Obesity is Associated With Myelin Oligodendrocyte Glycoprotein Antibody Associated Disease in Acute Optic Neuritis

Hadas Stiebel-Kalish (kalishhadas@gmail.com)

Sackler School of Medicine, Tel Aviv University, Felsenstein Medical Research Center, Sackler School of Medicine, Tel Aviv University, Division of Neuro-Ophthalmology, Rabin Medical Center

Kerstin Rubarth

Charité Universitaetsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt Universität zu Berlin, Institute of Biometry and Clinical Epidemiology, Charitéplatz 1, 10117 Berlin

Karni Blum

Sackler School of Medicine, Tel Aviv University, Felsenstein Medical Research Center, Sackler School of Medicine, Tel Aviv University, Division of Neuro-Ophthalmology, Rabin Medical Center

Alon Tiosano

Sackler School of Medicine, Tel Aviv University, Felsenstein Medical Research Center, Sackler School of Medicine, Tel Aviv University, Division of Neuro-Ophthalmology, Rabin Medical Center

Itay Lotan

Department of Neurology, Rabin Medical Center, Sackler School of Medicine, Tel Aviv University

Mark A. Hellmann

Department of Neurology, Rabin Medical Center, Sackler School of Medicine, Tel Aviv University

Adi Wilf-Yarkoni

Department of Neurology, Rabin Medical Center, Sackler School of Medicine, Tel Aviv University

Omer Bialer

Sackler School of Medicine, Tel Aviv University, Felsenstein Medical Research Center, Sackler School of Medicine, Tel Aviv University, Division of Neuro-Ophthalmology, Rabin Medical Center

Eoin P. Flanagan

Department of Neurology, Laboratory Medicine and Pathology, Center for MS and Autoimmune Neurology, Mayo Clinic, Rochester, MN

Sean J. Pittock

Department of Neurology, Laboratory Medicine and Pathology, Center for MS and Autoimmune Neurology, Mayo Clinic, Rochester, MN

M. Tariq Bhatti

Departments of Ophthalmology and Neurology, Mayo Clinic, Rochester, MN

Tanja Schmitz-Hübsch

Experimental and Clinical Research Center, Max Delbrueck Center for Molecular Medicine and Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu B

Paul Friedemann

Experimental and Clinical Research Center, Max Delbrueck Center for Molecular Medicine and Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu B

Susanna Asseyer

Experimental and Clinical Research Center, Max Delbrueck Center for Molecular Medicine and Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu B

John J. Chen

Departments of Ophthalmology and Neurology, Mayo Clinic, Rochester, MN

Research Article

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Abstract

Background: Optic neuritis (ON) is a frequent presentation of multiple sclerosis (MS), neuromyelitis optica spectrum disorder (NMOSD), and myelin oligodendrocyte glycoprotein-antibody disease (MOGAD) at onset. The pathophysiology underlying these diseases, especially MOGAD, is still being elucidated. While obesity has been reported to potentially be a risk factor for MS, this has not been explored in NMOSD or MOGAD. We aimed to investigate a possible association between obesity (body mass index [BMI] >30 kg/m²) and patients with MOGAD, NMOSD or MS.

Methods: Multicenter non-interventional retrospective data collection from a first ever demyelinating attack of ON in patients subsequently diagnosed with MOGAD, NMOSD or MS between 2005-2020. The following data was collected: age, gender, ethnicity, BMI at disease onset and the etiology of ON after diagnostic work-up. A mixed model analysis was performed to assess the ability of obesity or BMI to predict MOGAD-ON and distinguish MOGAD-ON from NMOSD- and MS-ON. Main outcome measures included BMI in patients with acute ON and subsequent diagnosis of MOGAD, NMOSD or MS.

Results: One-hundred and eighty-three patients were included: 44 with MOGAD, 49 with NMOSD, and 90 with MS. A higher BMI was significantly associated with a diagnosis of MOGAD-ON ($p<0.001$); in MOGAD patients the mean BMI was 31.6 kg/m² (standard deviation (SD) 7.2), while the mean BMI was 24.7 kg/m² (SD 5.3) in NMOSD patients and 26.9 kg/m² (SD 6.2) in MS patients. Mixed effects multionimal logistic regression, adjusted for age and gender with obesity as a binary variable revealed that obesity was associated with a higher odds ratio (OR) of a subsequent MOGAD diagnosis (OR 5.466, 95% CI: [2.039, 14.650], $p = 0.001$) in contradistinction with NMOSD.

