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Project Summary

Thermoregulatory Consequences of Long-Term Microwave Exposure at Controlled Ambient Temperatures

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This study was designed to identify and measure changes in thermoregulatory response systems, both behavioral and physiological, that may occur when squirrel monkeys are exposed to 2450-MHz CW microwaves 40 hours/week for 15 weeks. Microwave power densities explored were 1 and 5 mW/cm² (SAR = 0.16 W/kg per mW/cm²) and were presented at controlled environmental temperatures of 25, 30, and 35 °C. Standardized tests, conducted periodically, assessed changes in thermoregulatory responses. Dependent variables measured included body mass, certain blood properties, metabolic heat production, sweating, skin temperatures, deep body temperature, and behavioral responses by which the monkeys selected a preferred environmental temperature. Results showed no alteration of metabolic rate, internal body temperature, or thermoregulatory behavior by microwave exposure although the ambient temperature prevailing during chronic exposure could exert an effect. An increase in sweating rate occurring in the 35 °C environment was not enhanced significantly by microwave exposure. Skin temperature, reflecting vasomotor state, was reliably influenced by both ambient temperature and microwaves. The most robust consequence of microwave exposure was a reduction in body mass which appeared to be a function of microwave power density.

This Project Summary was developed by EPA's Health Effects Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Committees of both houses of the Congress (U.S. Senate, 1978; U.S. House of Representatives, 1979) have urged the establishment of research programs which would investigate the biological effects of long-term exposure to low-level radiation. Held to be of particular importance is "...basic research into the physiological mechanisms by which biological and/or behavioral effects of exposure to nonionizing radiation may occur..." The final report on this project describes some results of a four-year program of research for which the above description is highly appropriate. Specifically, the study investigated the changes in thermoregulatory mechanisms that may occur when squirrel monkeys are chronically exposed to low-level microwave fields at controlled environmental temperatures.

Thermoregulation refers to the ability of an organism to achieve and maintain a characteristic internal body temperature.

Two classes of responses can accomplish thermoregulation, behavioral and physiological (or autonomic). Behavioral responses, voluntary actions by the organism, control the thermal characteristics of the air-skin interface and can take two forms, either direct manipulation of the environment itself of bodily movement into a more favorable microclimate. The heat exchange between the organism and the environment is thereby closely regulated, which results in stability of the internal body temperature. Both types of behavior have been shown to change when an organism is exposed briefly to a microwave field.

Physiological responses are involuntary in endothermic species and may occur automatically whenever behavioral responses are impossible or inadequate, or under special circumstances; e.g., during exercise or febrile disease. Specific physiological responses include shivering and non-shivering thermogenesis, changes in peripheral vasomotor tone, sweating and/or panting. These responses also have been shown to change when endotherms are exposed briefly to a microwave field.

That long-term exposure to low-level microwave fields may alter thermoregulatory function is suggested by some of the Eastern European clinical literature. A neurocirculatory syndrome involving cardiac, neural, and metabolic function was often found in Soviet workers who had labored in close proximity to microwave sources for 10 years or more. The literature describes long-term alterations in body weight, blood pressure, body temperature, and certain conditioned reflexes. It has been reported that workers exposed to microwaves for more than 10 years are copious sweaters compared to short-term workers. However, in these Eastern European clinical studies, average microwave exposures are estimated, proper dosimetry is nonexistent, and other relevant environmental factors, such as temperature and humidity, are usually neither assessed nor controlled.

To date, laboratory investigation of the effects of long-term microwave exposure in animals has been carried out almost exclusively on small mammals (i.e., mice, rats, guinea pigs, and rabbits). No published study has stated as a specific purpose the assessment of the thermoregulatory consequences of such exposure, although a metabolic compensation in exposed animals has been inferred from measurements of body mass and food consumption. In general, rats and rabbits exposed for several weeks or months to low doses of microwaves eat less than controls but maintain body weight and increase fluid intake. Such findings have led some to conclude that the exposed animals profited from the microwave energy and the reduced energy demands of their bodies was reflected by a lowered food intake.

The effects of periodic and chronic microwave exposure at high power densities on the regulated body temperature of dogs was an early topic of investigation. Repeated exposure to 2800-MHz pulsed microwaves at 165 mW/cm^2 produced smaller and smaller increases in rectal temperature. Also reported was an adaptation to the procedure that took the form of a lower-than-normal body temperature. A very important variable appears to be the ambient temperature at which such chronic exposures are performed, high ambients emphasizing thermoregulatory abnormalities and low ambients de-emphasizing them.

