FINAL REPORT

Human Responses to Residential RF Exposure

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INTRODUCTION

The characterization of human biological responses to non-ionizing radiation is critical for determining whether concern about potential health effects is warranted. This study was the first to carefully examine the effects of residential radiofrequency (RF) exposure on melatonin and other human biomarkers in a residential human population. We examined the hypothesis that RF exposures are associated with reduced urinary melatonin metabolite excretion and alterations in immune parameters and other biomarkers in a population of 280 residents of Lookout Mountain in Golden Colorado. Lookout Mountain is a residential community that contains numerous radio and TV transmitters that broadcast to the entire Denver metropolitan area. The unique topography of Lookout Mountain may place some homes within a main beam of these transmissions (USEPA, 1987). Several publicly accessible areas closest to these towers have exceeded the U.S. general public non-ionizing radiation standard (200 $\mu W/cm^2$) on each occasion that they were measured (USEPA, 1987; JCDEH, 1996; Cleveland, 1998).

This project used a biologically based epidemiologic design to accomplish several objectives simultaneously. First, a detailed analysis of melatonin production in response to residential RF exposure was performed. Exposures were quantified for both RF and 60 Hz fields. The effects of each exposure were determined and interactions between RF and 60 Hz exposures were also evaluated. Second, the potential effects of RF exposure on a biomarker of DNA damage/repair was assessed. Information concerning the antioxidant role of melatonin in humans was also evaluated. The effects of RF and 60 Hz exposures on ornithine decarboxylase (ODC) activity, polyamines, and immune markers were assessed along with the role of melatonin in these responses. Children (8-21 years old) were included in the study population since they are considered a susceptible subset for magnetic field (MF) induced effects, and since stronger RF coupling occurs among children at the frequencies measured in this area (Gandhi, 1990). The broad goal of this investigation was to enhance our understanding of the biological effects of exposure to non-ionizing radiation in humans and help elucidate the role of melatonin suppression in pathways leading to increased health risks. The specific aims of this study were to:

1. Characterize residential RF and 60 Hz exposures among persons living in the vicinity of a large complex of radio and TV transmitters and referents;

2. Determine whether melatonin production is reduced in response to RF and 60 Hz fields by measuring 6-hydroxy melatonin sulfate (6-OHMS) the principal metabolite of melatonin in urine.

3. Determine whether oxidative DNA damage/repair is increased in response to RF and 60 Hz exposure by measuring urinary 8-hydroxy-2'-deoxyguanosine (8-OHdG), and establish whether changes in 8-OHdG are linked with altered 6-OHMS excretion;

4. Determine whether ornithine decarboxylase activity, polyamines, and immune markers are altered by RF and 60 Hz exposure and determine whether changes are linked to 6-OHMS excretion.

METHODS

The study population was derived from adult residents and children on Lookout Mountain, a community approximately 20 miles west of Denver, CO with exposure to RF fields from more than 600 radio and TV transmitters. A comparison group was selected from residents of adjacent communities 2 to 4 miles distant from the antenna farm. There were approximately 350 homes within 1 mile of the Lookout Mountain antennae (1,000 persons), 500 homes (1,500 persons) within 1-2 miles and an additional 6,500 persons in the comparison area.

The study area was defined by Interstate 70 (I-70) to the south, the Cody Park neighborhood to the west, and the natural topography which drops steeply in elevation to the north and east of the Lookout Mountain community. No homes below 7,100 feet in elevation were included in the study area. The source population was identified by matching Jefferson County Zoning office files to the U.S. Postal Service's rural route information, which yielded 94% concordance among the residences identified. A population census of each person living in these residences age 8 and older identified approximately 576 homes and 1,375 individuals in the study area. A curbside RF survey was performed along publicly accessible streets to ascertain power densities in the study area. A sample of 441 eligible study participants ($\geq$8 years old) was then identified for recruitment among strata of high ($\geq$4.0 $\mu W/cm^2$), medium (0.5-4.0 $\mu W/cm^2$) and low ($\leq$0.5 $\mu W/cm^2$) RF exposure categories. All adults from the high RF exposure category and all children (8-18 years old) from the high and medium categories were considered eligible. Individuals in the remaining categories were randomly selected from the census data base.

