



Changes in Health Status in a Group of CFS and CF Patients Following Removal of Excessive 50 Hz Magnetic Field Exposure

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ABSTRACT

In December 1998 a paper published in the *ACNEM Journal* examined the hypothesis that prolonged exposure to excessive 50 Hz (power line frequency) magnetic fields may act as an immune system stressor giving rise to symptoms similar to those reported in Chronic Fatigue Syndrome (CFS) or Chronic Fatigue (CF).¹ This paper was based on a number of case histories, most notably a well-documented Workcare Compensation case (Melbourne, 1991). Here, a group of female office workers developed CFS-like symptoms when working in a room with strong 50 Hz magnetic fields emitted from an electrical substation immediately below the floor.²

The present paper briefly reports the results of a small-scale pilot study utilising 49 subjects suffering from CFS or ongoing CF, who were exposed to varying strength magnetic fields in their home environment. Some subjects were found to have prolonged exposure to magnetic fields >2 mG (milliGauss), which was used as a benchmark level. These subjects (Group A) were provided with advice and assistance regarding reducing their exposure level. The remainder of the subjects (Group B: <2 mG exposure level) were given no such advice or assistance. Changes in health status in both groups were recorded over a 6-month period. Results from the data collected at the start of the study showed no relationship between magnetic field strength and CFS/CF symptom severity. However, the majority of Group A subjects reported an improvement in symptoms and a marked improvement in sleep patterns, possibly due to the decrease in exposure. These results are discussed in the context of previous research showing disturbed sleep in the presence of magnetic fields. Such disturbances may come about through the effect of magnetic fields on melatonin secretion, a hormone involved in circadian functioning.

KEY WORDS

Chronic Fatigue Syndrome (CFS); electromagnetic fields (EMF); power line frequency; sleep changes; melatonin.

INTRODUCTION

Clinical CFS is characterised by incapacitating fatigue (experienced as exhaustion and extremely poor stamina) of at least 6 months duration, usually with an abrupt onset accompanied by an 'infectious-like' illness. It can affect virtually every major system in the body as neurological, immunological, hormonal, gastro-intestinal, musculoskeletal, and psychological problems have been reported. Many patients with CFS are unable to work, whereas others continue to work at least part-time while drastically curtailing social activities.

Symptoms tend to wax and wane but are often severely debilitating and may last for many months or years. All segments of the population (including children) are at risk, but women under the age of 45 seem to be the most susceptible. As with most diseases, CFS affects people differently. Not everybody reaches the severe end of the CFS spectrum.

CFS is also referred to as CFIDS (Chronic Fatigue and Immune Dysfunction Syndrome), CEBV (Chronic Epstein-Barr Virus), ME (Myalgic Encephalomyelitis), as well as several other designations. It is a complex illness which has been intensively studied for the past 40 years without firm conclusions as to its cause. Diagnosis is largely

by exclusion of other possible diseases.

In addition to persistent and extreme fatigue, other CFS symptoms identified include the following: substantial impairment in short-term memory and concentration, depression, sore throat, tender lymph nodes, muscle pain, multi-joint pain without joint swelling or redness, unusual headaches, unrefreshing sleep, cognitive function problems (such as spatial disorientation and impairment of speech and/or reasoning), visual disturbances (blurring, sensitivity to light, eye pain), chills and night sweats, dizziness and balance problems, sensitivity to heat and cold, irregular heartbeat, abdominal pain, diarrhoea, irritable bowel, low temperature, numbness or a burning sensation in the face or extremities, dryness of the mouth and eyes (Sicca syndrome), hearing disorders, menstrual problems including PMS and endometriosis, hypersensitivity of the skin, chest pains, rashes, allergies and sensitivities to odours (including chemicals and medications), weight changes without changes in diet, hair loss, light-headedness, fainting, muscle twitching, and seizures.

