Original paper

Lifestyle and health of individuals with multiple sclerosis according to body mass index: initial results

Styl życia i stan zdrowia osób chorujących na stwardnienie rozsiane w zależności od wskaźnika masy ciała – wyniki wstępne

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Key words: diet, physical activity, multiple sclerosis, obesity, metabolic disorders.

Słowa kluczowe: dieta, aktywność fizyczna, stwardnienie rozsiane, otyłość, zaburzenia metaboliczne.

Abstract

Introduction: Increased body mass index (BMI) correlates with an increased risk of many diseases and is thought to be a risk factor in multiple sclerosis (MS).
Aim of the research: To assess the lifestyle and health of adult individuals with MS, according to their relative BMI.
Material and methods: The study participants comprised 115 individuals with MS. The participants underwent anthropometric measurements, functional tests, lifestyle assessments, and a biochemical blood parameter analysis that included the fasting glucose, triglyceride, HDL-cholesterol, vitamin D, and biotin concentrations.
Results: In total, 40.9% of the participants were overweight or obese. The compared groups did not differ significantly in terms of the degree of their physical disability. The overweight group showed a higher functional ability of the lower limbs than the underweight group. Conversely, the underweight and the normal-weight group showed a higher relative hand grip strength than individuals with overweight and obesity ($p < 0.05$). Metabolic syndrome was more prevalent in the overweight and obese participants ($p < 0.05$). The obese individuals drank sweetened carbonated or still drinks significantly more often than the other individuals. They also consumed potatoes more often and other vegetables less often than the other participants ($p < 0.05$).
Conclusions: Individuals with MS differed in terms of the values of their metabolic parameters, functional ability of the lower limbs, and relative hand grip strength, depending on their BMI. The occurrence of obesity may have resulted, at least partially, from differences in diet and physical activity.

Streszczenie

Wprowadzenie: Podwyższony wskaźnik masy ciała (BMI) wiąże się z większym ryzykiem rozwoju wielu chorób. Jest uznawany także za czynnik ryzyka wystąpienia stwardnienia rozsianego (MS).
Cel pracy: Ocena stylu życia i stanu zdrowia dorosłych chorych na SM w zależności od ich względnej masy ciała (BMI).
Materiał i metody: Badaniami objęto 115 chorych na MS. Przeprowadzono pomiary antropometryczne, testy funkcjonalne, ocenę stylu życia i analizę parametrów biochemicznych krwi, oznaczając stężenia: glukozy na czczo, triglicerydów, cholesterolu HDL, witaminy D i biotyny.
Wyniki: Nadwagę i otyłość stwierdzono łącznie u 40,9% osób. Porównywane grupy nie różniły się istotnie pod względem stopnia niepełnosprawności ruchowej. W grupie osób z nadwagą odnotowano większą sprawność funkcjonalną kończyn dolnych niż w grupie pacjentów z niedowagą. Wartości względnej siły mięśni dłoni okazały się wyższe u uczestników z niedowagą i z prawidłowym BMI niż u tych z nadwagą i otyłością ($p < 0,05$). W grupie pacjentów z nadwagą i otyłością istotnie częściej występował zespół metaboliczny ($p < 0,05$). Osoby z otyłością istotnie częściej piły słodzone napoje gazowane lub niegazowane, częściej spożywały ziemniaki, natomiast rzadziej – inne warzywa ($p < 0,05$).
Wnioski: U chorych z MS stwierdzono różnice w wartościach parametrów metabolicznych, sprawności funkcjonalnej kończyn dolnych oraz względnej sile mięśni dłoni w zależności od ich BMI. Występowanie otyłości, przynajmniej częściowo, może wynikać z różnic w sposobie żywienia i aktywności fizycznej.

Introduction

Multiple sclerosis (MS) is defined as a progressive, inflammatory, and demyelinating disease of the central nervous system. It is one of the most common neurological diseases diagnosed in young adults, which causes progressive disability. The prevalence of MS in Poland amounts to over 120 cases per 100,000 individuals [1, 2]. A key pathogenic factor in MS is the autoimmune process [3].

An increased body mass index (BMI) correlates with an increased risk of many chronic diseases, such as type 2 diabetes, cardiovascular diseases, and cancer. It is also associated with an increased mortality rate due to these diseases [4, 5] and an increased risk of inflammatory and autoimmune diseases [6]. Many authors also consider an increased BMI to be an important and potentially modifiable risk factor of MS [7–9]. Mokry *et al.* reported that an increase in the BMI by 1 SD was associated with an increase in the risk of MS by 41% [7]. The mechanisms underlying the increased risk of MS caused by overweight and obese conditions are still not fully explained. Nonetheless, the research indicates that obesity may constitute a factor in the development of MS by means of at least 3 common pathophysiological pathways: chronic inflammation related to increased concentrations of many pro-inflammatory cytokines (e.g. IL-6, IL-1β, TNF-α, IFN-γ, and CRP); disrupted adipokine production (e.g. leptin and adiponectin); and changes in the intestinal microbiome [10–12]. Furthermore, some authors have indicated that obesity may increase the risk of MS, leading to a decreased bioavailability of vitamin D, while in turn, a low concentration of vitamin D correlates with a pro-inflammatory state [13, 14]. However, other studies have not confirmed this relationship [15].

Marck *et al.* stated that the correlations between the BMI, comorbidities, and health results in individuals with MS may be bidirectional and related to the person's lifestyle [16]. Consequently, an increased BMI may result from limited physical activity due to the progressive physical disability in patients with MS [17].

Aim of the research

The aim of this study was to assess the lifestyle and health of adult individuals with MS, according to their relative body mass (BMI).

