

Latent subtypes of Comorbidities in Multiple Sclerosis patients: Insights from Social Media

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Abstract

Multiple Sclerosis is a chronic neurological disease associated with various physical and cognitive impairments. Individuals with MS might also experience medical and psychiatric comorbidities that can exacerbate the severity of the disease and lower their overall well-being. Therefore, it becomes essential to identify these co-occurring health conditions at the early stages to optimize treatment and improve patient outcomes. Consequently, the objective of this study is to explore the commonly occurring comorbidities among MS patients around the globe from social media discourse. Furthermore, it aims to unveil public perceptions, providing insights that might not be captured via clinical research methods. The results indicate that psychiatric and autoimmune comorbidities are the most prevalent, whereas visual disorders are the least common among MS patients. Understating such patterns can help prioritize and guide interventions aimed at tailoring MS comorbidity management strategies to address the specific needs of MS patients.

Keywords: Multiple Sclerosis, Comorbidities, Social media analytics, Topic analysis, public perception.

1. Introduction

Multiple Sclerosis (MS) is a chronic inflammatory, autoimmune neurodegenerative disease. Patients with MS commonly exhibit a high prevalence of medical and psychiatric comorbid conditions. Comorbidity is an additional disorder coexisting in a person with a given index disease, further complicating the disease (Magyari & Sorensen, 2020). Indeed, comorbidity in MS is associated with increased mortality rates, diagnostic delays, disability progression, and low quality of life, in addition to its impact on treatment options (Marrie, Cohen, et al., 2015).

MS comorbidities with the highest incidence are hypertension, stroke, and cancer, while those with the highest prevalence are depression, anxiety, hypertension,

hyperlipidemia, and chronic lung disease (Marrie, Reider, et al., 2015). Furthermore, studies show that people with MS have an increased occurrence of ischemic heart disease, cerebrovascular disease, peripheral vascular disease, and epilepsy relative to people without MS (Marrie et al., 2023). Comorbidity adversely affects outcomes throughout the disease, including quality of life, progression, and mortality (Marrie, 2017). In addition to comorbidity, genetics, ethnicity, and social determinants of health all influence MS outcomes. Yet, some comorbidities are potentially preventable or treatable, unlike unmodifiable factors such as genetics (Marrie et al., 2023).

Traditional clinical methods often miss the full spectrum of MS comorbidities by focusing on diagnosed conditions and specific intervals, potentially overlooking emerging or less common conditions noticed by patients outside clinical settings (Shah et al., 2018). Moreover, geographic and demographic constraints also limit their generalizability (Murthy et al., 2004). In contrast, patient-generated data from social media offers real-time insights into diverse experiences, revealing comorbidities not captured by traditional methods (Conway & O'Connor, 2016). The Internet and social media provide valuable Patient Generated Information (PGI), facilitating connections and support while allowing users to exchange experiences, opinions, and emotions with others facing similar health challenges (Lavorgna et al., 2017). Although various MS comorbidities have been explored in various traditional research studies, a gap remains in understanding the occurrence of comorbidities in MS patients via digital platforms. Therefore, this study aims to leverage social media discussions to provide an organic approach to capturing MS patients' perspectives and shared experiences regarding comorbidities. The insights gained from this analysis will be instrumental to healthcare providers and clinicians refining their comorbidity management strategies, thereby improving the quality of care and patient outcomes for those with MS.

2. Related work

Several studies have leveraged social media data to explore various aspects related to MS, including lifestyle factors influencing MS, adverse drug events associated with MS treatments, and suitable medications for MS patients during pregnancy and breastfeeding (Gorugantu et al., 2023; Nawar et al., 2022). The application of social media data extends beyond the field of MS, encompassing a broad spectrum of healthcare areas. A study employed a text-mining approach on social media to examine public discourse and emerging trends in malaria (Boit et al., 2020). Similarly, another study identified fourteen themes from social media data related to glaucoma (McGregor et al., 2014). Another research study has explored Twitter to analyze the main themes and misconceptions about antibiotics (Scanfeld et al., 2010). Another study has analyzed the social media data to examine the public concerns, views and health issues pertaining to measles vaccination (Radzikowski et al., 2016). Beyond the healthcare domain, social media analysis has been applied to various other fields. For instance, a study leveraged Twitter data to explore trending topics and themes regarding the experiences concerning the usage of e-cigarettes among marketers and consumers, (Lazard et al., 2016). Another study has analyzed digital platforms to investigate public opinion and the perceived motivations and obstacles associated with smart agriculture (Ofori & El-Gayar, 2019). Despite extensive research on MS comorbidities, traditional clinical data often miss evolving or less common conditions due to its snapshot nature and geographic limitations. This study addresses the gap by analyzing patient-generated data from social media to capture a more comprehensive and real-time perspective on the prevalence and incidence of comorbidities among MS patients globally. Therefore, this study aims to analyze social media data to explore the frequently occurring comorbidities among MS patients worldwide. This analysis will provide valuable insights into the prevalence of MS comorbidities that can assist healthcare providers and clinicians in tailoring their comorbidity management strategies to address the specific needs of MS patients, eventually enhancing the quality of care and patient outcomes.

3. Methodology

This research includes three stages: Data Discovery, Data Collection and Preparation, and Data Analysis. We used Brandwatch, an AI-powered social media analytics tool and consumer intelligence software employed on ReadMe Algorithm, to extract and analyze publicly accessible data (*Brandwatch | The Social Suite of the*

Future, 2021; Hopkins & King, 2010). The goal is to explore insights from user-generated online content.