Four to eight participants with a range of RF exposures were studied each week from September, 2002 to December, 2003. Data collection for each subject occurred over a 2.5 day period, typically from Friday afternoon until Monday morning. Exposure assessment included RF spot measurements inside and outside the home, and continuous personal monitoring for 60 Hz magnetic field and ambient light exposures. RF field intensity was recorded outside the home and at five locations within the home (bedroom, kitchen, living room, computer room or office, and room used most often, if different) using a Narda EMR-300 meter with a Type 18 isotropic E-field probe (flat response: 0.1 to 3,000 MHz, 0.2 V/m detection limit). In each room, a spatial average that included the approximate room center and four points midway between the room center and each corner was recorded at approximately one meter above the floor. Measurements were performed at the beginning of the 2.5-day data collection period and repeated at the end of this period. In a subset of 17 homes, RF power densities were logged continuously at 1-minute intervals during the 2.5 day data collection period using the RF meter adapted to a personal computer for data storage. Spot measurements were also repeated in a subset of homes 8-29 months later at 8 interior and 12 exterior locations.

A global positioning system (GPS) was used to identify the geographic coordinates and elevation of each exterior RF measurement (eTrex Legend, Part No. 190-00234-00, Garmin International Inc., Olathe, KN). The distance between each transmitter and residence was characterized using the ERSI ArcInfo program (Redlands, California) as part of a geographic information system (GIS). Line of sight visibility was determined using the viewshed analysis tool of ESRI ArcMap 9.0. The viewshed model determined line of sight visibility (yes/no) using a set of input points (transmitters) and a three dimensional input surface (digital elevation model). The viewshed results were overlayed on a GIS of points (residential coordinates) and the results tabulated. The average distance from each residence to the major 15 transmitters in the study area and the percentage of these transmitters visible from the home were used for statistical analyses.

Personal exposure to 60 Hz MFs and ambient light was logged continuously at 15 second intervals 24 hours per day using EMDEX II meters adapted with a Grasby Optronics light sensor (Burch et al., 2000). The EMDEX was worn at the waist during the day, and placed bedside on nonconductive material adjacent to the waist during sleep. The 24-hour trace on each day was divided into six periods corresponding to: sunset until bed time, bed time, waking until sunrise (if applicable), sunrise until 4 hours past sunrise, 4 hours before sunset until sunset, and mid-day. These periods were chosen because they characterize times of day (ie, around sunrise and sunset) when ambient light exposures (another form of electromagnetic energy) have a profound influence on human melatonin production. MF exposure intensity (geometric mean), cumulative exposure (mG-hrs) and temporal stability (standardized rate of change metric or RCMS) were averaged over each time period for each day of participation (Burch et al., 1999).

Each participant collected one overnight urine sample immediately following their first night of participation and a second overnight sample on their final night of participation. Each sample included the entire urinary output following sleep, plus any voids occurring during the sleep period. Samples were transported on ice and frozen at -70^{o} C until analysis. Melatonin production was assessed by radioimmunoassay of urinary 6-OHMS concentrations (Arendt et al., 1985; Aldous et al., 1988). Urinary 8-OHdG assays were performed by ESA laboratories (Chelmsford, MA) using a highly sensitive and specific triple column HPLC method with electron capture detection. Melatonin and 8-OHdG were measured in urine in two ways, as the total overnight output (total μg) and as the concentration of the analyte normalized to urinary creatinine concentration in the same urine sample. Total overnight production of melatonin and 8-OHdG were estimated as the product of the crude analyte concentration and the urine sample volume. The nocturnal concentrations were normalized to urinary creatinine levels and expressed as ng/mg creatinine. A blood sample was collected from adult participants on the final morning of participation. Blood samples were immediately transported to a clinical laboratory (LabCorps, Denver, CO) for analyses of: differential counts, T, B, and NK cell counts, cytotoxic and helper t cells, CD4/CD8 ratio, vitamins C and E, and blood lipids (total cholesterol and triglycerides for lipid adjustment of vitamin E). ODC is the rate-limiting enzyme catalyzing the synthesis of polyamine proteins (putrescine, spermine, spermidine) that are required for cell proliferation.ODC activity is one of the more consistently observed biological changes associated with magnetic field exposure in animal or cellular systems. ODC activity and polyamine assays in peripheral blood leucocytes were performed at the laboratory of Craig Byus, PhD, Professor of Biochemistry, University of California (Riverside, CA).