Conclusion: This study suggests an association between obesity and MOGAD. Our finding requires further exploration, but could have significant pathophysiologic implications if confirmed in larger prospective studies.

Introduction

Optic neuritis (ON) is one of the most common clinical presentation at disease onset of myelin oligodendrocyte glycoprotein-antibody associated disease (MOGAD), neuromyelitis optica spectrum disorder (NMOSD), and multiple sclerosis (MS)[1,2]. The pathophysiology of these diseases are still being elucidated, especially for MOGAD because it is the newest described entity[3,4]]. Prior studies have suggested that obesity may play a predisposing risk factor for MS[5–7]], but this has not been explored in NMOSD or MOGAD.

In addition, MOGAD-ON can sometimes be mistaken for pseudotumor cerebri because patients can present with severe headaches and bilateral optic disc edema[8–10]]. We serendipitously observed that another common similarity to pseudotumor cerebri is that many MOGAD patients have a high body mass index (BMI) at disease onset. Therefore, the goal of this study was to investigate the hypothesized association between BMI and MOGAD-ON compared to NMOSD-ON and MS-ON.

Patients And Methods

Following institutional review board approval (Israel: RMC-0498-18; USA: 21-001492, Germany: EA1/182/10), data was collected from adult patients (age ≥ 18 years) with first-ever ON between 2005–2020 from the three teaching hospitals (Rabin Medical Center, Israel; Mayo Clinic, Rochester, MN, USA; Charité – Universitätsmedizin Berlin, Germany) who were subsequently diagnosed with MOGAD, aquaporin 4-IgG positive NMOSD (AQP4-IgG + NMOSD) or MS. To prevent bias from steroid-induced weight gain or from other immunotherapy-induced weight-effects and bias from possible weight loss in chronic MS, only patients with a first episode of ON and with no prior demyelination attack were included. Patients in whom BMI data was not available before ON treatment were excluded.

ON was diagnosed based on a combination of at least three of the following clinical findings: decreased visual acuity, pain with eye movement, visual field defect, a relative afferent pupillary defect, changes in color vision, optic disc swelling on fundus examination, and/or compatible magnetic resonance imaging (MRI) findings. Diagnosis of the underlying etiology was performed as part of the clinical routine and documented at follow-up visit respecting diagnostic criteria for MS according to 2017 McDonald criteria[11]], NMOSD according to the 2015 international consensus diagnostic criteria and positive serum AQP4-IgG by cell-based assay[12]], and MOGAD in patients with clinical characteristics consistent with MOGAD and positive serum MOG-IgG using a commercial cell-based assay (Euroimmun AG Lübeck, Germany, Immunology Laboratory, Rabin Medical Center, Euroimmun AG Commercial Kit, and Mayo Clinic Neuroimmunology laboratory). Patients with seronegative NMOSD were excluded.

Overweight and obesity was defined as abnormal or excessive fat accumulation that presents a risk to health. Using the World Health Organizations' criteria, this study defined a BMI over 25 kg/m² as overweight, and over 30 kg/m² as obese (https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight). Age, gender, ethnicity, and BMI were collected from each patient prior to beginning treatment with IVMP and/or other immunotherapy.

Statistical analysis

Demographics were compared between groups with parametric Analysis of Variance (ANOVA) in case of metric variables and chi-squared test in case of categorical variables. To evaluate the BMI differences between the three diseases, a multinomial logistic regression adjusted for BMI, age, and sex, including a random effect for study center was performed. To explore whether obesity was associated with MOGAD and to obtain odds ratios, a mixed model analysis with obesity as a binary variable was performed, again adjusted for age and sex as potential confounders. The reference category for disease was set to AQP4-IgG + NMOSD. To compare the effects of BMI between the study centers, separate multinomial logistic regression models were fitted. Due to the small sample size of the study center in Germany, this was only done with the data from Israel and the USA. A p-value < 0.05 was considered to be statistically significant. Due to the exploratory characteristic of the study, no correction for multiplicity on p-values was applied. Therefore, the results should be considered as exploratory, non-confirmatory. Statistical analyses were

performed using SPSS (IBM Statistics Software, IBM Corporation Version 27, 2021) and R Studio (R Project for Statistical Computing, Version 4.1.0).