Material and methods

The study participants comprised 115 individuals with MS aged 20–65 years, including 87 (75.8%) women. The study was conducted at the Neurological Clinic in Kielce, Poland between October 2020 and January 2021. The study encompassed anthropometric measurements, an analysis of the biochemical blood parameters, functional tests, and an assessment of each of the participant's lifestyle. The study was conducted with the approval of the Bioethics Committee of the *Collegium Medicum* at the Jan Kochanowski University in Kielce No. 24/2020 from 25 April 2020.

The information about the form of MS, age of diagnosis, and comorbidities (including autoimmune diseases, cardiovascular diseases, and diabetes, as well as their treatment) was obtained from the participants' medical records. The glucose concentration in the blood serum was determined by the enzymatic method with glucose oxidase. The concentration of triglycerides was determined by means of the phosphogliceride oxidaseperoxidase method and HDL-cholesterol – by direct method with polyethylene glycol-modified enzymes. The laboratory tests were performed with a BS-200E MINDRAY instrument. Serum biotin and 25(OH)D concentrations were determined by enzyme immunoassay method with an Access 2 Beckman Coulter analyser. Blood pressure was measured with an Omron blood pressure monitor (model M3 Intellisense). The test was carried out on the artery of the right upper limb, when seated, and the average of 2 measurements was used in analyses. The measurements of body weight were done by means of an electronic scale (Tanita MC-780MA-N). Body height measurements were done by means of the scale's stadiometer. Non-elastic tape was used to measure waist circumference (WC) at a point midway between the lowest rib and the upper iliac crest. The Expanded Disability Status Scale (EDSS) was used to measure the degree of disability [18], and the participants were divided into 2 groups: < 4 points and ≥ 4 points (up to 6.5 points). The functional ability of the lower limbs was assessed using the timed 25-foot walk (T25FW). For the T25-FW, patients were instructed to walk as fast as they could in a safe manner along a marked 25-foot (7.6-m) course. This test was performed twice, and the obtained times were averaged. The functional ability of the upper limbs was assessed using the 9-hole peg test (9-HPT), in which each participant inserted 9 pegs into holes in a container and then pulled them out one by one as quickly as possible. Hand grip strength was measured in a sitting position, with the arm flexed at the elbow. The test was performed twice with each hand, and the absolute score (the sum of the strength of the right and left hand) and relative strength (strength relative to the body mass) were used for the analysis. The test was performed using a 290-lb/90-kg Kyto handheld dynamometer.

The dietary habits of the participants were assessed using the KomPAN questionnaire, which is validated for individuals aged 15–65 years [19]. Thirty-four questions concerning how frequently the participants consumed 34 different food products, including drinks and alcohol, were used in the analysis. Each of the 6 categories of answers (from the lowest to the highest frequency of consumption) was transformed and presented as the number of times per day,

in accordance with the procedure proposed by the authors of the questionnaire. Data concerning lifestyle and socioeconomic status were also collected using the KomPAN questionnaire. The declared sleep time was classified as ≤ 6, 7–8, or ≥ 9 h per day. Physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ). The participants were asked about the number of days and the time they had spent performing physical activity of different intensities (vigorous, moderate, and light) and sitting during the preceding 7 days. In accordance with the recommended protocol for the data analysis, the intensity of physical activity was expressed in units of the metabolic equivalent of task (MET) by multiplying the coefficient ascribed to each activity by the related number of minutes and days (MET-min/week). Afterwards, the participants were classified into one of three groups as follows: health enhancing physical activity (HEPA); minimal activity; and physical inactivity. The sitting time was expressed as the product of the number of days and minutes spent sitting (min/week).

Definitions used

Overweight and obese individuals were defined as having a BMI ≥ 25 kg/m^2 and ≥ 30 kg/m^2, respectively. A normal relative weight was defined as a BMI within the range 18.5–24.9 kg/m^2 and underweight as having a BMI < 18.5 kg/m^2. These metabolic disorders, which are components of metabolic syndrome (MetS), were analysed. MetS and its components were diagnosed in accordance with the International Diabetes Federation (IDF) guidelines [20].

The physical activity groups were defined in accordance with the guidelines of the European network for the promotion of health-enhancing physical activity [21, 22]. The following forms of activity were distinguished: HEPA – intense activity performed at least 3 days per week, achieving a minimum of 1500 MET-min/week, or 7 days of any combination of walking, or moderate or vigorous activity, to achieve a minimum of at least 3000 MET-min/week; minimal activity – intense activity performed 3 or more days per week for at least 20 min/day, or moderate or light (walking) activity for 30 min/day, or being active on a minimum of 5 days/week, while achieving a minimum of 600 MET-min/week; and physical inactivity – a failure to meet the above criteria.

Statistical analysis

Quantities and percentage values were provided for the categorised variables, i.e. sex, age, physical activity, place of residence, financial situation, and comorbidities. The differences in the distribution of these variables according to the BMI were assessed using the χ^2 test. The normality of the quantitative variables was assessed using the Shapiro-Wilk test. Next, the mean, SD, median, and the value of the first and third quartiles were calculated. Differences in mean values between the compared groups were calculated using the Anova test and Kruskal-Wallis test, depending on the type of distribution. A p-value ≤ 0.05 was considered to be statistically significant. The calculations were performed using the Polish version of Statistica 13.3 software.

Results

Women constituted three-quarters of the participants in the study. An overweight condition was found in 40.9% of the participants, which included 12.2% participants with obesity (Table 1). The obese participants were significantly older and had the lowest level of education ($p < 0.05$). The age of MS diagnosis_did not differ significantly in the compared groups. In addition, no differences were found in the declared financial situation or place of residence.

Individuals with obesity had the highest waist circumference (in cm) and WtHR (Table 2). The overweight participants had better lower limb functional ability than did the underweight participants. The underweight group showed the highest, and the group with obesity the lowest, relative handgrip strength ($p < 0.05$). The compared groups did not differ significantly in terms of the degree of physical disability, as measured with the EDSS.

