

# Associations between solar and geomagnetic activity and peripheral white blood cells in the Normative Aging Study

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## Abstract

It has been hypothesized that solar and geomagnetic activity can affect the function of the autonomic nervous system (ANS) and melatonin secretion, both of which may influence immune response. We investigated the association between solar geomagnetic activity and white blood cell counts in the Normative Aging Study (NAS) Cohort between 2000 and 2013. Linear mixed effects models with moving day averages ranging from 0 to 28 days were used to evaluate the effects of solar activity measures, interplanetary magnetic field (IMF), and sunspot number (SSN), and a measure of geomagnetic activity, K Index (K), on total white blood cell (WBC), neutrophil, monocytes, lymphocyte, eosinophil, and basophil concentrations. After adjusting for demographic and health-related factors, there were consistently significant associations between IMF, SSN, and K<sub>p</sub> index, with reductions in total WBC, neutrophils, and basophil counts. These associations were stronger with longer moving averages. The associations were similar after adjusting for ambient air particulate pollution and particle radioactivity. Our findings suggest that periods of increased solar and geomagnetic activity result in lower WBC, neutrophil, and basophil counts that may contribute to mild immune suppression.

## Introduction

Solar activity encompasses the quasi-periodic oscillation of all electromagnetic radiation emitted from the Sun to the space environment and Earth (Mendoza and Sánchez de la Peña, 2010). Alterations in solar intensity, magnetic field fluctuation, and solar winds modulate disturbances of the Earth's magnetic field, influencing biological and physiological responses of terrestrial life (Anderson, 1992; Barkhatov et al., 2008). Studies suggest variations in solar activity and Earth's magnetic field disturbances (or geomagnetic disturbances) may influence the function of the autonomic nervous system (ANS) through the disruption of circadian rhythms (Breus et al., 1995; McCraty et al.,

2017, Vieira et al., 2019). The ANS is tied to immune signaling as neurotransmitters released by the sympathetic and parasympathetic systems induce peripheral immune modulatory responses through receptors on immune cells (Kenney and Ganta, 2014). ANS dysregulation also plays a role in changing peripheral white blood cell counts suggesting that solar and geomagnetic activity may influence circulating white blood cell and differential count (Scheiermann et al., 2013).

Circulating leukocytes include neutrophils, lymphocytes, monocytes, eosinophils, and basophils. All leukocytes are derived from hematopoietic stem cells found in bone marrow. Depending on cell type, peripheral leukocytes may reflect bone marrow and systemic response to infection or response to an allergen or medication. Hematopoietic malignancies, pre-malignant conditions, and viral infections can disrupt bone marrow function that may be reflected in circulating white blood cell and differential counts (Chandran et al., 2015). While there are many known adverse health impacts related to decreased differential counts, few studies have investigated associations between solar or geomagnetic activity and immune response. Stoupel et al. (1995) compared immunoglobulin (IgA, IgG and IgM) levels during solar minimum and maximum, noting a decrease in all three immunoglobulin levels at solar maximum, as compared to solar minimum. A follow up study showed variations in autoimmune disease biomarkers including anticardiolipin and lupus anticoagulant with changes in geomagnetic activity, showing possible clinical implications related to geomagnetic storms (Stoupel et al., 2006). The immune impacts of solar and geomagnetic activity also occur beyond the boundaries of Earth's atmosphere. Astronauts experience higher exposures to solar activity from space weather and the responses observed provide insight for potential exposure relationships. Stowe et al. (1999) explored the relationship between short-term spaceflight and changes in neutrophil and lymphocyte counts. Changes in neutrophils and lymphocytes, attributable to sympathetic nervous system effects, were also observed among astronauts after adjusting for length of spaceflight (Stowe et al., 2003).

In this study we investigated the effects of solar [interplanetary magnetic field (IMF), sunspot number (SSN)], and geomagnetic activity [ $K_p$  Index] on immune dysregulation by evaluating changes in peripheral leukocytes and differential counts in a cohort of elderly healthy males living in the Greater Boston Area, Massachusetts, USA. We also assessed these effects after adjustment for fine particulate matter (PM), particle number (PN), black carbon (BC), and particle radioactivity (i.e. radioactivity associated with ambient particles) (Vieira and Koutrakis, 2021). To the best of our knowledge, this is the first epidemiologic investigation to provide a comprehensive assessment of the association

between solar activity and peripheral white blood cell and differential count in an aging cohort.

## Section snippets

### Study populations

Study participants were members of the Normative Aging Study (NAS) cohort, a closed cohort established by the U.S. Department of Veterans Affairs (U.S. VA) in 1963 (Bell et al., 1966). The NAS longitudinal study recruited men from the greater Boston area. At the beginning of the study, the participants' mean age was 42 years (range 21–81 years). All participants were free of chronic conditions at baseline and attended clinical physical examinations every 3–5 years. The study was approved by the

### Descriptive results

The descriptive statistics of the NAS Cohort study subjects for all visits and for the first visit are shown in Table 1. There were 728 individual subjects, with 2048 visits between 2000 and 2013. Of the 728 subjects, 728 presented for one visit, 537 presented for 2 visits, 413 presented for 3 visits, 286 presented for 4 visits, 87 presented for 5 visits, and 2 presented for 6 visits. At baseline, the mean age was 75.8 with a standard deviation of 6.9 years and 98% of participants were white.

### Discussion

This study demonstrates an association between greater exposure to solar and geomagnetic activity and lower peripheral leukocytes counts, with effects on granulocyte cell types (NEUT, BASO) The largest magnitudes of effect (and lowest standard errors) were observed with greater cumulative exposures as suggested by greater effects seen with longer moving day averages. The findings are consistent with suppression of bone marrow granulocyte precursor cells that ultimately differentiate into

### Conclusions

Overall, we found that different parameters representing solar and geomagnetic activity were associated with a significant decrease in absolute white blood cell counts, absolute neutrophil counts, and absolute basophil counts. This alludes to the idea that increased solar and geomagnetic activity may have a generalized immune-suppressive effect. This

study represents a novel approach to understanding the implication of solar activity on the immune system. Multiple exposure metrics of solar

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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