Research suggests that CFS results from a dysfunction of the immune system, involving a disruption of fundamental Central Nervous System (CNS) mechanisms, such as the sleep-wake cycle and the hypothalamic-pituitary-adrenal axis. One study found that more than a quarter of CFS patients had abnormal brain scans and subtle changes were found in the levels of neuroendocrine hormones.³ Other research has found electrolyte disturbances which sometimes included permanent changes in cell membranes' ability to pass electrolytes, permanent biochemical changes in mitochondrial function, and disturbances of insulin and T3-thyroid hormone functions.⁴

Unlike CFS, chronic fatigue (CF) is far more prevalent in the community and, as its name suggests, is characterised mainly by an ongoing feeling of fatigue and lack of energy that is not as debilitating as CFS. As there is no clear dividing line between these two conditions, people suffering chronic fatigue can be mistakenly diagnosed as having CFS.

We have hypothesised that exposure to power line frequency magnetic fields in the home and in the work-place may be a co-factor to consider when treating CFS/CF.³ The purpose of the present study was to begin the empirical investigation of our hypothesis. We located a number of people currently being treated by a medical practitioner for CFS/CF and then measured their exposure to magnetic fields in their homes. Because field studies of this type are fraught with difficulties and possible confounds, we thought it prudent to begin with a small sample pilot study to better identify any problems and to develop leads for a future, larger investigation.

METHOD

Subjects

All subjects were volunteers who initially heard about the pilot study through doctors who are members of the Australasian College of Nutritional & Environmental Medicine (ACNEM), through a notice placed in both the Victorian and South Australian CFS Societies' newsletters, or from discussions with the Hobart CFS group.

Subjects were drawn from Melbourne (Victoria), Adelaide (South Australia) and Hobart (Tasmania). The mean age of the 49 subjects was 44 years, with an age range from 17 to 72 years, consisting of 14 males and 35 females. The inclusion criterion was that all subjects were currently being treated by a medical practitioner for CFS or CF.

Questionnaire

The questionnaire consisted of two parts. First was a two-page questionnaire (*Bioscreen*) that listed 86 symptoms, with a severity scale of 0 to 4. Examples are: headaches, chest or heart pain, tinnitus or other noises in the ear, unrefreshed or prolonged sleep, allergies, forgetfulness, dermatitis, stress from work problems, symptoms of irritable bowel, etc.

The second part consisted of a further two pages that included questions on: length of time living at present address, time since being diagnosed by doctor, length of time with condition, brief description of symptoms felt, was onset gradual or with an initial flu-like illness, any indications from blood tests of low iron levels, trouble sleeping or dreaming, feelings after waking, do symptoms lessen when staying elsewhere. There were also questions on type of employment, if any, use of cordless and mobile phones and time spent using a computer as well as any symptoms felt after the extended use of a computer.

Approximately 180 questionnaires were sent out to doctors who had been previously contacted and had expressed possible interest for some of their patients. Fourteen were sent out to individuals who had contacted us as a result of the notices placed in CFS newsletters or discussions with CFS groups. In addition 8 were sent out as a result of a radio interview in Adelaide. Of the total of approximately 202 questionnaires sent out, 49 responded with no later drop-outs.

Magnetic Field Measurement

All measurements were taken with an F.W. Bell Triaxial ELF magnetic field meter. Where there were indications that the fields may be changing over time, a Trifield meter was left with subjects to check at different times for any fluctuations that might be occurring. Only the measurements taken with the F.W. Bell meter were used in the calculations.

For both Adelaide and Melbourne, two weeks were arranged in each city to conduct the initial magnetic field surveys. Survey times were by spot measurements taken at a pre-arranged time of the day according to each subject's availability. At each home, measurements were taken first with most appliances and lights off (low power configuration) and then with most appliances and lights on (high power configuration). Measurements were taken in the centre of all main rooms, one meter from the floor. Places where the subject may spend some time, such as a chair, couch or bed were especially checked. The locations of meter boxes in relation to bedheads were noted as well as magnetic fields on water pipes and proximity to power lines.