Most of the participants in all groups had been diagnosed with relapsing-remitting MS (Table 3). With respect to comorbidities, 14.7% of all the participants had hypertension, 7.8% had autoimmune diseases, and 5.2% had diabetes. The prevalence of comorbidities did not differ significantly between the compared groups. The prevalence of MetS and its components, according to the IDF definition, was significantly higher in the obese and overweight group (with the exception of elevated TG and lowered HDL-cholesterol). The current measurements and biochemical analyses showed no differences in blood pressure but significantly higher levels of TG and fasting glucose, as well as lower levels of HDL-cholesterol in the blood serum of overweight and obese patients ($p < 0.05$). Vitamin D (25[OH]D) and biotin concentrations were similar in the compared groups. There were also no differences in the use of vitamin D supplementation.

All the participants, regardless of their BMI, reported eating white bread, sweets, and meat, including cold meats, relatively frequently, while the consumption of fruit, vegetables, and fish was low (Table 4). The obese participants consumed potatoes and sweetened carbonated or still drinks significantly more often and tea, coffee, and vegetables significantly less often than the other participants. In addition, participants with obesity ate wholemeal bread more often than underweight participants. No significant differences in the consumption of alcohol or smoking were found.

Table 1. Demographic and socioeconomic data of the study participants with MS

Variable		Total $N = 115$		BMI < 18.5 kg/m² $N = 12$		BMI = 18.5–24.9 kg/m² $N = 55$		BMI = 25.0–29.9 kg/m² $N = 32$		BMI ≥ 30 kg/m² $N = 16$		*P*-value
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Gender	Women	87	75.7	9	75.0	47	85.4	20	62.5	11	**68.7**	0.098[A]
	Men	28	24.4	3	25.0	8	14.6	12	37.5	5	31.3	
Age	X ± SD; Me (Q1–Q3)	42.6 ±11.6; 43.0 (35.0–51.0)		35.3 ±9.8; 33.0 (30.0–41.5)		44.3 ±11.9; 44.0 (38.0–49.0)		40.9 ±10.4; 42.0 (34.0–48.0)		47.6 ±12.1; 50.5 (39.0–57.0)		0.005[B]
Age of MS diagnosis	X ± SD; Me (Q1–Q3)	31.7 ±9.7; 31.0 (24.0–39.0)		25.0 ±5.2; 24.0 (22.0–29.0)		34.6 ±7.7; 34.0 (28.0–42.0)		31.9 ±10.1; 30.5 (23.5–40.5)		32.3 ±10.5; 32.0 (23.0–41.0)		0.080[B]
Place of living	City	90	79.7	12	100.0	46	73.33	22	62.5	12	62.5	0.056[A]
	Rural area	23	20.3	0	0.0	9	26.67	8	37.5	6	37.5	
Education	Higher	65	68.0	9	75.0	34	64.1	15	48.4	7	43.7	0.009[A]
	Secondary	28	25.0	2	16.7	16	30.2	6	19.4	4	25.0	
	Primary and vocational	19	17.0	1	8.3	3	5.7	10	32.1	5	31.3	
Financial situation	Below average	12	10.4	0	0.0	7	12.7	3	9.7	2	12.5	0.391[A]
	Average	96	83.5	11	91.7	43	78.2	28	90.3	14	87.5	
	Above average	6	5.2	1	8.3	5	9.1	0	0.0	0	0.0	

X – arithmetic mean, SD – standard deviation, Me – median, Q – quintile, [A]χ^2 test; [B]Anova.

Nearly 40% of all the participants engaged in insufficient physical activity, whereas 20.9% declared HEPA (Table 5). No significant differences were found in the total energy expenditure or sitting time and the sleep duration between the 2 groups. Normal-weight participants were only observed to declare HEPA more frequently than participants with underweight or obesity.

Discussion

Our study, which was conducted among individuals with MS, showed significant differences in the values of the metabolic parameters, diet, and muscle strength, depending on the BMI.

Overweight and obese conditions were found in 28.7% and 12.2% of the participants, respectively. This means that the prevalence of overweight and obese individuals was lower than among the general population of Poland (43.2% and 24.4% in men and 30.5% and 25.0% in women, respectively) [23]. A meta-analysis conducted among 2914 patients with MS from different countries also showed that their mean BMI was significantly lower than in healthy controls. The authors of the meta-analysis suggested that the BMI probably decreases over the course of the disease [24]. A long-term observation indicated that following the onset of MS, the patients did not display the usual increase in BMI that occurs with age [25]. Markianos *et al.* stated that an important factor in the decrease in BMI may be the growing disability and the accompanying limitations in physical activity and eating disorders [26]. The median age of MS onset among the participants in our study was 31 years, which is mostly consistent with the results obtained by other authors [27]. In the overweight and obese group, MS was diagnosed on average 3–4 years later than in the normal-weight group. This difference is also consistent with the results obtained in other studies, even though it did not reach the level of statistical significance [28].

No significant differences in the degree of disability (EDSS) were found between the 2 groups in our study. Overweight participants had better lower limb functional ability than underweight participants, but the underweight group showed the highest relative handgrip strength. Muscle strength correlated strongly with body mass. Heavy persons have not only a higher fat mass, but also a higher lean mass than normal-weight persons, which is probably what makes the former stronger than the latter in terms of the absolute values [29]. However, heavy individuals may have a lower relative strength, i.e. strength relative to the total body mass, which is consistent with our results.

