Microwave sickness: a reappraisal

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Microwave sickness (MWS) has been a disputed condition. The syndrome involves the nervous system and includes fatigue, headaches, dysaesthesia and various autonomic effects in radiofrequency radiation workers. This paper describes the early reports of the syndrome from Eastern Europe and notes the scepticism expressed about them in the West, before considering comprehensive recent reports by Western specialists and a possible neurological basis for the condition. It is concluded that MWS is a medical entity which should be recognized as a possible risk for radiofrequency radiation workers.

Key words: Dysaesthesia; fatigue; microwave sickness; neurological; radiofrequency.

Received 30 June 2000; accepted 23 August 2000

Introduction

The health effects of radiofrequency radiations (RFR) are controversial. (See Appendix for an introduction to the biophysics of RFR.) There is general agreement that at high levels heating effects may occur, which may be associated with burns and cataracts, for example. Effects at lower levels are subject to debate. These include effects on reproduction, cancer and ill-defined symptoms sometimes termed 'microwave sickness' (MWS) or 'radiofrequency neurasthenia'. This syndrome, which includes fatigue, headaches, palpitations, insomnia, skin symptoms, impotence and altered blood pressure, was originally described in East European radar workers but has not been well accepted in Western medicine. Recent reports by Western occupational medicine specialists have prompted a reappraisal of this position. The condition is discussed from a historical point of view, beginning with the East European literature and then recent Western reports.

East European reports

The main early report describing MWS was by Sadcikova of the Academy of Medical Sciences, USSR, in 1974 [1]. Sadcikova studied three groups, two of which worked with microwaves. The frequencies and modulations are not stated but probably included radar (pulsed) frequencies in the GHz range. One of the groups of 1000 workers was exposed to up to a 'few mW/cm^2'. The second group of 180 had exposures that 'did not exceed several hundredths of a mW/cm^2', i.e. hundreds of microwatts (μW/cm^2). These two groups were young men who had worked with radio equipment for 5–15 years. It is not stated how these study groups were defined or whether there was completeness of the survey (e.g. were sick absentees followed up). The survey appears to have been cross-sectional of existing staff rather than a cohort followed up, so those who became very ill and left may have been lost to the study. A control group of 200 of similar age and sex, and similar work without microwave exposure was included. No details are given of the completeness of this group. It appears that subjects were surveyed by questionnaire and examined. The results are presented as percentages of subjects; raw data are not presented and statistical methods are not described.

Three main syndromes were defined by Sadcikova. The first was neurological or asthenia. This included feeling 'heavy in the head', tiredness, irritability, sleepiness and partial loss of memory. For example, tiredness affected 45% of those exposed to a few mW/cm^2, 55% of those exposed to several hundredths of a mW/cm^2 and 10% of controls. Similar marked differences were found for 'heavy in the head' and irritability. Another syndrome was described for 'autonomic vascular' changes, e.g. sweating, dermographism, blood pressure changes. A third syndrome was 'cardiac', including heart pains and ECG changes.

Changes were not markedly different between mW and μW/cm^2 exposures. Those with >5 years of exposure had more symptoms, but the numbers who had <5 years of exposure are not stated (and were probably few), which makes this relationship uncertain. Sadcikova states that

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cessation of work involving microwave radiation frequently resulted in stabilization of the process or recovery. This imperfect study by Sadcikova loosely defined MWS to variously include: neurological or asthenic symptoms, e.g. tiredness, irritability; autonomic changes, e.g. sweating, skin changes, blood pressure changes; and cardiac changes.

Another paper in the same WHO symposium by Siekierzinski [2] describes a study of 507 people working with radar and exposed above 0.2 mW/cm^2 and 334 people working below that level. No non-exposed control group was included. They were examined for 'neurosis' and ECG and other changes. No significant differences were found between the two groups. However, it is not clear what 'neurosis' meant, and specifically if it included symptoms such as tiredness or 'heavy in the head' as in Sadcikova's survey, and so may not be strictly comparable with that work. Also, importantly, the study had no control group for absolute reference and so small differences between the study groups, which were arbitrarily dichotomized, may have been obscured. Therefore, this negative study must be interpreted cautiously.

