

The Relationship between Geomagnetic Disturbances and Multiple Sclerosis at the Edge of the Auroral Zone

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Abstract

Objective: The impact of geomagnetic disturbances at the earth's surface is greatest at higher geomagnetic latitudes, particularly between 60-75°N. The prevalence of multiple sclerosis (MS) also has a latitudinal gradient. Therefore, the purpose of this study was to explore the hypothesis that geomagnetic disturbances may have a role in the development of multiple sclerosis (MS).

Methods: A retrospective design was used to examine the correlations between the birth rate of MS patients and two geomagnetic indices, sunspots and the A-index. Birth rate data was derived from a clinical database of patients residing in a region near 60° N geomagnetic latitude from 1920-1980.

Results: Results indicated that the intensity of geomagnetic disturbances, as measured by the A-index, had a stronger relationship to MS birth rate than the count of sunspots. Overall, the A-indices had small to moderate correlations with MS birth rates, combined ($r=0.31-0.50$) and by sex (male $r=0.28-0.43$; female $r=0.24-0.50$), over 60 years. Correlations were stronger as the length of exposure increased. That is, exposure in early childhood (birth year+3 years) and throughout childhood (birth year+12 years) exhibited generally higher correlations (early $r=0.28-0.49$; throughout $r=0.24-0.50$) than exposure during birth year alone ($r=0.30-0.39$).

Conclusion: The results of this study indicate that geomagnetic disturbances may be a risk factor in the development of MS. The cumulative effect of exposure may be of importance. The advantages of examining exposure in utero and childhood are that birth cohorts can examine risk factors occurring early in life, can reduce the impact of period effects, and can meet the assumption of order-effect as we search for causal factors contributing to MS. The mechanism whereby geomagnetic disturbances may affect disease is unknown and warrants further exploration.

Keywords: Multiple sclerosis; Geomagnetic disturbances; Canada; Childhood exposure

Background

For decades, researchers have sought to understand the relationship between geographic latitude and Multiple Sclerosis (MS). The key was to find factors associated with latitude that could affect human health. The theses of relationships between ultra-violet radiation [1,2] and/or vitamin D exposure to MS have been explored [3] but results have not been conclusive. Another line of investigation has been the relationship of geomagnetic latitude and MS. Geomagnetic latitude is analogous to geographic latitude with orientations to the magnetic north and south poles instead of the geographic poles. In the 1960s, Barlow [4] suggested that the prevalence of MS was more closely related to geomagnetic latitude than geographic. The influence of the sun also varies with latitude. Solar flares produce a variety of influences on the earth, such as geomagnetic disturbances (GMDs). GMDs are magnetic field oscillations in our environment caused by

the interaction of the solar wind with the Earth's magnetic field. The GMDs are strongest during magnetic storm conditions within the auroral zone which extends from 60° to 75° geomagnetic latitude [5]. A review by Palmer, Rycroft and Cermack [6] presented strong conclusions from research in the past 30 years which showed that GMDs have a greater effect on human health at higher geomagnetic latitudes. They suggest that 10-15% of the population are particularly sensitive to geomagnetic activity, based on studies of cardiovascular and psychological health. Recently, Sajedi and Abdollahi [7] presented an argument for GMDs as a possible risk factor in the development of MS. Their meta-analysis of world-wide prevalence statistics with geographic and geomagnetic latitudes showed a strong correlation between disease prevalence and angular distance to geomagnetic 60° latitude. In a second article, the same authors found moderate to strong correlations between GMDs and MS incidence [8]. Supporting these findings, Wade, Mehta and Papitashvili [9] found an inverse relationship between the strength of the earth's horizontal magnetic field and global MS prevalence rates. Weaker horizontal magnetic field strength at higher latitudes provides less protection from ionizing and

electromagnetic solar radiation and correlates with higher MS prevalence rates.

