The Relation of body mass index to cognitive functions and fatigue in patients with Multiple Sclerosis in Upper Egypt

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Abstract
Background: Cognitive impairment affects up to 70% of multiple sclerosis (MS) patients, significantly impacting their quality of life.
Objectives: This study examines the relationship between body mass index (BMI), cognitive performance, fatigue, and other clinical characteristics in MS patients in Upper Egypt.
Patients and methods: This cross-sectional study included 50 patients with clinically definite MS diagnosed per the 2017 McDonald criteria. Cognitive performance was assessed using the Symbol Digit Modalities Test (SDMT), California Verbal Learning Test (CVLT), and Brief Visuospatial Memory Test-Revised (BVMT). Fatigue was measured using the Fatigue Severity Scale (FSS). Clinical and demographic data were analyzed using correlation, t-tests, and logistic regression.
Results: Participants had a mean age of 31.06 ± 7.57 years and an average BMI of 24.05 ± 2.40. Higher BMI was significantly associated with poorer cognitive scores: SDMT ($r = -0.812$, $p < 0.001$), CVLT ($r = -0.608$, $p < 0.001$), and BVMT ($r = -0.737$, $p < 0.001$), as well as increased fatigue (FSS, $r = 0.517$, $p < 0.001$). Overweight participants had higher EDSS scores (4.53 ± 1.33 vs. 3.55 ± 1.77, $p = 0.010$) and longer illness duration. Logistic regression identified BMI ($p = 0.021$) and disease duration ($p = 0.004$) as independent predictors of cognitive impairment.
Conclusion: Higher BMI correlates with worse cognitive outcomes, greater fatigue, and increased disability in MS patients, emphasizing the need for targeted weight management as part of comprehensive care strategies.
Keywords: Multiple Sclerosis; Cognitive Impairment; Body Mass Index; Neuroinflammation, Fatigue.
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Introduction

Multiple sclerosis (MS) is a chronic, immune-mediated disease characterized by inflammation, demyelination, and neurodegeneration within the central nervous system (CNS). This complex condition leads to a variety of clinical symptoms, including physical disability, sensory disturbances, and cognitive impairments that affect memory, attention, and information processing speed. Cognitive deficits, reported in up to 70% of MS patients, significantly impact quality of life and daily functioning **(Amato et al., 2019)**. While much research has focused on the pathophysiology of cognitive impairment in MS, there is increasing interest in the potential influence of modifiable risk factors, such as body mass index (BMI).

BMI is an established indicator of body fat that has been linked to various health outcomes, including cardiovascular disease, diabetes, and metabolic syndrome. Emerging evidence suggests that obesity may exacerbate MS pathophysiology through mechanisms involving chronic systemic inflammation and metabolic dysregulation **(Stampanoni Bassi et al., 2020; Lutfullin et al., 2023)**. Obesity can promote pro-inflammatory cytokine production, potentially amplifying the neuroinflammatory processes that characterize MS **(Kim and Yeom, 2022).** However, the impact of BMI on cognitive outcomes in MS is debated. Some studies indicate a clear relationship between higher BMI and impaired cognitive function, associating it with reduced brain volume and poorer performance on cognitive tasks **(Shaker et al., 2020; Benedict et al., 2020).** Conversely, other studies report no significant association, highlighting the heterogeneity of findings and the need for further research **(Ben-Zacharia et al., 2021).**

Given the conflicting results in current literature, this study aims to explore the relationship between BMI and cognitive performance, as well as other clinical characteristics such as disease severity, relapse rate, disability, and fatigue in MS patients. By elucidating these relationships, this study aims to inform more comprehensive and targeted management strategies for individuals with MS.

Patients and methods

Study design and setting

This was a cross-sectional study conducted at the Neuropsychiatry Department of Qena University Hospitals, South Valley University, Egypt.

Study participants

The study included 50 patients diagnosed with clinically definite MS according to the 2017 revised McDonald criteria **(Thompson et al., 2018).** Inclusion criteria were patients aged 18–60 years who were willing to participate in the study. Exclusion criteria included any clinical or radiological findings suggesting diagnoses other than MS, age under 18 or over 60, and the presence of other systemic diseases or long-term treatments for unrelated medical conditions.