The analysis of comorbidities showed that hypertension was significantly more prevalent in the overweight and obese group than in the normal-weight group. Likewise, the former group showed a higher prevalence of MetS and its individual components,

Table 2. Somatic and functional characteristics of the participants with MS

Variable		Total *N* = 115		BMI < 18.5 kg/m² *N* = 12		BMI = 18.5–24.9 kg/m² *N* = 55		BMI = 25.0–29.9 kg/m² *N* = 32		BMI ≥ 30 kg/m² *N* = 16		*P*-value
		X ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	
Height [cm]		168.2 ±8.8	167.0 (163.0–174.0)	168.2 ±8.4	168.0 (164.3–172.0)	167.0 ±8.0	166.0 (161.0–172.0)	169.9 ±9.7	168.5 (162.5–176.5)	169.0 ±9.9	168.5 (163.3–175.0)	0.523[B]
Weight [kg]		68.9 ±16.3	65.0 (58.2–77.5)	49.3 ±5.5	49.0 (45.8–50.8)	61.5 ±7.5	61.7 (56.9–65.0)	76.4 ±10.2	75.1 (67.7–83.4)	93.7 ±17.5	94.2 (82.2–100.8)	< 0.001[B]
Waist circumference [cm]		85.7 ±13.7	83.0 (75.0–96.0)	68.6 ±4.7	68.8 (65.5–73.0)	79.4 ±6.5	79.0 (75.0–83.0)	92.2 ±9.2	92.8 (84.5–97.5)	106.9 ±11.8	108.0 (100.0–114.5)	< 0.001[B]
WtHR [cm/cm]		0.51 ±0.07	0.50 (0.45–0.55)	0.40 ±0.01	0.40 (0.40–0.40)	0.50 ±0.01	0.50 (0.50–0.50)	0.50 ±0.01	0.50 (0.50–0.60)	0.60 ±0.10	0.60 (0.60–0.70)	< 0.001[B]
9-HPT	Dominant hand	23.2 ±7.0	21.4 (18.6–25.3)	23.8 ±10.7	20.4 (17.8–25.1)	22.6 ±5.3	21.3 (19.0–24.8)	24.0 ±8.4	21.3 (18.9–27.4)	23.4 ±6.3	23.6 (18.2–27.0)	0.854[C]
	Non–dominant hand	25.0 ±8.1	22.8 (19.6–27.5)	25.2 ±11.3	20.9 (18.1–29.6)	24.0 ±5.9	23.4 (19.4–26.8)	26.3 ±9.3	23.4 (19.9–28.4)	25.4 ±9.7	22.1 (19.4–28.3)	0.725[C]
T25FW (average from 2 attempts)		6.26 ±3.85	5.15 (4.60–6.15)	4.5 ±0.6	4.5 (4.0–4.6)	5.9 ±2.4	4.6 (4.6–6.0)	7.2 ±5.8	5.4 (4.8–6.9)	6.7 ±3.2	5.3 (4.6–6.0)	0.047[C]
Handgrip strength [kG]		55.0 ±20.9	50.3 (43.4–65.0)	51.6 ±7.9	50.6 (44.3–57.1)	50.1 ±17.2	48.1 (41.8–52.9)	60.4 ±27.1	57.4 (43.7–75.6)	63.9 ±21.2	67.8 (46.4–76.9)	0.054[C]
Relative handgrip strength [kG/kg]		0.81 ±0.25	0.82 (0.64–0.99)	1.00 ±0.10	1.00 (1.00–1.10)	0.80 ±0.20	0.80 (0.70–0.90)	0.80 ±0.30	0.80 (0.60–1.00)	0.60 ±0.20	0.60 (0.50–0.80)	< 0.001[B]
EDSS score *n* (%)	< 4	92	80.0	9	75.0	46	83.6	23	71.9	13	86.7	0.501[A]
	≥ 4	23	20.0	3	25.0	9	28.4	9	13.1	2	13.3	

X – arithmetic mean, SD – standard deviation, Me – median, Q – quintile, [A]χ^2 test, [B]Anova, [C]non parametric Anova – Kruskal-Wallis test, post hoc test (NIR): body mass: (1) – (2): p < 0.001, (1) – (3): p < 0.001, (1) – (4): p < 0.001, (2) – (3): p < 0.001, (2) – (4): p < 0.001, (3) – (4): p < 0.001, waist circumference: (1) – (2): p < 0.001, (1) – (3): p < 0.001, (1) – (4): p < 0.001, (2) – (3): p < 0.001, (2) – (4): p < 0.001, (3) – (4): p < 0.001, WtHR: p < 0.001, (1) – (3): p < 0.001, (1) – (4): p < 0.001, (2) – (3): p < 0.001, (2) – (4): p < 0.001, (3) – (4): p < 0.001, relative handgrip strength: : (1) – (2): p < 0.002, (1) – (3): p < 0.001, (1) – (4): p < 0.001, (2) – (4): p < 0.006, (3) – (4): p = 0.036, T25FW (Dunn-Bonferroni): (1) – (3): p = 0.034.