Out of the initial 14 subjects in group A, the nature of the individual exposure sources made it possible to estimate that in 12 of the subjects their magnetic exposure strength was likely to remain stable over time. For the remaining two, additional measurements were made with the Trifield meter left with them for this purpose.

In several cases where the services of an electrician and/or plumber were required to fix the source of excessive magnetic fields, a later EMF survey was conducted to ensure that the fields were lowered or eliminated.

RESULTS

A detailed statistical analysis of the questionnaire data, carried out at Massey University, New Zealand, found no relationships between the magnetic field strength and the severity of symptoms. In other words, there were no dose-response relationships (a not unusual finding in this type of research). Neither were any symptoms specific to magnetic field exposure identified. However, the later health changes, predominantly in quality of sleep, reported by the subjects did indicate unusual symptoms, such as night time tinnitus, that seemed to be related to excessive magnetic field exposure at night.

Of the 49 subjects, 14 had prolonged magnetic field exposures >2

mG (28%), and of these 14, 9 were over 4 mG (18%). Interestingly, only 2 of the 14 exposure situations were due to proximity to power lines. This is in agreement with the March 2001 British NRPB report that identified internal sources within the home, not power lines, as being a significant source of exposure.⁵

Sources of exposure for the 14 subjects exposed to <2 mG (Group A):

- one was solely from proximity to power lines (3.6 mG);
- one was from proximity to power lines and conducting water piping (2.4 mG). Four were from the bed head next to meter box (4.4 / 2.9 / 8.3 / 3.0 mG);
- two were from electrical return currents on metal water pipes (2.2 / 6.6 mG);
- one was from a quartz halogen bedside light (6.2 mG);
- two were from sleeping with an energised electric blanket (8.7 / 20.6 mG);
- one was from a waterbed heater (6.6 mG);
- one was from a phone charger by the bed head and water bed heater (5.0 mG);
- one was from a chair against a wall with high magnetic fields from kitchen appliances on the other side of the wall (9.6 mG).

Three of the above 14 subjects were excluded from all further analyses for a variety of reasons (unable to reduce exposure due to power line proximity, reduction in exposure confounded by introduction of a gluten-free diet, a doubtful case of CFS/CF.) The removal of these 3 left 11 subjects in group A, with a group average exposure of 7.1 mG.

Group B (exposure < 2 mG) consisted of 34 subjects, with a group average exposure of 0.67 mG. One subject in Group B was excluded from further analysis due to his just moving into new home; so previous EMF exposure was unknown.

At intervals up to 6 months subjects were contacted and asked about changes in health/fatigue that may have occurred in the interim. These were classified in three categories: no improvement (or worse), slight improvement, and definite improvement.

Table 1: Percentage change in symptoms 6 months after initial contact.

Group A exposure >2mG, Group B < 2mG.			
IMPROVEMENT			
	None	Slight	Definite
Group A	45%	0%	55%
Group B	68%	18%	14%

Table 1 shows that 55% of the more highly exposed subjects (Group A) reported definite improvement in their symptoms. These were the subjects given advice and assistance on how to reduce their exposure. Group B subjects (< 2 mG exposure) received no such advice and only 14% reported a definite improvement in health 6 months after initial contact.

The greater improvement in group A is in agreement with recent Swedish research that found in persons apparently hypersensitive to electricity, intensive electrical environments intensified their symptoms, and that a reduction of electromagnetic fields in the living and work-place environment seemed to be highly positive as a means for rehabilitation.^{6,7}

Sleep changes

An unexpected change in this pilot study was a marked improvement in sleep quality for the group A subjects: 64% reported an improvement in sleep while only 12% reported a similar effect in Group B.

Interestingly, 4 subjects (36%) in Group A reported an end to tinnitus at night after reduction of magnetic field levels. No Group B subjects reported this.

It is instructive to examine the comments made by Group A subjects who experienced an improved sleep quality, in a little more detail:

Subject #4: No real change to fatigue but noticed better sleep, less time awake while in bed, sleeps more soundly, easier to get back to sleep. (Bed head was by meter box, 4.4 mG.)

