Body composition of women and men with complete motor paraplegia

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Objectives: To examine body composition, including the relationship between body mass index (BMI) and total body fat, in women and men with complete motor paraplegia and to make comparisons with able-bodied controls.

Methods: In 13 subjects with traumatic, complete motor paraplegia (six women, seven men) and 39 sex-, age-, and BMI-matched controls from the community (18 women, 21 men), we measured total and regional (upper extremities, trunk, and lower extremities) lean and fat mass using total body dual-energy X-ray absorptiometry.

Results: Both women and men with paraplegia had significantly lower lean mass in their lower extremities, as would be expected, and in their total body when compared with controls. However, they had significantly greater lean mass in their upper extremities than controls (4.4 kg vs. 3.6 kg, $P = 0.004$ and 8.6 kg vs. 6.7 kg, $P < 0.001$ in women and men, respectively); all subjects with paraplegia studied used manual wheelchairs. Although total body fat mass was significantly greater in women ($P = 0.010$) and men ($P = < 0.001$) with paraplegia compared with controls, for the equivalent total body fat mass, BMI was actually lower in women and men with paraplegia than controls (e.g. 20.2 kg/m² vs. 25.0 kg/m², respectively).

Conclusion: We report on body composition in persons with complete motor paraplegia, including women on whom limited information is currently available. Our results support the need to define better assessments of obesity in both women and men following spinal cord injury, particularly of central body fat distribution, as BMI underestimates adiposity in this population.

Keywords: Body composition, Body mass index (BMI), Fat tissue mass, Lean tissue mass, Paraplegia, Percent body fat, Spinal cord injury

Introduction

In the last decade, heart disease has become one of the leading causes of death following chronic spinal cord injury (SCI) for both women and men.^{1–4} As a result, evaluation and mitigation of cardiovascular risk factors has taken on increasing importance in the clinical care of persons with chronic SCI, in whom a key reversible risk factor is obesity.⁵ The assessment of obesity is difficult in the SCI population, as traditional clinical measures, such as body mass index (BMI), may underestimate adiposity,^{6,7} likely, in part, related

to the loss of lean muscle mass.⁸ There is growing awareness and interest in the importance of understanding body composition following chronic SCI, as that would assist development of appropriate clinical assessment tools and targets regarding body fat for this population.

Persons with chronic SCI are reported to have an increase in percent fat mass and reduced lean tissue,^{7,9–11} which is felt to be due to their relative physical inactivity.¹² While BMI is widely used as a marker of obesity,¹³ which is a predictor of cardiovascular disease,¹⁴ men with SCI are reported to have up to 13% greater fat mass compared to able-bodied men with the same BMI.¹⁵ However, studies examining

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body composition following SCI have often combined subjects with both tetraplegia and paraplegia, which may not be ideal as the relative activity level is different between both groups, and even among those with different degrees of paraplegia. There are even some data to suggest a greater prevalence of obesity in paraplegia than in tetraplegia.^{16,17} Furthermore, despite the proportion of women with SCI having increased over the last 25 years (<http://www.NSCISC.UAB.edu>), most studies examining body composition have involved men and, to the best of our knowledge, there has been only one report¹⁸ describing body composition for women with SCI specifically. In contrast to persons with tetraplegia, women and men with paraplegia physically have a greater ability to reverse inactivity and thereby potentially reduce obesity as a cardiovascular risk factor.¹⁹

Therefore, the goals of our study were to examine body composition, including the relationship between BMI and total body fat, in both women and men with chronic complete motor paraplegia, and to make comparisons with sex-, age-, and BMI-matched able-bodied controls from the general community population.

Methods

Study participants

Spinal cord injury subjects

Women and men between the ages of 20 and 50 years with traumatic, complete motor paraplegia (American Spinal Injury Association Impairment Scale (AIS) A or B)²⁰ for at least 2 years were recruited from the clinical practice of an academic SCI center and through an additional database of people with SCI. All subjects used manual wheelchairs. Study participants (six women and seven men; all white, non-Hispanic) had a level of injury between T3 and T12 and their time since injury ranged from 2 to 26 years.

Population-based control subjects

Comparisons were made to an established population-based cohort, representing an age-stratified, random sample of Rochester, Minnesota, residents²¹ who had similar measurements made of their body composition as those made of the study subjects with SCI. The cohort spanned ages from 21 to 97 years and included 375 women and 325 men, 98% of whom were white, reflecting the ethnic composition of the community. This population is highly characteristic of the U.S. white population.²² Subjects between the ages of 20 and 50 years were then matched, in a 3:1 ratio, to SCI subjects by sex, age ± 5 years, and BMI ± 5 mg/kg².

