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The Mini Nutritional Assessment combined with body fat for detecting the risk of sarcopenia and sarcopenic obesity in metabolic syndrome

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Abstract

Malnutrition is a key factor in metabolic syndrome (MS) and sarcopenia, assessing the nutritional status of these patients is a pressing issue. The purpose of this study was to clarify sarcopenia and sarcopenic obesity in patients with MS based on nutritional status. This was a case–control study between MS/non-MS. Body composition was measured by dual-energy X-ray absorptiometry. Muscle function was assessed by handgrip strength, five times sit-to-stand test, gait speed test and short physical performance battery (SPPB). The Mini Nutritional Assessment (MNA) was performed to assess the nutritional status in the participants in this study. Overall, a total of 56 % and 13 % of participants suffered from possible sarcopenia and sarcopenia, respectively. There was a higher rate of possible sarcopenic obesity in the MS group than in the non-MS group (48·9 % *v.* 24·7 %, $P < 0{\cdot}01$), and all the sarcopenia participants in the MS group had sarcopenic obesity. MNA score was significantly associated with sarcopenia status ($P < 0{\cdot}01$). The MNA combined with body fat score showed better acceptable discrimination for detecting sarcopenic obesity and sarcopenia in MS (AUC = 0·70, 95 % CI 0·53, 0·86). In summary, there was a higher prevalence of possible sarcopenic obesity in MS, and all the MS patients with sarcopenia had sarcopenic obesity in the present study. We suggest that the MNA should be combined with body fat percentage to assess the nutritional status of MS participants, and it also serves as a good indicator for sarcopenia and sarcopenic obesity in MS.

Keywords: **Mini Nutritional Assessment: Sarcopenia: Sarcopenic obesity: Metabolic syndrome: Anthropometry**

Metabolic syndrome (MS) is highly prevalent worldwide and increases the incidence of CVD[1]. The MS global prevalence varied from 12·5 % to 31·4 % according to the definition[2] and increases annually. A report from the National Health and Nutrition Examination Survey indicated that the prevalence of MS in the US adults aged 20 years or older increased from 28 to 37 % during 1999–2018[3]. An increasing prevalence of MS has also been observed in Taiwan. The prevalence of MS was 9·8 % and 13·9 % in men and women, respectively, during 1993–1996, and increased to 39·3 % in men and 30·3 % in women during 2017–2020; in groups aged 45–64 years, 65–75 years and over 75 years, the prevalence of MS was 36·7 %, 58·5 % and 67·0 %, respectively[4]. More than half of the population suffered from metabolic abnormalities in the Taiwanese older population. A high prevalence of MS has become an important public health issue. Insulin resistance in the MS may interfere with muscle utilisation of glucose and protein synthesis in skeletal muscle, thereby affecting muscle function and increasing the risk of sarcopenia[5]. Sarcopenia is a systemic skeletal muscle disorder associated with loss of muscle mass and strength that usually occurs with ageing, and muscle mass may decrease by approximately 6 % per decade after middle age[6,7]. Sarcopenia is a progressive disease that may increase the medical burden of morbidity and mortality on society[8,9]. The body composition changes during ageing, and metabolic disorders and body fat may increase while muscle mass may decrease in patients with MS[5,10], which may lead to sarcopenic obesity in MS.

Sarcopenic obesity is defined as an individual suffering from both sarcopenia and obesity[11]. The prevalence of sarcopenic obesity is increased during ageing[12]. The data from the 1999–2004 National Health and Nutrition Examination Survey showed that the rate of sarcopenic obesity was 12·6 % in men and 33·5 % in women aged ≥ 60 years, and the rate increased to 27·5 % and 48·0 % in men and women, respectively, in those aged over 80 years[13,14]. Sarcopenic obesity serves as a multifaceted metabolic disorder that might worsen simple sarcopenia. Insulin resistance, systemic chronic inflammation and malnutrition in

Abbreviations: MNA, Mini Nutritional Assessment; MS, metabolic syndrome.

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sarcopenic obesity may have cumulative adverse effects on the morbidity and mortality of metabolic diseases[15].

Malnutrition is a key factor for sarcopenia[16,17]. Malnutrition, including undernutrition and overnutrition, and low physical activity may be associated with sarcopenia and sarcopenic obesity[18,19]. Examining the nutritional status of MS patients in clinical or community settings is a pressing issue for dietitians. The Mini Nutritional Assessment (MNA) is a validated nutritional assessment tool and is widely used in community-dwelling older adults[20]. Although MNA is easy to perform, its suitability for examining nutritional status in patients with MS or sarcopenia must be explored. Therefore, we performed the MNA to assess the nutritional status in MS patients and investigated the correlation of nutritional status, anthropometric, metabolic parameters, muscle function and sarcopenia status. Whether the MNA is suitable for assessing nutritional status in MS and whether it can be used to assist in detecting sarcopenia and sarcopenic obesity in MS were also investigated in this study.

