMC and body composition (LBM and fat mass) were measured with DEXA scan using HOLOGIC QDR-2000 explorer (Hologic Inc., Bedford, MA, USA). The patients were asked to lie on a table and whole body scanning was carried out with a congruent beam of stable dual-energy radiation. DEXA provides a three compartment partition of the body: Bone mineral, fat mass and fat free mass. After completion of scan, the body composition results (region wise and total body) are provided by the system's software (BMC, LBM, fat, lean + BMC, total mass, %fat).

Table 1: Socio-demographic characteristics of the study population (N=95)

Characteristics	Number	Percentage
Gender		
Male	71	74.7
Female	24	25.3
Paraplegics	75	78.9
Tetraplegics	20	21.1
Level of injury		38
Cervical	20	21
Dorsal	27	28.4
Dorsolumbar junctional injuries (D10-L2)	35	36.9
Lumbar	13	13.7
Neurological status at the time of admission (AIS)		
A	53	55.8
B	42	44.2
C	Nil	0
D	Nil	0
E	Nil	0
Neurological status at 1 year post injury (AIS)		
A	22	23.15
B	19	20
C	39	41.05
D	15	15.8
E	Nil	0

AIS = Association impairment scale

One trained technician performed and analyzed all scans to ensure consistency. Followup of all the above mentioned parameters was done at 3, 6, and 12 months. The patients showing no signs of motor recovery during the course of the study were considered as motor complete (AISA A and B) (n=41), and those patients showing signs of motor recovery during the study period were considered as motor incomplete (AISA C and D) (n=54) [Table 1]. Those patients who were fit for surgery and had unstable spine were preferably stabilized with a pedicle screw fixation. Seventy four patients (77.9%) were managed conservatively and 21 (22.1%) patients were operated. All the patients were optimally rehabilitated. A standard protocol of early rehabilitation of patients like mobilization, promotion of exercises and gait training was followed. At the end of 1 year, post SCI changes in the body composition were assessed and statistical analysis was conducted.

Statistical analysis

Unpaired t-tests were performed to determine group differences and paired Student's t-tests were used to determine significant differences within the pairs. Relationship between various parameters of body composition were calculated using Pearson's correlation (r).

The procedures followed were in accordance with the ethical standards of the institutional committee on human experimentation. Ethical committee of the institute approved the study.

RESULTS

The average BMI of the patients was 23.09. The data in this section show comparison of values at the time of presentation and after 1 year of injury. As some differences in the values between the right and left sides of the body were found, the values from the right and left sides of the body were pooled to derive the mean values. BMC was found to be significantly lower ($P < 0.05$) in sublesional sites. There was an average of 14.5% decrease in BMC in the lower extremities [Figure 1]. In tetraplegics, arm and leg BMC were 14.2% and 12.8% less, respectively. In paraplegics, there was 15% decrease in leg BMC, but the arm BMC decreased by 3.6% only. The decrease in arm BMC was more in tetraplegics as compared to paraplegics, and it was statistically significant. In operated patients, there was 21.6% decrease ($P < 0.05$) in leg BMC, but the decrease of BMC in arms was not significant. There was an average of 13.3% decrease in the BMC of lower extremities in nonoperated patients, which was statistically significant, whereas upper limbs showed a decrease of 6.2% in BMC. An average decrease of 14.1% ($P < 0.0001$) in leg BMC and 7% in arm BMC was observed in patients with complete SCI [Table 2]. There was 14.9% decrease ($P < 0.05$) in leg BMC in motor incomplete patients.

	initial	3 m	6 m	1 yr
Left arm	157.8	161.8	153.3	147.1
Right arm	157.8	161	159.3	145.4
Left leg	417	388.7	385.8	345.8
Right leg	401.4	382.5	372.6	349.7
Head	525.4	526.9	530.2	511.7

Figure 1: Bone mineral content in spinal cord injury patients (total)

