Relationship of Obesity With Gait and Balance in People With Multiple Sclerosis

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ORIGINAL RESEARCH ARTICLE

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ABSTRACT

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Objective: The aim of this study was to examine the relationship of obesity with walking and balance in people with multiple sclerosis.

Design: This was a cross-sectional study performed at the Multiple Sclerosis Center, Sheba Medical Center, Israel. Four hundred thirty-six people with multiple sclerosis were divided into obese ($n = 178$) and normal-weight ($n = 258$) groups. Spatiotemporal parameters of gait, 2-Minute Walk test, 6-Minute Walk test, Timed Up and Go test, Timed 25-Foot Walk test, Multiple Sclerosis Walking Scale self-reported questionnaire, and posturography measures were determined.

Results: Compared with normal-weight patients, obese subjects walked significantly slower [98.7 (SD, 29.2) m/s vs. 106.4 (SD, 29.2) m/s; $P = 0.01$], with shorter step lengths [54.8 (SD, 11.6) cm vs. 58.1 (SD, 10.7) cm; $P = 0.003$] and a wider step width [12.1 (SD, 3.7) cm vs. 10.9 (SD, 4.6) cm; $P = 0.01$]. Furthermore, the obese group walked a shorter distance on the 6-Minute Walk test [378.2 (SD, 145.5) m vs. 426.1 (SD, 129.8) m; $P \leq 0.001$] and slower on the Timed 25-Foot Walk test [9.0 (SD, 8.0) seconds vs. 7.2 (SD, 2.4) seconds; $P = 0.006$] and the Timed Up and Go test [9.2 (SD, 6.3) seconds vs. 10.0 (SD, 6.1) seconds; $P = 0.002$]. No significant differences between groups were noted in the Multiple Sclerosis Walking Scale self-reported questionnaire and postural control measures.

Conclusion: Obesity affects walking but not postural control in people with multiple sclerosis despite the level of neurological disability.

Key Words: Balance, Gait, Multiple Sclerosis, Obesity

Multiple sclerosis (MS) is an autoimmune disease of the central nervous system causing progressive disability in young adults and affecting an estimated 2.5 million individuals worldwide.[1] In MS, demyelination and axonal loss occur in the central nervous system. Such damage frequently results in gait and balance impairments.[2] Following 45 years from diagnosis, 76% of people with MS (PwMS) require an ambulatory aid.[3] For the majority, this dysfunction is considered the most challenging life-changing aspect of the disease.[4]

Gait and balance difficulties in MS are usually related to 1 or more of the following factors: muscle weakness, spasticity, sensory deficit, visual problems, and fatigue.[5] In line with these prominent factors, overweight and obesity have been suggested as additional risk factors negatively affecting walking and balance capabilities in PwMS.[6]

After undergoing magnetic resonance imaging, overweight and obese PwMS were found to have more brain lesions during interferon β treatment compared with normal-weight patients.[7] Moreover, obesity was found associated with a greater risk of depression, lower functional capacity, and worse self-rated health status among MS patients.[8,9] Recently, a positive correlation between body mass index (BMI) and disability, evaluated by the Expanded Disability Status Scale (EDSS), was reported.[10]

Previous reports have demonstrated that obese adults walk at slower speeds and have poor postural control and a higher energy cost during walking compared with normal-weight adults.[11,12] In addition, altered gait kinematics comprising a slower walking speed, a shorter stride length, and more time spent in double support during walking have been observed in obese adults compared with normal-weight individuals.[13]

As for PwMS, a limited number of studies have examined the relationship between weight status and mobility. An association between self-reported BMI and the Patient Determined Disease Steps scale scores was identified in a large sample of PwMS of varying disability levels.[14] Another study reported that the relationship between BMI and mobility approached significance such that MS participants who were less mobile had a higher BMI.[15]

In contrast, weight status did not influence the progression of disability over a 2-year period in 269 PwMS.[16] Consequently, the association between BMI and walking remains equivocal in PwMS. Furthermore, to the best of our knowledge, there are no studies reporting whether obesity alters spatiotemporal parameters of gait or postural control in MS. This information may improve rehabilitation programs directed at maximizing mobility capabilities of PwMS.