Residing in the largest Canadian city nearest 60° N geomagnetic latitude, we sought to explore the thesis proposed by Sajedi and Abdollahi [7]. Previous research from our province indicated that Alberta has one of the highest prevalence rates of MS in Canada [10]. One of the limits expressed by Sajedi and Abdollahi [7] was that the time of life when GMDs may most affect an individual susceptible for MS was unknown. We chose to examine GMD exposure as a possible risk factor using MS birth cohorts. The advantages of examining exposure in utero and childhood are that birth cohorts can examine risk factors occurring early in life, can reduce the impact of period effects (e.g. registration procedures, new diagnostic classifications, treatment developments, etc.) [11] and can meet the assumption of order-effect as we search for causal factors contributing to MS. The purpose of our study was to examine if a relationship exists between birth year and intensity of GMDs for patients diagnosed with MS who reside near the edge of the auroral zone.

Methods

Birth statistics for patients diagnosed with MS were obtained from the clinical administrative database of the sole MS outpatient clinic in Edmonton from 1978 to 2012. This clinic has served northern Alberta since 1978. Prior to the opening of this dedicated MS clinic, patients were seen by general neurologists at the University or in the community. After the clinic opened, the majority of patients in the northern half of the province were seen at least once at the clinic. Upon request, the clinic neurologist would assess MS patients residing in long-term care facilities and these patients were included in the clinic files. Birth years spanned 1904 to 2002. The patients born prior to 1920 and after 1980 were small in number and were excluded from the analysis. Those born prior to 1920 represented much older patients to the new clinic in 1978 and patients may have chosen not to change physicians when the new clinic opened. The number of older patients may also have been affected by reduced longevity during the earlier part of the century [12]. Patients born after 1980 represent a cohort with a relatively early age of onset as they have only just reached the peak decade age of onset and may not accurately represent their age cohort [13]. Patients were included in the study if they received a diagnosis of probable, clinically definite, or laboratory confirmed MS by a clinic neurologist. Over 5000 patients were assessed through the clinic during the 35 year period. This study was approved by the Research Ethics Board at the University of Alberta.

Two patient variables were used in the study: birth year and gender. In order to compare number of births of MS patients for different years, we calculated the birth rate using the Alberta birth statistics from The Dominion Bureau of Statistics Canada [14-19] and Statistics Canada [20-22] for each year 1920-1980. We recognized that the birth rates calculated were under-estimated as we did not have birthdates for all MS patients in the province. This limited birth rate was sufficient for our goal to make the counts of birth rates comparable across the years, but not to present true MS birth rates for the province. Birth rates for MS births combined, male and female were calculated per 10,000 population.

Three GMD measures were used: (1) the yearly mean sunspot numbers for each year (SS); (2) the sum of the daily averaged amplitude of geomagnetic activity in a given year using the Aa index; and (3) the sum of the daily averaged amplitude of geomagnetic

activity in a given year using the Ap index. Geomagnetic activity is measured at an observatory with a magnetometer at 3 hour intervals during a 24 hour day and the largest value is selected at each interval and mathematically converted to an A-index. The A-index is the value obtained by computing an average of 8 successive 3 hour measurements in a 24 hour period [22]. The daily averages for each observatory are then averaged across observatories in various geographic locations to produce the Aa or Ap indices for the planet. Aa data have a longer history than the Ap data, but incorporate measurements from only 2 geomagnetic observatories. The Ap data began to be collected in 1932, but incorporate measurements from 13 geomagnetic observatories worldwide. Both measures were used in the current study in order to consider possible differences in the relationship to MS birth rates based on the breadth of geomagnetic data used. We obtained data for the GMD measures from public information provided by the National Geophysical Data Centre through the National Oceanic and Atmospheric Administration in the United States [22-24]. We conducted correlations between the MS birth rates and GMD measures by year. In order to assess the cumulative exposure in early childhood, we summed the GMD measures for 4 years (birth year+3 years) and correlated with the MS birth rate by year. To assess cumulative exposure throughout childhood, we summed the GMD measures for 13 years (birth year+12 years) and correlated with the MS birth rate by year.