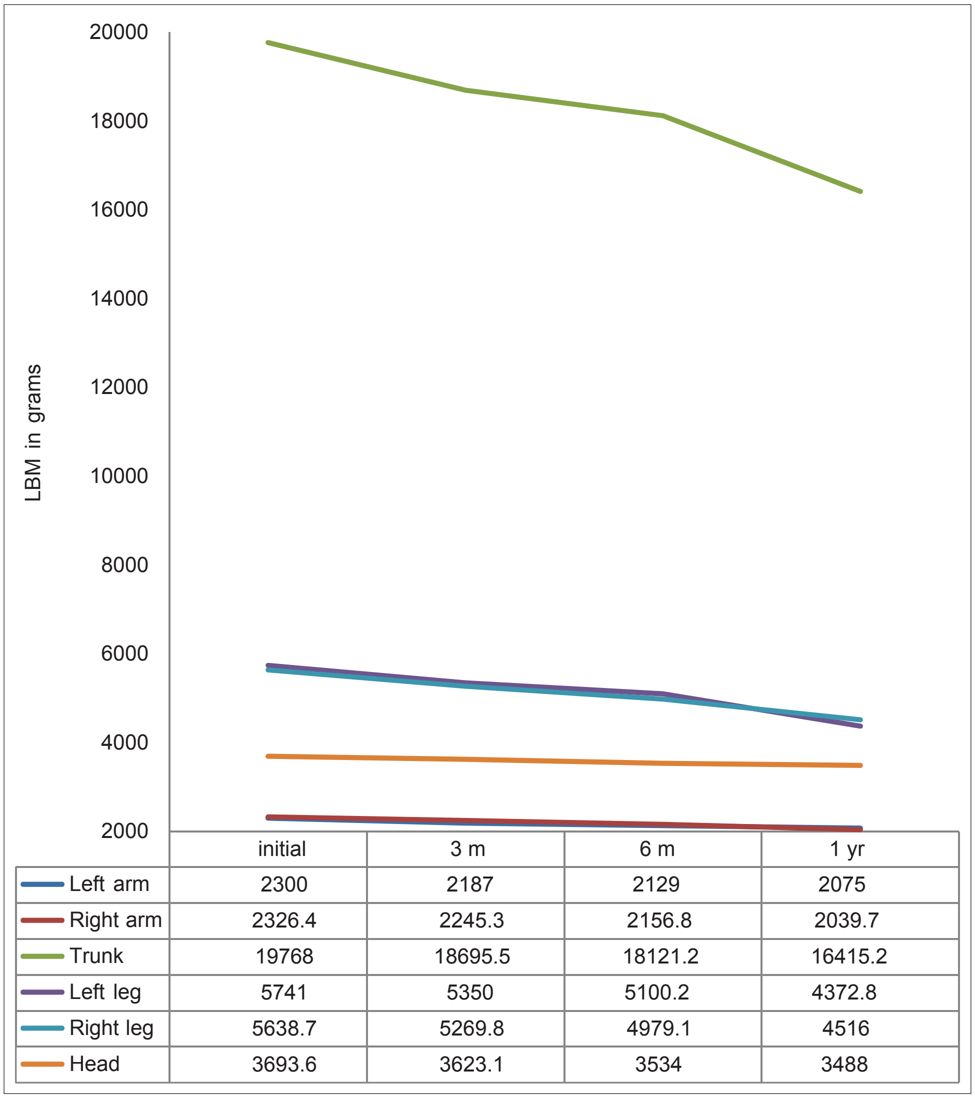
Table 2: Mean values of BMC (in grams) in tetraplegic vs. paraplegic, operated vs. nonoperated and motor complete versus motor incomplete patients at 3, 6 and 12 months followup

	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	*P* value**
			Tetraplegics						**Paraplegics**				
Left arm	154.2	157.3	149.9	134.2	<0.0001	12.9	159.3	163.4	154.7	154.1	0.018	3.2	0.004
Right arm	152.3	149.4	144.7	128.5	<0.0001	15.6	159.9	163.9	163.2	153.2	0.006	4.1	0.001
Left leg	418.9	376.2	367.3	356.5	<0.0001	14.9	418.1	393.7	389.3	344.9	<0.0001	17.5	0.48
Right leg	411.2	388.1	376.2	367.1	<0.0001	10.7	396.6	381.6	371.3	346.5	<0.0001	12.6	0.26
Head	455.4	455.8	452.5	454.0	0.84	0.3	543.2	544.7	548.9	535.8	0.48	1.3	0.001
			Operated patients						**Nonoperated patients**				
Left arm	166.6	163.4	162.9	158.0	0.03	5.1	155.8	161.7	151.0	147.5	0.006	5.3	0.12
Right arm	166.1	166.1	170.2	158.4	0.11	4.6	156.1	159.4	156.2	145.0	<0.0001	7.1	0.07
Left leg	450.3	387.6	381.9	337.8	0.028	24.9	409.1	390.7	385.4	350.0	<0.0001	14.4	0.45
Right leg	423.9	372.8	361.2	345.9	0.0002	18.4	401.2	385.8	375.4	352.2	<0.0001	12.2	0.73
Head	569.5	569.5	572.9	537.8	0.06	5.5	512.0	513.6	516.1	513.1	0.9	0.2	0.34
			Motor complete						**Motor incomplete**				
Left arm	158.4	162.3	153.8	147.3	<0.0001	7.0	158.0	161.8	153.5	153.3	0.12	2.9	0.29
Right arm	158.7	157.5	157.7	147.6	0.0005	6.9	157.8	165.3	161.4	148.4	0.007	5.9	0.89
Left leg	426.2	389.4	384.7	347.8	0.0001	18.3	407.7	390.7	384.6	346.7	<0.0001	14.9	0.93
Right leg	391.6	375.9	370.6	352.2	<0.0001	10	410.2	392.3	374.5	349.0	<0.0001	14.9	0.83
Head	535.2	531.2	531.4	525.1	0.31	1.8	511.0	519.1	525.0	509.9	0.94	0.2	0.49

**P value shows the statistical difference between the initial values and the values at 12 months in the group **P value shows the statistical difference between the values of patients at 12 months in the group, BMC = Bone mineral content*

There was an average of 20.5% loss of LBM in legs (*P* < 0.05) and 15.1% loss of LBM in trunk (*P* < 0.05). Tetraplegic patients had significant decrease in LBM, with an average 21.5% loss of LBM in legs and 10.3% loss of LBM in trunk. Values of LBM in paraplegic patients were 20.2% less in legs (*P* < 0.05) and 8.2% less in arms (*P* < 0.05) [Figure 2]. Significant decrease was observed in the LBM of lower extremities and trunk in operated patients, with 24.7% decrease in legs and 17.3% decrease in trunk [Table 3]. Significant decrease in LBM was observed in nonoperated patients at lower extremities and trunk, with an average of 19.1% decrease in legs and 14.1% decrease in the trunk. There was 23.4% decrease in LBM of legs at 1 year (*P* < 0.05). Motor incomplete patients had significant decrease in LBM of lower extremities and trunk, with an average decrease of 16.6% in lower extremities and loss of 13.3% LBM in trunk [Table 3].