Worth noting is that there are inconsistencies between previous reports as to the usage of BMI as an index of obesity in PwMS. A BMI of 30 kg/m^2 or greater has been established by the World Health Organization as the threshold for obesity in the general population.[17] However, according to Pilutti and Motl's[18] recent publication, this score frequently underestimates adiposity in PwMS. According to their findings, the BMI threshold that best identifies the percentage of body fat–defined obesity in MS is 24.7 kg/m^2.[18] In the current study, we follow their lead by using a BMI cutoff score of 24.7 kg/m^2 to differentiate between obese and normal-weight MS subjects.

Therefore, the objective of the current study was to examine whether obesity affects walking and balance in PwMS. We predicted that obese PwMS would walk slower with shorter steps and have poor postural control compared with normal-weight MS subjects.

METHODS

Study Design and Participants

This study was an observational cross-sectional study comprising 436 PwMS, 278 women and 158 men from the Multiple Sclerosis Center, Sheba Medical Center, Tel-Hashomer, Israel. Inclusion criteria included (1) a neurologist-confirmed diagnosis of definite MS according to the revised McDonald criteria[19]; (2) less than 7.0 on the EDSS,[20] equivalent to walking at least 20 m without resting; (3) gait and balance tests performed between January 2012 and October 2015; and (4) the patient was relapse-free for at least 30 days prior to testing. Exclusion criteria included (1) orthopedic disorders that could negatively affect mobility, (2) pregnancy, (3) cardiovascular disorders, (4) respiratory disorders, (5) or taking steroids or fampridine. The study was approved by the Sheba Institutional Review Board. All participating subjects signed an informed consent form for use of their data in the research project.

Gait and Balance Outcome Measures

Gait and balance measurements were performed at the Multiple Sclerosis Center and the Center of Advanced Technologies in Rehabilitation, Sheba Medical Center Tel-Hashomer, Israel.

Gait was studied using the GAITRite electronic mat (CIR Systems, Inc, Haverton, Pa). As the subject ambulates across the walkway, pressure is exerted by his feet, thus activating the sensors. Simultaneously, targeted software utilized special algorithms to automatically group the activated sensors and form footprints. The system integrates all footprints and provides the following spatiotemporal parameters: velocity, cadence, step/stride length, step/stride time, step width, and single/double time percentage according to gait cycle (GC). In addition, the walk ratio (step length/cadence) was calculated.[21]

The walk ratio is a simple speed-independent index used to describe temporal and spatial coordination, that is, a walking pattern. A decreased walk ratio due to a walking pattern of shorter and more frequent steps is considered as a nonspecific adaptive mechanism, facilitating the neuromuscular control of walking, namely, reflecting the quality of gait control.

A single valid walking trial was defined once the participant independently walked at his/her self-selected speed across the electronic mat in 1 direction without stopping. Each participant performed 6 consecutive walking trials. The values from all trials were then averaged to produce the final results.

Static postural control parameters were obtained from the Zebris FDM-T Treadmill (Zebris Medical GmbH, Isny im Allgäu, Germany). Dedicated software integrates the force signals and provides a set of outcome measures taken from the center of pressure (CoP) trajectories:

(1) the ellipse sway area (in mm^2), defined as a 95% confidence ellipse for the mean of the CoP anterior, posterior, medial and lateral coordinates;
(2) the CoP path length (in mm), defined as the absolute length of the CoP path movements throughout the testing period; and
(3) the sway rate (in mm/s), defined as the mean speed of movement of the CoP throughout the testing period.

Subjects stood barefoot on the treadmill belt (a 10-cm gap between heels, in a 5-degree toe-out position), in an upright static position with arms resting at their sides. Participants were instructed to maintain their posture as steady as possible while visually focusing on a dot located directly in front of them, 1 m away. Each subject completed a sequence of 3 consecutive postural control tests for 30 seconds with a 30-second break in between tests.

In addition to the instrumented gait and static balance measurements, the following clinical measures were collected.