Clinical and cognitive assessments

Data collection involved detailed medical histories and neurological examinations using the following tools:

1. **Expanded Disability Status Scale (EDSS)**: A standard scale used to quantify disability in MS, which ranges from 0 (normal neurological exam) to 10 (death due to MS) **(Kurtzke, 1983).**
2. **Brief International Cognitive Assessment for MS (BICAMS)**: A validated cognitive battery for MS, which includes the Symbol Digit Modalities Test (SDMT) to assess information processing speed, the California Verbal Learning Test (CVLT) for verbal memory, and the Brief Visuospatial Memory Test-Revised (BVMT-R) for visual memory **(Langdon et al., 2012).** The Arabic version of BICAMS, which has been validated for use in Arabic-speaking populations, was employed **(Farghaly**

et al., 2021). Cognitive impairment (CI) was assessed using established cutoff values derived from a previously published study by **Khedr et al, 2023**. This study provided validated thresholds for the Symbol Digit Modalities Test (SDMT), California Verbal Learning Test-II (CVLT-II), and Brief Visuospatial Memory Test-Revised (BVMT-R) based on a control group that was matched for age, sex, and educational level to the patient population in our study. Participants were classified as cognitively impaired if their performance fell below 1.5 standard deviations from the mean on at least two of the three tests **(Langdon et al. 2012)**, following the criteria established in the referenced study. This approach allowed us to assess CI reliably without the need to recruit a separate control group

3. **Fatigue Severity Scale (FSS)**: fatigue was assessed using the Fatigue Severity Scale (FSS), a widely used self-reported instrument designed to evaluate the severity and impact of fatigue on various aspects of daily functioning. The FSS consists of nine items, each rated on a 7-point Likert scale, with higher scores indicating greater fatigue severity. The scale has been extensively validated in multiple sclerosis (MS) populations and has demonstrated reliability and sensitivity in detecting fatigue-related impairments **(Krupp et al., 1989)**. Participants were instructed to complete the FSS based on their experiences over the past week. A mean score of ≥4 was used as the threshold for significant fatigue, in line with established guidelines**.**

BMI and additional clinical data

BMI was calculated using the formula: BMI = weight (kg) / height² (m²). Participants were categorized into normal weight or overweight groups based on the World Health Organization's (WHO) cutoff values, where a BMI of 18.5–24.9 kg/m² was considered normal weight, and a BMI of ≥25 kg/m² indicated overweight or obesity **(World Health Organization, 2000)**. Additional clinical data included age at disease onset, disease duration, number of relapses, and MRI findings to confirm MS diagnosis and assess lesion characteristics.

Ethical Code: All participants provided written informed consent, and the study received approval from the institutional ethics committee at the Faculty of Medicine in Qena (SVU-MED-NAP020-1-23-3-579).

Statistical analysis

Descriptive statistics were used to summarize demographic and clinical data. The normality of data distribution was assessed using the Shapiro-Wilk test for all continuous variables. This ensured the appropriate statistical methods were applied based on the distribution of the data. Pearson correlation analysis was conducted to examine the relationships between BMI and clinical or cognitive variables. Independent t-tests were used to compare clinical and cognitive measures between normal BMI and overweight groups. Logistic regression was applied to identify predictors of cognitive impairment, with statistical significance set at $p < 0.05$. Data were analyzed using SPSS version 26 (IBM Corp, Armonk, NY).

Results

The study cohort consisted of 50 individuals with a mean age of 31.06 ± 7.57 years (range: 16–47 years). Females comprised the majority of the sample (70%), while males made up 30%. Regarding marital status, 58% were married, 34% single, and 8% divorced. An average educational attainment of 10.06 ± 4.81 years (range: 0–16 years). The average Expanded Disability Status Scale (EDSS) score was 3.88 ± 1.69 (range: 1–7), indicating moderate disability levels across the sample. Body mass index (BMI) averaged 24.05 ± 2.40 (range: 19.83–27.96), and participants had been affected

by their condition for an average of 58.58 ± 54.75 months (range: 4–228 months). The age of disease onset was 25.74 ± 7.16 years (range: 14–45 years), and the cohort had experienced an average of 3.60 ± 2.50 relapses (range: 1–10). Cognitive performance scores varied widely, with an average Symbol Digit Modalities Test (SDMT) score of 27.56 ± 11.65, California Verbal Learning Test (CVLT) score of 40.66 ± 12.56, and Brief Visuospatial Memory Test (BVMT) score of 15.96 ± 6.55 (**Table.1**).