Table 3. Health of the participants with MS

Variables		Total *N* = 115		BMI < 18.5 kg/m² *N* = 12		BMI = 18.5-24.9 kg/m² *N* = 55		BMI = 25.0-29.9 kg/m² *N* = 32		BMI ≥ 30 kg/m² *N* = 16		*P*-value
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Type of MS	Relapsing remitting	102	898.7	11	91.7	48	87.3	29	90.6	14	87.5	0.369[A]
	Secondary progressive	5	4.3	0	0.0	2	3.6	3	9.4	0	0.0	
	Primary progressive	8	7.0	1	8.3	5	9.1	0	0.0	2	12.5	
Comorbidities	Autoimmune	9	**7.8**	1	8.3	3	5.5	4	12.5	1	6.3	0.692[A]
	Hypertension	17	14.7	0	0.0	6	10.9	8	25.0	3	18.8	0.133[A]
	Coronary heart disease	3	2.6	0	0.0	2	3.64	0	0.0	1	6.25	0.524[A]
	Diabetes	6	5.2	0	0.0	2	3.64	4	12.50	0	0.0	0.154[A]
MetS according to IDF (≥ 3 components)		23	20.0	0	0.0	4	7.3	10	31.3	9	56.3	0.002[A]
Number of MetS components	0	28	24.4	9	75.0	19	34.6	0	0.0	0	0.0	< 0.001[A]
	1	35	30.4	2	16.7	20	36.4	8	25.0	5	31.2	
	2	29	25.2	1	8.3	12	21.8	14	43.8	2	12.5	
	3	15	13.0	0	0.0	3	5.5	6	18.8	6	37.5	
	4	6	5.2	0	0.0	0	0.0	3	9.4	3	18.8	
	5	2	1.8	0	0.0	1	1.8	1	3.1	0	0.0	
Abdominal obesity		63	54.8	0	0.0	19	34.5	28	87.5	16	100.0	< 0.001[A]
Elevated glucose		21	18.3	0	0.0	5	9.1	10	31.3	6	37.5	0.004[A]
Elevated blood pressure		60	52.2	1	8.3	26	47.3	23	71.9	10	62.5	0.001[A]
Low HDL-cholesterol		12	10.4	1	8.3	4	7.3	4	12.5	3	18.8	0.578[A]
Elevated TG		16	13.9	2	16.7	4	7.3	6	18.8	4	25.0	0.224A
Smoking	Current	21	18.3	2	16.7	8	14.6	8	25.0	3	18.8	0.681[A]
	Former	52	46.4	5	41.7	23	42.6	17	56.7	7	46.4	0.628[A]
	None	58	50.4	5	41.7	27	49.1	20	62.5	6	37.5	0.673[A]
Vit. D supplementation	< 4000 IU	49	42.6	6	50.0	25	45.5	10	31.3	8	50.0	
	≥ 4000 IU	8	7.0	1	8.3	3	5.4	2	6.2	2	12.5	

Table 3. Cont.

Categorised variables	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*P*–value
Vitamin D concentration [ng/ml]	34.7 ±19.2	31.4 (21.0–40.6)	35.8 ±20.9	31.9 (23.0–40.6)	38.6 ±19.9	33.0 (27.0–46.0)	28.7 ±15.2	23.1 (17.0–36.5)	33.1 ±20.9	31.0 (21.4–39.5)	0.112[C]
Biotin concentration [ng/ml]	360.6 ±249.0	264.0 (217.0–386.0)	450.0 ±341.4	274.5 (211.5–742.5)	366.0 ±263.2	259.0 (207.0–386.0)	356.0 ±224.7	276.0 (224.5–400.5)	284.1 ±138.5	251.5 (182.5–	0.608[C]
Systolic blood pressure [mm Hg]	121.1 ±13.4	123.0 (112.0–130.5)	112.1 ±11.0	115.8 (99.8–120.0)	120.7 ±14.1	125.5 (109.0–130.0)	124.2 ±11.6	124.8 (117.8–131.8)	123.3 ±14.1	125.5 (115.8–131.0)	0.054[B]
Diastolic blood pressure [mm Hg]	81.0 ±8.8	81.0 (75.5–86.5)	76.8 ±4.7	77.3 (73.0–80.8)	79.9 ±9.5	80.0 (73.0–85.5)	83.9 ±6.8	84.8 (78.5–87.0)	82.4 ±10.5	83.3 (78.8–89.3)	0.057[B]
Fasting glucose [mg/dl]	92.1 ±12.4	90.0 (85.0–96.0)	84.7 ±6.2	87.5 (78.0–89.0)	88.9 ±7.6	88.0 (84.0–93.0)	98.3 ±17.4	94.5 (87.5–102.0)	96.3 ±11.1	95.5 (88.5–100.0)	< 0.001[C]
HDL-cholesterol [mg/dl]	62.7 ±12.4	64.0 (54.0–71.0)	69.8 ±15.3	66.5 (57.0–83.0)	64.4 ±13.1	64.4 (56.0–73.0)	60.2 ±12.5	60.0 (53.0–70.0)	56.1 ±9.6	55.0 (48.0–65.0)	0.020[B]
TG [mg/dl]	96.6 ±44.5	85.0 (64.0–113.0)	76.9 ±21.4	80.0 (58.5–94.0)	89.8 ±42.8	82.0 (58.0–117.0)	103.0 ±46.2	90.0 (78.5–111.0)	121.8 ±49.2	108.0 (92.5–154.0)	0.012[C]

X – arithmetic mean, SD – standard deviation, Me – median, Q – quintile, [A]χ^2 test, [B]Anova, [C]non-parametric Anova – Kruskal-Wallis test, post hoc test (NIR): HDL: (1) – (3): p = 0.029, (1) – (4): p = 0.006, TG: (Dunn-Bonferroni): (1) – (4): p = 0.033, (2) – (4): p = 0.033.

with the exception of HDL-cholesterol. These comorbidities are known to be caused by high adiposity [30, 31]. Sicras-Mainar *et al*. found that in a group of patients with MS from Spain, 31.1% had MetS, while 31.1% had dyslipidaemia and 23.0% had hypertension [32]. The prevalence of these disorders was slightly lower in our study group, which is probably due to a 10% lower share of participants with obesity. However, it should be noted that as many as 48.7% of all the participants had at least 2 components of MetS. This means that the disorders occurred more often than the prevalence of an overweight and obese condition alone would imply, which is consistent with the findings of other authors [17]. The presence of comorbidities in patients with MS may be related to a delayed diagnosis and could have a major effect on the course and treatment of the disease, as well as on the patients' degree of disability and their quality of life [33]. According to the literature, the risk of non-MS-related hospitalisation in patients with at least one comorbidity was twice as high as in those without any comorbidities [32].