Two-Minute Walk Test and 6-Minute Walk Test

Subjects were instructed to complete the test "at their fastest speed" and cover as much distance as possible by walking back and forth down a 30-m hallway and circling cones at each end. The total distance was registered.[22]

Timed Up and Go Test

The Timed Up and Go (TUG) test requires both static and dynamic balance. The starting point was determined after the subject was seated in a chair with his/her back flush against the chair. The subject was then instructed to stand, walk 3 m, turn around, walk back to the chair, and sit down. Timing began when the individual started to rise and ended when he/she returned to the chair and sat down.[23]

Timed 25-Foot Walk

The Timed 25-Foot Walk (T25FW) was performed on a clearly marked 25-ft-long path cleared of obstructions. The T25FW was performed twice, and the mean of the 2 trials was included in the analysis.[24]

Multiple Sclerosis Walking Scale

The 12-item Multiple Sclerosis Walking Scale (MSWS-12) is a patient-rated measure of walking ability.[25] The questions were based on the patient's walking limitations (due to MS) during the past 2 weeks; the higher the score, the more perceived walking difficulties.

The clinical tests selected for the present study capture different aspects of mobility capabilities in MS. The TUG test is a combined functional test examining the time it takes to rise from a chair, walk a short distance, turn around, and sit back down. The 6-Minute Walk Test (6MWT) is considered a walking endurance test. The 2-Minute Walk Test (2MWT) reflects walking accompanying major activity daily living tasks performed outside the home, whereas the T25FW reflects walking requirements within the home.

Statistical Analysis

Subjects with MS were divided into 2 groups: obese and normal weight. Allocation was determined according to the BMI score. The cutoff point for distribution was set at 24.7. People with MS with a BMI score of greater than 24.7 kg/m^2 were assigned to the obese group and those with 24.7 kg/m^2 or less were assigned to the normal-weight group.[18]

Group differences in age and sex distribution were determined using an independent-sample t and χ^2 tests, respectively. Outliers were determined for each outcome using box plots. All gait and balance parameters were normally distributed according to the Kolmogorov-Smirnov test. The differences in clinical, gait, and balance parameters between obese and normal-weight groups were determined using the multivariate analysis of covariance test. Covariates included age, sex, and the neurological impairment level, expressed by the EDSS score. Assumptions for multivariate analysis of covariance were reached according to matrix scatter plots and the Wilk λ test. For all outcome parameters, the F and *P* values are presented. All analyses were performed using SPSS software (version 22.0 for Windows; SPSS Inc, Chicago, Ill). All reported *P* values were 2-tailed. The level of significance was set at $P < 0.05$.

RESULTS

One hundred seventy-eight PwMS (40.8%) were classified as obese (mean BMI, 28.9 (SD, 3.8) kg/m^2], and 258 (59.2%) as normal weight [mean BMI, 21.4 (SD, 2.1) kg/m^2]. People with MS in the obese group were older compared with the normal-weight group, 49.6 (SD, 11.4) versus 40.4 (SD, 12.0) years; $P < 0.001$, respectively. No differences were observed between the groups in terms of sex ratio, EDSS score, EDSS subcategories score (pyramidal, cerebellar, sensory), and disease duration. The individuals' characteristics and neurological assessment scores are summarized in Table 1.

In terms of spatiotemporal parameters of gait, compared with normal-weight PwMS, obese subjects walked slower [98.7 (SD, 29.2) m/s vs. 106.4 (SD, 29.2) m/s, $P \leq 0.001$] with shorter step lengths [54.8 (SD, 11.6) cm vs. 58.1 (SD, 10.7) cm, $P \leq 0.001$] and demonstrated a wider step width [12.1 (SD, 3.7) cm vs. 10.9 (SD, 4.6) cm, $P \leq 0.001$] and a prolonged double-support period [29.3% GC (SD, 7.9% GC) vs. 25.1% GC (SD, 6.1% GC), $P < 0.001$] (Table 2).

Clinical Walking and Balance Tests

The obese group, scored by the T25FW test [9.0 (SD, 8.0) seconds vs. 7.2 (SD, 2.4) seconds, $P = 0.006$], walked slower. In addition, they walked a shorter distance when scored by the 6MWT [378.2 (SD, 145.5) m vs. 426.1 (SD, 129.8) m, $P \leq 0.001$]. No significant differences between groups were noted in the MSWS-12 self-reported questionnaire. Also, no significant differences were noted between the 2 MS groups as to the postural control measures. Scores of the walking and balance tests of the study groups are presented in Table 2. Figures 1 to 4 present the major parameters that were significantly different among the obese and normal-weight MS subjects.