There was 0.2% increase in fat mass in legs (statistically nonsignificant). Statistically significant differences were not observed at other sites also. There was significant increase in fat mass in the upper extremities in tetraplegics, with 10.6% increase in fat mass (*P* < 0.05) and 9.7% increase in trunk fat [Figure 3]. In paraplegics, there was 3.1% increase in fat mass in legs (nonsignificant), but trunk fat had statistically significant increase of 9.0% . Fat mass increased by 11.7% in trunk (*P* < 0.05) and 14% in lower extremities in operated patients [Table 4], and nonoperated patients had 2.3% increase in fat mass in trunk and 5% increase in fat mass in the lower extremities. There was 7.5% increase in fat mass in the legs of patients with complete motor injury and 4.3% increase was seen in the upper extremities; however, it was not statistically significant. There was 8% decrease in fat mass in the legs of patients with incomplete motor injuries and a decrease of 4.2% was seen in the values of trunk [Table 4].



	initial	3 m	6 m	1 yr
Left arm	2300	2187	2129	2075
Right arm	2326.4	2245.3	2156.8	2039.7
Trunk	19768	18695.5	18121.2	16415.2
Left leg	5741	5350	5100.2	4372.8
Right leg	5638.7	5269.8	4979.1	4516
Head	3693.6	3623.1	3534	3488

Figure 2: Lean body mass in spinal cord injury patients (total)

Table 3: Mean values of lean body mass in tetraplegic vs. paraplegic, operated vs. nonoperated, and motor complete vs. motor incomplete patients at 3, 6, and 12 months followup

	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	*P* value**
			Tetraplegics							**Paraplegics**			
Left arm	2319.8	2095.3	2015.8	1803.9	<0.0001	22.2	2270.4	2207.4	2173.3	2127.0	0.001	6.3	0.01
Right arm	2137.8	2107	1962.2	1755.3	<0.0001	17.8	2350.9	2273.0	2211.6	2109.6	<0.0001	10.2	0.009
Trunk	19,624.6	19,136.2	18,929.4	17,597.4	<0.0001	10.3	19,682.1	18,801.3	17,985.9	16,447.6	<0.0001	16.4	0.08
Left leg	6458.4	6029.4	5245.8	4892.9	<0.0001	24.2	5508.5	5178.5	5083.1	4288.5	<0.0001	22.2	0.01
Right leg	6172.9	5350.9	5221.3	5002.1	<0.0001	18.9	5448.6	5233.1	4938.5	4453.6	<0.0001	18.2	0.04
Head	3846.2	3867.8	3874.9	3791.3	0.29	1.4	3653.4	3561.5	3449.0	3446.0	0.001	5.6	0.006
			Operated patients							**Nonoperated patients**			
Left arm	2344.1	2392.6	2384.0	2309.3	0.77	1.4	2262.8	2124.6	2070.9	1987.9	<0.0001	12.1	0.017
Right arm	2646.1	2571.9	2556.6	2340.9	0.002	11.5	2209.6	2143.3	2046.3	1948.2	<0.0001	11.8	0.003
Trunk	20,752.8	19,115.6	18,018.0	17,161.6	<0.0001	17.3	19,362.7	18,802.6	18,231.8	16,555.8	<0.0001	14.4	0.36
Left leg	6041.1	5687.7	5610.7	4382.1	<0.0001	27.4	5614.1	5264.0	4977.3	4425.2	<0.0001	21.1	0.86
Right leg	5920.5	5629.0	5416.0	4606.4	<0.0001	22.1	5510.4	5152.6	4879.4	4558.4	<0.0001	17.2	0.85
Head	3603.3	3583.6	3548.8	3487.7	0.11	3.2	3719.7	3638.0	3535.8	3527.4	0.002	5.1	0.75
			Motor complete							**Motor incomplete**			
Left arm	2333.4	2194.6	2149.5	2092.2	<0.0001	10.3	2287.9	2169.7	2127.8	2015.2	<0.0001	11.9	0.5
Right arm	2314.1	2222.5	2170.2	2041.2	<0.0001	11.7	2295.4	2258.4	2144.4	2026.8	<0.0001	11.7	0.89
Trunk	19,400.7	18,527.6	18,142.0	16,184.6	<0.0001	16.5	20,024.6	19,325.1	18,240.5	17,355	<0.0001	13.3	0.03
Left leg	5771.3	5332.7	5103.9	4274.8	<0.0001	25.9	5625.9	5390.4	5134.9	4601.3	<0.0001	18.2	0.12
Right leg	5641.9	5241.3	5017.2	4461.7	<0.0001	20.9	5547.3	5279.7	4972.8	4710.4	<0.0001	15.0	0.26
Head	3556.3	3585.1	3542.8	3455.5	0.02	2.8	3875.3	3679.8	3533.3	3601.9	0.008	7.0	0.16