3.1 Data Discovery

During the data discovery stage, we developed a search query for Brandwatch to retrieve patient-generated social media posts on MS and comorbidities. The query includes numerous phrases aimed at capturing contributors who self-identify as patients. Based extant literature, we grouped the comorbidities into the following categories for further exploration and analysis: autoimmune, cancer, visual disorders, gastrointestinal, neurocardiology, psychiatric, respiratory, and musculoskeletal. Furthermore, we focused on worldwide social media posts written in English from January 1, 2013, to December 31, 2023.

3.2 Data Collection and Preparation

After developing our search query, we used Brandwatch to extract data from various social media platforms, including Online Forums, Twitter, Reddit, and Reviews. Reviews are user-generated feedback on health products, services, and pharmaceuticals, providing insights into the management of comorbidities, including treatment effectiveness and side effects (*Coverage Overview*, 2024). We incorporated phrases such as "I have Multiple Sclerosis" and "I have been living with Multiple Sclerosis" to specifically target content generated by individuals diagnosed with MS and to exclude content from unaffected individuals. Moreover, we included wildcard searches (*) to ensure the capture of a wide variety of relevant terms. For instance, using "cardiac*" as a search term encompassed related terms such as cardiac arrest, cardiac surgery, and cardiomyopathy. We manually examined the collected posts, focusing on notable spikes in tweet volume over specific years. This revealed that a significant number of unrelated posts were being included in the corpus, such as posts mentioning abbreviations like "MS degree," "MS Dhoni," "Microsoft," and "Mississippi", which were subsequently excluded. In addition, posts from Facebook, Instagram, and YouTube were omitted due to their predominantly image or video-based nature. As such, we focused our analysis on platforms that included relevant content. Posts consisting of hyperlinks were flagged as irrelevant and disregarded because they were largely related to research articles, news blogs, and promotional content about treatments, products, and services. This examination aided in refining the data inclusion and exclusion criteria during the initial data discovery phase.

3.3 Data Analysis

The online reviews were analyzed in two phases. Initially, the entire dataset was analyzed to understand users' perception of social media as a tool to exchange knowledge about co-occurring conditions and MS. Next, each comorbidity was analyzed in depth. We explored the prevalence of comorbidities by implementing Word Clouds and Topics Clusters. Topic Clusters are visual representations of relationships between different topics or themes in a dataset. These clusters are used to identify key themes, clusters, phrases, and keywords of related topics within a corpus, to explore the associations between different topics, and to aid in navigating and discovering relevant information within complex datasets. In the Topic Cluster graph, each node represents a concept or a topic, and the edges represent relationships or connections between these topics. These relationships are formed depending on various factors, including semantic similarity, co-occurrence of terms in documents, or alternative relevance metrics. Overall, topic cluster graphs provide a visual and intuitive way to explore and understand the structure of textual data, making it a valuable tool for demonstrating information organization, document summarization, and content recommendation (Topic Clusters, 2023).

4. Results

We extracted 24,826 posts between January 1st 2013 to December 31st, 2023. Further, we applied the rules and categorized the entire corpus into various subtypes of comorbidities – Autoimmune, Cancer, Visual disorders, Gastrointestinal, Neurocardiology, Psychiatric, Respiratory and Musculoskeletal. Most of the posts were from Online Forums (51%), followed by Reddit (25%) and then by Twitter and Reviews, accounting for 22% and 2%, respectively. In addition, the majority of

retrieved posts came from three key online forums: healthunlocked.com (18%), msworld.org (15%), and medhelp.org (13%). Most of the review data primarily came from sites such as drugs.com (18%), google.com (16%), trustpilot.com (15%), and vitals.com (10%). Moreover, investigating the demographics of the authors highlights that 78% of the posts about MS and comorbidities were generated by females, and only 22% of the posts were generated by males. Most of the gender data we obtained came from Twitter, with smaller contributions from online forums as well. Not all posts on these platforms included gender information, we could only analyze posts where gender was publicly available and linked to the user's account. Moreover, the results from the distribution of online posts over the pre-identified comorbid categories, demonstrated that 31% of the total posts discussed the presence of Psychiatric comorbidities along with MS, followed by Autoimmune comorbidities accounting for 25% of the total posts. The least discussed comorbidity in MS patients appears to be visual disorders, representing only 2% of the total posts. The remaining comorbidities include – cancer (12%), musculoskeletal issues (11%), gastrointestinal problems (8%), neurocardiology conditions (6%) and respiratory ailments (5%). We conducted further analysis on the volume of posts by MS patients over time for each comorbidity, as demonstrated in Figure 1, and observed a notable surge in posts related to respiratory comorbidities in 2020, likely attributed to the COVID-19 pandemic. Similarly, there was a significant increase in post volume that is associated with neurocardiology comorbidities in 2021, potentially influenced by discussions about the impact of COVID-19 vaccines on cardiovascular health, as highlighted in numerous studies (Vosko et al., 2023). Figure 2 represents the distribution by gender. Men more frequently discussed psychiatric comorbid conditions, whereas the highest percentage of the women mentioned autoimmune comorbidities.