DISCUSSION

The main finding of this study was that obesity alters walking in PwMS. Compared with normal-weight subjects, obese MS individuals walked at a slower speed, with a decreased step length, a wider step width, and a prolonged double-support period. Furthermore, obese subjects walked a shorter maximum distance according to the 6MWT and walked slower on the T25FW test. Worth noting, no differences were found between groups in terms of the EDSS score and disease duration, indicating that the gait differences between obese and normal-weight PwMS exist despite the level of neurological disability.

One may claim that the differences in walking performance between the MS groups are associated with age. Obese individuals were significantly older compared with their normal-weight counterparts

TABLE 1 Demographical and clinical status of the MS study group (n = 436)

Variable	Mean (SD) Normal (n = 258) (BMI ≤ 24.7 kg/m^2)	Mean (SD) Obese (n = 178) (BMI > 24.7 kg/m^2)	F, *P*
Age, y	40.4 (12.0)	49.6 (11.4)	65.0, $P < 0.001$[a]
Female/male, n	169/89	109/69	1.3, $P = 0.257$
Weight, kg	61.1 (8.9)	82.1 (13.3)	386.0, $P < 0.001$[a]
Height, cm	168.6 (8.2)	168.5 (9.5)	0.012, $P = 0.914$
BMI, kg/m^2	21.4 (2.1)	28.9 (3.8)	672.3, $P < 0.001$[a]
Disease duration, y	6.1 (7.4)	7.3 (8.1)	2.8. $P = 0.100$
MS type (RR/P)	251/7	161/17	2.1, $P = 0.148$
EDSS (score)	2.7 (1.8)	3.0 (1.8)	2.3, $P = 0.130$
Pyramidal	1.6 (1.2)	1.2 (1.2)	3.0, $P = 0.084$
Cerebellar	1.0 (1.1)	0.9 (1.0)	1.2, $P = 0.267$
Sensory	0.9 (1.1)	1.0 (1.0)	0.645, $P = 0.422$

BMI, body mass index; EDSS, expanded disability status scale; MS, multiple sclerosis; P, progressive; RR, relapsing-remitting.

TABLE 2 Walking and balance scores of the study group

Variable	Mean (SD) Normal (n = 258) (BMI ≤ 24.7 kg/m^2)	Mean (SD) Obese (n = 178) (BMI > 24.7 kg/m^2)	F, *P*
Clinical measures			
MSWS-12 (score)	31.0 (15.5)	33.5 (14.9)	1.9, $P = 0.135$
TUG, s	9.2 (6.3)	10.0 (6.1)	5.0, $P = 0.002^a$
T25FW, s	7.2 (2.4)	9.0 (8.0)	4.3, $P = 0.006^a$
2MWT, m	145.8 (47.1)	136.9 (48.4)	9.2, $P \leq 0.001^a$
6MWT, m	426.1 (129.8)	378.2 (145.5)	12.5, $P \leq 0.001^a$
Instrumented walkway			
Velocity, m/s	106.4 (29.1)	98.7 (29.2)	12.9, $P \leq 0.001^a$
Cadence, m/min	108.2 (17.0)	106.1 (16.2)	3.7, $P = 0.012^a$
Walk ratio, mm/(steps/min)	5.4 (0.8)	5.2 (1.0)	23.6, $P \leq 0.001^a$
Mean step length, m	58.1 (10.7)	54.8 (11.6)	21.5, $P \leq 0.001^a$
Mean step time, s	0.57 (0.12)	0.58 (0.14)	2.3, $P = 0.079$
Mean double support, % GC	25.1 (6.1)	29.3 (7.9)	19.8, $P < 0.001^a$
Mean single support, % GC	37.4 (3.2)	35.4 (4.1)	16.9, $P < 0.001^a$
Mean step width, cm	10.9 (4.6)	12.1 (3.7)	7.3, $P < 0.001^a$
Posturography			
CoP path length, mm	188.6 (150.5)	216.2 (161.3)	2.2, $P = 0.182$
Ellipse area, mm^2	142.3 (218.0)	152.7 (190.5)	1.5, $P = 0.355$
Sway rate, mm/s	10.3 (11.0)	11.1 (8.2)	0.9, $P = 0.367$

BMI, body mass index; MSWS-12, multiple sclerosis status scale; TUG, timed up and go; T25FW, timed 25-foot walk; 2MWT, 2-min walk test; 6MWT, 6-min walk test; GC, gait cycle; CoP, Center of pressure.