Results

One-hundred and eighty three patients were included in this study. The overall mean age at time of ON was 38.89 years (standard deviation (SD) 14.09), 36.6% were male, and the mean BMI was 27.43 kg/m² (SD 6.67). In Israel, 25% (21/84) of the patients were classified as obese, which is comparable to the 27% (3/11) of patients in Germany. The proportion of obese patients in the USA was 34% (30/88). Subsequent etiology for ON was AQP4-IgG + NMOSD in 49 patients (26.8%), MOGAD in 44 patients (24.0%) and MS in 90 patients (49.2%). Table 1 details the mean age, gender and BMI of patients, stratified by ON etiology.

Table 1. Demographic characteristics of patients with first-ever acute optic neuritis (ON) stratified by etiology

	MOGAD **n= 44**	**NMOSD** **n= 49**	**MS** **n=90**	**p-value**
Age at ON onset (years), mean (SD) / median [IQR]	44.48 (14.20) / 45.50 [32.50, 54.00]	41.84 (16.92) / 38.00 [26.00, 54.00]	34.54 (10.72) /32.00 [25.25, 42.00]	<0.001
Female sex, n(%)	27 (61%)	42 (86%)	27 (52%)	<0.001
BMI (kg/m^2), mean (SD)	31.60 (7.15)	24.69 (5.31)	26.89 (6.18)	<0.001
Overweight, n(%)	12 (27.27%)	8 (16.33%)	23 (25.56%)	0.387
Obese, n(%)	23 (52.27%)	8 (16.33%)	23 (25.56%)	<0.001

Abbreviations: MOGAD, myelin oligodendrocyte glycoprotein antibody disease; NMOSD, neuromyelitis optica spectrum disorder; MS, multiple sclerosis; ON, optic neuritis; SD, standard deviation; IQR, interquartile range; N, sample size; BMI, body mass index

The mean (SD) BMI was 31.6 kg/m² (7.2) in the MOGAD group, 26.9 kg/m² (6.2) in the MS group and 24.7 kg/m² (5.3) in the NMOSD group (p<0.001), as depicted in Figure/infographic 1.

Mean (SD) age was 41.84 years (17.0) in NMOSD, 44.84 years (14.2) in MOGAD and 34.54 years (10.7) in MS (p < 0.001). Figure 2 depicts the similar means of BMI between the three cohorts from Israel, the USA and Germany.

All patients were White except for one MOGAD patient who was Black (BMI of 33.5), three NMOSD patients were Black (mean BMI 24.7 kg/m²), one NMOSD patient was Asian (BMI 19.6 kg/m²), one NMOSD patient was American Indian (BMI 26.6 kg/m²) and one NMOSD patient was Hispanic (BMI 29.0 kg/m²).

Mixed effects multionimal logistic regression

In patients with acute ON, obesity was associated with a higher odds ratio (OR) of subsequent MOGAD diagnosis (OR 5.466, 95% CI: [2.039, 14.650], p = 0.001 in contradistinction with NMOSD (Table 2, supplementary material). A higher BMI showed a trend towards a subsequent MS diagnosis following ON (OR 1.1074, 95% CI: [0.998, 1.115], p = 0.056), (Figure 1, Table 2-3, (supplemental material)).

The mixed model analysis adjusted for gender, age and BMI for obtaining the diagnosis MOGAD or MS in reference to NMOSD revealed that the OR for females to be diagnosed as MOGAD and MS was 0.31(95% confidence interval (CI): [0.106, 0.911], p =0.033) and 0.172 (95% CI: [0.066, 0.447], p < 0.001), respectively, in comparison to being diagnosed with NMOSD. Increasing age was negatively associated with the diagnosis of MS in comparison with NMOSD (OR: 0.959, 95% CI: [0.931, 0.988], p = 0.005).

The ethnic variance between the centers and within each diagnosis group, as detailed in the paragraph above, was too low to add ethnicity to the mixed effects model analysis.