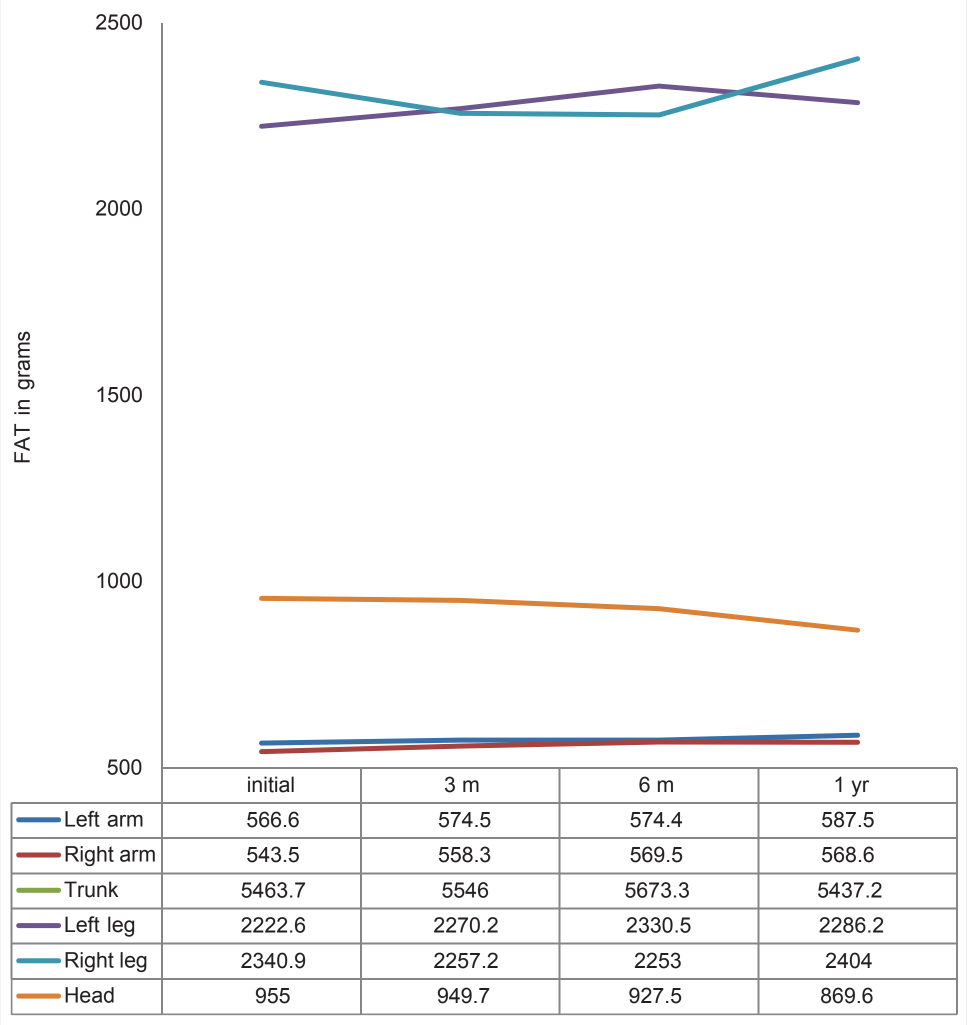
**P* value shows the statistical difference between the initial values and the values at 12 months in the group, ***P* value shows the statistical difference between the values of patients at 12 months in the group

Table 4: Mean values of fat mass in tetraplegic vs. paraplegic, operated vs. nonoperated, and motor complete vs. motor incomplete patients at 3, 6, and 12 months followup