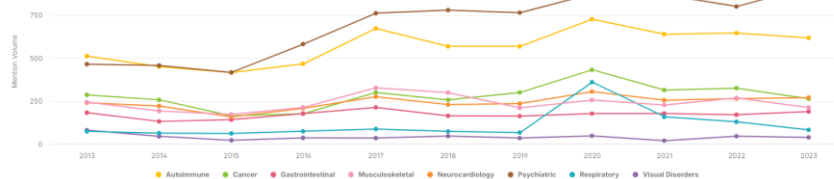


Figure 1: Volume over time graph on comorbidities in MS patients



Figure 2: Distribution of comorbidities by gender

4.1 Topic Analysis

Psychiatric comorbidities are the most frequently discussed topic among MS patients, with a total mention count of 7,708 mentions, and the reach of these discussions approached 7.72 million individuals worldwide, wherein reach refers to the estimated number of individuals who have been exposed to a particular content or discussion (Reach, 2024; Reach and Impressions Explained, 2024). Words like health anxiety, depression, stress, and chronic pain were highly mentioned in the conversations among MS patients, as highlighted in Figure 3. Based on the topic cluster on psychiatric posts from Figure 4, stress and anxiety were commonly mentioned psychiatric symptoms, while pain and anxiety were associated with medical marijuana. Health anxiety was associated with panic attacks, nerve damage, internal tremors, brain tumors, and a feeling of pins and needles. Depression was also frequently associated with disease.

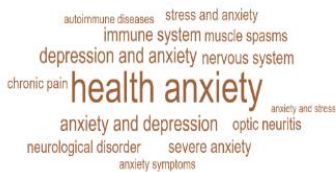


Figure 3: Word Cloud - Psychiatric comorbidity



Figure 4: Topic Cluster on Psychiatric Comorbid Posts

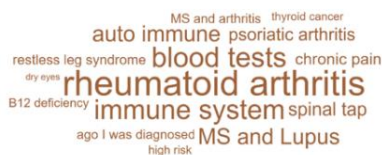


Figure 5: Word Cloud - Autoimmune comorbidity

Autoimmune-related comorbidities were reflected in 6,285 posts, with a total reach of 6.01 million individuals. As shown in Figure 5, rheumatoid arthritis, lupus, thyroid disease, and psoriatic arthritis dominated this category. According to Figure 6, MS and autoimmune-related comorbidities were associated with blood sugar, blood pressure, and Danlos syndrome. Moreover, Pernicious Anemia was linked to

B12 deficiency, while optic neuritis was associated with Clinically Isolated Syndrome (CIS).

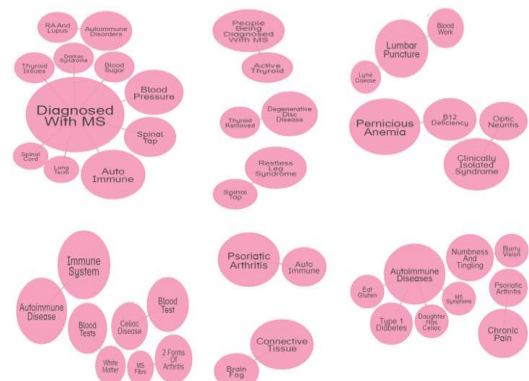


Figure 6: Topic Cluster on Autoimmune Comorbid Posts

Cancer-related posts amounted to around 20,000, with a reach of 19.6 million individuals. Figure 7 shows that most of the discussions were related to lung, colon, thyroid, skin, and breast cancer. Figure 8 depicts an association between MS and breast cancer, with a significant presence of breast cancer as denoted by the size of the bubble. There is also an association between ovarian cancer and health anxiety.



Figure 7: Word Cloud - Cancer comorbidity

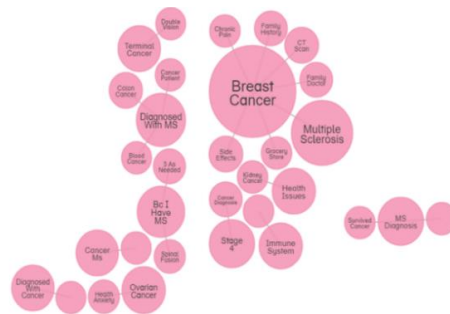


Figure 8: Topic Cluster on Cancer Comorbid Posts

Approximately 2,616 posts were related to musculoskeletal comorbidity, reaching 2.5 million individuals. Discussions related to comorbidities mentioned fibromyalgia and degenerative disc disease, along with symptoms that tend to be associated with MS, such as muscle spasms, nerve damage, and muscle twitching (Figure 9). Figure 10 captures health anxiety associated with such comorbidities and related symptoms. It depicts references to pain medications,

describes the first clinical onset of potential multiple MS, with ON as a common presenting symptom (Efendi, 2015). Posts also linked celiac disease (CD) to blood tests. Because CD can mimic MS, blood tests are conducted to detect the presence of CD antibodies (Ünlütürk et al., 2021).

Among cancer-related comorbidities, different types of cancer were included in the posts. This is in line with the extant literature. MS is hypothesized to have a significant impact on certain types of cancer, either offering protection or being associated with their occurrence. Protection may be due to unregulated immune function in MS (Bahar et al., 2023). The increased risk of cancer is usually site-specific such as the brain, malignant melanoma, digestive organs, and breast (Marrie, Reider, et al., 2015). It could be attributed to lifestyle behaviors such as smoking, which is more common among people with MS, frequent referrals and MRI tests leading to early detection of brain cancer, and side effects of the new high-efficacy DMT (Grytten et al., 2021). This variability highlights the need for further research.