(49.6 vs. 40.4 years). However, we dismiss this argument following studies of aged gait in adults, which demonstrated that gait characteristics such as velocity and stride length remain relatively unchanged until the seventh decade of life.[26]

Worth mentioning is that the self-reported MSWS-12 questionnaire showed no significant differences between the groups, indicating that obese PwMS do not report further walking difficulties compared with those with normal weight.

The subgroups were also similar in terms of neurological disability (i.e., EDSS). Possibly, these observations are due to the limited ability of these measurement tools to capture definite gait changes in PwMS.

This assumption is in line with previous studies demonstrating gait deterioration in PwMS in the absence of clinical disability.[27,28] The fact that the EDSS score of the present group was 2.7, indicating minimal walking impairment, strengthens this hypothesis. Consequently, PwMS and their practitioners should be aware that even in the absence of a pronounced walking decline, obesity negatively effects walking in PwMS.

From a clinical standpoint, although the scientific literature is scarce, we believe that the present study's findings encourage weight reduction programs for the MS community. Recently, 82 PwMS participated in a trial examining the efficacy of a 6-month Internet-delivered intervention program directed at increasing lifestyle physical activity.[29] The authors reported that the total mass of fat and total body mass were lower in the intervention group than in the control subjects after trial. We speculate that such interventions can positively affect major gait characteristics such as walking speed and step length. Hopefully, these improvements may result in a lower energy cost during walking, consequently reducing the level of physical fatigue, a common

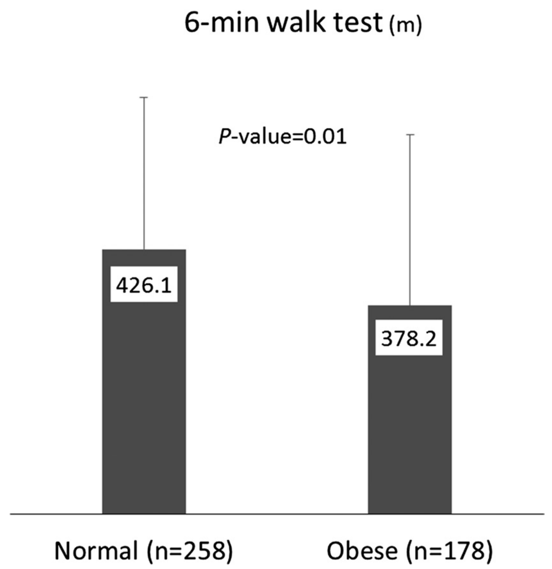

FIGURE 1 *Six-Minute Walk Test scores among the obese and normal-weight MS subjects.*

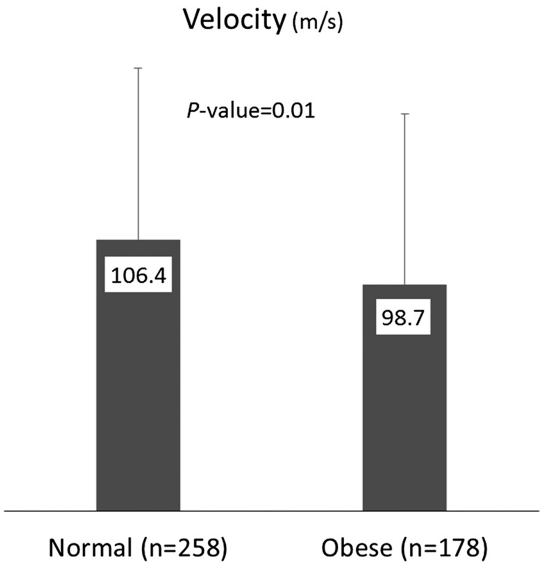

FIGURE 2 *Walking speed among the obese and normal-weight MS subjects.*

FIGURE 4 *Timed 25-Foot Walk scores among the obese and normal-weight MS subjects.*

symptom in the MS population. Nevertheless, future trials investigating the effect of similar types of interventions on gait characteristics in MS are warranted in order to confirm these assessments.