The results of some studies indicate that supplementation with vitamin D may counteract its insufficiency in patients with MS and could help to maintain a beneficial profile of anti-inflammatory cytokines [34]. Among the participants in our study, the overweight and obese individuals showed a significantly lower vitamin D concentration compared to the normal-weight individuals, despite the lack of corresponding differences in the use of supplementation. This was probably due to the fact that obesity usually leads to a decreased bioavailability of vitamin D because its active form is stored and degraded in the adipose tissue [35]. Biotin is a vitamin that is engaged in the synthesis of myelin. Research suggests that a high dosage of biotin may alleviate the related disability and delay the progress of MS. However, the condition of some patients worsened following a biotin intake, as measured with the EDSS [36, 37]. In our study group, the biotin concentration in the serum did not differ depending on the BMI.

The overweight and obese participants ate potatoes significantly more often than the normal-weight participants, and drank tea and coffee and ate other vegetables significantly less often. A low consumption of vegetables is a well-documented risk factor for excessive body mass among the Polish population [38]. Previous studies have also confirmed that a 'traditional-carbohydrate' dietary pattern (DP), which involves a high intake of refined grain products, sugar, sweets, and potatoes, is associated with a higher risk of abdominal obesity and elevated TG concentration, whereas a 'westernised' DP, which involves a high intake of sugary drinks, was correlated with hyperglycaemia [39]. The results of some studies indicated that higher coffee and tea consumption is related to a lower risk of MetS [40–42]. These studies have found that coffee polyphenols, have many anti-

Table 4. Frequency of consumption of foods in participants with MS

Variable	Total *N* = 115		BMI < 18.5 kg/m² *N* = 12		BMI = 18.5–24.9 kg/m² *N* = 55		BMI = 25.0–29.9 kg/m² *N* = 32		BMI ≥ 30 kg/m² *N* = 16		*P*-value[c]
	X ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	
White bread and bakery products	0.89 ±0.68	1.00 (0.50–1.00)	0.69 ±0.55	0.50 (0.32–1.00)	0.93 ±0.72	1.00 (0.50–2.00)	0.93 ±0.67	1.00 (0.50–1.00)	0.84 ±0.72	1.00 (0.50–2.00)	0.791
Wholemeal bread	0.44 ±0.55	0.14 (0.06–0.50)	0.18 ±0.32	0.03 (0.00–0.28)	0.46 ±0.60	0.14 (0.06–0.50)	0.45 ±0.52	0.50 (0.06–0.50)	0.57 ±0.56	0.50 (0.10–1.00)	0.048
White rice, pasta, fine-ground groats	0.30 ±0.23	0.14 (0.14–0.50)	0.34 ±0.20	0.50 (0.14–0.50)	0.30 ±0.26	0.14 (0.14–0.50)	0.30 ±0.21	0.32 (0.14–0.50)	0.31 ±0.20	0.32 (0.14–0.50)	0.780
Buckwheat oats wholegrain pasta	0.31 ±0.38	0.14 (0.06–0.50)	0.26 ±0.37	0.10 (0.03–0.32)	0.40 ±0.47	0.50 (0.06–0.50)	0.23 ±0.2	0.14 (0.06–0.50)	0.20 ±0.26	0.10 (0.06–0.14)	0.158
Fast foods	0.07 ±0.09	0.06 (0.00–0.06)	0.11 ±0.13	0.06 (0.06–0.10)	0.50 ±0.06	0.06 (0.00–0.06)	0.07 ±0.12	0.06 (0.00–0.06)	0.06 ±0.04	0.06 (0.06–0.06)	0.103
Fried foods	0.33 ±0.34	0.14 (0.06–0.50)	0.33 ±0.21	0.50 (0.14–0.50)	0.33 ±0.35	0.14 (0.14–0.50)	0.33 ±0.40	0.14 (0.06–0.50)	0.35 ±0.21	0.50 (0.14–0.50)	0.736
Butter	0.83 ±0.68	0.50 (0.14–1.00)	0.78 ±0.21	0.50 (0.32–1.0)	0.95 ±0.76	1.00 (0.14–2.00)	0.72 ±0.63	0.50 (0.06–1.0)	0.73 ±0.47	0.50 (0.50–1.00)	0.655
Lard	0.06 ±0.15	0.00 (0.00–0.06)	0.05 ±0.14	0.00 (0.00–0.10)	0.06 ±0.16	0.00 (0.00–0.06)	0.08 ±0.16	0.00 (0.00–0.06)	0.03 ±0.04	0.00 (0.00–0.06)	0.556
Margarine or vegetable oils	0.33 ±0.48	0.14 (0.00–0.50)	0.12 ±0.18	0.06 (0.00–0.10)	0.36 ±0.55	0.14 (0.00–0.50)	0.34 ±0.51	0.14 (0.00–0.50)	0.33 ±0.33	0.14 (0.10–0.50)	0.236
Milk	0.46 ±0.57	0.14 (0.06–1.00)	0.46 ±0.60	0.14 (0.06–0.75)	0.51 ±0.61	0.14 (0.06–1.00)	0.45 ±0.59	0.14 (0.06–0.50)	0.38 ±0.41	0.14 (0.06–0.75)	0.961
Fermented milk drinks	0.38 ±0.38	0.50 (0.06–0.50)	0.46 ±0.43	0.32 (0.06–1.00)	0.32 ±0.37	0.14 (0.06–0.50)	0.47 ±0.41	0.50 (0.14–0.50)	0.35 ±0.27	0.50 (0.14–0.50)	0.218
Fresh cheese curd products	0.25 ±0.25	0.14 (0.06–0.50)	0.17 ±0.20	0.06 (0.06–0.32)	0.27 ±0.27	0.14 (0.06–0.50)	0.24 ±0.20	0.14 (0.06–0.50)	0.31 ±0.27	0.14 (0.14–0.50)	0.266
Cheese	0.33 ±0.32	0.14 (0.06–0.50)	0.40 ±0.28	0.50 (0.14–0.50)	0.30 ±0.36	0.14 (0.06–0.50)	0.30 ±0.27	0.14 (0.06–0.50)	0.43 ±0.30	0.50 (0.14–0.50)	0.187
Cured meat/ smoked sausages	0.51 ±0.43	0.50 (0.14–0.50)	0.38 ±0.34	0.32 (0.10–0.50)	0.49 ±0.48	0.50 (0.14–0.5)	0.53 ±0.41	0.5 (0.32–0.5)	0.61 ±0.35	0.50 (0.5–1.0)	0.267
Red meat	0.23 ±0.21	0.14 (0.06–0.50)	0.23 ±0.20	0.14 (0.06–0.50)	0.20 ±0.20	0.14 (0.06–0.50)	0.29 ±0.24	0.14 (0.06–0.50)	0.25 ±0.21	0.14 (0.14–0.50)	0.309
White meat	0.37 ±0.24	0.50 (0.14–0.50)	0.47 ±0.10	0.50 (0.50–0.50)	0.38 ±0.27	0.50 (0.14–0.50)	0.33 ±0.24	0.50 (0.10–0.50)	0.37 ±0.20	0.50 (0.14–0.50)	0.192
Fish	0.16 ±0.22	0.14 (0.06–0.14)	0.13 ±0.13	0.10 (0.06–0.14)	0.20 ±0.30	0.14 (0.06–0.14)	0.14 ±0.12	0.14 (0.06–0.50)	0.10 ±0.05	0.10 (0.06–0.14)	0.786