For musculoskeletal comorbidities, fibromyalgia (FM) was a prominent mention. The finding aligns with reports from the literature that point to the coexistence of FM and MS. FM is characterized by chronic pain (Marrie et al., 2012). It can potentiate anxiety and depression and negatively impact the quality of life in MS patients (Thomas et al., 2023). Hence, the need exists to consider FM in the management of pain in MS. Degenerative disc disease (DDD) was a common mention. Limited data is available on the association between DDD and MS. Data from one study suggests a greater than-expected prevalence of DDD for age among MS patients. Possible explanations include altered biomechanics and increased fibronectin, both shown to accelerate disc degeneration (Omid-Fard et al., 2024). Our results show a link between DDD and CBD oil. Evidence exists that treatment with CBD oil results in a reduction in pain intensity in MS patients, yet more research is needed on the effect of CBD oil on DDD (S et al., 2021). Muscle spasms, muscle twitches, and muscle spasticity appeared frequently in the posts; all are symptoms rather than comorbidities of MS.

Gastrointestinal comorbidities such as acid reflux and liver disease were frequent posts. The finding has its support in the literature. Acid reflux may be attributed to nerve dysfunction (Levinthal et al., 2013). Alternatively, it may be the result of corticosteroid treatment for acute relapses (Biswas et al., 2012). Liver function was mentioned in association with the blood tests. This could be explained by the effect of DMT on the liver, warranting regular blood tests to monitor liver function (Biolato et al., 2021). Liver damage was associated with pain medications. Indeed, the

damaging effect of pain relief medications on the liver has been documented (Bessone, 2010). Although an autoimmune disease and because it affects the digestive tract presenting with gastrointestinal symptoms, ulcerative colitis mentions appeared in posts related to gastrointestinal rather than autoimmune comorbidities (Nociti & Romozzi, 2022). Posts linked ulcerative colitis to autoimmune disease, rightfully so. Bowel movements and bowel problems appeared as common topics. Problems with bowel movements occur as MS symptoms as opposed to comorbidities.

Under neurocardiology, comorbidities such as peripheral neuropathy and chest pain were the main topics. Peripheral neuropathy can affect autonomic nerves, leading to cardiac autonomic neuropathy. Chest pain was associated with shortness of breath, neck and jaw, and blood clots. The literature points to an increased risk among MS patients of heart conditions that relate to the influence of the autonomic nervous system on the activity of the heart and brain (van der Wall & van Gilst, 2013). These include hypertension, congestive heart failure, and ischemic heart failure (Marrie, Cohen, et al., 2015). Mentions about chest pain, shortness of breath, neck and jaw pain, and left arm pain reflect symptoms suggestive of the said heart conditions (Jurgens et al., 2022).

Although a neuro-ophthalmological condition, intracranial hypertension appeared in association with the optic nerve. The association is supported by studies on elevated intracranial pressure in intracranial hypertension and its damaging effect on the optic nerve (Bonelli et al., 2024). Despite not being neurocardiology comorbidities, there were frequent mentions of optic neuritis (ON) and peripheral visions. ON is discussed in the visual comorbidities section. Peripheral vision was associated with blood pressure. This is consistent with studies on hypertensive retinopathy, where elevated blood pressure causes retinal damage and leads to deterioration of the peripheral vision (Dziedziak et al., 2022).

Within respiratory comorbidities, asthma was a key topic. This is in accord with research that describes asthma as significantly more common in people with MS compared to the general population (Hill et al., 2019). Mentions included lung disease, lung condition, and lung issues. Chronic lung disease, including asthma and chronic obstructive pulmonary disease, is, in fact, more common in MS patients with negative effects on disability progression and mortality. The association could be attributed to shared genetic and environmental factors such as smoking (Marrie et al., 2016). People with MS are also more likely to suffer from altered lung function due to respiratory muscle weakness (Kular, 2024). In addition, DMT-treated patients, especially those receiving the newer drugs,

have an increased infectious risk to diseases such as tuberculosis (Zingaropoli et al., 2022). Pulmonary embolism was frequently mentioned, in line with reports on its higher occurrence in MS patients. This could be explained by the overstimulation of innate immunity that can lead to local and systemic thrombotic events (Koudriavtseva, 2014). The condition may also occur as an adverse effect of some new DMT (Soltys et al., 2022). Lung cancer, though a cancer-related comorbidity, emerged as a main topic. Studies show that smoking is more common among MS patients. It is an important environmental risk factor for MS and a major risk factor for lung cancer (Manouchehrinia et al., 2022). The findings underscore the importance of comprehensive care for MS patients, which should include the management of comorbidities.

A visual comorbidity, glaucoma, was mentioned in association with medical marijuana. Studies have shown that an increased risk of glaucoma exists in MS patients, with the two conditions sharing common aspects of pathogenesis (Bazelier et al., 2012). Marijuana has been reported to decrease intraocular pressure, yet with a limited duration of action. As a result, the use of marijuana to manage glaucoma would have to be repeated throughout the day, leading to adverse effects, potential substance abuse, and/or withdrawal symptoms. Currently, there appears to be no clear evidence to support the usefulness of marijuana in the treatment of glaucoma, and patients must be advised not to stop the use of proven glaucoma therapies (Sun et al., 2015). Optic neuritis (ON) was frequently mentioned. It occurs as the first manifestation of MS in nearly 20% of cases and may occur during the course of the disease in 50% of patients. ON leads to visual problems (Kale, 2016). This was reflected in mentions of visual difficulties, visual snow, and visual disturbances.