The detailed results are shown in Tables 4 and 5 (supplemental material). The OR for BMI in the mixed effects multinomial logistic regression models are 1.190 (MOGAD vs. NMOSD) and 1.074 (MS vs. NMOSD) and are comparable with the fixed effects multinomial logistic regression models using Israel data (OR: 1.182, 1.021 respectively) and USA data (OR:1.281, 1.165 respectively) only.

Discussion

Our study found an association between obesity (BMI ≥ 30 kg/m^2) and the likelihood of MOGAD diagnosis in patients with acute ON. While obesity during adolescence has been reported to be associated with an increased risk of MS[13]], to our knowledge, the association between MOGAD and obesity has not been explored in the past. Obesity is a well-known risk factor in immunological diseases[14,15]]. Potential mechanisms include that levels of vitamin D metabolites are lower in obese people than in people with normal weight as decreased levels of serum 25- hydroxyvitamin D appear to increase MS risk. Furthermore, adipose tissue produces a variety of proinflammatory cytokines, including leptin. Leptin induces proinflammatory Th1-regulated immune responses and reduces regulatory T-cell activity[16]]. Th1-promoting effects of obesity may increase the risk of developing MS, in particular in subjects with a HLA-genetic susceptibility to both MS and obesity[17]].

In our cohort, patients with MS-ON had a higher BMI compared to patients with a NMOSD-related ON. While obesity was associated with a diagnosis of MOGAD, there was only a trend toward obesity among MS patients. This may suggest a relationship between obesity-induced inflammation and a higher risk for MOGAD. If this finding is corroborated in future larger studies and in varying ethnicities, it may uncover a novel pathogenic mechanism in MOGAD. In addition, a heightened awareness of obesity in MOGAD patients may prevent the misdiagnosis of obese patients with severe headaches and bilateral disc edema as harboring pseudotumor cerebri.

Limitations of this study include its retrospective nature and that data was recorded primarily from ON cases from three neuroimmunology tertiary referral centers, which may have caused a bias towards more atypical or severe disease. In addition, patients were predominantly White and therefore our conclusions may not be applicable to other ethnicities. There was not enough ethnicity variance among the centers to include it in the mixed model analysis, but the few Asian, American Indian, Black, and Hispanic patients included in the study did not differ from the average BMI within the respective disease category. BMI data was collected from patients presenting with ON because they were mostly recruited from neuro-ophthalmology clinics. It is expected that the differences in BMI would extend across any presentation of the demyelinating diseases, however, a larger number of patients across with different presentations are required to confirm these findings. Last, we did not assess comorbidities and medication. The main strength of our study is that it results from real-life clinical practice and objectifies a finding from clinical observation within a multicenter study.

Conclusions

Our study suggests that there is an association between obesity and MOGAD in a retrospective study of 183 patients: 44 with MOGAD, 49 with NMOSD, and 90 with MS. A higher BMI was significantly associated with a diagnosis of MOGAD-ON ($p<0.001$); in MOGAD patients the mean BMI was 31.6 kg/m² (standard deviation (SD) 7.2), while the mean BMI was 24.7 kg/m² (SD 5.3) in NMOSD patients and 26.9 kg/m² (SD 6.2) in MS patients. Future prospective investigation of the association between obesity and MOGAD may help shed light on the pathogenic mechanisms of this intriguing disorder.

Declarations

Ethical Approval

Institutional review board approval (Israel: RMC-0498-18; USA: 21-001492, Germany: EA1/182/10) with waiver of patient consent in anonymous retrospective deindentified data collection for Israel and USA, and with written consent for Germany (available upon request).

Consent to Participate

Not applicable

Data availability

Data are available upon reasonable request.

Funding

No funding was procured for this work.

Conflict of Interest

None. No conflict of interest relevant to this study

Author contributions

HSK, SA and JJC collected anonymized patient data, HSK, SA, KR and JJC analyzed the data, KR: statistical analysis, table and figures, HSK, SA, JJC and KR and FP drafted the manuscript All authors participated in interpretation of data and manuscript revisions.

Financial Disclosures

Hadas Stiebel-Kalish: Received speakers honoraria from Roche unrelated to this project.