Results

The sample included a total of 5014 patients, 3303 females and 1611 males. The pattern of MS birth rates showed higher rates through the 1940s, 50s and 60s. Figure 1 shows the correlation between the MS birth rate and average number of sunspots in the year of birth. There was a significant relationship between the number of sunspots per year and the MS births combined, $r=0.26$, $p<0.05$, and MS births female, $r=0.28$, $p<0.05$. Correlations between sunspots and MS births male did not reach significance, $r=0.17$, $p>0.05$.

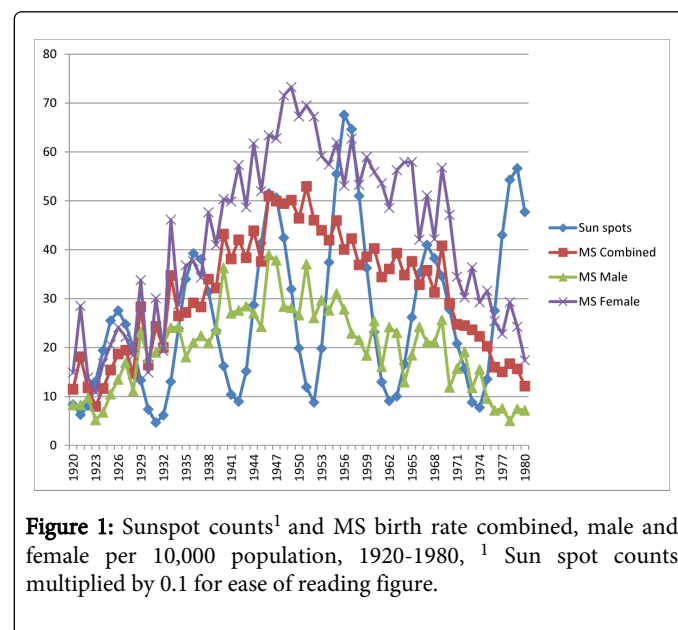


Figure 1: Sunspot counts¹ and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Sun spot counts multiplied by 0.1 for ease of reading figure.

The relationships between the Aa and Ap measures and MS birth rate were very similar (Figures 2 and 3). Statistically significant correlations existed between Aa and Ap and MS births combined,

$r=0.37$, $p<0.01$, and $r=0.39$, $p<0.01$, respectively. Correlations were also significant between both measures and MS births male, Aa at $r=0.30$, $p<0.05$, and Ap at $r=0.31$, $p<0.05$, and MS births female, Aa at $r=0.38$, $p<0.01$, and Ap at, $r=0.39$, $p<0.01$.

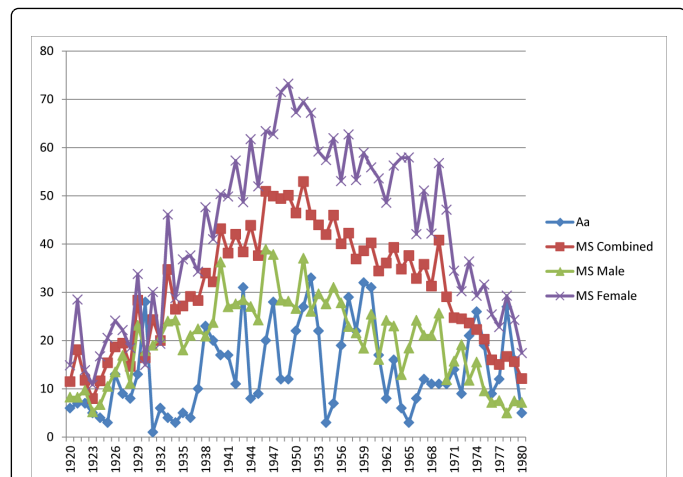


Figure 2: Aa and MS birth rate combined, male and female per 10,000 population, 1920-1980.