Djordjevic *et al.* [3] studied 322 radar workers and 220 non-radar controls. Exposures to radar were for 5–10 years and generally <5 mW/cm^2. Blood tests and biochemistry were similar in the two groups. Of six subjective complaints studied, three—headache, fatigue and irritability—occurred in 28% of radar workers and 15% of controls. The difference was attributed by the authors to working conditions, e.g. noise and poor lighting, although the authors stated in the study design that they had chosen the controls matching for 'character of working regime'. Therefore, this may or may not be the correct explanation, so the study can also be interpreted as offering some support to Sadcikova's observations.

Western reports

Reports about MWS such as those cited above were treated with some scepticism by Western medical authorities [4,5]. Then, in 1982, Forman *et al.* [6] provided the first Western bloc report regarding MWS. Two USAF men who were separately, accidentally acutely irradiated with microwave radiation (radar) were followed up clinically for 12 months. Both men developed similar psychological symptoms, which included emotional lability, irritability, headaches and insomnia. Several months after the incidents, hypertension was diagnosed in both patients. No organic basis for the psychological problems could be found, nor could any secondary cause for the hypertension. The authors concluded that the two cases, with comparable subjective symptoms and hypertension following a common exposure, provided strong, circumstantial evidence of cause and effect, and noted similarities to the East European reports. Recently, Braune *et al.* [7] have reported increases in blood pressure in subjects exposed double blind to mobile phones.

In 1997, Schilling [8] provided a detailed report of effects of overexposure in three engineers working on 785 MHz television in the UK. They were exposed to fields >>20 mW/cm^2 for 1–3 min. Subsequently, they have experienced headaches, dysaesthesia, lassitude and loss of stamina for up to 3 years. They had previously been fit with no history of mental or other ill-health. This report, by an experienced occupational physician, is most pertinent to the MWS debate. The fact that the symptoms arose after an overexposure should not obscure the fact that after this they suffered long-term subjective effects, including headaches, lassitude and general malaise. This gives strong support to the view that RFR can cause the symptoms of MWS. Schilling [9] has reported further similar cases involving overexposure to FM VHF. Following two separate incidents with exposures of up to 10 and 20 mW/cm^2, two men in each incident developed persistent symptoms including effects on the central nervous system (headaches, fatigue and malaise), peripheral nerves (dysaesthesia, impaired sensation) and autonomic nervous system (diarrhoea). The symptoms have lasted >4 years in some cases.

Hocking has studied various exposures to RFR. In one accident, two men were exposed to unmodulated 4.1 GHz at between 0.31 and 4.6 mW/cm^2 for ~90 min [10]. Neither had short- or long-term symptoms, hence this was interpreted as a negative study. However, Schilling's cases, occurring after AM and FM exposure, raise the possible importance of modulations, and the absence of modulations may be a key issue in this negative report. Hocking [11] has also described cranial symptoms in a case series of 40 mobile phone users. These included dysaesthesia on the scalp, visual disturbance in a few and a feeling of 'fuzziness' in the head in a few. The reports of 'fuzziness' are similar to Sadcikova's description of 'heavy in the head'.