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Sean Pittock: Dr. Pittock has a patent # 8 889 102 (Application#12-678350) -Neuromyelitis Optica Autoantibodies as a Marker for Neoplasia issued, and a patent # 9 891 219B2 (Application#12-573942) Methods for Treating Neuromyelitis Optica (NMO) by Administration of Eculizumab to an individual that is Aquaporin-4 (AQP4)-IgG Autoantibody positive issued. He has a patent pending for GFAP, Septin 5, MAP1B, KLHL11, PDE10A IgGs as markers of neurological autoimmunity and paraneoplastic disorders. He has consulted for Alexion, Euroimmune, Medimmune/Horizon, Astellas, Genentech/Roche, Sage Therapeutics, Prime Therapeutics. He has received research support from Grifols, Medimmune/Horizon, Genentech/Roche and Alexion. He has received research support from NIH, Guthy Jackson Charitable Foundation, Autoimmune Encephalitis Alliance.

Eoin P. Flanagan: Dr Flanagan has served on advisory boards for Alexion, Genentech and Horizon Therapeutics. He has received speaker honoraria from Pharmacy Times. He received royalties from UpToDate. Dr Flanagan was a site primary investigator in a randomized clinical trial on Inebilizumab in neuromyelitis optica spectrum disorder run by Medimmune/Viela-Bio/Horizon Therapeutics. Dr Flanagan has received funding from the NIH (R01NS113828). Dr Flanagan is a member of the medical advisory board of the MOG project. Dr Flanagan is an editorial board member of the Journal of the Neurological

Sciences and Neuroimmunology Reports. A patent has been submitted on DACH1-IgG as a biomarker of paraneoplastic autoimmunity.

Tanja Schmitz-Hübsch received speakers honoraria Bayer and Biogen.

F. Paul serves as Academic Editor, PLoS ONE, and Associate Editor, Neurology Neuroimmunology and Neuroinflammation; is member of Novartis OCTIMS study steering committee and MedImmune/Viela Bio steering committee; reports speaker honoraria and travel grants from Bayer, Novartis, Biogen Idec, Teva, Sanofi-Aventis/Genzyme, Merck Serono, Alexion, Chugai, MedImmune, Shire, Roche, Actelion, and Celgene and consultancies for Sanofi Genzyme, Biogen Idec, MedImmune, Shire, and Alexion; and received research support from Bayer, Novartis, Biogen Idec, Teva, Sanofi-Aventis/Genzyme, Alexion, and Merck Serono, German Research Council (DFG Exc 257), Werth Stiftung of the City of Cologne, German Ministry of Education and Research (BMBF Competence Network Multiple Sclerosis), EU FP7 Framework Program (combims.eu), Arthur Arnstein Foundation Berlin, The Guthy-Jackson Charitable Foundation, and National Multiple Sclerosis Society of the United States.

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References

1. Jitprapaikulsan J, Chen JJ, Flanagan EP, Tobin WO, Fryer JP, Weinshenker BG, et al. Aquaporin-4 and Myelin Oligodendrocyte Glycoprotein Autoantibody Status Predict Outcome of Recurrent Optic Neuritis. Ophthalmology. American Academy of Ophthalmology; 2018;125:1628–37.
2. Jurynczyk M, Messina S, Woodhall MR, Raza N, Everett R, Roca-Fernandez A, et al. Clinical presentation and prognosis in MOG-antibody disease: a UK study. Brain. 2017;1–11.
3. Spadaro M, Winklmeier S, Beltrán E, Macrini C, Höftberger R, Schuh E, et al. Pathogenicity of human antibodies against myelin oligodendrocyte glycoprotein. Ann Neurol [Internet]. Ann Neurol; 2018 [cited 2022 Jan 31];84:315–28. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/30014603/
4. Dale RC, Tantsis EM, Merheb V, Kumaran RYA, Sinmaz N, Pathmanandavel K, et al. Antibodies to MOG have a demyelination phenotype and affect oligodendrocyte cytoskeleton. Neurol Neuroimmunol neuroinflammation [Internet]. Neurol Neuroimmunol Neuroinflamm; 2014 [cited 2022 Jan 31];1. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/25340056/
5. Mokry LE, Ross S, Timpson NJ, Sawcer S, Davey Smith G, Richards JB. Obesity and Multiple Sclerosis: A Mendelian Randomization Study. PLoS Med [Internet]. PLoS Med; 2016 [cited 2022 Jan