Methods

Participants

The present study was designed as a case–control study. We recruited participants with MS and non-MS from the Department of Family and Community Medicine at the Chung Shan Medical University Hospital in Taiwan. MS was diagnosed by the criteria based on the guidelines of Health Promotion Administration (2007)[21]. Participants who had three of the following five characteristics were considered to have MS: (1) abdominal obesity (waist circumference ≥ 90 cm in male and ≥ 80 cm in female); (2) impaired fasting glucose ≥ 100 mg/dl; (3) hypertriacylglycerolaemia (TAG ≥ 150 mg/dl); (4) low HDL-cholesterol < 40 mg/dl in male and < 50 mg/dl in female; and (5) increased blood pressure (systolic blood pressure ≥ 130 mmHg and diastolic blood pressure ≥ 85 mmHg). Participants using antidiabetic, antihypertensive and lipid-lowering medications were also considered to have impaired fasting glucose, increased blood pressure and dyslipidemia, respectively. The exclusion criteria of the participants were as follows: (1) participants who were diagnosed with cancer, severe heart, lung, liver cirrhosis or end-stage chronic kidney disease; and (2) pregnant or lactating. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human participants were approved by the Institutional Review Board of Chung Shan Medical University Hospital, Taiwan (CSMNH No: CS2-20196). Written informed consent was obtained from all patients.

Demographic and anthropometric assessments

The characteristics of the participants, including age, sex, smoking, alcohol use, exercise and medications were collected by questionnaires. A twelve-item Short-Form Health Survey (SF-12) was used to evaluate life quality of all participants[22]. Blood pressure was measured by a digital electronic sphygmomanometer (Hartmann Tensoval® duo control). Height and body weight were measured by a height meter (Jeng-Jyi M-150 L) and a weight scale (Tanita BC-545N) and were used to calculate the BMI (kg/m^2). Waist, mid-arm and calf circumference were measured by a measuring tape. Moreover, DXA (Hologic, ASY-05119) was used to measure total lean mass, skeletal muscle mass percentage, lean mass index, appendicular skeletal muscle mass index (ASMI), total fat mass, body fat percentage and estimated visceral adipose tissue (Est. Vat).

Blood collection and biochemical measurements

Fasting venous blood specimens were collected in vacutainers with K2-EDTA anticoagulant or without anticoagulant. Plasma and serum samples were prepared for biochemical measurements after centrifugation at 4°C and 3000 rpm for 15 min. The biochemical measurements, including fasting glucose, glycated Hb, lipid profiles (including total cholesterol, HDL-cholesterol and TAG), albumin, creatinine, blood urea nitrogen, glutamic oxaloacetic transaminase and glutamic pyruvic transaminase were measured by an automated chemistry analyser (Beckman Coulter, DXC 800), and the level of high-sensitivity C-reactive protein was measured by an automatic clinical analyser (Hitachi 7600-110).

Nutritional and dietary assessments

The MNA was used to evaluate the nutritional status of the participants[23]. This scale was composed of eighteen questions, including appetite, dietary intake, anthropometric, mobility, mental and psychological conditions, and the patient's self-evaluation. The total score of this scale distinguishes participants between normal nutritional status (≥ 24 points), at risk of malnutrition (17–23·5 points) and malnourished (< 17 points)[23]. Twenty-four-hour dietary recall was used to investigate the dietary intake of the participants, and the subjects' total energy content, carbohydrate, lipid, and protein intake were analysed by the record.

Frailty and muscle function

Frailty was determined by Fried's frailty phenotype criteria. There were five components, including unintentional weight loss, depression, low physical activity, slow gait speed and low handgrip strength. Participants who met three or more criteria were considered frail[24]. Muscle function was assessed using the SARC-F (strength, assistance with walking, rising from a chair, climbing stairs and falls) and SARC-Calf (strength, assistance with walking, rising from a chair, climbing stairs, falls and calf circumference). The SARC-F questionnaire was composed of five components, including strength, assistance walking, rise from chair, climb, and falls, and the SARC-Calf was composed of SARC-F and calf circumference. In addition, muscle strength, strength endurance and physical performance were estimated. Muscle strength was evaluated as handgrip strength by a handgrip dynamometer (TAKEI, TKK-5401), and strength endurance was measured by five times sit-to-stand tests, and 6-m and 6-min gait speed. Furthermore, the short physical performance battery (SPPB) which includes a balance test, gait speed test and five times sit-to-stand tests was used to assess the physical performance of all participants[25].

British Journal of Nutrition

Sarcopenia was diagnosed according to the AWGS criteria[26]. The participants who met any of the indicators, such as low ASMI (ASMI < 7 kg/m^2 in male and < 5·4 kg/m^2 in female), low muscle strength (handgrip strength < 28 kg in male and < 18 kg in female), low physical performance (6-m gait speed < 1 m/sec or five times chair-stand test ≥ 12 s or SPPB ≤ 9 points) and low calf circumference (male < 34 cm and female < 33 cm), were considered to have possible sarcopenia[26]. The definition of sarcopenic obesity was the coexistence of sarcopenia and obesity, in which obesity was diagnosed by body fat percentage (male ≥ 25 % and female ≥ 30 %).