Bergqvist [12] has recently reviewed some of the literature regarding radiofrequency neurasthenia (i.e. MWS) and concluded that studies have not revealed any consistent evidence for an effect. However, he omitted to consider the major study by Sadcikova [1] and misinterpreted the Siekierzinski [2] study as being between exposed and 'non-exposed' groups [12], which is crucially incorrect for the reasons discussed above. He refers to the large study by Robinette *et al.* [13] of admissions to hospital of 20 000 US naval personnel who worked with radar at levels >1 mW/cm^2 compared with 20 000 who worked at levels <1 mW/cm^2, which found no excess admissions for mental disorders in the more exposed group. However, it is rare for those suffering from neurasthenia to be admitted to hospital since the condition is usually investigated and treated on an out-patient basis and so a null finding is to be expected. Also, the differences in exposure between groups were blurred as the low exposure group took recreation on deck where they were exposed up to 1 mW/cm^2, thus lessening the likelihood of finding differences. He also discusses some workplace studies which are too small to allow conclusions to be drawn. Therefore, there is good reason to disagree with Bergqvist's conclusion.

The mechanism of injury that could cause MWS has not been clear. Even with the high levels of overexposure in Schilling's cases, the cause of the persistent effect on the nervous system is not known; there were no localizing signs on examination or on brain scan such as would have been expected from heating of tissue. Modulated radiofrequency at low levels of exposure has been shown to affect calcium flux in chicken brains [14] and effects on neurotransmitters have also been shown in animal experiments [15]. Recently, Hocking and Westerman [16] have reported a subtle abnormality of nerve conduction on the scalp in a patient with persistent dysaesthesiae after low-level exposure from a mobile phone. The A and C fibres were shown to have altered current perception thresholds leading to the sensory abnormalities. Similar alterations in neural function in the central and autonomic nervous systems could provide a neurological basis for MWS.

The diagnosis of the condition is largely by exposure history, clinical data (particularly dysaesthesiae) and exclusion of other organic and psychiatric causes. At present, there are no diagnostic tests specific for RFR injury, although Nilsson *et al.* [17] found an abnormal protein in the CSF of asymptomatic radar workers. Provocation tests may be considered, but present ethical and technical problems.

Conclusion

The cases reports by Forman *et al.* and Schilling have helped better define the syndrome of MWS, which effects the central nervous system (headaches, fatigue and malaise), peripheral nerves (dysaesthesia, impaired sensation) and autonomic nervous system (diarrhoea, raised blood pressure). The symptoms have lasted for years in some cases.

The cases of Forman *et al.* and of Schilling which occurred after a brief overexposure give validity to the condition of MWS, and hence substance to Sadcikova's [1] original description of symptoms which occurred after much lower exposures. The recent description of a change in neurological function after low-level exposure from a mobile phone suggests a neural basis for the syndrome. MWS should be considered a potential health risk for RFR workers. Further work is needed to characterize the dose–response relationship and the role of modulations.

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Appendix [18]

Biophysics of RFR

RFR includes electromagnetic waves ranging from 300 kHz to 300 GHz frequencies. It is different from power line frequency (which is 50 Hz) and has different interactions with the body in that RFR couples (interacts) much better and has modulations which may have biological effects. Modulations, e.g. frequency (FM) or amplitude (AM), are small modifications to the carrier wave which allow it to carry information such as sound, or there may be pulsed modulations, e.g. radar.

Whole-body interaction

The different frequencies of RFR have widely differing wavelengths which result in different coupling (uptake) by the body. kHz waves are very long (~100 m) and have minimal uptake. Waves at 30–300 MHz are 5–1 m long, respectively, and have maximal coupling. The higher MHz and GHz waves are centimetres–millimetres in length, respectively, and exposure results in localized deposition in skin, eyes, testis, head or superficial layers of the body. Thus, energy deposition into the body is complex and varies across the RFR spectrum.

Mechanism of action

Once RFR is coupled to the body, it can interact to cause biological effects. There is general agreement that if sufficient energy is absorbed, it can cause heating by the rapidly alternating field agitating dipolar molecules, particularly water, and so cause deleterious effects (similar to warming food in a microwave oven). The present safety standards are largely based on preventing these heating effects. There is dispute as to whether lower levels of energy can cause biological effects (non-thermal, athermal mechanisms). Modulations may be important in this regard [14].