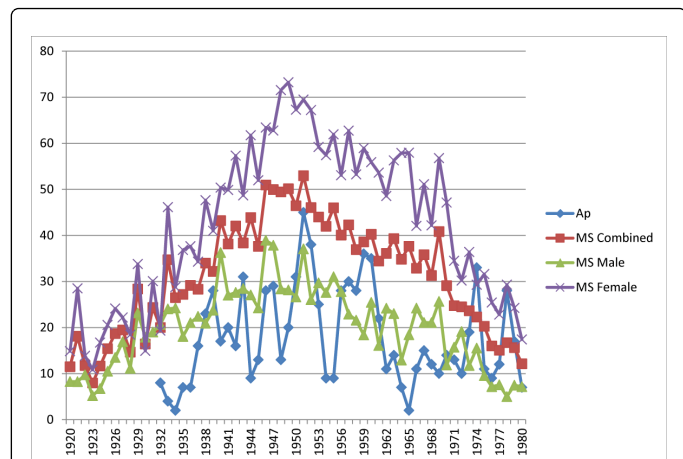


Figure 3: Ap¹ and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Ap index available from 1932.

Cumulative exposure for the average number of sunspots through early childhood (birth year+3 years) and MS birth rate reached significance for the MS births female comparison only, $r=0.25$, $p<0.05$ (MS births combined $r=0.23$, $p>0.05$; MS births male $r=0.14$, $p>0.05$) as shown in Figure 4. Figure 5 shows the cumulative Aa relationships with MS birth rate. The cumulative Aa measure was significantly correlated for all three comparisons (combined $r=0.46$, $p<0.01$; male $r=0.36$, $p<0.01$; female $r=0.49$, $p<0.01$). Figure 6 shows the cumulative Ap relationships with MS birth rate. The cumulative Ap measure was significantly correlated with MS births combined ($r=0.39$, $p<0.01$) and MS births female ($r=0.41$, $p<0.01$), but not MS births male ($r=0.28$, $p>0.05$).

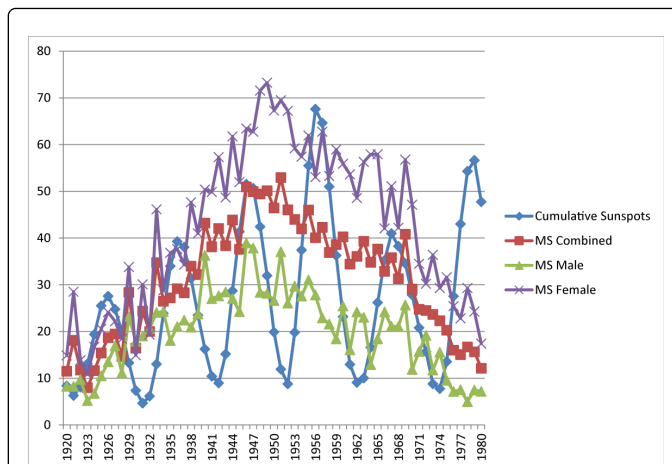


Figure 4: Cumulative sunspot counts¹ through early childhood and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Sun spot counts summed for 4 years then multiplied by 0.1 for ease of reading figure.

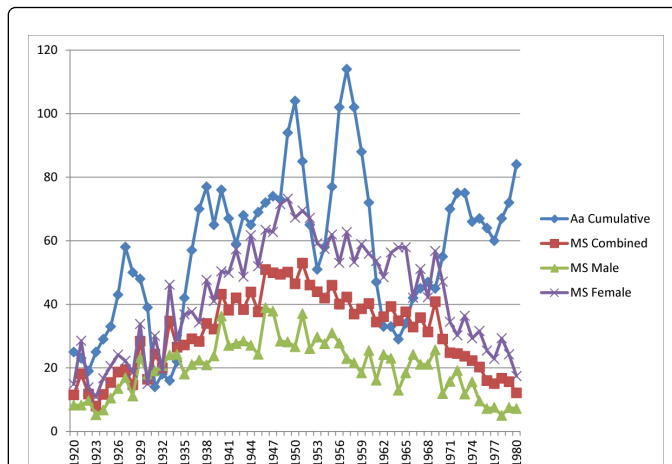


Figure 5: Cumulative Aa index¹ through early childhood and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Aa index summed for 4 years.