Statistical analyses

All statistical analyses were performed using SigmaPlot software (version 12.0). Continuous variables are shown as the mean and standard deviation (median), while categorical variables are shown as percentages. The normality of the distribution of the data was analysed by Shapiro–Wilk test. The differences in continuous variables were examined using Student's t test or the Mann–Whitney U test. The differences in categorical variables were examined by using a χ^2 test or Fisher's exact test. Spearman's rank order correlation coefficient was used to examine the correlations among body composition, metabolic parameters, nutritional status, muscle assessment and sarcopenia status. Receiver operating characteristic was used to evaluate the optimal cut-off value of the nutritional status score for detecting possible sarcopenia, sarcopenic obesity and sarcopenia in MS and non-MS. The results were considered statistically significant at $P < 0·05$.

Results

Demographic data of the participants

A total of 163 participants were enrolled in this study. Ninety participants were MS (male/female = 50/40) and seventy-three participants were non-MS (male/female = 27/46). The characteristics of the participants in the present study are shown in Table 1. Participants in the MS group had a significantly higher male proportion, blood pressure, BMI and waist circumference than those in the non-MS group ($P < 0·05$). It is not surprising that participants in the MS group had a significantly higher hematological data, such as fasting glucose, glycated Hb, lipid profiles (TAG and total cholesterol:HDL-cholesterol ratio) and high-sensitivity C-reactive protein levels than non-MS participants ($P < 0·05$). With regard to nutritional and dietary assessments, participants in the MS group had significantly lower values for MNA plus abdominal obesity score ($P < 0·01$) and protein intake of total energy content ($P = 0·01$) than those in the non-MS group. However, there was no significant difference in lifestyle or frailty scores between the two groups.

Anthropometric and muscle function assessments

Table 2 shows the muscle mass and endurance assessment. Participants with MS had a significantly higher mid-arm circumference, total fat mass, body fat and Est. VAT area, but a lower total lean mass:total fat mass ratio and skeletal muscle mass than the non-MS group ($P < 0·01$). In addition, male participants in the MS group had significantly higher values for calf circumference ($P < 0·01$), total lean mass ($P = 0·02$) and lean mass index ($P < 0·01$), whereas female participants had a significantly higher android:gynoid ratio ($P < 0·01$) and lower 6-min gait speed ($P = 0·04$) in the MS group than in the non-MS group.

With regard to sarcopenia status, 55·6 % and 11·1 % of participants in the MS group suffered from possible sarcopenia and sarcopenia, respectively. There was a significantly higher proportion of possible sarcopenic obesity in the MS group than in the non-MS group (48·9 % *v.* 24·7 %, $P < 0·01$). The proportion of sarcopenia was not significantly different between the two groups (11·1 % *v.* 15·1 %, $P = 0·61$), but participants with sarcopenia in the MS group were all sarcopenic obese.

Correlations between anthropometric, muscle function assessment, metabolic parameters and nutritional status

The correlations between body composition, muscle function, metabolic parameters and nutritional status are shown in Table 3. Calf circumference, total lean mass/total fat mass ratio, skeletal muscle mass, body fat, lean mass index, ASMI, Est. VAT area and android:gynoid ratio were significantly correlated with waist circumference, MS, abdominal obesity, nutritional assessment score and muscle status (Table 3, $P < 0·05$).

Nutritional assessment score in detecting possible sarcopenia, sarcopenic obesity and sarcopenia

We performed receiver operating characteristic analyses to confirm the validity of nutritional assessment scores for detecting possible sarcopenia, sarcopenic obesity and sarcopenia (Table 4). The MNA + body fat score showed an acceptable discrimination for detecting sarcopenic obesity and sarcopenia in the MS group (AUC = 0·70, 95 % CI 0·53, 0·86), and the optimal cut-off value of MNA + body fat score was 23·75 (sensitivity 90·00 %, specificity 58·75 % and Youden's index 0·49). In the non-MS group, MNA and MNA + abdominal obesity scores showed acceptable discrimination for detecting sarcopenic obesity and sarcopenia, but MNA + body fat scores showed excellent discrimination for detecting sarcopenic obesity (AUC = 0·90, 95 % CI 0·82, 0·98) and sarcopenia (AUC = 0·84, 95 % CI 0·69, 0·98). The optimal cut-off value of MNA + body fat score for detecting sarcopenic obesity and sarcopenia was 22·75 (sarcopenic obesity: sensitivity 87·50 %, specificity 83·08 %, Youden's index 0·71; sarcopenia: sensitivity 81·82 %, specificity 85·48 %, Youden's index 0·67).