6. Conclusion

This study presents a comprehensive analysis of online discussions surrounding multiple sclerosis (MS) and its comorbidities from 2013 to 2023. By extracting and categorizing over 24,000 posts across various digital platforms, we gained valuable insights into the prevalent concerns, demographic trends, and temporal shifts within the MS community. The findings highlight the pivotal role of online forums, Reddit, and Twitter as platforms for sharing experiences, seeking support, and disseminating information related to MS and its associated comorbidities.

Furthermore, the gender disparity observed in the author's demographics underscores the importance of tailored interventions and resources that address the

diverse needs of individuals within the MS community. Analysis of comorbidity distribution reveals varying levels of discussion across different health issues, with psychiatric concerns emerging as the most prevalent topic. This underscores the complex interplay between physical and mental health in individuals with MS and emphasizes the need for integrated care approaches that address holistic well-being. Temporal analysis highlights notable shifts in discussion patterns, including spikes in respiratory and neurocardiology comorbidities coinciding with significant global events such as the COVID-19 pandemic and discussions around vaccine safety. These findings underscore the dynamic nature of online discourse and its responsiveness to external influences and emerging healthcare trends. Moreover, the detailed examination of specific comorbidities provides valuable insights into the diverse range of challenges faced by individuals with MS. These insights can inform the development of targeted interventions, raise awareness about lesser-discussed health concerns, and guide healthcare providers in delivering more holistic and patient-centered care.

A limitation of our study is the potential ambiguity in determining whether additional health conditions mentioned in posts truly represent comorbidities, as some may reflect concerns rather than existing conditions. Additionally, another limitation is that we were unable to automatically capture and visualize overlaps where posts may fall under multiple comorbidity categories.

Overall, this research contributes to a deeper understanding of the experiences, needs, and priorities of individuals living with MS and underscores the importance of leveraging digital platforms for community engagement, support, and healthcare advocacy. By fostering inclusive and accessible online spaces, healthcare stakeholders can empower individuals with MS to navigate their health journey more effectively and enhance their overall quality of life.

7. References

- Bahar, Y., Yildiz, E., Bahar, A. R., & Karabudak, R. (2023). Is cancer risk reduced in multiple sclerosis? Results from a tertiary referral center. *Turkish Journal of Medical Sciences*, 53, 8. <https://doi.org/10.55730/1300-0144.5660>
- Barzegar, M., Mirmosayyeb, O., Gajarzadeh, M., Afshari-Safavi, A., Nehzat, N., Vaheb, S., Shaygannejad, V., & Maghzi, A.-H. (2021). COVID-19 Among Patients With Multiple Sclerosis. *Neurology Neuroimmunology & Neuroinflammation*, 8(4), e1001. <https://doi.org/10.1212/NXI.0000000000001001>
- Bazelier, M. T., Mueller-Schotte, S., Leufkens, H. G., Uitdehaag, B. M., van Staa, T., & de Vries, F. (2012). Risk of cataract and glaucoma in patients with multiple sclerosis. *Multiple Sclerosis Journal*, 18(5), 628–638. <https://doi.org/10.1177/1352458511426737>