None of the subjects with SCI or matched controls had severe renal insufficiency (glomerular filtration rate (GFR) <30 ml/minute/1.73 m²)²³ or were current oral corticosteroids users. Prior to matching, we also excluded any control subjects who had an underlying neuromuscular disease (e.g. stroke, multiple sclerosis, and myasthenia gravis).

The study was approved by the Institutional Review Board and all subjects provided written informed consent.

Body composition measurements

Body composition was assessed using the Lunar Prodigy instrument (Lunar Prodigy, Madison, WI, USA). Total body lean mass (kg) and total body fat mass (kg) was determined from the whole body scan (coefficient of variation (CV), 1.6 and 2.6%, respectively). From these scans, separate assessments of the lean and fat mass of the upper extremities, trunk, and lower extremities could be determined (Fig. 1).

BMI (kg/m²) was calculated from the height and weight of each subject. Each SCI subject was weighed in their wheelchair, and then the wheelchair alone was weighed, with the difference being the body mass (kg) of the subject. Self-reported height prior to their injury was recorded for subjects with paraplegia. Each control subject's weight was measured in light clothes

Figure 1 GE Lunar Prodigy total body scan for estimates of total body and regional lean and fat mass. The area in the triangle (pelvis) is not included in the trunk or lower extremity estimates.

without shoes and their height was measured using a stadiometer.

Statistical analyses

Analyses were performed separately for women and men. We used linear regression analyses to test for differences in body composition variables between the subjects with SCI and controls, after adjusting for age and BMI. Linear regression analyses were also used to examine the relationship between BMI and percent fat in both groups. Analyses were performed using SAS 9.3 and R 2.14 and the significance level was set at 0.05.

Results

We studied six women and seven men with traumatic, complete motor paraplegia, all of whom were white, non-Hispanic. Individual characteristics related to their history of SCI are presented in Table 1. Among the six women with paraplegia, three women had high thoracic spinal cord lesions, occurring between T3 and T7, while three had lesions between T9 and T12. There were two women who had spastic lower extremities, while the remaining four were flaccid. Among the seven men with paraplegia, there were three who had high thoracic spinal cord lesions occurring between T3

and T7, while four men had lesions between T9 and T12. Spasticity was noted in five men, while the other two men had flaccid lower extremities. Median duration of injury for women was 7 years (range 2–23 years), with two women living with SCI greater than 10 years. Men had a median duration of injury of 7 years (range 3–27 years), with three men living with SCI greater than 10 years.

We studied 39 matched control subjects (18 women and 21 men) who were also all white, non-Hispanic. The SCI and control subjects had similar age, height, weight, and BMI (Table 2).

Total body and regional lean mass

Total body lean mass was significantly lower in both women (adjusted mean difference (95% confidence interval, CI): -3.4 kg (-6.7 , -0.2 kg)) and men (-7.1 kg (-11.5 , -2.7 kg)) with paraplegia from traumatic SCI when compared with their respective matched controls (Table 3). Women with paraplegia had significantly lower lean mass in the lower extremities ($P < 0.001$) but significantly greater lean mass in their upper extremities ($P = 0.004$) than controls (Table 3). There were no differences in trunk lean mass between groups (Table 3). Similar to women,

Table 1 Characteristics related to their spinal cord injury in the 13 study subjects (six women and seven men)

Subjects	Age (years)	Level of injury	AIS*	Spastic/flaccid	Duration of injury (years)
Females					
1	34	T3	A	Spastic	17
2	41	T11	A	Flaccid	2
3	42	T6	A	Flaccid	9
4	43	T12	A	Spastic	23
5	44	T7	A	Flaccid	3
6	44	T12	B	Flaccid	6
Males					
1	25	T5	A	Spastic	7
2	28	T11	A	Flaccid	7
3	45	T9	A	Flaccid	6
4	46	T6	A	Spastic	27
5	48	T11	B	Spastic	3
6	49	T11	A	Spastic	27
7	50	T5	A	Spastic	15

*American Spinal Injury Association Impairment Scale (AIS).²⁰

Table 2 Clinical characteristics of 13 subjects with spinal cord injury and 39 able-bodied sex-, age-, and body mass index-matched control subjects