Table 1. Demographic and Clinical Characteristics of the Study Cohort

Variables		N	Mean ± SD / Frequency	Range / Percentage
Age		50	31.06 ± 7.57	(16 - 47)
Sex	**Male**	50	15	(30%)
	Female		35	(70%)
Years of Education		50	10.06 ± 4.81	(0 - 16)
EDSS Score		50	3.88 ± 1.69	(1 - 7)
Body Mass Index		50	24.05 ± 2.40	(19.83 - 27.96)
Duration of Illness		50	58.58 ± 54.75	(4 - 228)
Age of Onset		50	25.74 ± 7.16	(14 - 45)
Total Number of Attacks		50	3.60 ± 2.50	(1 - 10)
SDMT		50	27.56 ± 11.65	(9 - 52)
CVLT		50	40.66 ± 12.56	(20 - 74)
BVMT		50	15.96 ± 6.55	(6 - 28)
FSS m		50	4.47 ± 1.55	(1 - 6.56)

EDSS (Expanded Disability Status Scale), BMI (Body Mass Index), SDMT (Symbol Digit Modalities Test), CVLT (California Verbal Learning Test), BVMT (Brief Visuospatial Memory Test), and FSS m (Fatigue Severity Scale mean score).

Clinical characteristics

Most participants (86%) were nonsmokers, while 14% reported current smoking. The first presenting symptoms varied; motor symptoms were the most common (32%), followed by multifocal symptoms (28%), optic neuritis (ON) (18%), brainstem symptoms (8%), and sensory symptoms (8%). Only 6% presented with cerebellar symptoms initially. Recovery after the first relapse was incomplete in 70% of cases, with only 30% experiencing complete recovery.

Clinical evaluations revealed different clinical presentations: 40% exhibited hemiparesis, while 28% showed no weakness. Monoparesis was present in 14% of cases, paraparesis in 8%, and quadriparesis in 10%. Visual impairment was prevalent in 94%, sensory impairments in 86%, cerebellar symptoms in 42%, brainstem symptoms in 30%, and bladder dysfunction in 44%. Spasticity was documented in 12% of cases. Regarding disease-modifying therapy (DMT), 88% were on interferon, 6% on fingolimod, and 6% were untreated. Cognitive impairment was identified in 28% of participants, while 72% were cognitively intact. Regarding body weight, 66% of participants were of normal weight, while 34% were overweight. MRI findings indicated periventricular lesions in 100%, juxtacortical lesions in 88%, brainstem lesions in 46%, and cerebellar lesions in 34%. Lesion enhancement was noted in 22%, and cervical spine involvement was observed in 30% of participants (**Table.2**).

Table 2. Summary of Clinical Evaluations and MRI Findings

Category			Frequency
Marital State	Divorced		4 (8%)
	Married		29 (58%)
	Single		17 (34%)
Smoking	Nonsmoker		43 (86%)
	Smoker		7 (14%)
First Presenting Symptom	Brainstem		4 (8%)
	Cerebellar		3(6%)
	Motor		16 (32%)
	Multifocal		14 (28%)
	ON		9 (18%)
	Sensory		4 (8%)
Recovery After First Relapse	Complete		15 (30%)
	Incomplete		35 (70%)
Clinical evaluation	Weakness	No	14 (28%)
		Hemiparesis	20 (40%)
		Monoparesis	7 (14%)
		Paraparesis	4 (8%)
		Quadriparesis	5 (10%)
	Visual		47 (94%)
	Sensory		43 (86%)
	Cerebellar		21 (42%)
	Brain Stem		15 (30%)
	Bladder		22 (44%)
	Spasticity		6 (12%)
DMT Type	Fingolimod		3 (6%)
	Interferon		44 (88%)
	No treatment		3 (6%)
Cognitive impairment	Impaired		14 (28%)
	Not impaired		36 (72%)
BMI	Normal		33 (66%)
	Overweight		17 (14%)
MRI findings	Juxtacortical Lesions		44 (88%)
	Periventricular Lesions		50 (100%)
	Brainstem Lesions		23 (46%)
	Cerebellar Lesions		17 (34%)
	Enhancement Lesions		11 (22%)
	Cervical spine		15 (30%)

DMT (Disease Modifying Therapies), BMI (Body Mass Index), MRI (Magnetic Resonance Imaging).