	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	Initial	3 months	6 months	1 year	*P* value*	% change at 1 year	*P* value**
			Tetraplegics							**Paraplegics**			
Left arm	549.3	583.8	589.4	590.9	0.03	7.5	571.0	569.3	569.8	596.9	0.02	4.5	0.8
Right arm	541.7	589.6	612.0	616.9	<0.0001	13.8	549.1	549.1	556.6	553.3	0.68	0.7	0.14
Trunk	6838.5	6912.9	6935.4	7502.2	0.017	9.7	5210.6	5213.2	5338.6	4737.3	0.007	9.0	<0.0001
Left leg	2369.6	2663.5	2687.9	2707.1	0.0002	14.2	2181.5	2171.5	2229.9	2095.7	0.17	3.9	0.0013
Right leg	2478.7	2569.4	2567.8	2719.6	0.055	9.7	2316.8	2183.9	2165.3	2262.0	0.8	2.3	0.05
Head	1052.8	994.5	982.6	964.1	0.11	8.4	927.3	940.1	913.8	848.8	<0.0001	8.4	0.0003
			Operated patients							**Non-operated patients**			
Left arm	550.2	540.0	545.9	584.7	0.16	6.2	571.0865	581.5541	581.9405	598.7743	0.01	4.8	0.74
Right arm	543.8	530.4	557.2	544.0	0.99	0.03	548.6149	565.3716	571.5176	573.1338	0.02	4.4	0.5
Trunk	5027.6	5040.9	5143.4	4438.0	0.04	11.7	5702.554	5721.495	5825.631	5569.585	0.45	2.3	0.02
Left leg	2193.0	2167.9	2202.9	2038.2	0.15	7.0	2229.112	2305.575	2361.406	2277.351	0.44	2.1	0.2
Right leg	2808.4	2188.3	2151.0	2215.3	0.4	21.1	2221.096	2286.859	2278.235	2398.98	0.12	8.0	0.4
Head	910.4	900.2	874.8	832.5	0.005	8.5	966.0838	966.1541	943.5446	884.6536	<0.0001	8.4	0.1
			Motor complete							**Motor incomplete**			
Left arm	557.1722	562.7278	565.8704	588.187	0.01	5.5	578.7244	585.0878	584.6878	605.5268	0.08	4.6	0.6
Right arm	548.5519	564.8037	574.0815	565.8463	0.12	3.1	546.278	548.2195	560.8244	567.8415	0.15	5.2	0.9
Trunk	5613.785	5609.154	5664.869	5380.18	0.24	4.1	5473.761	5520.907	5687.939	5239.485	0.3	-4.2	0.7
Left leg	2161.905	2266.909	2286.793	2214.648	0.4	2.4	2299.15	2285.998	2378.493	2237.449	0.5	-2.6	0.8
Right leg	2179.976	2302.63	2263.337	2455.735	0.06	12.6	2576.117	2215.641	2232.69	2230.17	0.34	-13.4	0.25
Head	920.3296	927.1056	909.6685	866.9644	0.0005	5.8	997.8463	983.8512	952.9732	881.289	0.0006	11.6	0.5

**P* value shows the statistical difference between the initial values and the values at 12 months in the group ***P* value shows the statistical difference between the values of patients at 12 months in the group

Significant increase (trunk $P = 0.003$; legs $P < 0.0001$) in fat percentage for all patients was observed at all sites. There was 17.3% increase in fat percentage in the lower limbs for all patients. Tetraplegic patients had significant increase in the fat percentage of arms, trunk, and legs. Significant increase was seen in the percentage fat of lower



	initial	3 m	6 m	1 yr
Left arm	566.6	574.5	574.4	587.5
Right arm	543.5	558.3	569.5	568.6
Trunk	5463.7	5546	5673.3	5437.2
Left leg	2222.6	2270.2	2330.5	2286.2
Right leg	2340.9	2257.2	2253	2404
Head	955	949.7	927.5	869.6

Figure 3: Fat in spinal cord injury patients (total)

extremities in paraplegics. Difference in the percentage fat of arm, trunk, and leg in operated patients was 2.8%, 1.1%, and 6.1%, respectively. Difference in the percentage fat of arm, trunk, and leg in nonoperated patients was 2.4%, 2.1%, and 5%, respectively. In patients with complete injury, percentage fat increase was 5.7% in legs, 1.5% in trunk, and 2.4% in upper extremities. In patients of incomplete injury, percentage fat increase was 4.6% in legs, 2.4% in trunk, and 2.6% in upper extremities [Table 5].

Arm BMC and arm lean tissue mass were significantly related within groups of tetraplegics ($r = 0.521$, $P < 0.05$) and paraplegics ($r = 0.732$, $P < 0.001$) [Figure 4]. Moderate to strong relationship was found between leg BMC and leg lean tissue mass in patients with incomplete injuries ($r = 0.565$, $P < 0.001$). However, the relationship was not significant in motor-complete injuries ($r = 0.055$, $P > 0.05$) [Figure 5]. Significant correlation was not observed between body fat percentage and BMI in the present study [Figure 6].

DISCUSSION

We found a significant decrease in BMC at sublesional sites, 1 year after SCI (up to 16.9% linear decrease in lower extremities). Biering-Sorensen *et al*. reported 25% lower BMC of the femoral neck and shaft and >50% lower value for the proximal tibia than the normal value.[13] Patients with cervical lesions had lower BMC values in the femoral bones than those with thoracic lesions.[13] In 1990, Biering-Sorensen *et al*. reported that BMC of the lower extremities decreased after injury, reaching new steady-state levels at 40-50% and 60-70% for proximal tibia and femoral neck, respectively, at about 2 years post injury.[14] Wilmet *et al*. observed a rapid decrease of BMC in the paralyzed areas, of approximately 4% per month during the first year in areas rich in trabecular bone and 2% per month in areas containing mainly compact bone.[10] McDonald *et al*. also observed 40% lower BMC in legs in paraplegic patients ($P < 0.0001$), while tetraplegics had significantly less BMC in the arms (−25%; $P < 0.0001$), legs (−46%; $P < 0.0001$) and trunk (−30%;

Table 5: Values of percentage fat in tetraplegic vs. paraplegic, operated vs. nonoperated, and motor-complete vs. motor-incomplete patients at 3, 6, and 12 months follow up