Table 4. Cont.

Variable	Total *N* = 115		BMI < 18.5 kg/m² *N* = 12		BMI = 18.5–24.9 kg/m² *N* = 55		BMI = 25.0–29.9 kg/m² *N* = 32		BMI ≥ 30 kg/m² *N* = 16		*P*-value[c]
	X ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	*X* ± SD	Me (Q1–Q3)	
Eggs	0.35 ±0.31	0.14 (0.14–0.50)	0.35 ±0.28	0.32 (0.14–0.50)	0.34 ±0.29	0.14 (0.14–0.50)	0.37 ±0.38	0.50 (0.14–0.50)	0.33 ±0.27	0.32 (0.10–0.50)	0.994
Legume-based foods	0.11 ±0.13	0.06 (0.06–0.14)	0.12 ±0.13	0.06 (0.06–0.14)	0.10 ±0.13	0.06 (0.06–0.06)	0.13 ±0.15	0.06 (0.06–0.14)	0.10 ±0.12	0.06 (0.06–0.14)	0.610
Potatoes	0.42 ±0.30	0.50 (0.14–0.50)	0.27 ±0.21	0.14 (0.14–0.50)	0.41 ±0.36	0.50 (0.14–0.50)	0.44 ±0.2	0.50 (0.50–0.50)	0.53 ±0.27	0.50 (0.50–0.50)	0.050
Fruit	0.94 ±0.64	1.00 (0.50–1.00)	1.05 ±0.75	0.75 (0.50–2.00)	1.00 ±0.66	1.00 (0.50–2.00)	0.91 ±0.65	0.50 (0.50–1.00)	0.47 ±0.46	0.50 (0.50–1.00)	0.593
Vegetables	0.93 ±0.63	0.50 (0.50–1.00)	0.96 ±0.66	0.50 (0.50–1.50)	1.05 ±0.66	1.00 (0.50–2.00)	0.88 ±0.63	0.50 (0.50–1.00)	0.61 ±0.44	0.50 (0.50–0.50)	0.049
Sweets	0.46 ±0.47	0.50 (0.14–0.50)	0.69 ±0.55	0.50 (0.32–1.00)	0.47 ±0.52	0.50 (0.06–0.50)	0.41 ±0.43	0.32 (0.06–0.50)	0.39 ±0.25	0.50 (0.14–0.50)	0.300
Instant soups or ready-made soups	0.02 ±0.04	0.00 (0.00–0.06)	0.02 ±0.04	0.00 (0.00–0.03)	0.01 ±0.03	0.00 (0.00–0.00)	0.02 ±0.04	0.00 (0.00–0.00)	0.05 ±0.05	0.06 (0.00–0.06)	0.056
Tinned (jar) meats	0.03 ±0.06	0.00 (0.00–0.06)	0.03 ±0.04	0.00 (0.00–0.06)	0.02 ±0.03	0.00 (0.0–0.06)	0.04 ±0.09	0.00 (0.00–0.06)	0.03 ±0.03	0.03 (0.00–0.06)	0.346
Tinned (jar) vegetables	0.21 ±0.21	0.14 (0.06–0.50)	0.26 ±0.22	0.14 (0.06–0.50)	0.06 ±0.22	0.06 (0.06–0.5)	0.23 ±0.22	0.14 (0.06–0.50)	0.16 ±0.18	0.14 (0.06–0.14)	0.578
Fruit juices	0.29 ±0.21	0.14 (0.06–0.50)	0.20 ±0.23	0.06 (0.03–0.50)	0.32 ±0.50	0.06 (0.06–0.5)	0.31 ±0.37	0.14 (0.06–0.50)	0.22 ±0.27	0.10 (0.06–0.32)	0.527
Fruit and vegetable juices	0.19 ± 0.30	0.14 (0.00–0.14)	0.10 ±0.19	0.03 (0.00–0.06)	0.21 ±0.37	0.06 (0.0–0.14)	0.21 ±0.22	0.06 (0.06–0.50)	0.18 ±0.27	0.06 (0.06–0.14)	0.170
Tea. Coffee	0.94 ±0.90	1.00 (0.00–2.00)	0.89 ±0.89	0.75 (0.06–2.00)	0.73 ±0.86	0.14 (0.00–2.00)	1.30 ±0.89	2.00 (0.06–2.00)	0.50 ±0.92	1.00 (0.00–2.00)	0.035
Sweetened carbonated or still drinks	0.12 ±0.25	0.06 (0.00–0.06)	0.20 ±0.31	0.06 (0.03–0.28)	0.09 ±0.29	0.00 (0.00–0.06)	0.08 ±0.14	0.06 (0.00–0.06)	0.26 ±0.22	0.14 (0.06–0.50)	< 0.001
Energy drinks	0.02 ±0.06	0.00 (0.00–0.00)	0.06 ±0.14	0.00 (0.00–0.06)	0.01 ±0.03	0.00 (0.00–0.00)	0.02 ±0.04	0.00 (0.00–0.00)	0.02 ±0.04	0.00 (0.00–0.00)	0.208
Water	1.52 ±0.74	2.00 (1.00–2.00)	1.63 ±0.70	2.00 (1.50–2.00)	1.50 ±0.73	2.00 (1.00–2.00)	1.58 ±0.75	2.00 (1.25–2.00)	1.41 ±0.83	2.00 (0.75–2.00)	0.768
Alcoholic beverages	0.08 ±0.15	0.06 (0.00–0.06)	0.07 ±0.06	0.06 (0.03–0.14)	0.08 ±0.15	0.06 (0.00–0.06)	0.10 ±0.19	0.06 (0.00–0.06)	0.08 ±0.12	0.06 (0.03–0.06)	0.800