31];13. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/27351487/

6. Guerrero-García JDJ, Carrera-Quintanar L, López-Roa RI, Márquez-Aguirre AL, Rojas-Mayorquín AE, Ortuño-Sahagún D. Multiple Sclerosis and Obesity: Possible Roles of Adipokines. Mediators Inflamm [Internet]. Mediators Inflamm; 2016 [cited 2022 Jan 31];2016. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/27721574/
7. Gianfrancesco M, Barcellos L. Obesity and Multiple Sclerosis Susceptibility: A Review. J Neurol neuromedicine [Internet]. J Neurol Neuromedicine; 2016 [cited 2022 Jan 31];1:1–5. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/27990499/
8. Lotan I, Brody J, Hellmann MA, Bialer O, Ganelin-Cohen E, Michaeli N, et al. Myelin oligodendrocyte glycoprotein-positive optic neuritis masquerading as pseudotumor cerebri at presentation. J Neurol. 2018;265.
9. Narayan RN, Wang C, Sguigna P, Husari K, Greenberg B. Atypical Anti-MOG syndrome with aseptic meningoencephalitis and pseudotumor cerebri-like presentations. Mult Scler Relat Disord. Elsevier; 2019;27:30–3.
10. Biotti D, Bonneville F, Tournaire E, Ayrignac X, Dallière CC, Mahieu L, et al. Optic neuritis in patients with anti-MOG antibodies spectrum disorder: MRI and clinical features from a large multicentric cohort in France. J Neurol. Springer Berlin Heidelberg; 2017;264:2173–5.
11. Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, et al. Diagnosis of multiple sclerosis : 2017 revisions of the McDonald criteria. Lancet Neurol. 2018;17:162–73.
12. Wingerchuk D, MD F, Banwell B, MD F, Bennett J, MD P, et al. International consensus diagnostic criteria for neuromyelitis optica spectrum disorders. [Internet]. Neurology. 2015. p. 177–89. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=yrovftq&NEWS=N&AN=00006114-201507140-00013
13. McKay KA, Jahanfar S, Duggan T, Tkachuk S, Tremlett H. Factors associated with onset, relapses or progression in multiple sclerosis: A systematic review. Neurotoxicology [Internet]. Neurotoxicology; 2017 [cited 2022 Jan 9];61:189–212. Available from: https://pubmed-ncbi-nlm-nih-gov.beilinson-ez.medlcp.tau.ac.il/27045883/
14. Tsigalou C, Vallianou N, Dalamaga M. Autoantibody Production in Obesity: Is There Evidence for a Link Between Obesity and Autoimmunity? Curr Obes Rep [Internet]. Curr Obes Rep; 2020 [cited 2022 Jan 10];9:245–54. Available from: https://pubmed.ncbi.nlm.nih.gov/32632847/
15. Versini M, Jeandel PY, Rosenthal E, Shoenfeld Y. Obesity in autoimmune diseases: not a passive bystander. Autoimmun Rev [Internet]. Autoimmun Rev; 2014 [cited 2022 Jan 10];13:981–1000. Available from: https://pubmed.ncbi.nlm.nih.gov/25092612/
16. Hedström AK, Olsson T, Alfredsson L. High body mass index before age 20 is associated with increased risk for multiple sclerosis in both men and women. Mult Scler J. 2012;18:1334–6.
17. Hedström AK, Lima Bomfim I, Barcellos L, Gianfrancesco M, Schaefer C, Kockum I, et al. Interaction between adolescent obesity and HLA risk genes in the etiology of multiple sclerosis. Neurology. 2014;82:865–72.