Correlation analysis

Correlation analysis revealed significant associations between BMI and clinical variables (**Table.3**). BMI was positively correlated with age ($r = 0.458$, $p = 0.001$), EDSS score ($r = 0.449$, $p = 0.001$), and duration of illness ($r = 0.451$, $p = 0.001$). In contrast, cognitive performance scores were inversely correlated with BMI: SDMT ($r = -0.812$, $p < 0.001$), CVLT ($r = -0.608$, $p < 0.001$), and BVMT ($r = -0.737$, $p < 0.001$). Functional independence, as measured by the Fatigue Severity Scale (FSS), was positively correlated with BMI ($r = 0.517$, $p < 0.001$).

Table 3. Correlation Between BMI and Clinical Variables

Variable	Pearson Correlation	Sig. (2-tailed)
Age	0.458**	0.001
EDSS Score	0.449**	0.001
Duration of Illness	0.451**	0.001
Age of Onset	0.120	0.407
Total Number of Attacks	0.344*	0.014
SDMT	-0.812**	0.000
CVLT	-0.608**	0.000
BVMT	-0.737**	0.000
FSS m	0.517**	0.000

EDSS (Expanded Disability Status Scale), SDMT (Symbol Digit Modalities Test), CVLT (California Verbal Learning Test), BVMT (Brief Visuospatial Memory Test), and FSS m (Fatigue Severity Scale mean score).

Comparative analysis of weight groups

(Table.4) demonstrates significant differences in clinical and cognitive measures. Overweight participants had a significantly higher mean age (35.12 ± 6.08 vs. 28.97 ± 7.48; p = 0.004) and fewer years of education (6.88 ± 5.06 vs. 11.70 ± 3.81; p < 0.001) compared to their normal BMI counterparts. The overweight group also displayed a higher mean EDSS score (4.53 ± 1.33 vs. 3.55 ± 1.77; p = 0.010) and longer illness duration (91.24 ± 67.01 vs. 41.76 ± 38.55 months; p = 0.008). Cognitive impairment was more severe in the overweight group, with significantly lower scores on the SDMT (18.47 ± 7.18 vs. 32.24 ± 10.76; p < 0.001), CVLT (33.18 ± 9.86 vs. 44.52 ± 12.17; p = 0.008), and BVMT (11.24 ± 3.96 vs. 18.39 ± 6.31; p < 0.001).

Table 4. Comparison of Clinical and Cognitive Measures between Normal Weight and Overweight Groups

Variable	Normal Weight (Mean ± SD)	Overweight (Mean ± SD)	P-value
Age	28.97 ± 7.48	35.12 ± 6.08	0.004
Years of Education	11.70 ± 3.81	6.88 ± 5.06	0.000
EDSS	3.55 ± 1.77	4.53 ± 1.33	0.010
Duration of Illness	41.76 ± 38.55	91.24 ± 67.01	0.008
Age of Onset	25.24 ± 7.87	26.71 ± 5.62	0.133
Total Number of Attacks	3.21 ± 2.47	4.35 ± 2.45	0.661
SDMT	32.24 ± 10.76	18.47 ± 7.18	0.000
CVLT	44.52 ± 12.17	33.18 ± 9.86	0.008
BVMT	18.39 ± 6.31	11.24 ± 3.96	0.000

EDSS (Expanded Disability Status Scale), SDMT (Symbol Digit Modalities Test), CVLT (California Verbal Learning Test), BVMT (Brief Visuospatial Memory Test).

Cognitive impairment analysis

(**Table.5**) indicates that participants with cognitive impairment were older (34.43 ± 6.56 vs. 29.75 ± 7.61; p = 0.016) and had fewer years of education (7.71 ± 5.36 vs. 10.97 ± 4.33; p = 0.018) compared to those without impairment. Impaired individuals exhibited a higher EDSS score (4.50 ± 1.23 vs. 3.64 ± 1.79; p = 0.051), longer illness duration (114.21 ± 60.94 vs. 36.94 ± 33.12 months; p < 0.001), and higher BMI (25.99 ± 1.92 vs. 23.29 ± 2.14; p = 0.002). Functional independence was also lower among impaired individuals, as evidenced by a higher mean FSS score (5.27 ± 0.83 vs. 4.16 ± 1.66; p = 0.009).