Characteristics	Women			Men		
	SCI (N = 6)	Able-bodied (N = 18)	P-value	SCI (N = 7)	Able-bodied (N = 21)	P-value
Age, years	41.5 ± 3.8	41.2 ± 3.9	0.853	41.6 ± 10.4	41.4 ± 8.5	0.965
BMI, kg/m ²	22.6 ± 4.2	23.0 ± 3.3	0.817	23.5 ± 3.7	24.8 ± 2.8	0.355
Height, cm	170.1 ± 7.8	165.5 ± 6.2	0.156	184.0 ± 8.0	179.2 ± 5.3	0.079
Weight, kg	65.3 ± 13.2	62.9 ± 10.2	0.656	79.1 ± 8.4	79.5 ± 9.3	0.916
% Total body fat	45.5 ± 10.2	38.3 ± 6.7	0.002	35.9 ± 12.0	27.4 ± 7.7	<0.001

Table 3 Site-specific lean and fat mass of 13 subjects with spinal cord injury and 39 able-bodied sex-, age-, and body mass index-matched control subjects, by sex

Characteristics	Women			Men		
	SCI (N = 6)	Able-bodied (N = 18)	P value*	SCI (N = 7)	Able-bodied (N = 21)	P value*
Lean mass						
Total body, kg	32.0 ± 4.1	35.6 ± 3.2	0.040	46.5 ± 6.1	53.8 ± 4.3	0.003
Trunk, kg	16.6 ± 1.9	17.8 ± 1.5	0.168	22.4 ± 3.7	25.4 ± 2.3	0.018
Upper extremities, kg	4.4 ± 0.7	3.6 ± 0.6	0.004	8.6 ± 1.0	6.7 ± 0.6	<0.001
Lower extremities, kg	8.3 ± 1.8	11.3 ± 1.3	<0.001	11.5 ± 2.6	17.9 ± 1.8	<0.001
% Lean mass						
Total body	50.6 ± 9.9	57.8 ± 6.5	0.002	59.9 ± 12.1	68.5 ± 7.4	<0.001
Trunk	53.0 ± 10.3	59.2 ± 8.2	0.008	56.5 ± 15.4	65.4 ± 9.0	0.002
Upper extremities	61.9 ± 13.2	59.5 ± 6.0	0.457	75.1 ± 8.1	75.0 ± 6.4	0.339
Lower extremities	40.4 ± 8.7	53.2 ± 6.3	<0.001	55.4 ± 10.6	69.7 ± 6.9	<0.001
Fat mass						
Total body, kg	31.1 ± 14.6	24.4 ± 7.5	0.010	28.9 ± 11.8	22.2 ± 7.8	<0.001
Trunk, kg	14.9 ± 6.4	12.1 ± 4.3	0.012	17.0 ± 8.0	12.9 ± 4.8	0.001
Upper extremities, kg	2.7 ± 1.7	2.2 ± 0.8	0.138	2.5 ± 1.3	1.9 ± 0.8	0.002
Lower extremities, kg	12.6 ± 6.4	9.4 ± 2.8	0.018	8.4 ± 2.5	6.7 ± 2.3	<0.001
% Fat mass						
Total body	45.5 ± 10.2	38.3 ± 6.7	0.002	35.9 ± 12.0	27.4 ± 7.7	<0.001
Trunk	44.2 ± 10.1	38.3 ± 8.3	0.011	40.3 ± 15.3	32.1 ± 9.2	0.003
Upper extremities	33.3 ± 13.7	35.5 ± 6.4	0.558	20.2 ± 8.4	19.8 ± 6.7	0.194
Lower extremities	56.1 ± 9.5	42.6 ± 6.5	<0.001	40.1 ± 10.2	25.4 ± 7.2	<0.001

*P values reflect models adjusted for age and BMI.

men with paraplegia had significantly lower lean mass at their lower extremities, and significantly greater upper extremity lean mass ($P < 0.001$) when compared with controls (Table 3). In contrast to women, men with paraplegia had lower trunk lean mass than their controls (Table 3). Interestingly, the upper extremity percentage of lean mass was similar between both women and men with paraplegia and their matched controls, while the percentage of lean mass of the total body, trunk and lower extremity was lower in women as well as men with paraplegia when compared with their controls (Table 3).

Total body and regional fat mass

Total body fat mass was significantly greater in both women (adjusted mean difference (95% CI): +7.5 kg (2.0, 13.0 kg)) and men (+9.6 kg (5.2, 14.0 kg)) with paraplegia from traumatic SCI when compared with their respective matched controls (Table 3). When examining fat mass by body region, women with paraplegia had greater fat mass at all body regions studied relative to their controls, although it did not reach statistical significance at the upper extremities (Table 3). Trunk, upper extremity and lower extremity fat mass were all significantly greater in men with paraplegia than their matched controls (Table 3). When examining the proportion of fat mass by region, both women and men with paraplegia had significantly higher percent fat mass than controls in all regions except for the upper extremities, where it was similar between groups (Table 3).