Cumulative exposure for the average number of sunspots throughout childhood (birth year+12 years) and MS birth rate showed moderate correlations with all three MS birth rate measures (combined, $r=0.51$, $p<0.01$; male $r=0.40$, $p<0.01$; female $r=0.53$, $p<0.01$) as shown in Figure 7. Figure 8 shows the cumulative Aa relationships with MS birth rate, which were significantly correlated with all three MS birth rate measures (combined $r=0.50$, $p<0.01$; male $r=0.43$, $p<0.01$; female $r=0.50$, $p<0.01$). Figure 9 shows the cumulative Ap relationships with MS birth rate. The cumulative Ap measure was significantly correlated with MS births combined ($r=0.31$, $p<0.05$), and MS births male ($r=0.37$, $p<0.01$), but not MS births female ($r=0.24$, $p>0.05$).

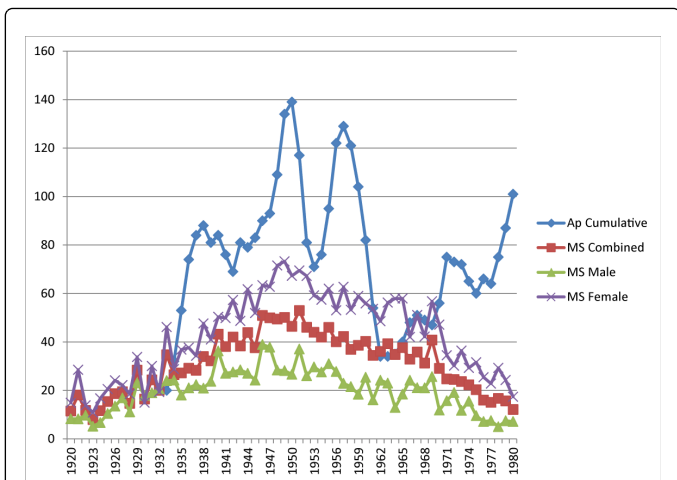


Figure 6: Cumulative Ap¹ index and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Ap index summed for 4 years. Data available from 1932.

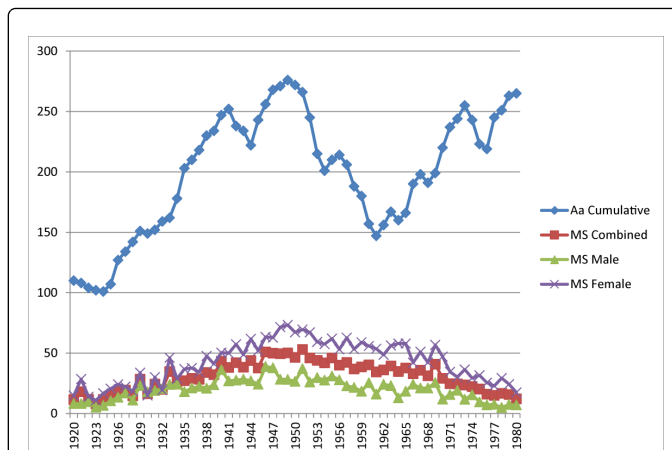


Figure 8: Cumulative Aa index¹ throughout childhood and incidence of MS births combined, male and female per 10,000 population, 1920-1980, ¹ Aa index summed for 13 years.