	Initial	3 months	6 months	1 year	% change at 1 year	*P* value*	Initial	3 months	6 months	1 year	% change at 1 year	*P* value*	*P* value**
	Tetraplegics						**Paraplegics**						
Left arm	25.4	32.62	29.79	32.14	26.5	0.009	23.41467	23.91333	23.98	24.81067	3.7	0.1	0.003
Right arm	24.815	25.28	27.515	27.66	11.4	0.004	21.01733	21.428	24.25867	23.64013	12.5	0.002	0.07
Trunk	24.7	27.17	26.835	28.945	17.1	<0.0001	20.612	21.01867	21.33733	21.904	6.2	0.02	<0.0001
Left leg	26.135	27.969	29.475	29.8	14.1	<0.0001	25.65067	26.98667	29.1656	31.36	22.2	<0.0001	0.5
Right leg	29.52	29.045	30.71	31.055	5.1	0.053	27.104	27.66947	28.968	31.684	16.6	<0.0001	0.8
Head	20.666	20.92	21.63	23.38	13.1	0.06	20.60133	20.65067	21.84533	23.024	11.6	0.0004	0.8
	Operated patients						**Nonoperated patients**						
Left arm	20.82857	20.50952	21.22857	23.65238	13.4	0.13	24.68514	27.23243	26.33108	27.12027	10.1	0.01	0.1
Right arm	18.4619	18.87619	25.88571	21.60048	17.3	0.02	22.76892	23.19324	24.67703	25.30541	11.4	0.002	0.09
Trunk	19.04762	19.1381	19.62857	20.15238	5.7	0.3	22.16081	23.21486	23.30811	24.30405	9.9	0.0003	0.01
Left leg	24.37619	26.39524	28.16238	30.52381	25.5	0.001	26.14324	27.42	29.53392	31.17568	19.1	<0.0001	0.7
Right leg	25.2619	26.58095	27.60476	30.77143	21.8	0.0006	28.27973	28.35014	29.82568	31.77297	12.4	<0.0001	0.6
Head	19.31429	18.98571	19.93333	22.57619	16.5	0.009	20.98405	21.19595	22.32973	23.2473	11	0.001	0.6
	Motor complete						**Motor incomplete**						
Left arm	24.12963	26.21852	24.58148	26.53704	9.9	0.02	23.44146	25.12439	26.02195	26.1122	11.5	0.07	0.8
Right arm	21.59259	22.25741	24.47593	24.75185	14.8	0.0003	22.1122	22.21463	25.56098	24.13683	9	0.09	0.7
Trunk	21.82407	22.48519	22.4463	23.33333	6.8	0.02	21.00976	22.0878	22.55854	23.4561	11.4	0.003	0.9
Left leg	25.83704	27.24074	28.57593	31.61296	22.4	<0.0001	25.64146	27.13122	30.09317	30.26585	17.9	0.0009	0.5
Right leg	27.39259	28.58907	29.35	31.91111	16.8	<0.0001	27.90244	27.12927	29.31463	31.07805	11.1	0.002	0.6
Head	20.71148	21.10741	21.61481	23.06667	11.1	0.001	20.4878	20.18049	22.0439	23.14146	13.2	0.01	0.9

**P* value shows the statistical difference between the initial values and the values at 12 months in the group, ***P* value shows the statistical difference between the values of patients at 12 months in the group

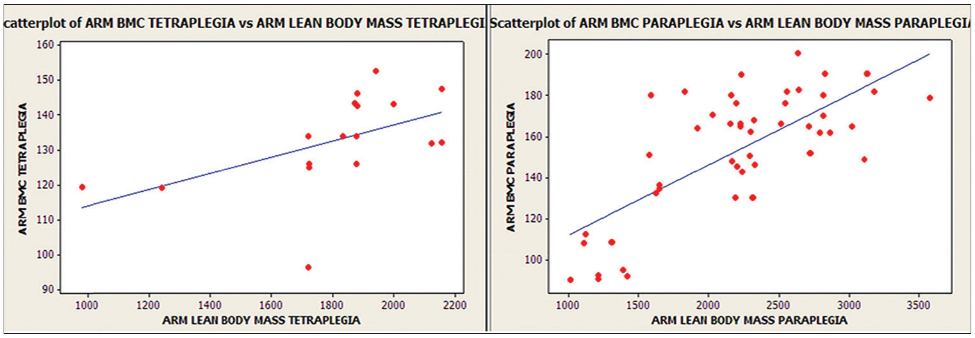


Figure 4: Relationship of arm bone mineral content (BMC) with arm lean tissue mass for tetraplegia and paraplegia (tetraplegia: $R = 0.521$, $P < 0.05$; paraplegia: $R = 0.732$, $P < 0.001$)