Subject #5: No longer suffers from tinnitus, or 'buzzing' in body at night, better sleep (deeper) and wake in the morning easier. Very sure of an improvement. Not much difference in fatigue though. (Used heated water bed, 6.6 mG.)

Subject #7: Sleeping much better, deeper, waking more refreshed, more energy, headaches less frequent, tinnitus at night ended. (Transformer was by bed head and used heated water bed, 5.0 mG.)

Subject #9: Excellent - back to normal, no longer lying awake at night trying to get back to sleep, no longer has ear-ringing at night, energy returned. (Bed head was by meter box, 8.3 mG.)

Subject #28: Sleeping really well now, longer, dreaming, with less anxiety, less vivid, less fatigue, now sleeps 10 hours a night without waking, hasn't been sick for quite a time now. (Electric blanket left on at night, 20.6 mG.)

Subject #41: Dramatic improvement, feeling better with slight improvement in sleep (more, deeper and longer), energy levels better, slow and steady improvement, overall 70-80% improvement. (Bed head by meter box, 3.3 mG.)

Subject #47: Sleeping better, having vivid dreams, never before remember dreaming, thinking more focused and clear, buzzing and tingling at night gone, no head noises, no foggy feeling, no longer trying to think through cotton wool, do not need to struggle in order to be clear-headed, still have tiredness, fatigue. (Electrical return currents on water pipes, 6.6 mG.)

These changes would seem to be a direct consequence of removal of previous night-time magnetic fields; they do not appear to be directly related to fatigue. In other words, a marked improvement in sleep does not necessarily mean an improvement in fatigue, at least in the short term.

DISCUSSION

The present investigation did not find any dose-response relationships between severity of CFS/CF symptoms and magnetic field strength. Nor were any particular symptoms linked to exposure level. In future studies, attention must be given not only to point exposure levels in the home, but to how long residents are exposed and what other sources of exposure there might be (e.g. the workplace). It is notoriously difficult to establish dose-response relationships in magnetic field research with humans, but before accepting that such relationships are nonexistent, we must be sure of the quality of our exposure measurements.

The most interesting result to come out of this pilot study was the apparent effect of reducing magnetic field exposure on sleep, though it is possible that Group A's improvement might have been due in part to the fact that they knew that they were being 'treated' (i.e. fields reduced). Sleep is not a matter of simply switching off the brain; it is a complex process that involves stages of deep and light sleep that occur over a full sleep cycle of about 8 hours for most adults. The later stages of this cycle are crucial for physical recovery and psychological wellbeing. Any factor that interrupts the cycle can cause physical and physiological effects such as fatigue, dizziness, inability to concentrate, perceptual changes, mood changes, etc.⁸

The question of whether power line magnetic fields can affect sleep was specifically examined in a paper titled: "A 50-Hz electromagnetic field impairs sleep", published in the *Journal of Sleep Research* in 1999. The researchers took 18 healthy adults (8 females, 10 males, age range 18-50 years) who were good sleepers and compared their sleep with and without exposure to a 10 mG

magnetic field (one night on - one night off). The results clearly showed a significant reduction in total sleep time, sleep efficiency, stages 3 and 4 slow wave sleep, and slow wave activity. Circulating levels of melatonin, growth hormone, prolactin, testosterone and cortisol were not affected. The authors concluded that "commonly occurring low frequency electromagnetic fields may interfere with sleep".

The authors point out that, as this study was conducted with healthy volunteers using only one night of exposure, patient groups exposed over a longer period might be more sensitive. Furthermore, it is conceivable that increased intensity of the field or of duration of exposure might yield larger effects.⁹ The fact that hormone levels were unaffected after the one night's exposure is in agreement with the findings of Wilson, Stevens and co-workers at the Pacific Northwest National Laboratory, in Washington, USA. Their research, mainly on electromagnetic field effects on melatonin in the home and workplace, indicates that melatonin levels are generally affected over the longer term (30 days or longer) by magnetic field exposure, suggesting effects may be cumulative.¹⁰