Figures

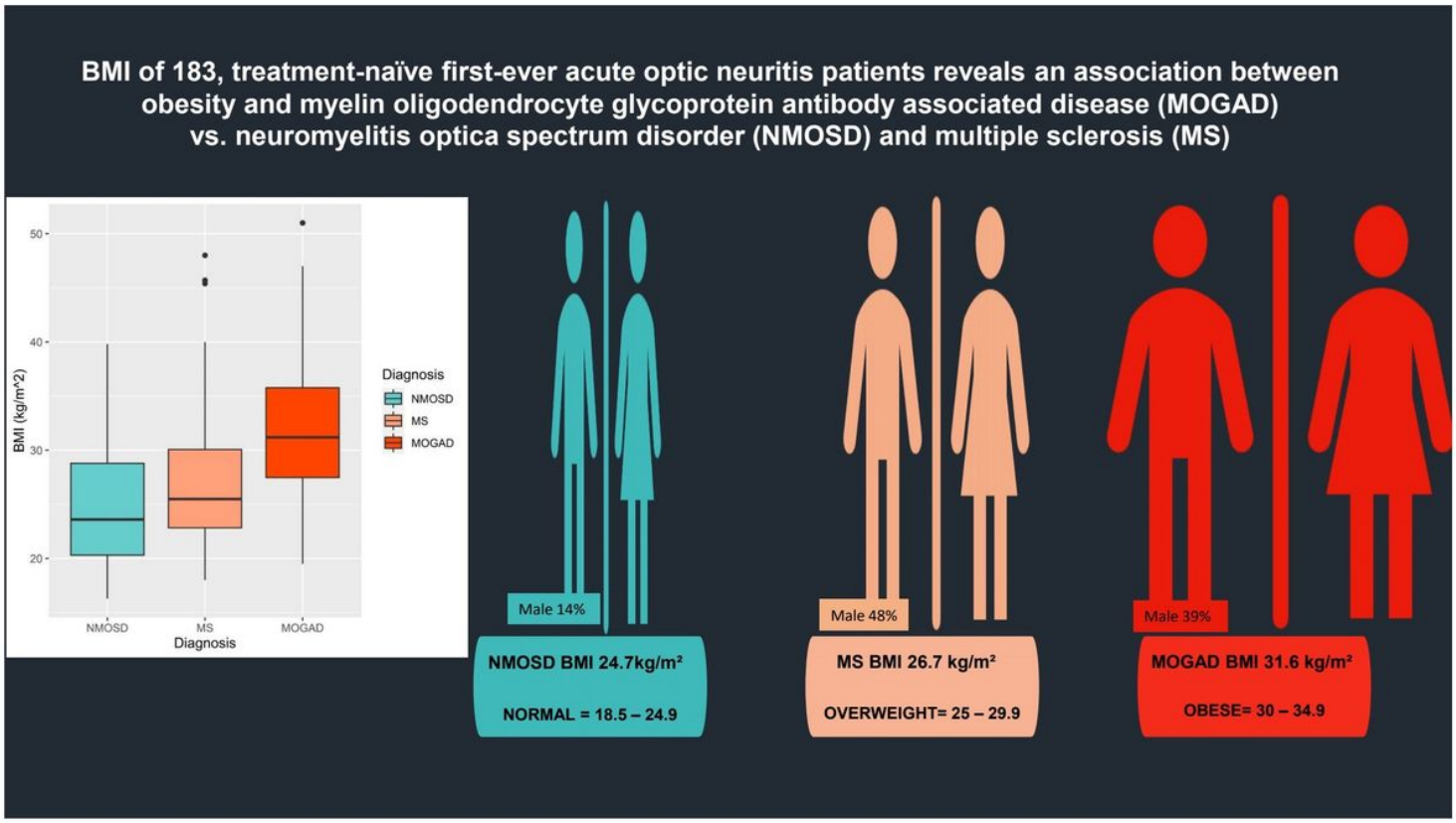

Figure 1

Infographic of body mass index (BMI) at presentation of first-ever acute optic neuritis in patients with myelin oligodendrocyte glycoprotein antibody associated disease (MOGAD), neuromyelitis optica spectrum disorder (NMOSD) and multiple sclerosis (MS). Legends: Plots demonstrating the distribution of BMI by group. The boxplot lines correspond to the 25^{th}, 50^{th} and 75^{th} percentiles. The male symbol represents the percentage of male patients in each group.