Discussion

Metabolic disorders may be associated with sarcopenia. A report from the 2009–2010 Korea National Health and Nutrition Examination Survey indicated that participants with MS may have an increased risk of sarcopenia, and the association existed in all age groups[27]. In the present study, we found that 11·1 % of the participants suffered from MS and sarcopenia (Table 2). The rate of sarcopenia in the MS group was similar to that in the non-MS, but we found that the sarcopenia participants in the MS group all had sarcopenic obesity. Regarding muscle function, we

British Journal of Nutrition

Table 1. Demographic data*

	MS (*n* 90)			Non-MS (*n* 73)			
	Means	SD	Medians	Means	SD	Medians	*P*
Age (years)	57·9	14·9	60·0	54·0	17·8	56·0	0·20
Males							
n	50			27			**0·03**
%	56 %			37 %			
Systolic blood pressure (mmHg)	131·1	16·3	128·0	119·1	19·6	116·0	< **0·01**
Diastolic blood pressure (mmHg)	79·5	12·7	80·0	72·8	10·2	74·0	< **0·01**
BMI (kg/m2)	27·9	5·0	27·2	23·2	4·6	22·5	< **0·01**
Waist (cm)							
Male	100·6	11·2	99·0	89·3	12·0	87·0	< **0·01**
Female	91·6	11·9	89·5	80·1	8·5	79·0	< **0·01**
Hematology							
Fasting glucose (mg/dl)	116·9	19·8	113·0	100·3	11·9	98·0	< **0·01**
Glycated Hb (%)	6·2	1·1	6·0	5·6	0·6	5·4	< **0·01**
TAG (mg/dl)	154·3	139·0	121·0	78·0	42·2	69·0	< **0·01**
HDL-cholesterol (mg/dl)							
Male	44·6	11·8	41·6	50·1	10·9	48·2	**0·03**
Female	51·7	13·3	47·4	67·5	13·6	62·3	< **0·01**
Total cholesterol:HDL-cholesterol ratio	4·4	2·6	3·9	3·4	0·9	3·4	< **0·01**
Serum albumin (g/dl)	4·6	0·3	4·5	4·6	0·3	4·6	0·83
Serum creatinine (mg/dl)	0·9	0·3	0·9	0·8	0·2	0·8	0·23
Blood urea nitrogen (mg/dl)	14·9	4·5	14·0	14·1	5·0	14·0	0·22
Glutamic oxaloacetic transaminase (U/L)	24·7	9·1	23·5	27·7	23·5	22·0	0·88
Glutamic pyruvic transaminase (U/L)	30·8	20·6	23·5	25·7	23·8	19·0	< **0·01**
High-sensitivity C-reactive protein (mg/dl)	0·2	0·3	0·1	0·1	0·2	0·1	< **0·01**
	n	%		*n*	%		
Metabolic abnormalities							
Abdominal obesity	78	86·7 %		24	32·9 %		< **0·01**
Hypertension	72	80·0 %		18	24·7 %		< **0·01**
Hyperglycemia	80	88·9 %		31	42·5 %		< **0·01**
Hypertriacylglycerolaemia	67	74·4 %		10	13·7 %		< **0·01**
Low HDL-cholesterol	65	72·2 %		6	8·2 %		< **0·01**
Lifestyle habits							
Smoker (current/ever/non)†	9 %, 3 %, 88 %			16 %, 1 %, 82 %			0·27
Alcohol (current/ever/non)‡	6 %, 2 %/92 %			4 %, 0 %,96 %			0·40
Exercise§	64	71 %		48	66 %		0·57
Nutritional assessment							
MNA score (point)							
Means	26·4		26·5	26·0		26·5	0·82
SD	1·9			2·8			
At risk of malnutrition‖	9	10·0 %		12	16·4 %		0·25
Malnourished¶	0	0 %		1	1·4 %		
	Means	SD		Means	SD		
MNA + abdominal obesity score**	23·8	2·1	24·0	25·0	2·9	25·5	< **0·01**
MNA + body fat score**	23·8	2·2	24·0	24·5	3·0	24·5	0·06
Frailty assessment							
Fried frailty phenotype (point)	0·8	0·8	1·0	0·7	0·8	0·0	0·57
Frailty							
n	1			1			0·08
%	1·1 %			1·4 %			
Life quality assessment							
Physical health score (point)	82·5	12·4	87·5	84·1	12·7	87·5	0·19
Mental health score (point)	91·3	12·2	95·8	87·6	14·7	91·7	0·05
Total health score (point)	173·8	20·9	183·3	171·6	23·4	179·2	0·74
Dietary assessment							
Total energy content (kcal)	1798·0	381·5	1776·0	1728·0	407·2	1675·0	0·26
Carbohydrate (g)	214·4	60·2	216·3	207·9	65·2	207·2	0·51
Carbohydrate of total energy content (%)	48·0	10·0	49 %	48·0	11·0	49 %	0·93
Fat (g)	76·7	25·5	76·0	70·3	23·4	72·3	0·10
Fat of total energy content (%)	38·0	9·0	38 %	37·0	10·0	36 %	0·25
Protein (g)	71·7	22·5	67·4	75·5	21·6	71·4	0·21
Protein of total energy content (%)	16·0	4·0	16 %	18·0	5·0	17 %	**0·01**

MS, metabolic syndrome; MNA, Mini Nutritional Assessment.
Statistical significance values are bolded.
* Means ± SD (medians).
†Current smoker: individuals currently smoking one or more cigarettes per d; ever: quit smoking ≥ 6 months.
‡Current alcohol: individuals regularly drinking one or more alcoholic beverages per d; ever: quit smoking ≥ 6 months.
§Exercise: individuals exercising regularly at least three times every week.
‖At risk of malnutrition: MNA score between 17 and 23·5 points.
¶Malnourished: MNA score less than 17 points.
** The score was MNA score minus 3 points as participates had abdominal obesity or higher body fat (male ≥ 25 %, female ≥ 30 %).