Sleep problems were also reported in a study published in the *European Journal of Internal Medicine* in 2000. Here, it was found that many people living near twin 400 kV transmission lines in Coutiches, France, and exposed to a magnetic field >2 mG, had a modified iron metabolism, which they termed "pseudo-iron deficiency". The authors propose a high bone marrow uptake of iron, explaining the apparent low iron levels in the blood.¹¹ It was noted that after several months the iron parameters would return to normal when people moved away from the exposed residences.¹² Besides tiredness/fatigue, one of the symptoms commonly reported by subjects (especially children) was an inability to sleep. It was especially noted that the insomnia would disappear when the power level was lower than usual, and return when the level normalised. The children slept normally when sent to grandparents' or relatives' homes.¹³

If indications are that only one night's exposure to a 50 Hz magnetic field can cause observable sleep impairment in healthy people, what might be the effects from prolonged exposure (years) on people with compromised immune systems, such as with CFS?

Melatonin

One possible way a magnetic field could affect sleep is by affecting the production of melatonin, a hormone produced by the pineal gland. The pineal gland is the major control gland over this cycle, with melatonin production controlled by signals from the postganglionic sympathetic fibres (neurons) connected to the hormone-producing cells of the pineal gland. The firing rate of the incoming neurons varies according to the phase of the light/dark cycle. At night, these neurons exhibit an increased rate of firing, inducing the release of the neurotransmitter norepinephrine, leading to a rise in melatonin production.^{14, 15}

During the day, light falling on photoreceptor cells in the retina produces signals that quell the firing rate of the sympathetic neurons and, as a result, melatonin production and secretion remain low. The differential firing of the neurons between the day and night accounts for the circadian rhythm in melatonin production. The day/night variation in pineal melatonin synthesis is characteristic of all [diurnal] mammalian species, including man.¹⁶

Shortly after its production, melatonin quickly enters the bloodstream and gains access to all bodily fluids and therefore every cell, and cell nucleus, in the body.¹⁷ The ability to enter every cell in the body is important for melatonin's function as an antioxidant, scavenging highly toxic, oxygen-based free radicals produced as a consequence of the utilization of oxygen by all organisms.^{18, 19, 20} Unchecked, free radicals can damage macromolecules such as DNA, proteins and lipids, through a process referred to as oxidative stress.

Besides its role as an anti-oxidant, melatonin is also known for its sleep-enhancing property.²¹ This may explain the phenomenon of jet-lag, where individuals fly through several time zones to end up at

a place in which the body's circadian rhythms are temporarily out of phase with the new location's day/night cycle. During the re-adjustment time, humans experience several signs, among them difficulty sleeping, and it is believed that the disturbance of the melatonin rhythm is partially responsible for this.²²

In a paper on melatonin suppression by static and extremely low-frequency electromagnetic fields, Reiter states: "Epidemiologists should look for other possible changes, including psychological depression, fatigue, sleep inefficiency, chronic feelings of jet lag, endocrine disturbances and other symptoms; all these may result from a chronically low melatonin rhythm".²³ Thus, magnetic field effects might be implicated in a wide range of disorders through their effect on melatonin. There are now several studies which strongly suggest that these very low frequency fields can indeed suppress melatonin.

At a workshop on electromagnetic fields, light-at-night, and human breast cancer (1997), Dr. Scott Davis of the Fred Hutchinson Cancer Research Centre, presented evidence that higher magnetic field levels at night were associated with significantly lower melatonin levels during the same night.²⁴ This research was published in the *American Journal of Epidemiology* (2001), where the authors concluded that: "These results suggest that exposure to night-time residential 60-Hz magnetic fields can depress the normal nocturnal rise in melatonin".²⁵