BMI and percent total body fat mass

Although study subjects were matched by BMI, women and men with paraplegia had significantly greater percent total body fat mass compared with their controls (adjusted mean difference (95% CI): +7.7% (3.2, 12.2%)) and (+11.1% (6.0, 16.2%)) for women and men, respectively) (Table 3). In both our female and male control subjects, a BMI of 25.0 kg/m² (upper limit of normal for BMI) predicted a proportion of total body fat that was equivalent to the proportion of total body fat that would be predicted for a BMI of 20.2 kg/m² in our women and men with paraplegia (Fig. 2). Overall women and men with paraplegia each had a 9.6% higher total body fat mass compared with controls for the same BMI.

Discussion

We report on body composition, including the relationship between BMI and total body fat, separately for women and men with complete motor paraplegia and compare them with able-bodied controls. Few studies are available on body composition of women with SCI and our findings add relevant information to this limited body of literature. Despite our relatively small sample size, we found that both women and men with paraplegia had greater lean mass in their upper extremities, when compared with controls, even though they had lower total body lean mass overall. We also observed that women and men with paraplegia had greater total body and regional fat mass when compared

Figure 2 Scattered plots fitted with regression lines showing the relationship between percent total body fat and BMI (kg/m^2) in men and women. For regression models involving subjects with complete motor paraplegia, the R^2 value was 0.68 for women and 0.58 for men. For regression models involving able-bodied controls, the R^2 -square value was 0.64 for women and 0.68 for men.

with controls. Nevertheless, for the equivalent total body fat mass, women as well as men with paraplegia had lower BMI values than controls, suggesting that BMI will underestimate obesity in both women and men with complete motor paraplegia.

Both women and men with SCI in our study had higher lean mass in their upper extremities when compared with their able-bodied controls. While this observation in a cohort of primary manual wheelchair users is not necessarily unexpected, this finding has not been previously reported in men. In contrast, Spungen *et al.*¹⁵ found men with paraplegia to have a significantly lower percentage of lean tissue in the upper extremities, but found no significant difference in absolute arm lean mass, when compared with able-bodied controls. While Maggioni *et al.*⁹ reported significantly higher fat free mass in the arms of persons with paraplegia than controls, fat-free mass accounts for both lean and bone tissue. In both studies, only male subjects with paraplegia were evaluated, and upper extremity use for transfers and wheelchair propulsion were not reported, irrespective of whether completeness of injury was documented. On the other hand, our findings of greater upper extremity lean mass in women with complete motor paraplegia than controls are consistent with results recently reported by Yazar-Fischer *et al.*¹⁸ in their population of women with paraplegia. Although we did not directly measure upper extremity activity in either our participants with SCI or their matched controls, our cohort with complete motor paraplegia all independently transferred themselves and

propelled manual wheelchairs. It is possible that these activities contributed to their greater upper extremity lean mass relative to controls.

Persons with SCI are reported to acquire more fat mass over time, but also to lose lean mass due to disuse in areas of paralysis.^{10,24} We observed a greater proportion of fat mass particularly at the trunk and lower extremities of both women and men with paraplegia compared with controls. Our findings in men are consistent with reports by others studying men with complete motor paraplegia.^{9,10,15} In contrast to our results in women, the recent study by Yazar-Fischer *et al.*¹⁸ found no difference in the proportion of total or regional fat mass between women with paraplegia and controls. However, some of the women with paraplegia in their study had incomplete injuries and time since SCI was not reported. Whether that may have contributed to these differences with our findings is unclear. Interestingly, while we did observe a higher fat mass in the upper extremities of our subjects with paraplegia compared with controls, the percent fat mass was similar between the groups, both for women and men.