British Journal of Nutrition

Table 2. Anthropometric and muscle function assessment*

	MS (*n* 90)			Non-MS (*n* 73)			
	Means	SD	Medians	Means	SD	Medians	*P*
Muscle mass							
Mid-arm circumference (cm)							
Male	31·2	3·8	30·5	29·0	3·6	29·0	< **0·01**
Female	29·1	3·6	28·0	25·9	3·3	26·0	< **0·01**
Calf circumference (cm)							
Male	40·1	4·7	39·8	37·1	4·1	36·0	< **0·01**
Female	35·8	3·7	36·3	34·2	3·4	34·0	0·05
Total lean mass (kg)							
Male	56·2	10·7	53·8	50·5	8·7	50·0	**0·02**
Female	36·1	6·4	36·0	35·2	6·1	34·6	0·48
Total fat mass (kg)							
Male	24·2	9·4	22·2	17·9	9·2	16·7	< **0·01**
Female	25·0	6·7	26·8	18·0	11·9	15·9	< **0·01**
Total lean mass:total fat mass ratio							
Male	2·5	0·8	2·4	3·3	1·1	3·0	< **0·01**
Female	1·5	0·5	1·4	2·2	0·8	2·0	< **0·01**
Skeletal muscle mass (%)							
Male	67·8	5·2	68·2	71·3	7·1	72·1	< **0·01**
Female	57·4	5·4	57·4	64·1	9·8	64·2	< **0·01**
Body fat (%)							
Male	28·5	5·6	28·2	24·2	6·4	24·2	< **0·01**
Female	39·1	5·8	40·2	30·7	6·5	31·4	< **0·01**
Lean mass index (kg/m2)							
Male	19·5	3·6	18·3	17·4	2·3	17·2	< **0·01**
Female	14·9	2·4	14·3	14·0	2·0	13·8	0·10
ASMI (kg/m2)							
Male	8·7	1·6	8·2	7·9	1·2	7·8	0·05
Female	6·1	1·2	5·7	5·9	1·0	5·6	0·36
Est. VAT area (cm2)							
Male	160·6	56·2	159·5	108·7	39·1	105·0	< **0·01**
Female	142·9	51·0	144·0	78·7	35·1	73·0	< **0·01**
Android:gynoid ratio							
Male	1·4	0·2	1·3	1·3	0·2	1·3	0·11
Female	1·1	0·1	1·0	0·9	0·2	0·9	< **0·01**
Muscle strength and endurance							
Handgrip strength (kg)							
Male	36·3	8·4	36·0	35·9	8·2	34·6	0·86
Female	21·3	4·2	21·7	22·0	4·4	21·7	0·45
Five times sit-to-stand tests (s)							
Male	9·3	2·7	9·0	9·4	4·0	8·8	0·56
Female	10·2	4·3	9·1	9·0	2·8	8·4	0·37
6-m gait speed (m/s)							
Male	1·14	0·19	1·12	1·10	0·26	1·13	0·54
Female	1·04	0·28	1·03	1·15	0·24	1·09	0·08
6-min gait speed (m/sec)							
Male	1·06	0·22	1·05	1·07	0·31	1·08	0·70
Female	0·98	0·22	1·04	1·08	0·23	1·07	**0·04**
SPPB (points)							
Male	11·3	1·7	12·0	11·4	1·6	12·0	0·40
Female	11·1	1·6	12·0	11·6	0·7	12·0	0·28
Low calf circumference (%)	12	13·3 %		18	24·7 %		0·10
Low handgrip strength (%)	20	22·2 %		13	17·8 %		0·62
Low 6-min gait speed (%)	40	44·4 %		28	38·4 %		0·53
Low SPPB (%)	12	13·3 %		3	4·1 %		0·08
SARC-F (point)	0·5	1·1	0·0	0·3	0·7	0·0	0·27
SARC-Calf (point)	1·8	3·9	0·0	2·7	4·7	0·0	0·60
	n	%		*n*	%		
SARC-F ≥ 4 points	4	4·4 %		1	1·4 %		0·50
SARC-Calf ≥ 11 points	3	3·3 %		6	8·2 %		0·31
Sarcopenia status							
Possible sarcopenia	50	55·6 %		41	56·2 %		0·94
Possible sarcopenic obesity†	44	48·9 %		18	24·7 %		< **0·01**
Sarcopenia	10	11·1 %		11	15·1 %		0·61
Sarcopenic obesity†	10	11·1 %		8	11·0 %		0·83

MS, metabolic syndrome; ASMI, appendicular skeletal muscle mass index; Est. Vat, estimated visceral adipose tissue; SPPB, short physical performance battery; SARC-F, strength, assistance with walking, rising from a chair, climbing stairs and falls; SARC-Calf, strength, assistance with walking, rising from a chair, climbing stairs, falls and calf circumference. Statistical significance values are bolded.