Table 5. Comparison of Clinical and Cognitive Measures between Cognitively Impaired and Not Impaired Groups

Variable	Not Impaired (N = 36)	Impaired (N = 14)	P-value
Age (Mean ± SD)	29.75 ± 7.61	34.43 ± 6.56	0.016
Years of Education	10.97 ± 4.33	7.71 ± 5.36	0.018
EDSS Score	3.64 ± 1.79	4.50 ± 1.23	0.051
Duration of Illness	36.94 ± 33.12	114.21 ± 60.94	0.000
Age of Onset	26.56 ± 7.52	23.64 ± 5.89	0.022
Total Number of Attacks	2.89 ± 1.97	5.43 ± 2.85	0.065
BMI	23.29 ± 2.14	25.99 ± 1.92	0.002
FSS	4.16 ± 1.66	5.27 ± 0.83	0.009

EDSS (Expanded Disability Status Scale), BMI (Body Mass Index) and FSS (Fatigue Severity Scale).

Logistic regression analysis

Finally, (**Table.6**) identified duration of illness as a significant predictor of cognitive impairment (B = 0.038, p = 0.001, Exp(B) = 1.039). Each additional month of illness increased the odds of impairment by 3.9%. Including BMI as a predictor revealed it to be a significant independent predictor (B = 0.645, p = 0.021, Exp(B) = 1.906), indicating that higher BMI nearly doubled the risk of cognitive impairment. The duration of illness remained significant (B = 0.039, p = 0.004, Exp(B) = 1.040), confirming its independent contribution to predicting cognitive impairment.

Table 6. Logistic regression analysis of cognitive impairment predictors

Variables		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	**Duration of illness**	0.038	0.011	11.200	1	0.001	1.039
	Constant	-3.489	0.901	14.999	1	0.000	.031
Step 2[b]	**Body mass index**	0.645	0.280	5.312	1	0.021	1.906
	Duration of illness	0.039	0.014	8.383	1	0.004	1.040
	Constant	-19.471	7.350	7.018	1	0.008	.000

Discussion

This cross-sectional study evaluated the relationship between body mass index (BMI) and Cognition as well as other clinical data in multiple sclerosis (MS) patients. The analysis revealed higher BMI was inversely correlated with cognitive performance, as shown by lower scores on the SDMT, CVLT, and BVMT. In addition significant positive correlations between higher BMI and age, EDSS score, and illness duration. Additionally, Logistic regression analysis identified both BMI and disease duration as significant independent predictors of cognitive impairment, that highlighting the BMI's role in influencing clinical outcomes of MS. These findings align with previous literatures (need references), which has indicated that elevated BMI correlates with increased disability and poorer cognitive performance in MS patients.

Our findings are supported by multiple studies in the field. **Owji et al. (2019)** reported that higher BMI was associated with poorer cognitive outcomes in MS patients, consistent with the present results. Additionally, **Shaker et al. (2020)** found that elevated BMI negatively impacted cognitive and executive functions, reinforcing our findings of diminished cognitive performance in individuals with higher BMI. Research by **Muñoz Ladrón de Guevara et al. (2022)** on fibromyalgia patients also supports the broader link between BMI and cognitive deficits, particularly in attention and memory domains, suggesting that BMI's impact on cognition may extend across conditions with similar inflammatory profiles.

Contrastingly, **Ben-Zacharia et al. (2021)** found no significant association between BMI and cognitive function in

patients with relapsing-remitting MS, indicating variability that could be attributed to differences in study populations, methodologies, or MS subtypes. This underscores the complexity of BMI's relationship with cognitive function, which may depend on demographic and clinical variables.

Kim and Yeom (2022) provided a nuanced perspective by proposing that the relationship between BMI and cognitive function might be nonlinear. They found that cognitive performance improved up to a certain BMI threshold and declined beyond it, especially among individuals with cardiovascular risk factors. This suggests that cardiovascular and metabolic health must be considered when interpreting results, as these factors can modulate BMI's impact on cognition and overall clinical outcomes.

The negative correlation between higher BMI and cognitive performance in MS can be attributed to several mechanisms: Inflammation and Neurodegeneration: Higher BMI is associated with chronic systemic inflammation, characterized by elevated levels of pro-inflammatory cytokines that can exacerbate the neuroinflammatory processes inherent to MS. This persistent inflammation may impair synaptic plasticity, contributing to cognitive decline, particularly in areas such as attention and memory **(Kim and Yeom, 2022; Muñoz Ladrón de Guevara et al., 2022). Stampanoni Bassi et al. (2020)** emphasized that obesity worsens central inflammation, potentially accelerating neurodegeneration and exacerbating cognitive deficits.