At the Second World Congress for Electricity and Magnetism in Biology and Medicine (1997), Japanese researchers from the Faculty of Medicine, University of Tokyo, presented research that specifically looked at melatonin levels and electric blanket use. This study set out to determine whether the effects of comparably long-term power line frequency exposure (from electric blanket use) on suppression of the melatonin rhythm in humans, could be replicated. The participants were 9 healthy male volunteers, aged between 23 and 37. It was found that exposure to magnetic fields, of the intensity generated by the electric blanket, suppressed peak value and/or delayed melatonin rhythm in 7 out of 8 subjects. They concluded that: "The present findings may suggest a possibility that exposure to ELF-EMF [extremely low frequency electromagnetic fields] by electric blankets, if magnitude and duration are sufficient, could lead to changes in melatonin production and its rhythm, at least in highly sensitive individuals".²⁶

A preliminary study of 60 workers at a Finnish garment factory found "a highly significant effect" of electromagnetic fields in reducing nocturnal melatonin levels. Magnetic field measurements were taken for the two types of machines used in the factory and operators were assigned to high or low exposure groups, based on the type of machine they were using, with average exposures either above or below 10 mG. Non-exposed non-industrial workers were used as controls. The results showed strong effects of both magnetic field exposure and smoking on night-time levels of melatonin. No difference was found in melatonin levels on week nights and Sunday nights, indicating "that the possible suppression caused by magnetic field exposure is chronic, with little recovery during the weekend".²⁷

Finally, in a study of 192 electric utility workers, Reif and Burch, from Colorado State University, found that some electromagnetic field exposures are associated with lower levels of melatonin. They found a significant association between magnetic field exposures and lower daytime melatonin levels on the second and third of three days of measurement. The lack of an effect on the first day (following a weekend or equivalent) may indicate a cumulative effect of exposure. Some studies have suggested that electromagnetic effects on melatonin may depend on whether the field is continuous or intermittent. Reif and Burch found that magnetic fields in the home that were "temporally coherent" (less intermittent) had a very significant association with lower melatonin levels at night. They concluded that: "The intensity and temporal characteristics of magnetic fields appear to be involved in melatonin suppression".²⁸

In the concluding remarks of the book, *The Melatonin Hypothesis: Breast Cancer and Use of Electric power* (1997) the authors wrote:

"The electromagnetic spectrum, particularly in the visible range,

suppresses melatonin synthesis in the pineal gland of all vertebrates, including man. Thus, electromagnetic energy has an important function in controlling the internal milieu of vertebrates... A major challenge of future research is to define the health effects of changes in melatonin production, and to determine whether wavelengths outside the visible range reproducibly alter the circadian synthesis of this important chemical mediator."²⁹

In summary, our findings of improved sleep patterns when relatively strong magnetic fields were reduced in the home at night, can be accounted for in terms of an increase in melatonin secretion, which enabled better quality sleep. Of course, at this juncture, such a conclusion is speculative. We hope to incorporate melatonin assays in our future work. Melatonin levels should correlate positively with sleep duration and quality and be negatively correlated with magnetic field intensity and/or duration.

CONCLUSIONS

The present study had quite limited aims, being a pilot for a more ambitious future investigation. That we found no relationship between exposure level and symptom severity was not entirely surprising. Clearly, our method of assessing exposure level and duration of exposure to magnetic fields must encompass more than an assessment of average exposure based on one or two readings. If possible, the full-scale investigation being planned will use meters that can be carried by subjects and which can store many readings across the course of a day. Only then can we be sure that there is no dose-response relationship between CFS symptoms and field levels.

Undoubtedly, the most interesting and exciting finding was that relatively strong magnetic fields may impair sleep. Although caution is required in drawing conclusions from such a limited sample, the results suggest that it may be worthwhile to directly assess circulating melatonin levels in future studies.

The effects of magnetic fields on the human body and central nervous system are likely to be subtle. Thus, any study in this area must be mindful of sample size. Large samples are required to provide sufficient statistical power to detect what are probably very small effects. That said, even small effects operating as co-factors in a severe illness may be enough to have a devastating impact. Therefore, it seems to us that a carefully controlled, large-scale investigation of magnetic field exposure as a co-factor in CFS and other related disorders is warranted.

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