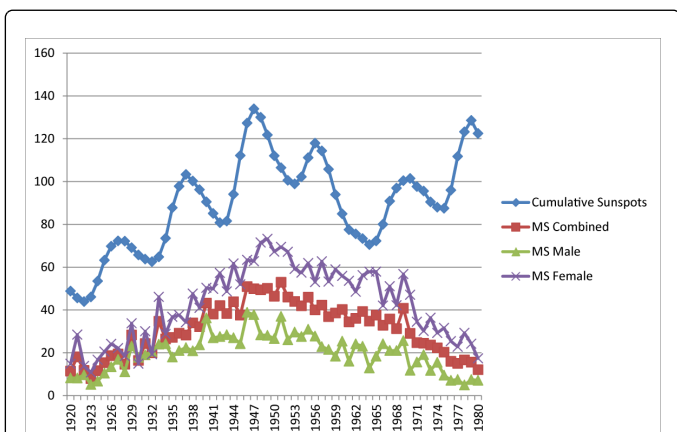


Figure 7: Cumulative sunspot counts¹ throughout childhood and MS birth rate combined, male and female per 10,000 population, 1920-1980, ¹ Sun spot counts summed for 13 years then multiplied by 0.1 for ease of reading figure.

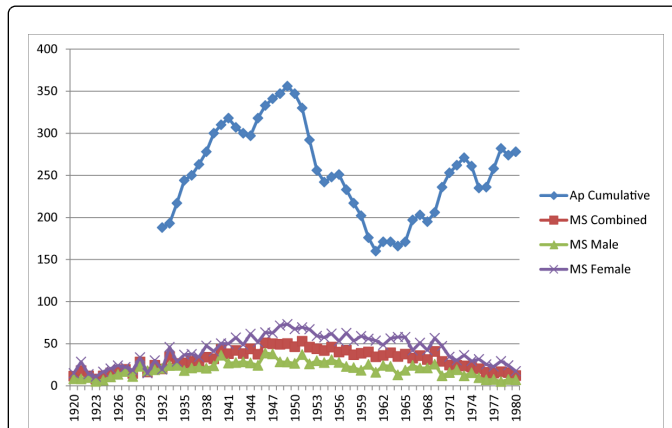


Figure 9: Cumulative Ap index¹ throughout childhood and incidence of MS births combined, male and female per 10,000 population, 1920-1980, ¹ Ap index summed for 13 years. Data available from 1932.

MS birth rate	SS	Aa	Ap	SS (4 yrs)	Aa (4 yrs)	Ap (4 yrs)	SS (13 yrs)	Aa (13 yrs)	Ap (13 yrs)
MS combined	0.36*	0.48**	0.50**	0.40**	0.66**	0.62**	0.82**	0.84**	0.58**
MS male	0.25	0.44**	0.37*	0.34*	0.56**	0.42**	0.74**	0.82**	0.65**
MS female	0.37**	0.45**	0.46*	0.39**	0.65**	0.59**	0.78**	0.78**	0.41**

* p ≤ 0.05; ** p ≤ 0.01

Table 1: Correlations between MS birth rate and GMD measures 1920-1970 for birth year, birth year+early childhood, and birth year +throughout childhood (n=4402).

The figures show that the last 10 years (patients born in the 1970s) did not hold a pattern of positive correlation. One of the reasons may be that this latter age group, in their 30s, have not yet sought or confirmed diagnosis at the MS clinic. The clinic database indicated

that the average age of diagnosis was 33 years (SD=10) for those who had this information available (n=1253). Therefore, the incidence rates through the 1970s may be under-represented for the clinic. If we move

the time frame of the study to 1920-1970, the correlations are stronger (Table 1), increasing to 0.41-0.84 for exposure throughout childhood.

Discussion

In keeping with the thesis proposed by Sajedi and Abdollahi [7], the results of this study found small to moderate relationships between the magnitude of GMDs and the incidence of MS births. Although a correlational relationship does not indicate cause, it is possible that GMD exposure in utero and childhood may be a risk factor in the development of MS. In this paper, exposure to GMDs was prior to a diagnosis of MS, meeting the criteria of order effect for a causal relationship (i.e. the cause precedes the effect). GMDs may partially explain the latitude gradient seen in world-wide prevalence rates. Our findings showed that cumulative exposures in birth year through early childhood or throughout childhood were more strongly related to a diagnosis of MS in later years than exposure during birth year alone. Therefore, the influence of GMDs may not be a limited event, but cumulative exposure over time. The relationship between GMDs and MS warrants further exploration.