Statistical analyses were performed using the Statistical Analysis System (SAS) computer program (version 9.1, SAS Institute Inc., Cary, NC). Exterior and interior RF measurements were converted to $\mu W/cm^2$ since residential RF measurements obtained in this study were expected to be in the far field (Dahme, 1999). RF values below the limit of detection were given a value of one half the detection limit ($0.01\ \mu W/cm^2$) for analysis. Multivariate statistical analyses were used to determine whether RF exposures alter 6-OHMS or 8-OHdG excretion, modify leukocyte ODC activity or polyamine levels, or affect white blood cell differential counts and T cell subsets. Initially, a univariate screening process was be used to identify factors associated with each biomarker. Variables were selected for screening if data from at least 10% of the study subjects are available for analysis within each level of a given predictor variable. Mean biomarker levels in subjects with or without a given characteristic were compared statistically (Proc Mixed) and selected for further analysis if the statistical significance of each comparison is less than 0.10. Factors meeting these criteria were included as potential confounders in subsequent multivariate statistical analyses by including each predictor simultaneously in the statistical model and determining the statistical significance of the exposure based on the type III sums of squares. The Proc Mixed procedure for repeated measures was used for exposures and outcomes measured on

both data collection days (ie, RF measurements and urinary markers) and the Proc GLM (Generalized Linear Models) procedure in SAS was used to evaluate outcomes that were measured on only one day (ie, immune markers). In both cases, subjects were initially grouped into quartiles by house average RF power density, proximity, elevation, or visibility, and the adjusted (least-squares) mean of each biological marker was calculated within each quartile. Adjusted mean biomarker levels in the lowest and highest quartiles were then compared using the least significant differences statistic. The effects of RF exposures on each biological marker were also evaluated as continuous variables.

Similar analyses were used to evaluate the effect of personal exposure to extremely low frequency (60 Hz) magnetic fields on each biological marker. Initially, time weighted average exposures during each period (sunset until bed time, bed time, waking until sunrise, sunrise until 4 hours past sunrise, 4 hours before sunset until sunset, and mid-day) were evaluated as continuous variables to determine which time period had the strongest association with each biological marker. More detailed analysis of geometric mean, cumulative and temporally stable ELF exposures were then performed using the time period from sunset to bed-time for all markers (evening). Adjusted means for each biological marker were calculated within exposure quartiles and values in the lowest and highest quartiles were compared statistically. To evaluate potential interactions between RF and ELF exposures, both exposure variables and their cross product were included in the statistical model. Interactions with other relevant factors (melatonin production) were evaluated similarly.

RESULTS

The study population is shown in table 1. A total of 280 subjects were studied, of whom 138 (49.3%) were male. The vast majority of participants were white (93.4%). The distribution of the study population according to mean household exposure to RF fields by tertile is shown in table 2. Children between 8 and 17 years of age comprised 23.9% of the sample (n=67) and were over-represented in the lowest tertile of RF exposure. Age was considered as a potential confounder in all analyses and included in multivariate models evaluating 6-OHMS as described above.

The relationship between residential exposure to RF and total and overnight production of melatonin is shown in table 3. Residential RF exposure was not associated with melatonin production. Similarly, other metrics for RF exposure including distance to the transmitters, line of sight visibility and elevation were not associated with either measurement of melatonin. The relationship between melatonin metabolite excretion and exposure to extra low frequency (ELF) magnetic fields was also evaluated (table 4). Exposure to ELF was analyzed using metrics for the time weighted average (TWA) geometric mean, the TWA cumulative exposure and the TWA temporal stability of the magnetic field. The data in table 4 show the analyses for exposure to ELF magnetic fields during the period from sunset to bedtime (evening). With one exception, no statistically significant associations between evening exposure to magnetic fields and total or nocturnal excretion of 6-OHMS were found. The TWA cumulative average exposure to magnetic fields was associated with an <u>increase</u> in nocturnal 6-OHMS concentration. This association is in the opposite direction from that described by ourselves and others in the literature (Burch et al., 1999).

It is conceivable that RF and MF may act together to alter melatonin production and excretion through a common pathway. Therefore, we assessed the effects of exposure to ELF among persons above and below the median RF exposure on total and nocturnal melatonin excretion (table 5). There were no associations detected between ELF exposure and melatonin excretion among persons exposed to RF

below the median house average. However, among those exposed to RF above the median, persons in the highest quartile of exposure to ELF had an increase in both their total overnight melatonin excretion and their melatonin concentration when either geometric mean or cumulative exposure to ELF was used as the exposure metric.

