Objective: To assess the relationship between body mass index (BMI) and adiposity as well as the influence of injury level on this relationship in 24 women with spinal cord injury (SCI) and 23 able-bodied (AB) women with similar age, race, and BMI.

Design and Methods: Body composition was measured by dual energy X-ray absorptiometry (DXA). Analysis of covariance was performed to compare total and regional soft tissue percent fat (PF) measures between groups.

Results: Women with SCI had a higher soft tissue PF than AB women at any given BMI. The BMI-adjusted soft tissue PF (mean ± SE) was (44.4 ± 1.8)%, (37.8 ± 1.3)%, and (35.9 ± 1.1)% for tetraplegic, paraplegic, and AB women, respectively. The BMI explained about equal amounts of the variance in soft tissue PF among paraplegic and AB women (65%), but only 28% in tetraplegic women.

Conclusion: This study confirms a limited use of BMI in measuring adiposity in women with SCI, particularly among those with tetraplegia. Our observation of lower BMI cutoff points for defining obesity (28 kg/m² for paraplegia and 21 kg/m² for tetraplegia) needs further confirmation. The underweight/malnutrition issue also deserves the consideration while proposing the ideal weight and BMI range for persons with SCI.
Sixteen SCI women had a motor complete lesion (American Spinal Injury Association Impairment Scale [AIS] A or B), while eight women had an incomplete lesion (AIS C or D). Study participants were recruited from the University of Alabama at Birmingham (UAB) SCI Model System via mailings and community fitness centers via advertising fliers. The study was approved by the UAB Institutional Review Board, and written consent was given before the testing was initiated.

Recumbent height is measured on the right side of the body from the top of the participant’s head to his or her heels while the participant is in a supine position with a non-stretch tape in both groups. Body weight was measured on a wheelchair scale with the subject in the wheelchair first, and then wheelchair was weighed by itself and subtracted from the total weight. AB women were weighed standing on the same wheelchair balance scale used for women with SCI. BMI was calculated by dividing the body weight (kg) by height (m²). Total body and regional (arm, leg, and trunk) fat and lean masses were measured by dual energy X-ray absorptiometry ([DXA]; Hologic QDR-4500W, Madison, WI). Bone tissue was excluded from PF calculations for minimizing the bias from metal fixation attached to the spine or bones.

Statistical analysis
Data were analyzed using Statistical Package for Social Sciences version 19 (IBM SPSS Statistics 19, IBM Corp., Somers, NY). Descriptive analyses were conducted to summarize the total and regional fat mass, lean mass, and PF across three groups. To account for the BMI difference between the paraplegic and tetraplegic groups (27.7 ± 8.2 vs. 23.3 ± 4.2), analysis of covariance was performed to compare body composition between groups while adjusting for BMI. Significance level was set a priori at \( P < 0.05 \).

Results
Regardless of injury level, women with SCI had a higher soft tissue PF than AB women at any given BMI. The BMI-adjusted soft tissue PF (mean ± SE) was (44.4 ± 1.8)%, (37.8 ± 1.3)%, and (35.9 ± 1.1) % for tetraplegic, paraplegic, and AB women, respectively (Figure 1A). Women with tetraplegia possessed significantly larger amount of total fat mass (kg) than AB and paraplegic women, particularly in the trunk and arm areas (Figure 1B). There was no significant difference in the total and regional fat mass between AB and paraplegic women. As compared with the AB group, women with tetraplegia had significantly lower total and regional (trunk, arm, and leg) lean mass, while women with paraplegia had significantly lower total and leg lean mass, but higher arm lean mass (Figure 1C). Interestingly, women with tetraplegia possessed a lower amount of lean mass in arms, but a higher amount of lean mass in legs than women with paraplegia.

Discussion
To our knowledge, this is the first study of women with SCI conducted to examine the relationship between BMI and adiposity and the influence of injury level in this relationship. Our finding of approximately 8.5% higher soft tissue PF in women with SCI is consistent with previous studies of primarily men with SCI (6,8,9,11,14) that showed a 7.5-10.2% greater total body PF in the SCI group versus the AB group with similar BMI. This study also supports the premise that BMI is limited in detecting the loss of lean mass and accumulation of fat mass after SCI as a result of decrease in physical activity and lack of neuronal stimulation below the injury level.

Previous studies reported that the BMI explained about 35% of the variance in measured total body PF in persons with SCI (11). The present study further demonstrated that the underestimation of BMI in describing adiposity is particularly problematic for women with tetraplegia. For example, BMI explained about equal amounts of the
variance in soft tissue PF among paraplegic and AB women (65%), but only 28% in tetraplegic women (Figure 1A).

A BMI cutoff of 22.1-26.5 kg/m² has been suggested for use in defining obesity in the SCI population by a previous study of 63 men and 14 women with SCI, based on risk levels of the total body PF and C-reactive protein (8). Because of the common issue concerning metal fixation attached to the spine and bones in persons with SCI, the present study computed soft tissue PF, but not total body PF, for comparison across groups. To preliminarily investigate the BMI cutoff for obesity in women with SCI, we first identified the soft tissue PF corresponding to a BMI of 30 in the AB group (Figure 1A), which is 39%. Our observation based on 23 AB women with an average age of 44 years is reasonably close to the recent NHANES findings of 42%, 41%, and 42% total body PF cut-offs corresponding to a BMI of 30 for non-Hispanic whites, non-Hispanic blacks, and the Hispanic of Mexican origin among women of age 30-49 years (13). Given a soft tissue PF of 39%, the corresponding BMI in this study was approximately 28 kg/m² for paraplegic women and 21 kg/m² for tetraplegic women.

Interestingly, we observed that leg lean mass was significantly higher in women with tetraplegia than women with paraplegia, which might be partially explained by the difference in the completeness of injury. There are more motor incomplete injuries in the tetraplegia group than in the paraplegia group (22% vs. 13%), which indicates a higher degree of motor function and preservation of lean mass in the lower extremities among women with tetraplegia.

In conclusion, this study confirms a limited use of BMI in measuring adiposity in women with SCI, particularly among those with tetraplegia. Our observation of lower BMI cutoff points for defining obesity needs further confirmation by studies of a large and representative sample of men and women with SCI across various injury characteristics as well as validation with well-defined health outcomes, using sensitivity and specificity analyses. The underweight/malnutrition issue also deserves the consideration while proposing the ideal weight and BMI range for persons with SCI, as the prevalence of underweight (BMI < 18.5 kg/m²) is much higher in the SCI population than in the general population (4.5%-7.5% vs. 0.7%-2.4%) (4). The limitations of the present study include a small sample size that precluded this study from stratifying the analysis by completeness of injury. DXA measurements may underestimate the loss of lean muscle tissue in the SCI population; therefore caution should be used when employing DXA alone to estimate body composition in adults with SCI.

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