Few primates have been chronically exposed to radiofrequency fields and none for the express purpose of measuring changes in thermoregulatory function. The literature describes several studies in which rhesus monkeys, living outdoors in large family groups, irradiate themselves with 9.3 GHz pulsed microwaves at a range of power densities as they work daily for apple juice rewards. No deleterious effects on the eyes have been observed after several years, and operant responding, social behavior, health, and fecundity are all normal. Another study exposed rhesus monkeys for 22 months to extremely low-frequency electromagnetic fields but found no changes in general health; the major difference between exposed and control animals was an increased growth rate in the exposed monkeys.

Discussion

There is a clear need for basic information on the thermoregulatory consequences of long-term low-level exposure of primates to microwaves, preferably at different ambient temperatures. This project summary describes a longitudinal study of highly trained animals (initially naive to microwaves) that combined both physiological and behavioral tests. Following the assessment of baseline levels of thermoregulatory function, squirrel monkeys were either sham-exposed or exposed to 2450-MHz continuous wave (CW) microwaves, 40 h/wk for 15 weeks. Power densities were 1 or 5 mW/cm^2 at controlled ambient temperatures of 25, 30 or 35°C. Periodic physiological and behavioral tests were performed to assess thermoregulatory function during and after chronic exposure. The purpose of this study was to determine:

1. whether this exposure alters the normally-preferred ambient temperature and the ambient temperature selected during brief exposures to microwaves of higher field strength;
2. whether this exposure can produce "irritability" as measurd by changes in the pattern of thermoregulatory responding;
3. whether significant changes occur in body mass and in standard hematological parameters;
4. whether this exposure changes the setpoint for body temperature, alters the normal physiological responses of heat production and heat loss in cold, neutral, and warm environments, or alters vasomotor activity; and
5. whether ambient temperature and microwave energy interact synergistically to produce changes in thermoregulatory function.

This longitudinal study was undertaken to determine whether or not the normal thermoregulatory responses of squirrel monkeys may be altered during and after chronic exposure (40 h/wk for 15 wk) to 2450-MHz CW microwaves, at power densities of 0, 1, and 5 mW/cm^2, when ambient temperature is simultaneously controlled at 25, 30 or 35°C. The findings were largely negative: no changes that occurred in metabolic heat production, resting metabolic rate, normal regulated body temperature, or the microwave threshold for the alteration of thermoregulatory behavior could be ascribed unequivocally to chronic microwave exposure. Chronic exposure to the 35°C environment, irrespective of concomitant microwave exposure, increased sweating rate and lowered the environmental temperature selected by most animals. Significant shifts in mean skin temperature were difficult to interpret because of variability in baseline data, a difficulty compounded by the small sample size. No trends in the data over time indicated a cumulative influence of microwave exposure on thermoregulatory mechanisms. Tests of hematological and serum chemistry parameters yielded random results that were of dubious relevance to the exposure treatments. The most reliable finding appeared to be a reduction in body mass of the microwave-exposed animals

egardless of exposure temperature, an ffect that was most pronounced in those nimals exposed at 5 mW/cm².

The study was exploratory, in the sense hat a wide range of chronic exposure onditions was examined for possible hermoregulatory consequences. As a esult, very few animals constituted each reatment group, rendering statistical nalysis of the data very difficult. An lternative approach would have involved xposing larger numbers of animals to nany fewer exposure conditions. How-ver, no relevant experimental evidence xisted on which to select the "critical" xposure conditions. In the belief that nicrowave exposure in thermoneutral nd warm environments posed a greater hreat to efficient thermoregulation than imilar exposure in the cold, the selected xposure conditions had the potential for eat stress, in the context of the thermo-egulatory capacity of the squirrel mon-ey. Hence, the three ambient temper-tures at which chronic exposure oc-urred were equivalent to the middle and wo extremes of the thermoneutral zone f the species in question. The power lensities selected were either well below 1 mW/cm²) or near (5 mW/cm²) the ower limit of those that just provoke hanges in thermoregulatory responses luring acute microwave exposure under naximally-favorable environmental con-litions. The conditions selected set the tage most favorably for the manifestation f cumulative effects and/or the enhance-nent of particular response changes to ne environmental variable by a second ariable acting synergistically. That most f the results were negative or equivocal eflects the influence of many factors, all f which are detailed in the final report.

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The complete report, entitled "Thermoregulatory Consequences of Long-Term Microwave Exposure at Controlled Ambient Temperatures," (Order No. PB 84-236 603; Cost: $11.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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Telephone: 703-487-4650

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