BMI is a tool to estimate excess body adiposity, and a BMI $>25 \text{ kg}/\text{m}^2$ is classified as overweight, while BMI $>30 \text{ kg}/\text{m}^2$ defines obesity. Although the corresponding percentage of body fat for a given BMI will vary by sex, age, and race/ethnicity,²⁵ $>25\%$ body fat and $>35\%$ body fat have been the suggested cutoffs for defining obesity in men and women, respectively,²⁶ and generally are consistent with a BMI of $>30 \text{ kg}/\text{m}^2$.²⁷ The participants with SCI in our study had BMI values that ranged

from normal to overweight (non-obese), but the average percentage of total body fat was >35% for men and >45% for women. Thus, the majority of our participants fell into the obese range based on percentage of body fat even though their BMI did not indicate obesity. None of the participants appeared significantly overweight to the research team either. A growing number of studies have now shown that BMI underestimates obesity in persons with SCI.^{6,7,11,15,18,28,29} Spungen *et al.*¹⁵ reported that men with SCI have up to 13% more body fat than their able-bodied controls with the same BMI, results that are very similar to our findings of women and men with paraplegia both having almost 10% more body fat than their controls for any given BMI.

There have been ongoing efforts to determine a lower BMI cut off for persons with SCI. Indeed, Wahman *et al.*²⁹ and Laughton *et al.*⁶ proposed that a BMI > 22 kg/m² should be considered the cutoff for obesity in persons with SCI. However, increasingly it is being recognized in the general population that abdominal obesity is a better indicator of cardiovascular risk than BMI, and measures such as waist-to-hip ratio or waist circumference are being considered now as more appropriate tools in assessing obesity for risk stratification.³⁰ Recently, Eriks-Hoogland *et al.*²⁸ reported that waist circumference may be a potentially more promising measure of obesity than BMI in men with complete motor paraplegia.²⁸ Our study demonstrated greater absolute and percent fat mass at the trunk for women as well as men with paraplegia compared with able-bodied controls, suggesting that waist circumference may also be useful in the assessment of obesity for women with SCI. Validation work would still be required. Nevertheless, it is unclear if the waist circumference values would be similar at predicting cardiovascular risk in SCI as in individuals without SCI. In addition, abdominal distension and loss of muscle tone still may confound measurements in most persons with SCI, except for the lowest levels of paraplegia, unless measured in recumbency. Regardless, rather than trying to identify different cutoffs of BMI to define obesity in women and men with SCI, efforts at better estimating central visceral adiposity to assess health risks may not only be more clinically relevant, but also more practical.

Based on our work and those of others, we conclude that obesity will be under-recognized in both women and men with paraplegia if traditional BMI cutoffs are used. As obesity is a potentially reversible risk factor for cardiovascular disease, early recognition is critical. Reversing obesity involves both diet and activity

changes. While persons with paraplegia have enough intact upper body musculature to participate in aerobic activity, they still lack use of the larger muscles of their lower extremities, which limit calorie expenditure during exercise. Long-term interventions to reduce the relative decrease in lower extremity lean mass, such as with functional electrical stimulation (FES), are being studied.^{31–34} To date, only one study³⁴ has found a concomitant decrease in whole body fat, while the others have reported no change in adipose mass or body composition. FES may be a promising intervention to prevent muscle loss, and thereby reverse or prevent obesity, but the optimal frequency and duration of FES is still unknown. Regardless, a focus on healthy living and exercise need to be included in the rehabilitation program and life-long care of both women and men with chronic complete motor paraplegia.

While we did not limit recruitment other than by age, our SCI population was entirely white, non-Hispanic, reflecting the local community population. However, we did study women as well as men with SCI. It is unclear if our observations can be extrapolated to other ethnicities and older age groups, including post-menopausal women. The number of participants with SCI in our study was small, but we were still able to observe significant differences in body composition at most sites relative to able-bodied controls. We also specifically chose to study persons with complete motor paraplegia. Body composition of persons with complete motor tetraplegia is likely to differ from our findings, given lack of volitional movement. In order to calculate BMI for persons with paraplegia, self-reported height was used with risk of potential errors in recall. However, given the age range of subjects studied, we would not have expected height loss. In exploratory analyses, neither level of injury, nor presence of spasticity, demonstrated any impact on lower extremity lean or fat mass; however, our subject number was too small to make a robust conclusion on these effects.

Conclusion

In summary, we found that upper extremity lean mass was greater in both women and men with complete motor paraplegia when compared with able-bodied controls. We hypothesize that these findings may be due to the fact that all our SCI participants independently transferred themselves and propelled manual wheelchairs. We also report that both women and men with complete motor paraplegia have greater overall and regional fat mass than able-bodied controls who were matched for BMI. Although our sample size was

small, this study provides further needed evidence that BMI underestimates the percentage of total body fat in women, not just men, with complete motor paraplegia. Our findings support the need to identify better assessments of obesity in both women and men following SCI instead of relying on BMI. These study results would also endorse efforts at estimating central body fat distribution to define obesity in women and men with complete motor paraplegia.

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