* Means ± SD (medians).

†Sarcopenic obesity: patients with sarcopenia and obesity (body fat percentage: male ≥ 25 %, female ≥ 30 %).

Table 3. Correlation between body composition, metabolic parameters and nutritional status

	Calf circumference (cm)	*P*	Total lean mass: total fat mass ratio	*P*	Skeletal muscle mass (%)	*P*	Body fat (%)	*P*	Lean mass index (kg/m2)	*P*	ASMI (kg/m2)	*P*	Est. VAT area (cm2)	*P*	Android: gynoid ratio	*P*
Waist (cm)	**0·68**	< **0·01***	**–0·24**	< **0·01**	**–0·26**	< **0·01**	**0·28**	< **0·01**	**0·70**	< **0·01**	**0·65**	< **0·01**	**0·78**	< **0·01**	**0·59**	< **0·01**
Systolic blood pressure (mmHg)	–0·05	0·51	–0·09	0·28	–0·10	0·19	0·10	0·49	0·11	0·18	0·05	0·51	**0·36**	< **0·01**	**0·27**	< **0·01**
Diastolic blood pressure (mmHg)	**0·22**	< **0·01**	0·02	0·78	0·02	0·80	–0·00	1·00	**0·30**	< **0·01**	**0·27**	< **0·01**	**0·35**	< **0·01**	**0·37**	< **0·01**
Fasting glucose (mg/dl)	0·12	0·12	**–0·18**	**0·03**	**–0·17**	**0·03**	**0·19**	**0·01**	**0·19**	**0·02**	0·13	0·11	**0·39**	< **0·01**	**0·26**	< **0·01**
TAG (mg/dl)	**0·41**	< **0·01**	–0·14	0·07	**–0·17**	**0·04**	**0·18**	**0·02**	**0·35**	< **0·01**	**0·32**	< **0·01**	**0·44**	< **0·01**	**0·36**	< **0·01**
HDL-cholesterol (mg/dl)	**–0·38**	< **0·01**	–0·09	0·27	–0·05	0·50	0·04	0·59	**–0·52**	< **0·01**	**–0·48**	< **0·01**	**–0·44**	< **0·01**	**–0·57**	< **0·01**
Total cholesterol:HDL-cholesterol ratio	**0·26**	< **0·01**	0·03	0·69	0·00	0·99	0·00	0·95	**0·32**	< **0·01**	**0·30**	< **0·01**	**0·22**	< **0·01**	**0·34**	< **0·01**
Metabolic syndrome (%)	**0·33**	< **0·01**	**–0·27**	< **0·01**	**–0·27**	< **0·01**	**0·30**	< **0·01**	**0·31**	< **0·01**	**0·24**	< **0·01**	**0·56**	< **0·01**	**0·34**	< **0·01**
Abdominal obesity (%)	**0·50**	< **0·01**	**–0·44**	< **0·01**	**–0·45**	< **0·01**	**0·46**	< **0·01**	**0·35**	< **0·01**	**0·30**	< **0·01**	**0·60**	< **0·01**	**0·28**	< **0·01**
Hypertension (%)	0·11	0·16	**–0·22**	< **0·01**	**–0·25**	< **0·01**	**0·25**	< **0·01**	**0·20**	**0·01**	0·11	0·15	**0·44**	< **0·01**	**0·21**	< **0·01**
Hyperglycemia (%)	0·00	0·97	–0·09	0·24	–0·06	0·47	0·09	0·26	0·14	0·08	0·09	0·27	**0·28**	< **0·01**	**0·26**	< **0·01**
Hypertriacylglycerolaemia (%)	**0·33**	< **0·01**	–0·02	0·83	–0·01	0·93	0·04	0·58	**0·35**	< **0·01**	**0·32**	< **0·01**	**0·45**	< **0·01**	**0·39**	< **0·01**
Low HDL-cholesterol (%)	**0·22**	< **0·01**	–0·08	0·34	–0·08	0·32	0·10	0·22	**0·26**	< **0·01**	**0·21**	< **0·01**	**0·34**	< **0·01**	**0·25**	< **0·01**
Nutritional assessment (point)																
MNA score	**0·28**	< **0·01**	0·10	0·18	0·09	0·26	–0·08	0·34	**0·27**	< **0·01**	**0·27**	< **0·01**	**0·16**	< **0·05**	**0·30**	< **0·01**
MNA + abdominal obesity score†	–0·02	0·83	**0·30**	< **0·01**	**0·30**	< **0·01**	**–0·29**	< **0·01**	0·05	0·54	0·08	0·30	**–0·18**	**0·02**	0·09	0·24
MNA + body fat score†	**0·17**	**0·03**	**0·43**	< **0·01**	**0·41**	< **0·01**	**–0·42**	< **0·01**	**0·29**	< **0·01**	**0·31**	< **0·01**	–0·09	0·23	**0·24**	< **0·01**
Muscle status																
Low calf circumference (%)	**–0·64**	< **0·01**	0·11	0·16	**0·17**	**0·03**	**–0·16**	< **0·05**	**–0·40**	< **0·01**	**–0·41**	< **0·01**	**–0·41**	< **0·01**	**–0·29**	< **0·01**
Low handgrip strength (%)	**–0·32**	< **0·01**	–0·06	0·44	–0·05	0·49	0·07	0·35	**–0·22**	< **0·01**	**–0·21**	< **0·01**	–0·06	0·42	–0·06	0·42
Low 6-min gait speed (%)	**–0·22**	< **0·01**	–0·04	0·60	–0·10	0·21	0·05	0·50	–0·09	0·28	–0·13	0·11	0·06	0·43	0·06	0·43
Low SPPB (%)	**–0·18**	< **0·01**	–0·06	0·45	–0·07	0·37	0·06	0·43	–0·04	0·62	–0·04	0·58	0·11	0·17	0·11	0·17
Possible sarcopenia	**–0·52**	< **0·01**	–0·15	0·06	–0·11	0·17	0·13	0·09	**–0·36**	< **0·01**	**–0·40**	< **0·01**	–0·11	0·16	**–0·23**	< **0·01**
Sarcopenic obesity	**–0·36**	< **0·01**	**–0·25**	< **0·01**	**–0·26**	< **0·01**	**0·26**	< **0·01**	**–0·46**	< **0·01**	**–0·46**	< **0·01**	–0·11	0·17	**–0·23**	< **0·01**
Sarcopenia	**–0·41**	< **0·01**	**–0·19**	**0·01**	**–0·19**	**0·01**	**0·19**	**0·01**	**–0·48**	< **0·01**	**–0·48**	< **0·01**	–0·15	0·06	**–0·27**	< **0·01**