- Bessone, F. (2010). Non-steroidal anti-inflammatory drugs: What is the actual risk of liver damage? *World Journal of Gastroenterology*, *16*(45), 5651–5661. <https://doi.org/10.3748/wjg.v16.i45.5651>
- Biolato, M., Bianco, A., Lucchini, M., Gasbarrini, A., Mirabella, M., & Grieco, A. (2021). The Disease-Modifying Therapies of Relapsing-Remitting Multiple Sclerosis and Liver Injury: A Narrative Review. *CNS Drugs*, *35*(8), 861–880. <https://doi.org/10.1007/s40263-021-00842-9>
- Biswas, S., Benedict, S. H., Lynch, S. G., & LeVine, S. M. (2012). Potential immunological consequences of pharmacological suppression of gastric acid production in patients with multiple sclerosis. *BMC Medicine*, *10*(1), 57. <https://doi.org/10.1186/1741-7015-10-57>
- Boeschoten, R. E., Braamse, A. M. J., Beekman, A. T. F., Cuijpers, P., van Oppen, P., Dekker, J., & Uitdehaag, B. M. J. (2017). Prevalence of depression and anxiety in Multiple Sclerosis: A systematic review and meta-analysis. *Journal of the Neurological Sciences*, *372*, 331–341. <https://doi.org/10.1016/j.jns.2016.11.067>
- Boit, J., El-Gayar, O., & El-Gayar, O. (2020). *Topical Mining of malaria Using Social Media. A Text Mining Approach*.
- Bonelli, L., Menon, V., Arnold, A. C., & Mollan, S. P. (2024). Managing idiopathic intracranial hypertension in the eye clinic. *Eye*, 1–10. <https://doi.org/10.1038/s41433-024-03140-y>
- Brandwatch | The social suite of the future. (2021). Brandwatch. <https://www.brandwatch.com/>
- Brummer, T., Ruck, T., Meuth, S. G., Zipp, F., & Bittner, S. (2021). Treatment approaches to patients with multiple sclerosis and coexisting autoimmune disorders. *Therapeutic Advances in Neurological Disorders*, *14*, 17562864211035542. <https://doi.org/10.1177/17562864211035542>
- Bsteh, G., Gradl, C., Heschl, B., Hegen, H., Di Pauli, F., Assar, H., Leutmezer, F., Traxler, G., Krajnc, N., Zulehner, G., Hiller, M.-S., Rommer, P., Wipfler, P., Guger, M., Enzinger, C., Berger, T., & Investigators, for the A.-M. (2022). Impact of vaccination on COVID-19 outcome in multiple sclerosis. *European Journal of Neurology*, *29*(11), 3329–3336. <https://doi.org/10.1111/ene.15488>
- Conway, M., & O'Connor, D. (2016). Social Media, Big Data, and Mental Health: Current Advances and Ethical Implications. *Current Opinion in Psychology*, *9*, 77–82. <https://doi.org/10.1016/j.copsyc.2016.01.004>
- Coverage Overview. (2024, January 10). Consumer Research. <https://consumer-research-help.brandwatch.com/hc/en-us/articles/360012759037-Coverage-Overview>
- Dziedziak, J., Zaleska-Żmijewska, A., Szaflik, J. P., & Cudnoch-Jędrzejewska, A. (2022). Impact of Arterial Hypertension on the Eye: A Review of the Pathogenesis, Diagnostic Methods, and Treatment of Hypertensive Retinopathy. *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research*, *28*, e935135. <https://doi.org/10.12659/MSM.935135>
- Efendi, H. (2015). Clinically Isolated Syndromes: Clinical Characteristics, Differential Diagnosis, and Management. *Noro Psikiyatri Arsivi*, *52*(Suppl 1), S1–S11. <https://doi.org/10.5152/npa.2015.12608>
- Frasca, L., Ocone, G., & Palazzo, R. (2023). Safety of COVID-19 Vaccines in Patients with Autoimmune Diseases, in Patients with Cardiac Issues, and in the Healthy Population. *Pathogens*, *12*(2), Article 2. <https://doi.org/10.3390/pathogens12020233>
- Gorugantu, L. M., El-Gayar, O., & Nawar, N. (2023). Social Media Analysis of Modifiable Lifestyle Factors in Multiple Sclerosis. *AMCIS 2023 Proceedings*. https://aisel.aisnet.org/amcis2023/sig_health/sig_health/15
- Grytten, N., Myhr, K.-M., Celius, E. G., Benjaminsen, E., Kampman, M. T., Midgard, R., Vatne, A., Aarseth, J. H., Riise, T., & Torkildsen, Ø. (2021). Incidence of cancer in multiple sclerosis before and after the treatment era- a registry- based cohort study. *Multiple Sclerosis and Related Disorders*, *55*, 103209. <https://doi.org/10.1016/j.msard.2021.103209>
