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ORIGINAL RESEARCH

# Body Mass Index Underestimates Adiposity in Persons With Multiple Sclerosis

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**Abstract**

**Objectives:** To examine the relation between body mass index (BMI) and adiposity assessed by dual-energy x-ray absorptiometry in persons with multiple sclerosis (MS) and non-MS controls as well as to determine the accuracy of standard and alternate BMI thresholds for obesity.

**Design:** Cross-sectional.

**Setting:** University research laboratory.

**Participants:** The sample included persons with MS (n=235) and controls (n=53) (N=288).

**Interventions:** Not applicable.

**Main Outcome Measures:** Main outcome measures included BMI, whole body soft tissue composition (ie, percent body fat [%BF], fat mass, and lean soft tissue mass), bone mineral content, and bone mineral density.

**Results:** We observed significant strong associations between BMI and sex-specific %BF in persons with MS and non-MS controls, and BMI explained ∼40% of the variance in %BF in both MS and control samples. Receiver operating characteristic curve analyses indicated that the standard BMI threshold for obesity (ie, 30kg/m$^2$) had excellent specificity (93%−100%) but poor sensitivity (37%−44%) in persons with MS and non-MS controls. The BMI threshold that best identified %BF-defined obesity was 24.7kg/m$^2$ in the MS sample and 25.1kg/m$^2$ in the control sample.

**Conclusions:** We determined a strong association between BMI and adiposity; however, the current BMI threshold for classifying obesity underestimates true adiposity in persons with MS. A similar relation was observed between BMI and obesity in non-MS controls. The non-MS sample included primarily middle-aged women, and similar BMI-%BF misclassifications have been reported in these samples.

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Body mass index (BMI) is a widely used tool for identifying obesity and assessing health risk associated with excess body fat (BF). A BMI of ≥30kg/m$^2$ has been established by the World Health Organization[1] as the threshold for obesity in the general population. Although BMI has many advantages, such as cost-effectiveness and ease of use, there are important limitations of this tool.[2-4] In particular, BMI is a surrogate marker of obesity and does not distinguish between fat and lean tissues and therefore does not provide a direct measure of an individual's adiposity.[2,4,5] Consequently, BMI might overestimate or underestimate true adiposity and, importantly, lead to a misinterpretation of potential health risk.

Previous research has examined the ability of BMI to identify obesity in healthy and clinical populations.[2,4,6-8] These studies suggest that a strong association exists between BMI and BF, but the diagnostic performance of BMI in identifying obesity is limited. There is evidence to suggest that the standard BMI threshold for obesity frequently underestimates adiposity, particularly in older adults and populations with chronic health conditions.[2,6-9] For instance, a BMI threshold of 30kg/m$^2$ failed to identify 73.9% of persons who were obese according to percent fat mass assessed by bioelectrical impedance in a sample of 77 individuals with chronic spinal cord injury.[7] Similarly, a BMI threshold of 24.9kg/m$^2$, rather than 30kg/m$^2$, demonstrated a higher degree of accuracy for identifying obesity according to percent body fat (%BF) assessed by dual-energy x-ray absorptiometry (DXA) in 317 healthy, sedentary, postmenopausal women.[6] The development of BMI thresholds that accurately identify true adiposity in healthy and clinical populations has

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important implications for the intervention and management of chronic disease risk.

There has been increasing interest in the role of adiposity in the development and progression of multiple sclerosis (MS).[10,11] Indeed, studies have identified that 50% to 70% of persons with MS are classified as overweight or obese according to the standard BMI thresholds.[12-15] If a similar relation exists between BMI and adiposity in persons with MS as in other clinical populations, the prevalence of obesity, and risk of obesity-related chronic health conditions, would, in fact, be underestimated. Furthermore, the relation between BMI and obesity might differ as a function of disability level in persons with MS.[8] Indeed, there is evidence of differences in the relation between BMI and obesity with respect to certain population characteristics. For instance, the diagnostic performance of BMI in identifying obesity decreases with increasing age[2] and is worse in persons with tetraplegia than in those with paraplegia.[16] Examining the diagnostic performance of BMI in identifying obesity in persons with MS is particularly important, because BMI has recently been recommended as a metric of body composition, one of the core outcome measures for exercise studies.[17] However, no studies to date have examined the relation between BMI and adiposity in MS.