Vascular Contributions and Metabolic Dysregulation: BMI-related metabolic disturbances, including insulin resistance and altered lipid metabolism, can impair cerebral perfusion and contribute to structural brain changes detrimental to cognitive health. Studies have documented the link between higher BMI and reduced gray and white matter integrity, which is crucial for cognitive function **(Shaker et al., 2020).** Obesity-associated blood-brain barrier dysfunction can also facilitate the infiltration of inflammatory mediators, further impacting cognition **(Marrie et al., 2019).**

Neuroprotective Effects at Low BMI: Paradoxically, studies have indicated that extremely low BMI might also be associated with adverse cognitive outcomes due to insufficient neuroprotective lipid reserves. This suggests that maintaining BMI within an optimal range is crucial for cognitive health, avoiding both excess adiposity and extremely low body fat levels.

The clinical implications of these findings emphasize the importance of incorporating weight management strategies into comprehensive MS care. The association between higher BMI and increased disability, as well as poorer cognitive performance, highlights the potential benefits of regular BMI monitoring and targeted interventions such as nutritional counseling and supervised physical activity. These strategies could help mitigate cognitive decline and reduce the overall disease burden, improving patients' quality of life. **Galiano-Castillo et al. (2016)** demonstrated that weight management programs can positively influence both cognitive and functional outcomes, supporting this recommendation.

A multidisciplinary approach involving neurologists, dietitians, and mental health professionals can enhance treatment by addressing the physical and cognitive challenges associated with obesity in MS. Considering comorbid conditions such as diabetes and cardiovascular risk factors, as noted by **Marrie et al. (2019),** can further optimize patient outcomes and support personalized treatment plans.

Limitations of the Study: While this study provides valuable insights into the relationship between BMI and cognitive and clinical outcomes in MS, several limitations must be acknowledged: Cross-Sectional Design: The cross-

sectional nature of the study precludes causal inferences. Longitudinal research is needed to determine whether BMI directly influences cognitive and clinical outcomes over time. Sample Size and Generalizability: The relatively small sample size (N=50) limits the generalizability of the findings. Larger, multi-center studies are needed to validate these results and assess their applicability to various MS subtypes and demographics. Potential Confounding Factors: Factors such as physical activity, medication use, and comorbidities were not fully controlled for, which could have influenced the results. Future studies should include these variables to provide more comprehensive insights. Lack of detailed analysis on the impact of depression, which may influence cognitive performance and fatigue levels in patients. While depression was not a primary focus, its potential role is acknowledged and should be explored in future research to provide a more comprehensive understanding of these factors in multiple sclerosis. Reliance on Self-Reported Data: The use of self-reported assessments for clinical data introduces potential bias. Incorporating objective measures, such as neuroimaging and biomarker analysis, could improve the reliability of future findings.

Recommendation: Longitudinal studies: Tracking BMI changes over time and their impact on cognitive and clinical outcomes would help establish causality and clarify whether BMI is a modifiable risk factor. **Intervention-Based studies**: Clinical trials exploring the effectiveness of weight management programs on cognitive and physical outcomes in MS patients could provide valuable insights into potential treatment strategies. **Mechanistic investigations**: Further studies on the biological pathways connecting BMI, inflammation, and cognitive decline in MS could elucidate the underlying mechanisms, such as inflammatory markers and structural brain changes observed via neuroimaging. **Multi-Factorial analyses**: Research assessing how BMI interacts with genetic predispositions, lifestyle factors, and comorbid conditions could offer a comprehensive understanding of its influence on cognitive and clinical outcomes.

Conclusion

This study highlights the significant association between higher BMI and poorer cognitive and clinical outcomes in MS patients, reinforcing the need to consider BMI as a critical factor in MS management. Integrating weight management into care plans may help mitigate cognitive decline and reduce disease burden. However, further research, particularly longitudinal and intervention-based studies, is needed to confirm these associations and develop effective therapeutic strategies. Understanding the complex interplay between BMI, inflammation, and cognitive function will be essential for advancing comprehensive and personalized care for MS patients.

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