- Haddad, F., Dokmak, G., & Karaman, R. (2022). The Efficacy of Cannabis on Multiple Sclerosis-Related Symptoms. *Life*, *12*(5), 682. <https://doi.org/10.3390/life12050682>
- Hill, E., Abboud, H., & Briggs, F. B. S. (2019). Prevalence of asthma in multiple sclerosis: A United States population-based study. *Multiple Sclerosis and Related Disorders*, *28*, 69–74. <https://doi.org/10.1016/j.msard.2018.12.012>
- Hopkins, D. J., & King, G. (2010). A Method of Automated Nonparametric Content Analysis for Social Science. *American Journal of Political Science*, *54*(1), 229–247. <https://doi.org/10.1111/j.1540-5907.2009.00428.x>
- Jurgens, C. Y., Lee, C. S., Aycocock, D. M., Masterson Creber, R., Denfeld, Q. E., DeVon, H. A., Evers, L. R., Jung, M., Pucciarelli, G., Streu, M. M., Konstam, M. A., & null, null. (2022). State of the Science: The Relevance of Symptoms in Cardiovascular Disease and Research: A Scientific Statement From the American Heart Association. *Circulation*, *146*(12), e173–e184. <https://doi.org/10.1161/CIR.0000000000001089>
- Kale, N. (2016). Optic neuritis as an early sign of multiple sclerosis. *Eye and Brain*, *8*, 195–202. <https://doi.org/10.2147/EB.S54131>
- Kehler, M. D., & Hadjistavropoulos, H. D. (2009). Is health anxiety a significant problem for individuals with multiple sclerosis? *Journal of Behavioral Medicine*, *32*(2), 150–161. <https://doi.org/10.1007/s10865-008-9186-z>
- Koudriavtseva, T. (2014). Thrombotic Processes in Multiple Sclerosis as Manifestation of Innate Immune Activation. *Frontiers in Neurology*, *5*. <https://doi.org/10.3389/fneur.2014.00119>
- Kular, L. (2024). The lung-brain axis in multiple sclerosis: Mechanistic insights and future directions. *Brain, Behavior, & Immunity - Health*, *38*, 100787. <https://doi.org/10.1016/j.bbih.2024.100787>
- Lavorgna, L., Lanzillo, R., Morra, V. B., Abbadessa, G., Tedeschi, G., & Bonavita, S. (2017). Social Media and Multiple Sclerosis in the Posttruth Age. *Interactive Journal of Medical Research*, *6*(2), e7879. <https://doi.org/10.2196/ijmr.7879>
- Lazard, A. J., Saffer, A. J., Wilcox, G. B., Chung, A. D., Mackert, M. S., & Bernhardt, J. M. (2016). E-Cigarette Social Media Messages: A Text Mining Analysis of Marketing and Consumer Conversations on Twitter. *JMIR Public Health and Surveillance*, *2*(2), e6551. <https://doi.org/10.2196/publichealth.6551>
- Levinthal, D. J., Rahman, A., Nusrat, S., O'Leary, M., Heyman, R., & Bielefeldt, K. (2013). Adding to the Burden: Gastrointestinal Symptoms and Syndromes in Multiple Sclerosis. *Multiple Sclerosis International*, *2013*, e319201. <https://doi.org/10.1155/2013/319201>
- Magyari, M., & Sorensen, P. S. (2020). Comorbidity in Multiple Sclerosis. *Frontiers in Neurology*, *11*. <https://www.frontiersin.org/articles/10.3389/fneur.2020.00851>
- Maljaei, M. B., Moradi, M., Nobari, N. T., Bahreini, A., & Namjoo, I. (2020). Vitamin B12 Deficiency and MS Incidence; Which One Sooner? *International Journal of Preventive Medicine*, *11*, 145. https://doi.org/10.4103/ijpvm.IJPVM_135_19
- Manouchehrinia, A., Huang, J., Hillert, J., Alfredsson, L., Olsson, T., Kockum, I., & Constantinescu, C. S. (2022). Smoking Attributable Risk in Multiple Sclerosis. *Frontiers in Immunology*, *13*. <https://doi.org/10.3389/fimmu.2022.840158>
- Marrie, R. A. (2017). Comorbidity in multiple sclerosis: Implications for patient care. *Nature Reviews Neurology*, *13*(6), Article 6. <https://doi.org/10.1038/nrneuro.2017.33>
- Marrie, R. A., Cohen, J., Stuve, O., Trojano, M., Sørensen, P. S., Reingold, S., Cutter, G., & Reider, N. (2015). A systematic review of the incidence and prevalence of comorbidity in multiple sclerosis: Overview. *Multiple Sclerosis (Houndmills*,