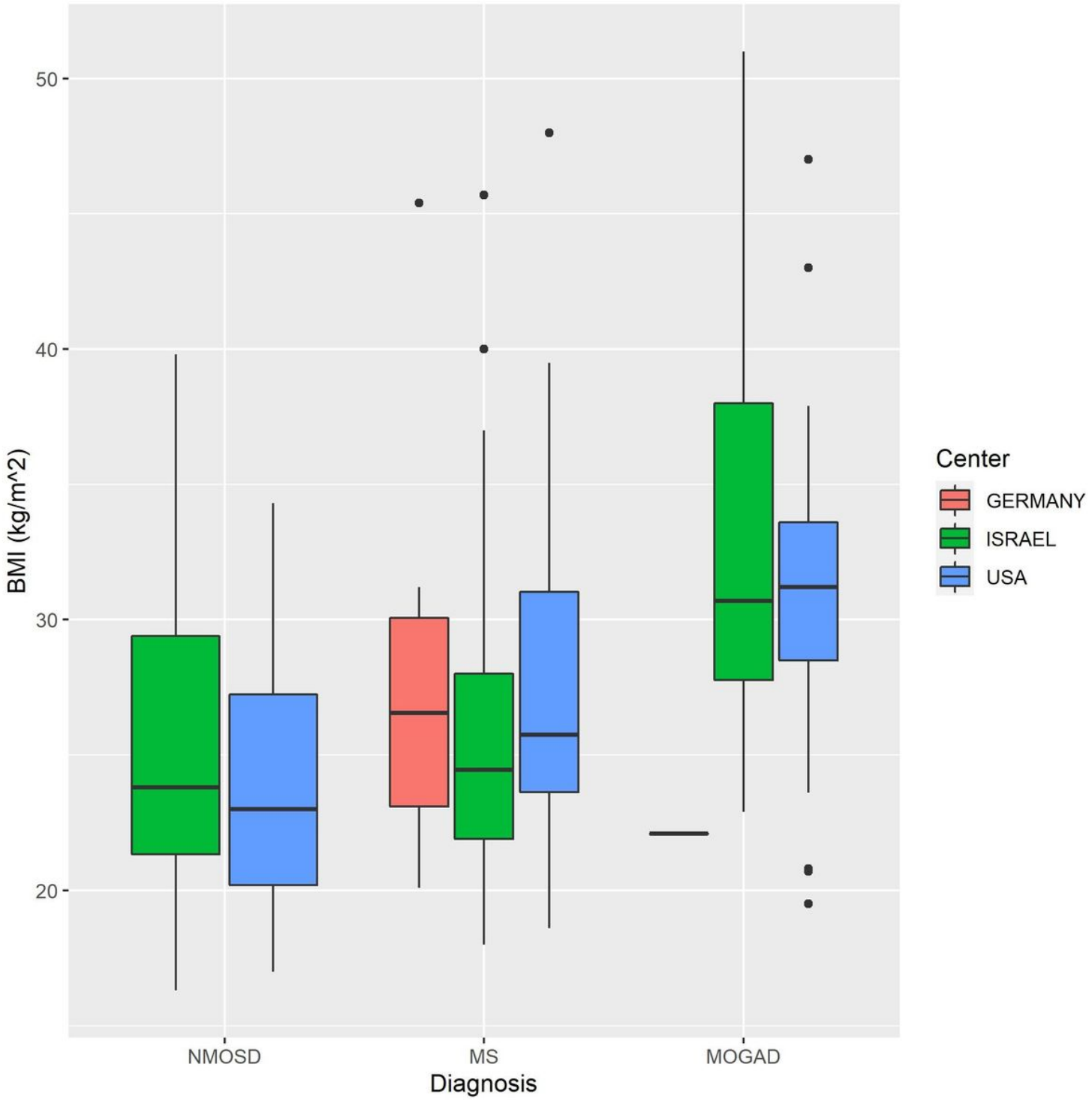

Figure 2

Body mass index (BMI) at presentation of 183 first-ever acute optic neuritis in patients with myelin oligodendrocyte glycoprotein antibody associated disease (MOGAD), neuromyelitis optica spectrum disorder (NMOSD) and multiple sclerosis (MS) is similar in the cohorts from Israel, the USA and Germany.

Legends: Plots demonstrating the distribution of BMI by group. The boxplot lines correspond to the 25th, 50th and 75th percentiles.

Supplementary Files

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