We evaluated potential associations between exposure to RF and urinary excretion of 8-OHdG as a marker of DNA damage. Persons in the highest quartile of residential average exposure to RF had concentrations of urinary 8-OHdG that were not significantly different from persons in the lowest quartile of RF exposure (table 6). Similarly, persons living nearest the transmitters, with higher line of sight visibility to the towers or at higher elevation did not have a significant increase in urinary 8-OHdG concentration compared to persons in the lowest exposure quartile for each metric in either the total overnight or first morning void (nocturnal) urine sample. We also evaluated the potential relationship between melatonin production and 8-OHdG (table 7). Persons who had higher excretion of melatonin in their urine also had higher total overnight excretion of 8-OhdG and higher concentrations of 8-OHdG in their overnight urine samples in both crude and adjusted analyses. The relation between total overnight excretion and concentration of 8-OHdG exposure to ELF 60 Hz fields was also evaluated (table 8). We found evidence of an association between evening exposure to ELF and total overnight excretion of 8-OHdG when the magnetic field exposure was classified as the geometric mean or the cumulative overnight exposure.

The potential relationship between residential RF exposure and a panel of immune markers was assessed (table 9). The house average RF exposure was divided into quartiles and persons living in homes in the highest quartile of exposure compared to persons living in homes in the lowest quartile. An increase in the total number of T cells per ml was found when exposure was considered in quartiles ($p=0.04$) or as a continuous variable ($p=0.09$). The increase in T cells appeared to be due to an increase in both helper and cytotoxic T cells. The total number of circulating lymphocytes per ml was also increased ($p = 0.05$), but no association was apparent when the RF was analyzed as a continuous variable. Previous research has suggested that biological effects of MF on the immune system may be modulated through melatonin. Potential associations between melatonin and the immune markers were assessed by comparing the concentrations of the markers among persons in the highest and lowest tertiles of melatonin excretion (table 10). The concentrations of total lymphocytes, total T cells, helper T cells and natural killer (NK) cells were higher among persons with higher melatonin excretion. Similar associations were seen between melatonin excretion and helper T cells and NK cells when the data were analyzed as continuous variables (table 10). Therefore, we then evaluated the association between exposure to RF and immune markers among persons with total overnight melatonin excretion above and below the median (table 11). Paradoxically, associations between RF exposure and immune markers were found among persons with melatonin excretion below the median but not among persons with melatonin excretion above the median. For the group of individuals with low melatonin excretion, the concentrations of total white blood cells, total lymphocytes, total T cells, helper T cells, and cytotoxic T cells were all significantly increased among persons in the highest compared to the lowest quartile of household RF exposure.

The relationship between RF exposure and ODC activity and polyamine concentrations was explored (table 12). RF exposure appeared to be associated with a decrease in ODC activity in both mitogen stimulated and unstimulated blood leucocytes. The decrease in unstimulated ODC activity is consistent with a previous study of ODC activity in response to ELF exposures among electric utility workers (Ichinose et al., 2004). No associations between RF exposure and any of the polyamines were detected.

Table 1. Gender and Minority Inclusion Lookout Mountain, Golden Colorado, 2002-2003

Gender	American Indian or Alaskan Native	Asian	Native Hawaiian or Pacific Islander	Black or African American	White	More than one Race	Refused	Total
Male	1	3	0	0	131	3	0	138
Female	2	6	0	1	131	1	1	142
Total	3	9	0	1	262	4	1	280

Table 2. Population demographics by RF exposure[1] for participants, Lookout Mountain, Golden Colorado, 2002-2003

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Exposure Category (μw/cm^2)	N (%)	Homes (%)	Adults (%)	Children[2] (%)	Males (%)	Females (%)
Low (0-.15)	95 (34)	60 (37)	67 (32)	28 (42)	43 (31)	52 (37)
Mid (0.16-.784)	93 (33)	52 (32)	75 (35)	18 (27)	52 (38)	41 (29)
High (0.785-6.3)	92 (33)	49 (30)	71 (33)	21 (31)	43 (31)	49 (35)
Total	280	161	213	67	138	142

[1]RF exposure based on house average (in-house measurements)
[2]Children – 8-17 yrs of age

Table 3. Melatonin Metabolite Excretion and Residential RF Exposures[1]
Lookout Mountain, Golden Colorado, 2002-2003