ASMI, appendicular skeletal muscle mass index; Est. Vat, estimated visceral adipose tissue; MNA, Mini Nutritional Assessment; SPPB, short physical performance battery.
Statistical significance values are bolded.
* Spearman's correlation coefficients (*P* value, *n* 163).
†The score was MNA score minus 3 points as participates had abdominal obesity or higher body fat (male ≥ 25 %, female ≥ 30 %).

Table 4. The optimal cut-off value for nutritional scores to detect sarcopenic obesity and sarcopenia

	MS (*n* 90)					
	AUC	95 % CI	Optimal value	Sensitivity	Specificity	Youden's index
Sarcopenic obesity						
MNA score	0·66	0·48, 0·83	26·75	90·00 %	51·25 %	0·41
MNA + abdominal obesity score*	0·62	0·44, 0·79	23·75	80·00 %	56·25 %	0·36
MNA + body fat score*	**0·70**	**0·53, 0·86**	**23·75**	**90·00 %**	**58·75 %**	**0·49**
	Non-MS (*n* 73)					
	AUC	95 % CI	optimal value	Sensitivity	Specificity	Youden's index
Sarcopenic obesity						
MNA score	0·81	0·69, 0·92	25·75	87·50 %	69·23 %	0·57
MNA + abdominal obesity score*	0·75	0·58, 0·91	24·25	62·50 %	72·31 %	0·35
MNA + body fat score*	**0·90**	**0·82, 0·98**	**22·75**	**87·50 %**	**83·08 %**	**0·71**
Sarcopenia						
MNA score	0·79	0·66, 0·93	25·75	81·82 %	70·97 %	0·53
MNA + abdominal obesity score*	0·73	0·56, 0·90	22·75	54·55 %	87·10 %	0·42
MNA + body fat score*	**0·84**	**0·69, 0·98**	**22·75**	**81·82 %**	**85·48 %**	**0·67**

MS, metabolic syndrome; MNA, Mini Nutritional Assessment.
Statistical significance values are bolded.
* The score was MNA score minus 3 points as participates had abdominal obesity or higher body fat (male ≥ 25 %, female ≥ 30 %).

did not detect a lower muscle strength and endurance in the MS group (Table 2), but we found that body composition rather than physical impairment (muscle strength and endurance) was more related to metabolic abnormalities (Table 3). Most MS with sarcopenia participants suffered from abdominal obesity in the present study. Beavers et al. indicated that MS might be associated with poorer physical performance; however, the association was attenuated after considering body fat mass in the model[28]. Recently, a systematic review and meta-analysis of sarcopenic obesity also found that the risk of sarcopenia was attenuated in elderly individuals with obesity ('obesity paradox')[29]. Similar finding was observed in this study; calf circumference was significantly higher in MS (Table 2), and there was a positive correlation between calf circumference and metabolic disorders (Table 3). It seems that a higher calf circumference in MS may not only imply a higher muscle mass but also a higher body fat. As a result, calf circumference may not be a good indicator for muscle mass assessment in MS patients. Sarcopenic obesity is associated with mortality, metabolic disorders, cognitive impairment and functional limitation[29]. Insulin resistance increases the accumulation of intramyocellular lipid and intermuscular adipocytes, and muscle attenuation in MS, concurrent with sarcopenic obesity[30]. Clarifying body composition, such as body fat and muscle mass, in MS patients is important, and it may not be suitable to use calf circumference or physical performance as traditional methods for screening sarcopenia in MS.