Interestingly, no differences were observed in the postural control measures between the MS weight groups. This finding is in contrast to parallel studies performed in nonpathological populations demonstrating that obesity is related to poor postural control.[30]

We raise several explanations for this observation. First, the conflict could be related to the different BMI cutoff score used to determine obesity. The common BMI cutoff score for obesity in the general population is higher than the score used in the present study, BMI of 30.0 kg/m^2 versus 24.7 kg/m^2, respectively. However, as we previously noted, the 24.7 score is more appropriate in determining obesity in PwMS.[18]

We also speculate that obesity has a negative impact on dynamic activities more than static activities in PwMS possibly due to differences between walking and balance requirements in terms of energy cost. This assumption is partly supported by a previous report demonstrating a significant association between higher energy costs with slower gait speeds, decreased stride length, and a prolonged double-support period in persons with mild MS.[31] However, in order to confirm this hypothesis, future research examining the relationship between energy cost, static balance, gait, and obesity in MS is essential.

Limitations of the Study

There were several strengths of the current study including the large sample of PwMS and the instrumented walking and postural control measurement tools. However, several limitations of the study warrant attention. Subjects with MS were divided into only 2 groups, obese and normal weight. We did not include a third group defined as overweight. The main reason for this division concerned our desire to stay in line with the cutoff score presented by Pilutti and Motl[18]; therefore, overweight PwMS were distributed between the obese and normal-weight groups.

Consequently, future studies should examine whether mobility characteristics are different between obese and overweight and between overweight and normal-weight PwMS. We further acknowledge

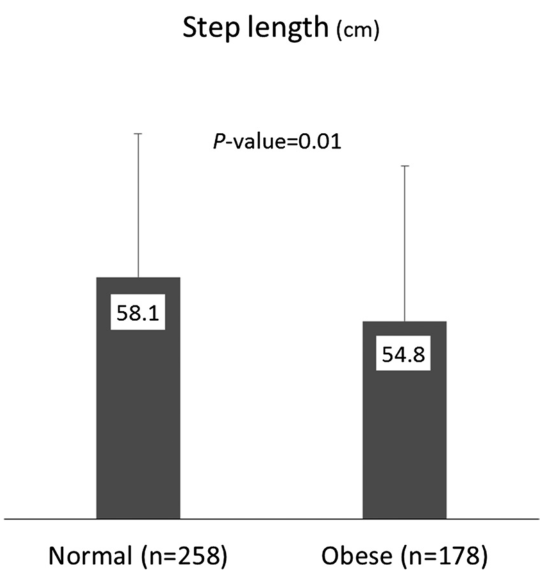

FIGURE 3 *Mean step length among the obese and normal-weight MS subjects.*

that we assessed obesity solely according to the BMI value while there are many other variables that can determine obesity. Nevertheless, given the strong correlations between the BMI and other body composition outcomes (i.e., % body fat, fat mass, body mineral density) in MS, this is a minimal concern. Tertiary, because of the cross-sectional design of the study, information was not gathered as to other related factors such as muscle weakness, spasticity, sensory deficit, fatigue, and differences in physical activity level known, common causes of walking and balance limitations in PwMS. Therefore, our conclusions should be addressed with caution.

Finally, we did not include controlled healthy adults; hence, we cannot confirm that the effects of obesity on gait and balance in MS differ from those seen in the healthy population. However, this was not the aim of the present study because we wanted to focus on the MS population who frequently suffer from impaired walking and balance.

CONCLUSIONS

We sought to examine obesity as a factor influencing gait and balance in PwMS as this could become an important target for intervention. The relatively high prevalence of obesity in PwMS (40.8%) indicates the importance of this investigation. Although it seems that obese PwMS do not report additional complaints related to walking compared with normal-weight MS individuals, their gait is altered. Accordingly, it may be important to remind PwMS to keep their body weight in the reference range in order to preserve a better walking ability.

Supplementary Checklist

STROBE Checklist: http://links.lww.com/PHM/A271

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