Quartiles of Exposure	Total Sleep Period 6-OHMS Excretion (μg)	Nocturnal 6-OHMS Concentration (ng/mg cr)
Residential Average RF ($\mu W/cm^2$)		
< 0.05	14.1	40.3
0.06 - 0.64	13.9	39.6
0.65 - 1.83	14.3	43.1
> 1.83	13.7	43.0
Continuous Exposure (p-value)	(0.76)	(0.64)
Average Distance to Transmitters (km)		
< 1.0	13.8	43.1
1.1 - 1.4	13.2	40.3
1.5 - 2.5	14.8	41.3
> 2.5	14.4	43.1
Continuous Exposure (p-value)	(0.22)	(0.56)
Line of Sight Visibility (%)		
< 7	14.0	42.4
8 - 53	12.2	35.1
54 - 87	15.4	48.5
> 87	13.5	47.2
Continuous Exposure (p-value)	(0.95)	(0.22)
Elevation (mean feet above sea level)		
< 7,311	13.2	39.0
7,312 - 7,372	13.0	40.0
7,373 - 7,471	15.4	47.8
> 7,471	13.8	41.1
Continuous Exposure (p-value)	(0.54)	(0.34)

1 – Least squares means adjusted for potential confounding factors. Total 6-OHMS Excretion: age, month of participation, body mass index, education, vegetable consumption.
6-OHMS concentration: age, gender, month of participation, body mass index, education, smoking, aspirin consumption.
* $p < 0.05$, ** $p < 0.01$ vs quartile 1

Table 4. Melatonin Metabolite Excretion and ELF Magnetic Field Exposures[1], Lookout Mountain, Golden Colorado, 2002-2003

Quartiles of Exposure[2]	Total Sleep Period 6-OHMS Excretion (μg)	Nocturnal 6-OHMS Concentration (ng/mg cr)
TWA Geometric Mean (mG)		
< 0.24	14.2	45.6
0.25 - 0.37	15.4	51.3
0.38 - 0.66	13.0	41.1
> 0.66	18.3†	55.9
Continuous Exposure (p-value)	(0.08)	(0.05)
TWA Cumulative Exposure (mG-hrs)		
< 0.9	13.5	38.8
1.0 - 1.8	16.1	44.8
1.9 - 3.7	14.2	49.5
> 3.7	17.1	58.7*
Continuous Exposure (p-value)	(0.20)	(0.06)
TWA Temporal Stability (per 15 sec)		
> 0.80	14.1	44.7
0.63 - 0.80	17.4	50.8
0.38 - 0.62	15.2	47.8
< 0.37	14.5	48.1
Continuous Exposure (p-value)	(0.80)	(0.64)

1 – Least squares means adjusted for potential confounding factors. Total 6-OHMS Excretion: age, month of participation, body mass index, education, vegetable consumption.
6-OHMS concentration: age, gender, month of participation, body mass index, education, smoking, aspirin consumption.
2 -Time weighted average 60 Hz personal exposures from sunset until bedtime.
ELF - Extremely low frequency
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ vs quartile 1

Table 5. Melatonin Metabolite Excretion and Combined Exposure to RF and ELF Magnetic Fields[1] Lookout Mountain, Golden Colorado, 2002-2003

Quartiles of Exposure[2]	Total Sleep Period 6-OHMS Excretion (µg)	Nocturnal 6-OHMS Concentration (ng/mg cr)	Total Sleep Period 6-OHMS Excretion (µg)	Nocturnal 6-OHMS Concentration (ng/mg cr)
	House Average RF Below Median		House Average RF Above Median	
Geometric Mean (mG)				
< 0.24	16.2	54.7	12.5	38.1
0.25 - 0.37	16.2	48.1	15.2	55.0
0.38 - 0.66	13.1	40.1	13.6	44.6
> 0.66	16.8	49.0	21.1*	63.2*
Cumulative Exposure (mG-hrs)				
< 0.9	15.6	44.8	11.5	34.8
1.0 - 1.8	17.8	50.2	14.7	41.6
1.9 - 3.7	14.5	48.2	14.7	54.6
> 3.7	13.8	48.5	21.2**	73.5**

1 – Least squares means adjusted for potential confounding factors. Total 6-OHMS Excretion: age, month of participation, body mass index, education, vegetable consumption.
6-OHMS concentration: age, gender, month of participation, body mass index, education, smoking, aspirin consumption.
2 -Time weighted average 60 Hz personal exposures from sunset until bedtime.
ELF - Extremely low frequency
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ vs quartile 1