A strength of this study is its long period of observation. Fifty to 60 years is the longest period of time in the literature to study the relationship between MS and geomagnetic activity. A limitation of the study was that birthplace and childhood residence data was not available in the clinic database. We were unable to confirm where patients lived in their early years. However, according to the Center for Global Development [29], only 3% of people do not live in the country where they were born. The likelihood that MS patients residing in Alberta were born in Alberta, or at least in Canada, is high. Future studies may want to control for place of birth and childhood home.

The goal of this study was to place the correlation between GMDs and MS within a time context, that is, patients' exposure in birth year and childhood. One hypothesis is that GMDs may most affect individuals during the third trimester in utero, when CNS myelination begins [25] or during the first 3 years after birth, when substantial myelination occurs [26]. This is supported by evidence that solar radiation can influence the human genome [27]. Another hypothesis is that exposure during childhood may affect the risk of MS, as people who migrate to higher latitudes after adolescence maintain the risk of MS related to their lower latitude country of origin [28]. Examining exposure in childhood differs from the purpose of previous studies on the topic that examined the relationships among MS incidence or prevalence and geomagnetic latitudes or indices [7,8]. Although moderate to strong correlations between MS incidence and geomagnetic activity were found by Abdollahi and Sajedi [8], the authors commented on limitation to using MS diagnosis. This limitation is the lag time between first attack of the disease (i.e. onset) and confirmation of diagnosis. Since incidence rates are usually based on diagnosis, it is more difficult to establish the relationship between GMDs and onset of the disease as there are no national or world-wide databases which capture onset information [8]. Alternatively, since the majority of people live in the country where they are born [29], it is likely that exposure in childhood and at onset occurred at the same geomagnetic latitude.

The cause of MS is not fully understood but thought to be a combination of genetic, immunological and environmental factors. GMDs could be an environmental factor. The mechanism whereby GMDs may influence human health, such as MS, is unknown. GMDs produce magnetic field fluctuations with periods of 1-100 sec that are

on the order of 10⁻⁶ Tesla or approximately a factor of 10 smaller than the Earth's magnetic field. Such magnetic field fluctuations can induce currents in an electrically conducting system, such as the human body. However, if any GMD effects on brain development exist, it is more likely due to the rate of the magnetic field fluctuations as opposed to the magnitude of the field strength, as suggested in the review by Palmer et al. [6]. The frequency of GMDs can affect heart rate in some individuals and has been shown to affect melatonin production in humans [6]. Since a link has already been made between melatonin and MS [30], a plausible theory is that GMDs play a secondary role in MS etiology, mediating the body's melatonin production. Since only a small percentage of the population may be sensitive to the fluctuations, the sensitivity may be genetically based.

A variety of plausible hypotheses may be applicable to MS. One is that GMDs may alter normal calcium ion homeostasis which could inappropriately activate immune system cells, initiating neuronal degeneration [31]. Alternatively GMDs or other forms of cosmic radiation may damage oxygen and nitrogen atoms in the body sufficiently to alter molecules such as myelin basic protein (MBP). The immune system might detect these altered molecules, causing an inflammatory response in the brain, optic nerve and/or spinal cord. Research has shown that the autoantibody response in MS is not stereotypic but variable. Some researchers have found anti-MBP [32-34], anti-PLP [35-37], anti-MAG [38-40], anti-MOG [41-43], anti-glycolipid [44-46], anti oligodendrocyte-specific protein (OSP) [47] and anti myelin associated oligodendrocyte glycoprotein (MOBP) [48,49]. If GMD damage were variable from patient to patient, then autoantibody profiles could also be variable. Depending on the amount or location of damage to MBP or other proteins within the myelin sheath, MS cases might be mild or quite severe such as the Marburg variant. Krone and Granger's review of the literature [50] suggests that GMDs and other cosmic radiation may alter iron-containing melanoma-like neuromelanin which, in turn, may promote demyelination in MS patients. Further studies of these relationships are necessary to explore GMDs as a possible risk factor for MS and to clarify possible mechanisms.

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