Morphofunctional assessment is a recently proposed method to assess disease-related malnutrition and includes measurements of body composition, muscle function (dynamometers and gait speed) and biochemical markers[31,32]. This new approach might be suitable for patients with MS. In the present study, we measured the biomarkers related to MS and nutritional protein, such as serum albumin and high-sensitivity C-reactive protein, and we found that the level of high-sensitivity C-reactive protein was significantly higher in MS participants, but the level of serum albumin was not significantly different between the two groups (Table 1). Even the participants with possible sarcopenia in the MS group had shown a significantly lower level of albumin than those without possible sarcopenia (data not shown, $P = 0{\cdot}02$), the median value of albumin in the MS was 4·50 mg/dl, and this level seems not low enough to reflect an undernutritional status. Comprehensive assessment can more accurately assess nutritional status in disease states, but in clinical settings, effective (low-cost and time-consuming) methods must be established. In the present study, we used the MNA for nutrition assessment, because compared with other nutritional assessment tools, the MNA has examined dietary status in more detail in the questionnaire. However, we did not find a significant difference in MNA score between the MS and non-MS groups in the present study, and we have noted that MNA uses BMI as a body composition examination in the questionnaire, and the score for this item is increased (3 points) as participants' BMI = 23 or greater. This finding implies that participants with a higher BMI were likely to obtain a higher score on the MNA measurement, and it is unreasonable for obese participants to obtain higher MNA scores to indicate that they are in a normal nutritional state. Therefore, we subtracted the scores (3 points) as participants with abdominal obesity or higher body fat to recalculate the scores, and then we found that the score of the MS group was significantly lower than that of the non-MS group (Table 1). In addition, we found that the MNA score was not only suitable for nutritional status assessment but was also related to muscle mass, muscle function and sarcopenic status (Tables 3 and 4). Our findings are also supported by Liguori et al. who found that the MNA score was related to muscle mass and muscle strength[33]. Therefore, the MNA score may also reflect muscle status in patients.

To understand whether the MNA could detect sarcopenia, we performed receiver operating characteristic analyses (Table 4). Our data indicated that in the participants without MS, the original MNA score showed good discrimination for detecting

sarcopenia and sarcopenic obesity, and MNA combined with abdominal obesity or body fat scores seemed better. However, in the participants with MS, the MNA combined with body fat score was a more suitable indicator for detecting sarcopenia and sarcopenic obesity than the original MNA. After we recalculated the score of MNA considering body fat, the optimal cut-off value was 23·75 to detect sarcopenia or sarcopenic obesity (Table 4), and this new score was lower than 24, which represents that individuals were at risk of malnutrition, more consistent with the original MNA definition. As a result, we suggest that performing the MNA as a nutritional assessment in MS patients should additionally consider body fat status and may also be suitable in detecting the risk of sarcopenia.

Because the definition of sarcopenic obesity is controversial, many indicators could be used to diagnose obesity. Waist circumference, BMI and body fat percentage are the most commonly used indicators to determine obesity. Most participants with MS had a higher waist circumference (86·7 %), and using waist circumference as an indicator of obesity may overestimate the prevalence of sarcopenic obesity in MS patients. BMI is also easily collected anthropometric data in the clinical setting, but body weight presents the total weight for muscle and fat mass. The anthropometric indicator of obesity should clarify the muscle and fat mass separately. Based on the results of our study, we consider that body fat may be a better indicator for sarcopenic obesity in patients with MS in practice.

In this cross-sectional study, we were unable to establish a causal relationship between sarcopenia and MS, but we found that participants in the MS group had lower protein intake (Table 1) and a low score for selected consumption protein food in the MNA questionnaire. Participants with MS appear to be at higher risk for sarcopenic obesity, and an adequate diet strategy for building muscle and losing fat should be further targeted for these groups. The present study provides a preliminary insight into nutritional status, and anthropometric measurements can assist in detecting the risk of sarcopenia. Future studies with larger sample sizes are needed for verification.

Conclusion

Participants with MS showed a higher prevalence of possible sarcopenia, and all the MS patients with sarcopenia were obese. Using the MNA as a nutritional assessment for MS patients, we recommend that the MNA should be combined with anthropometric measurement (body fat percentage), which can also serve as a good indicator of sarcopenia and sarcopenic obesity in MS patients.

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C. H. Y. performed the study and recruited the participants. Y. W. L. and W. J. C. helped perform the study, sample and data analyses. P. T. L. conceived the study, participated in its design and coordinated the study. C. H. Y., Y. W. L. and P. T. L. drafted the manuscript. All authors read and approved the final manuscript.

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British Journal of Nutrition

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