Table 6. Oxidative DNA Damage/Repair and Residential RF Exposures[1]
Lookout Mountain, Golden Colorado, 2002-2003

Quartiles of Exposure	Total Sleep Period 8-OHdG Excretion (μg)	Nocturnal 8-OHdG Concentration (ng/mg cr)
Residential Average RF ($\mu W/cm^2$)		
< 0.05	1.6	5.4
0.06 - 0.64	1.7	5.3
0.65 - 1.83	1.6	5.4
> 1.83	1.5	6.0
Continuous Exposure (p-value)	(0.53)	(0.60)
Average Distance to Transmitters (km)		
< 1.0	1.5	5.9
1.1 - 1.4	1.6	5.5
1.5 - 2.5	1.5	4.8
> 2.5	1.7	6.0
Continuous Exposure (p-value)	(0.36)	(0.75)
Line of Sight Visibility (%)		
< 7	1.7	5.8
8 - 53	1.6	5.2
54 - 87	1.4	5.6
> 87	1.6	5.1
Continuous Exposure (p-value)	(0.18)	(0.68)
Elevation (mean feet above sea level)		
< 7,311	1.7	6.1
7,312 - 7,372	1.6	5.9
7,373 - 7,471	1.4	4.7
> 7,471	1.8	5.6
Continuous Exposure (p-value)	(0.99)	(0.07)

1 – Least squares means adjusted for potential confounding factors. Total 8-OHdG Excretion: gender, alcohol consumption, vitamin C consumption, blood pressure medication.
Nocturnal 8-OHdG concentration: gender, alcohol consumption.
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ vs quartile 1

Table 7. Melatonin Production and 8-Hydroxy-deoxyGuanosine Excretion

Tertile of 6-OHMS Excretion	Total Sleep Period 8-OHdG Excretion (μg)	Nocturnal 8-OHdG Concentration (ng/mg cr)
Crude:		
Tertile 1	1.4	5.1
Tertile 2	1.6	5.4
Tertile 3	2.0**	6.8**
Adjusted:[1]		
Tertile 1	1.4	5.2
Tertile 2	1.5	5.2
Tertile 3	1.9**	6.4*

1 - Least squares means adjusted for potential confounding factors.
Total 8-OHdG Excretion: gender, alcohol consumption, vitamin C consumption, blood pressure medication.
Nocturnal 8-OHdG concentration: gender, alcohol consumption.
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ vs tertile 1

Table 8. Oxidative DNA Damage/Repair and ELF Magnetic Field Exposures[1], Lookout Mountain, Golden Colorado, 2002-2003

Quartiles of Exposure[2]	Total Sleep Period 8-OHdG Excretion (μg)	Nocturnal 8-OHdG Concentration (ng/mg cr)
TWA Geometric Mean (mG)		
< 0.19	1.3	5.7
0.20 - 0.30	1.8	6.2
0.31 - 0.55	1.5	6.0
> 0.55	1.8*	5.3
Continuous Exposure (p-value)	(0.16)	(0.36)
TWA Cumulative Exposure (mG-hrs)		
< 0.8	1.4	6.0
0.9 - 1.4	1.4	5.2
1.5 - 2.2	1.8*	6.2
> 2.2	1.8†	5.8
Continuous Exposure (p-value)	(0.05)	(0.52)
TWA Temporal Stability (per 15 sec)		
> 0.86	1.5	5.6
0.59 - 0.85	1.6	6.6*
0.29 - 0.58	1.7	5.6
< 0.29	1.6	5.3
Continuous Exposure (p-value)	(0.40)	(0.96)

1 – Least squares means adjusted for potential confounding factors. Total 8-OHdG: gender, alcohol consumption, vitamin C consumption, blood pressure medication.
Nocturnal concentration: gender, alcohol consumption.
2 - Time weighted average 60 Hz personal exposures from sunset until bedtime.
ELF - Extremely low frequency.
† p. 0.10, * p. 0.05, & ** p. 0.01 vs. quartile 1.