X – arithmetic mean, SD – standard deviation, Me – median, Q – quintile, [A]χ^2 test, [B]Anova, [C]non-parametric Anova-Kruskal-Wallis test, post hoc test (Dunn-Bonferroni): wholemeal (brown) bread: (1) – (4): p = 0.045, potatoes: (1) – (4): p = 0.047, tea. coffee: (2) – (3): p = 0.031, (2) – (4): p = 0.033, sweetened carbonated or still drinks: (1) – (4): p < 0.001, (2) – (4): p < 0.001, (3) – (4): p = 0.009.

Table 5. Physical activity and sleep duration

Variable		Total *N* = 115		BMI < 18.5 kg/m² *N* = 12		BMI = 18.5–24.9 kg/m² *N* = 55		BMI = 25.0–29.9 kg/m² *N* = 32		BMI ≥ 30 kg/m² *N* = 16		*P*-value
		X ± SD	Me (Q1–Q3)	X ± SD	Me (Q1–Q3)	X ± SD	Me (Q1–Q3)	X ± SD	Me (Q1–Q3)	X ± SD	Me (Q1–Q3)	
Physical activity [MET-min/week]		2057.2 ±2021.0	1440.0 (693.0–2676.0)	1722.6 ±1717.8	1384.5 (348.5–2779.5)	1699.0 ±5106.7	693.0 (0.0–1580.0)	1522.5 ±1848.2	891.0 (0.0–2394.0)	2752.2 ±3082.7	879.8 (0.0–1260.0)	0.824[C]
Sitting time [min/week]		2273.6 ±1318.4	2100.0 (1260.0–3360.0)	2001.4 ±1779.3	2520.0 (35.50–3150.0)	1308.0 ±1533.3	420.0 (0.0–2520.0)	1167.4 ±1657.4	560.0 (0.0–1680.0)	919.3 ±1075.6	840.0 (0.0–1260.0)	0.623[C]
Categorical variables		*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*P*-value
Physical activity categories	Physical inactivity	45	39.1	4	33.3	25	45.5	12	37.5	4	25.0	0.042[A]
	Minimal activity	46	40.0	5	41.7	5	9.0	7	21.9	7	43.8	
	HEPA	24	20.9	3	25.0	25	45.5	13	40.6	5	31.2	
Sleep duration during working days [h/day]	≤ 6	30	26.5	2	16.7	13	24.1	9	29.0	6	37.5	0.760[A]
	6.1–8.9	73	64.6	9	75.0	35	64.8	19	61.3	10	62.5	
	≥ 9	10	8.9	1	8.3	6	11.1	3	9.7	0	0.0	
Sleep duration during weekends [h/day]	≤ 6	18	15.7	1	8.3	7	12.7	5	15.6	5	31.3	0.529[A]
	6.1–8.9	71	61.7	7	58.3	34	61.8	21	65.6	9	56.3	
	≥ 9	26	22.6	4	33.4	14	25.5	6	18.8	2	12.4	

HEPA – health enhancing physical activity, MET – Metabolic Equivalent of Task, X – arithmetic mean, SD – standard deviation, Me – median, Q – quintile, [A]χ^2 test; [B]Anova; [C]non parametric Anova-Kruskal-Wallis test.

oxidant, anti-inflammatory, anti-diabetes, antihypertensive, and other health-promoting properties [42, 43]. Maintaining a normal body weight and a healthy metabolic profile could also result from more intense physical activity (HEPA) in individuals with normal weight [17, 22].

The primary limitation of this study was the relatively small sample size, and the lack of a possibility to calculate the participants' daily calorie intake and a subjective assessment of the physical activity, i.e. using a questionnaire. Furthermore, it should be noted that adiposity is difficult to assess with a good degree of accuracy using the BMI.

Conclusions

The BMI significantly differentiated the health outcomes, functional ability of the lower limbs, and relative hand grip strength, as well as some of the components of lifestyle in the participants with MS. The overweight and obese participants showed a higher prevalence of metabolic disorders than the normal-weight and underweight participants.

The differences in BMI may have at least partially resulted from differences in the dietary patterns and physical activity.

Further research on the lifestyle and the prevalence of metabolic risk factors in patients with MS is necessary to facilitate clinical care and to prevent and delay the deterioration of health, such as by educating the patients about healthy eating and the importance of physical activity.

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Conflict of interest

The authors declare no conflict of interest.

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