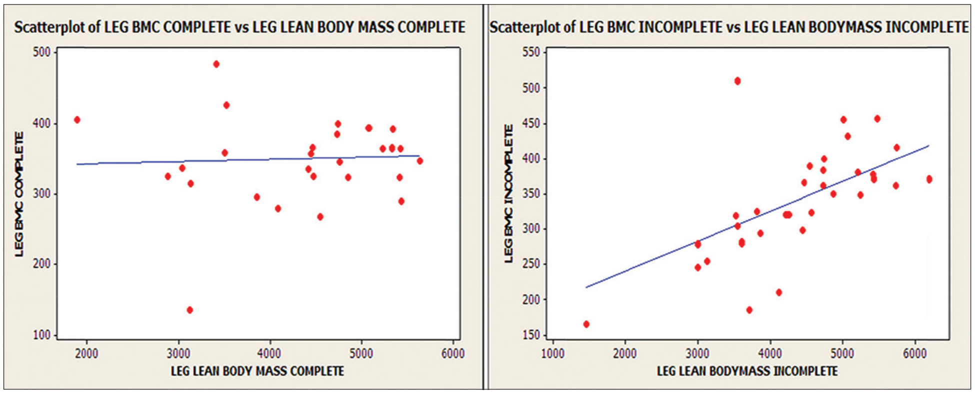


Figure 5: Relationship of leg BMC with leg lean tissue mass for those with complete or incomplete SCI (complete: $R = 0.055$, $P > 0.05$; incomplete: $R = 0.565$, $P < 0.001$)

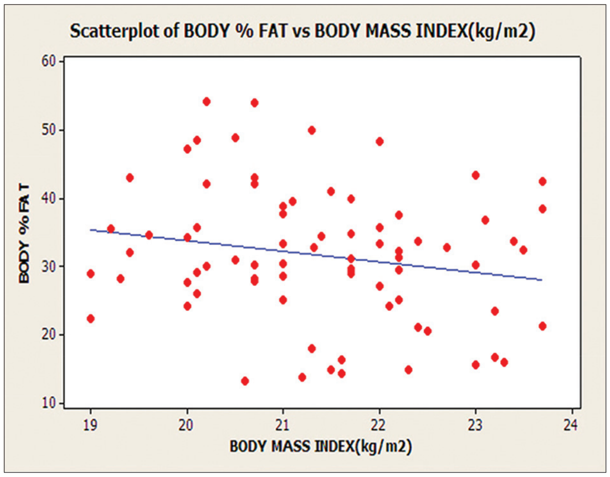


Figure 6: Relationship of total body fat percent with body mass index for spinal cord injuries at I year (SCI: $R = -0.19$, $P > 0.05$)

$P < 0.0001$).[11] In the present study, the tetraplegic patients had significantly lower ($P < 0.05$) arm BMC compared with paraplegic patients, whereas BMC in the leg, trunk, and total body was not significantly different between the two groups. These observations are similar to the findings of Spungen *et al*.[9] and McDonald *et al*.[11] Wilmet *et al*.[10] reported that complete motor paralysis was associated with greater bone loss, and in patients who were likely to recover, a program of prevention of bone loss should be instituted early in the course of disease.[10] This was not seen in the present study.

We observed dramatic loss of LBM below the level of the lesion in all patients (up to 22.6% loss of LBM of lower limbs). Wilmet *et al*. reported 15% loss of lean mass in the lower limbs in the first year after SCI.[10] Jones *et al*. also reported significant reduction in lean tissue mass (16% less) and bone (12% less) in those with SCI, in comparison to the control group.[15] In a study by McDonald *et al*., lean tissue mass was 38% less in legs and 11% less in trunk in the paraplegia group and 35% less in arms and 37% less in legs in the tetraplegia group.[11] Similarly, Spungen *et al*. also reported significant loss of lean tissue mass in both the tetraplegic and paraplegic groups than in the controls.[9] The possible reason for the decrease in LBM in the arms of paraplegics can be the higher amount of absolute fat mass in the arms and sacropenia observed after SCI. Castro *et al*. observed significantly decreased cross sectional area of the muscles of legs and thighs at 6 months of SCI on magnetic resonance images.[4] Modlesky *et al*. also reported a disproportionate loss of muscle in the paralyzed thighs after SCI, relative to the other nonfat constituents.[16] Similar to Spungen *et al*.'s findings, we observed significantly lower arm lean mass in tetraplegics.[9] McDonald *et al*. also reported 36% less LBM in arms ($P < 0.0001$) and 16% less LBM in trunk ($P < 0.05$) in the tetraplegic group than in the paraplegic group.[11] A potential reason for the significant difference observed between the paraplegic and tetraplegic groups could be that the subjects with paraplegia are likely to use their arms for the activities of daily living such as pushing a wheel chair, while the subjects in the tetraplegic group would not place these exercise demands on their arms. We observed up to 18.2% decrease in LBM of the lower limbs in patients with incomplete injuries, as compared to 25.9% in those with complete injuries ($P < 0.05$), as also reported by Spungen *et al*.[9] Arm BMC and arm lean tissue mass were significantly related [Figure 4] within the groups of tetraplegia ($r = 0.521$, $P < 0.05$) and paraplegia ($r = 0.732$, $P < 0.001$) in the present study. Similar findings were also observed by Spungen *et al*.[9] Moderate to strong relationship [Figure 5] was found between leg BMC and leg lean tissue mass in patients with incomplete injuries ($r = 0.565$, $P < 0.001$) in the present study; however, the relationship was not significant in motor complete injuries ($r = 0.055$, $P > 0.05$). Similar findings were observed by Spungen *et al*., who found a moderate to strong co-relationship between leg BMC and leg lean tissue mass in the control group ($r = 0.86$, $P < 0.0001$) and the incomplete SCI group ($r = 0.74$, $P < 0.0001$), whereas the relationship was weak in the complete SCI group ($r = 0.25$, $P = 0.01$).[9] In subjects with complete SCI, a much weaker relationship was noted between these variables, as might have been expected in the absence of function and gravity bearing activity. Moreover, complete motor paralysis is associated with greater bone loss in the denervated extremities than in those with incomplete lesions.[9] McDonald *et al*. concluded in their study that the total lean tissue was highly correlated to the total BMC in the SCI group and the control group.[11] Castro *et al*. suggested that there was massive loss of contractile protein early after SCI, while the mechanisms responsible for loss of muscle size were not clear. It was suggested that the development of muscular imbalance as well as diminution of muscle mass would compromise the force potential early after SCI.[5]