To that end, we conducted a secondary analysis of cross-sectional data to examine the relation between BMI and adiposity assessed by DXA in a large sample of participants with MS and a non-MS reference sample. We sought to determine the accuracy of standard and alternate BMI thresholds for identifying obesity according to sex-specific %BF assessed by DXA. Sex-specific %BF cut points have been commonly used in large-scale epidemiologic research examining the diagnostic performance of BMI in the general adult population.[4] We were further interested in examining the effect of MS disability on the relation between BMI and adiposity to provide an indication of potential differences in this relation with respect to ambulatory ability. On the basis of the relation between BMI and obesity reported in older adults and other clinical populations, we expect that BMI will underestimate adiposity in persons with MS. Furthermore, we expect that BMI will have poorer diagnostic performance in persons with MS with greater disability levels. Such an examination will be important to establish the validity of BMI as a marker of obesity in persons with MS.

# Methods

## Participants

We conducted a secondary analysis of data from 235 persons with MS and 53 non-MS controls who had participated in 5 previous research studies involving body composition assessment at a university research laboratory between January 17, 2006 and July 18, 2014.[18-21] Three studies involved cross-sectional examinations of fitness, functional, and symptomatic outcomes in persons with MS, and 2 were prospective studies involving physical activity or exercise training interventions. Data from participants with MS were included from 5 (n=77, n=61, n=34, n=33, n=30) research studies, and data from control participants were included from 2 (n=33, n=20) of these studies. The inclusion criteria for all participants were age 18 to 65 years; ambulatory with or without an assistive device; and absence of risk factors for participation in exercise on the basis of the Physical Activity Readiness Questionnaire.[22] In addition, participants with MS had a clinically definite diagnosis of MS and were relapse-free during the past 30 days before assessments. Non-MS controls were matched to participants with MS on sex, age, height, and weight.

***List of abbreviations:***

| | |
|---|---|
| **BF** | **body fat** |
| **%BF** | **percent body fat** |
| **BMC** | **bone mineral content** |
| **BMI** | **body mass index** |
| **DXA** | **dual-energy x-ray absorptiometry** |
| **MS** | **multiple sclerosis** |
| **PDDS** | **Patient Determined Disease Steps** |
| **WC** | **waist circumference** |

## Outcome measures

### Disability

The Patient Determined Disease Steps (PDDS)[23] scale was used to characterize the level of neurological disability of the MS sample. The PDDS has demonstrated good validity on the basis of associations with the clinically determined Expanded Disability Status Scale.[24,25] To examine the effect of disability on body composition, participants with MS were stratified into 2 groups according to PDDS scores. Individuals who did not experience gait disability (ie, PDDS score<3.0) were coded as "0," and participants who did experience gait disability (ie, PDDS score≥3.0) were coded as "1." This would provide an indication of the effect of limitations in walking on body composition. The stratification of PDDS groups according to gait disability has been used in previous research.[26,27]

### Height and weight

Height and weight were measured in the laboratory to the nearest 0.1cm or 0.1kg, respectively, using a Weigh Beam Eye-Level scale with a stadiometer.[a]

### Body mass index

BMI was calculated as the weight in kilograms divided by the height in meters squared. BMI was classified using standard threshold values: underweight, BMI <18.5kg/$m^2$; normal weight, BMI 18.5 to 24.9kg/$m^2$; overweight, BMI 25.0 to 29.9kg/$m^2$; and obese, BMI ≥30.0kg/$m^2$.[1]

### Dual-energy x-ray absorptiometry

Whole body soft tissue composition (ie, %BF, fat mass, and lean soft tissue mass), bone mineral content (BMC), and bone mineral density were assessed by DXA using a Hologic QDR 4500A bone densitometer.[b] The accuracy of the densitometer was verified daily by scanning the manufacturer's hydroxyapatite spine phantom of a known density. %BF-defined obesity was assessed by DXA and classified as ≥25% BF for men and ≥35% BF for women. These sex-specific %BF thresholds have been used most commonly in large-scale epidemiological studies and have been associated with risk factors for cardiometabolic disease, including elevated blood pressure, blood glucose level, insulin level, cholesterol level, fibrinogen level, and C-reactive protein concentration.[2-4,9,28]

## Procedures

All procedures were reviewed and approved by a university institutional review board. Participants provided written informed