- Basingstoke, England), 21(3), 263–281. <https://doi.org/10.1177/1352458514564491>
- Marrie, R. A., Fisk, J. D., Fitzgerald, K., Kowalec, K., Maxwell, C., Rotstein, D., Salter, A., & Tremlett, H. (2023). Etiology, effects and management of comorbidities in multiple sclerosis: Recent advances. *Frontiers in Immunology*, 14. <https://www.frontiersin.org/journals/immunology/articles/10.3389/fimmu.2023.1197195>
- Marrie, R. A., Patten, S., Tremlett, H., Svenson, L. W., Wolfson, C., Yu, B. N., Elliott, L., Profetto-McGrath, J., Warren, S., Leung, S., Jette, N., Bhan, V., & Fisk, J. D. (2016). Chronic lung disease and multiple sclerosis: Incidence, prevalence, and temporal trends. *Multiple Sclerosis and Related Disorders*, 8, 86–92. <https://doi.org/10.1016/j.msard.2016.05.009>
- Marrie, R. A., Reider, N., Cohen, J., Stuve, O., Trojano, M., Sorensen, P. S., Reingold, S. C., & Cutter, G. (2015). A systematic review of the incidence and prevalence of cancer in multiple sclerosis. *Multiple Sclerosis Journal*, 21(3), 294–304. <https://doi.org/10.1177/1352458514564489>
- Marrie, R. A., Yu, B. N., Leung, S., Elliott, L., Warren, S., Wolfson, C., Tremlett, H., Blanchard, J., & Fisk, J. D. (2012). The incidence and prevalence of fibromyalgia are higher in multiple sclerosis than the general population: A population-based study. *Multiple Sclerosis and Related Disorders*, 1(4), 162–167. <https://doi.org/10.1016/j.msard.2012.06.001>
- McGregor, F., Somner, J. E. A., Bourne, R. R., Munn-Giddings, C., Shah, P., & Cross, V. (2014). Social media use by patients with glaucoma: What can we learn? *Ophthalmic and Physiological Optics*, 34(1), 46–52. <https://doi.org/10.1111/opo.12093>
- McKay, K. A., Tremlett, H., Fisk, J. D., Zhang, T., Patten, S. B., Kastrukoff, L., Campbell, T., Marrie, R. A., & For the CIHR Team in the Epidemiology and Impact of Comorbidity on Multiple Sclerosis. (2018). Psychiatric comorbidity is associated with disability progression in multiple sclerosis. *Neurology*, 90(15), e1316–e1323. <https://doi.org/10.1212/WNL.0000000000005302>
- McWhirter, L., Smyth, H., Hoeritzauer, I., Couturier, A., Stone, J., & Carson, A. J. (2023). What is brain fog? *Journal of Neurology, Neurosurgery, and Psychiatry*, 94(4), 321–325. <https://doi.org/10.1136/jnnp-2022-329683>
- Murthy, V. H., Krumholz, H. M., & Gross, C. P. (2004). Participation in cancer clinical trials: Race-, sex-, and age-based disparities. *JAMA*, 291(22), 2720–2726. <https://doi.org/10.1001/jama.291.22.2720>
- Navar, N., El-Gayar, O., Ambati, L. S., & Bojja, G. R. (2022). Social Media for Exploring Adverse Drug Events Associated with Multiple Sclerosis. *Proceedings of the 55th Hawaii International Conference on System Sciences*.
- Nociti, V., & Romozzi, M. (2022). Multiple Sclerosis and Autoimmune Comorbidities. *Journal of Personalized Medicine*, 12(11), Article 11. <https://doi.org/10.3390/jpm12111828>
- Ofori, M., & El-Gayar, O. (2019). The State and Future of Smart Agriculture: Insights from mining social media. *2019 IEEE International Conference on Big Data (Big Data)*, 5152–5161. <https://doi.org/10.1109/BigData47090.2019.9006587>
- Omid-Fard, N., Thornhill, R. E., Torres, C., Almansoori, T. M., Rush, C. A. E., & Glikstein, R. (2024). MRI Markers of Degenerative Disc Disease in Young Patients With Multiple Sclerosis. *Canadian Association of Radiologists Journal*, 75(1), 136–142. <https://doi.org/10.1177/08465371231180815>
- Radzikowski, J., Stefanidis, A., Jacobsen, K. H., Croitoru, A., Crooks, A., & Delamater, P. L. (2016). The Measles Vaccination Narrative in Twitter: A Quantitative Analysis. *JMIR Public Health and Surveillance*, 2(1), e5059. <https://doi.org/10.2196/publichealth.5059>
- Rahn, K., Slusher, B., & Kaplin, A. (2012). Cognitive Impairment in Multiple Sclerosis: A Forgotten Disability Remembered. *Cerebrum: The Dana Forum on Brain Science*, 2012, 14.
- Reach. (2024, June 4). Consumer Research. <https://consumer-research-help.brandwatch.com/hc/en-us/articles/360012853598-Reach>
- Reach and Impressions Explained. (2024, August 23). Social Media Management. <https://social-media-management-help.brandwatch.com/hc/en-us/articles/4568366110365-Reach-and-Impressions-Explained>
- S, G., Hb, S., K, L., R, T., Bs, R., Ps, S., F, S., & Ab, O. (2021). Safety and efficacy of low-dose medical cannabis oils in multiple sclerosis. *Multiple Sclerosis and Related Disorders*, 48, 102708. <https://doi.org/10.1016/j.msard.2020.102708>
- Scanfeld, D., Scanfeld, V., & Larson, E. L. (2010). Dissemination of health information through social networks: Twitter and antibiotics. *American Journal of Infection Control*, 38(3), 182–188. <https://doi.org/10.1016/j.ajic.2009.11.004>
- Shah, N. D., Steyerberg, E. W., & Kent, D. M. (2018). Big Data and Predictive Analytics: Recalibrating Expectations. *JAMA*, 320(1), 27–28. <https://doi.org/10.1001/jama.2018.5602>
- Soltys, J., Padarti, A., Martin, B., Butler, T., & Kilgo, W. (2022). Cerebral venous thrombosis and pulmonary embolism following natalizumab infusion: Case series. *Neuroimmunology Reports*, 2, 100145. <https://doi.org/10.1016/j.nerep.2022.100145>
- Sun, X., Xu, C. S., Chadha, N., Chen, A., & Liu, J. (2015). Marijuana for Glaucoma: A Recipe for Disaster or Treatment? *The Yale Journal of Biology and Medicine*, 88(3), 265–269.
- Thomas, C., Schneider, B. T., Verza, C. S., Fassina, G., Weber, L. R., Moreira, M., Fusinato, P. T., & Forcelini, C. M. (2023). Prevalence of fibromyalgia in a Brazilian series of patients with multiple sclerosis. *Arquivos de Neuro-Psiquiatria*, 81(9), 803–808. <https://doi.org/10.1055/s-0043-1772673>
- Topic Clusters. (2023). CoSchedule Blog. <https://coschedule.com/content-marketing/topic-clusters>
- Ünlütürk, Z., Bir, L., & Demir, M. (2021). Gluten intolerance antibodies in Multiple Sclerosis and clinically isolated syndrome: Coexistent or coincidental? *Clinical and Experimental Neuroimmunology*, 12. <https://doi.org/10.1111/cen3.12636>
- van der Wall, E. E., & van Gilst, W. H. (2013). Neurocardiology: Close interaction between heart and brain. *Netherlands Heart Journal*, 21(2), 51–52. <https://doi.org/10.1007/s12471-012-0369-4>
- Vlahiotis, A., Sedjo, R., Cox, E. R., Burroughs, T. E., Rauchway, A., & Lich, R. (2010). Gender differences in self-reported symptom awareness and perceived ability to manage therapy with disease-modifying medication among commercially insured multiple sclerosis patients. *Journal of Managed Care Pharmacy: JMCP*, 16(3), 206–216. <https://doi.org/10.18553/jmcp.2010.16.3.206>
- Vosko, I., Zirlik, A., & Bugger, H. (2023). Impact of COVID-19 on Cardiovascular Disease. *Viruses*, 15(2), Article 2. <https://doi.org/10.3390/v15020508>
- Zingaropoli, M. A., Pasculli, P., Iannetta, M., Perri, V., Tartaglia, M., Crisafulli, S. G., Merluzzo, C., Baione, V., Mazzochi, L., Taglietti, A., Pauri, F., Frontoni, M., Altieri, M., Gaeta, A., Antonelli, G., Conte, A., Mastroianni, C. M., & Ciardi, M. R. (2022). Infectious risk in multiple sclerosis patients treated with disease-modifying therapies: A three-year observational cohort study. *Multiple Sclerosis Journal - Experimental, Translational and Clinical*, 8(1), 20552173211065731. <https://doi.org/10.1177/20552173211065731>