Table 9. Immune Markers and Residential RF Exposure, Lookout Mountain, Golden Colorado, 2002-2003[1]

Immune Marker	Quartiles of House Average RF Exposure					
	1	2	3	4	p-value: 1 vs. 4	p-value: continuous
Total White Blood Cells	5,408	5,605	5,409	5,742	0.32	0.70
Total Lymphocytes	1,631	1,782	1,741	1,863	0.05	0.20
Total T Cells	1,253	1,360	1,375	1,461	0.04	0.09
Helper T Cells	849	911	870	976	0.08	0.27
Cytotoxic T Cells	346	388	414	412	0.10	0.12
CD4:8 Ratio	2.5	2.3	2.1	2.4	0.72	0.43
NK Cells	103	126	108	106	0.92	0.61
B Cells	181	210	196	218	0.15	0.33

1 – Least squares means adjusted for: season of participation, concern about RF fields, number of residents.

Table 10. Immune Markers and Overnight Melatonin Production, Lookout Mountain, Golden Colorado, 2002-2003[1]

Immune Marker	Tertiles of Total Sleep Period 6-OHMS Excretion				
	1	2	3	p-value: 1 vs. 3	p-value: continuous
Total White Blood Cells	5,141	5,326	5,446	0.30	0.30
Total Lymphocytes	1,623	1,767	1,841	0.04	0.24
Total T Cells	1,239	1,388	1,401	0.07	0.29
Helper T Cells	814	902	928	0.06	0.06
Cytotoxic T Cells	350	414	402	0.18	0.72
CD4:8 Ratio	2.3	2.2	2.3	0.95	0.09
NK Cells	94	91	149	0.01	0.02
B Cells	175	195	192	0.45	0.61

1 – Least squares means adjusted for: season of participation, concern about RF fields, number of residents.

Table 11. Immune Markers and Residential RF Exposure[1]: Stratified by Overnight Melatonin Metabolite Excretion, Lookout Mountain, Golden Colorado, 2002-2003

Immune Marker	Quartiles of House Average RF Exposure				
	1	2	3	4	p-value: 1 vs. 4
	Total Sleep Period 6-OHMS Excretion Below Median				
Total White Blood Cells	4,620	5,475	4,968	5,750	0.02
Total Lymphocytes	1,343	1,680	1,720	1,811	≤0.01
Total T Cells	1,049	1,318	1,334	1,445	≤0.01
Helper T Cells	717	857	911	949	0.01
Cytotoxic T Cells	265	385	339	431	≤0.01
CD4:8 Ratio	2.7	2.2	2.7	2.2	0.16
NK Cells	50	78	122	67	0.63
B Cells	142	189	184	202	0.08
	Total Sleep Period 6-OHMS Excretion Above Median				
Total White Blood Cells	5,695	5,628	5,459	5,676	0.97
Total Lymphocytes	1,763	1,910	1,811	1,957	0.38
Total T Cells	1,338	1,449	1,454	1,601	0.16
Helper T Cells	854	960	873	1,062	0.10
Cytotoxic T Cells	415	423	506	467	0.53
CD4:8 Ratio	2.1	2.3	1.7	2.3	0.56
NK Cells	99	157	89	142	0.30
B Cells	200	226	198	154	0.27

1 – Least squares means adjusted for: season of participation, concern about RF fields, number of residents, age, month of participation, body mass index, education, vegetable consumption.

Table 12. Leukocyte Ornithine Decarboxylase Activity and Polyamine Concentrations by Residential RF Exposure, Lookout Mountain, Golden Colorado, 2002-2003[1]

Immune Marker	Quartiles of House Average RF Exposure					
	1	2	3	4	p-value: 1 vs. 4	p-value: continuous
	Mitogen Stimulated					
ODC Activity[2]	0.16	0.08	0.24	0.08	0.09	0.57
Putrecine	1.93	2.73	3.23	2.21	0.65	0.20
Cadaverine	1.20	1.66	1.97	1.39	0.58	0.20
Spermidine	0.69	0.72	1.24	0.89	0.38	0.12
Spermine	1.54	1.79	2.71	1.84	0.52	0.19
	Unstimulated					
ODC Activity[2]	0.07	0.05	0.06	0.02	<0.01	0.06
Putrecine	2.64	2.16	3.32	1.70	0.07	0.23
Cadaverine	1.60	1.45	2.40	1.22	0.21	0.59
Spermidine	1.10	0.68	1.00	0.81	0.30	0.43
Spermine	2.45	1.51	3.52	1.79	0.18	0.56

1 – Least squares means adjusted for: season of participation, concern about RF fields, number of residents.
2 – ODC activity expressed as pmol/107 cells/hr.

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