We observed minor increase in the fat mass at 1 year. Bauman *et al*. also reported the absolute leg fat to be similar in SCI and non-SCI twin.[17] We observed a significant increase ($P < 0.05$) in fat mass in the upper limbs of tetraplegics compared to paraplegics, whereas Spungen *et al*. observed significantly higher fat in the arm and leg in both tetraplegia and paraplegia groups in comparison to the control group, but the difference between tetraplegia and paraplegia groups was insignificant.[9] McDonald *et al*. reported that paraplegia group had 28% more fat mass in legs ($P < 0.02$) and 35% more fat mass in trunk ($P < 0.04$).[13] The paraplegia group had 38% more fat in legs and 39% more total body fat than the tetraplegia group.[11] Similar to Spungen *et al*.'s findings, we also found higher absolute fat mass in groups with complete injury than in incomplete injury group.[9] We observed even a decrease in fat mass in the lower extremities and the trunk in patients with motor incomplete injuries. This may be due to more active rehabilitation of patients in motor incomplete group as they had incomplete injuries. Contrary to the expected findings, we also found higher fat mass increase in the trunk and legs in operated patients compared to those managed conservatively. Several factors may explain the unpredictable nature of fat mass changes following SCI. Changes in fat mass may be variable and dependent on the interaction of different patient-specific variables, e.g. advancing age has been associated with less lean mass and increased fat mass in individuals with SCI. The activity levels may also play an important role.[18]

We observed 19.3% increase in the fat percentage in lower limbs and this might be related to muscle atrophy, which results in apparent increase in percentage fat in legs. Tetraplegics had 31.4% more increase in fat percentage than paraplegics in the upper extremities. In patients of complete injury, fat percentage was 16.67% more in trunk and 35.2% more in arms when compared to those with incomplete injury. McDonald *et al*. reported in their study that paraplegia group had 36% higher trunk fat percentage ($P < 0.001$), 60% higher leg fat percentage ($P < 0.0001$), and 37% higher total body fat percentage, as compared to the control group.[11]

Dopler-Nelson *et al*. reported that more than 90% of obese SCI subjects from a regional SCI clinic met the criteria for metabolic syndrome, which puts them at risk for type II diabetes, cardiovascular disease and stroke. Identification of obese patients at risk for metabolic syndrome using easily obtainable clinical criteria for obesity should be a high priority for clinical care.[19] Recently, it has been shown that many of the disorders associated with obesity occur prematurely and at a higher prevalence in the population with SCI than in the able bodied population. Adults with SCI have higher rates of carbohydrate intolerance, insulin resistance,[20,21] lipid abnormalities[22,23] and heart disease[24] than the able bodied population is likely to have, and these factors may contribute to the reduced lifespan of individuals with SCI. Low-energy fractures have been reported to occur in individuals with SCI during events that would not normally cause fractures, such as a transfer from a bed to chair, or being turned in bed.[25] Complications related to fractures in SCI population present additional source of morbidity.[1] By estimating the body composition in the patients with SCI, appropriate steps can be taken up early to minimize the effects and risks of the diseases, thus reducing the morbidity and mortality in this subset of the population.

Not much significant correlation was found between the body fat percentage and BMI in the present study [Figure 6]. Spungen *et al*. demonstrated in their study that correlation between BMI and total body fat percentage was statistically significant; however, in their study, the duration of injury was around 10 years and fat mass had increased with increased duration of injury.[9] McDonald *et al*. reported that changes in the body composition observed in the subjects with SCI had profound effects on the relationship between BMI and total fat percentage, as compared to the control subjects.[11] They suggested that due to these alterations in body composition, BMI significantly underestimates the level of obesity in individuals. Findings of the present study may be explained on the basis of low BMI, dietary habits and low fat mass in the Asian population. Further research is needed in this field to define new standards of obesity in the SCI population.

Our study has some limitations. The age may have effect on the outcomes in the present study. Only nine patients were aged more than 50 years. Majority of patients were adults below 50 years and this might have negated this confounding variable to some extent. A standard protocol was followed for rehabilitation of the patients. However, some patients might not have optimal rehabilitation. The inclusion of large number of patients in the present study might have negated this confounding variable to some extent.

We conclude that patients with SCI not only lose motor and/or sensory functions, but also may experience dramatic muscle and bone changes during the first year of SCI. These changes usually depend on the level and severity of lesions. These adverse body composition and bone changes may negatively impact body metabolism, which may increase the risks of microvascular diseases and fractures. It will be prudent to take measures like early mobilization, rehabilitation and specific interventions to prevent bone loss and deterioration in body composition early in the course of the SCI.

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