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Acute Effects of Recreational Exposure to Freshwater Cyanobacteria– a Prospective Epidemiology Study

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Abstract

Case studies and anecdotal reports document a range of acute illnesses associated with exposure to cyanobacteria in recreational waters. Studies on the epidemiology of recreational exposure to cyanobacteria are limited and somewhat conflicting, and much uncertainty remains regarding measures of exposure, susceptibility of individuals with a history of allergic illness, and the relative contribution of cyanobacterial exotoxins to these acute illnesses. Preliminary statistical analysis of a prospective cohort study of 1,331 subjects recruited in eastern Australia and central Florida has not revealed any significant difference in specific illnesses between unexposed groups and those exposed to various levels of cyanobacteria.

Introduction

Cyanobacteria are common inhabitants of freshwater lakes and reservoirs throughout the world. Human case reports and anecdotal references dating from 1949 describe a range of acute illnesses associated with recreational exposure to cyanobacteria: hay fever-like symptoms, itchy skin rashes and gastrointestinal symptoms are most frequently reported. Some papers give convincing descriptions of allergic responses to cyanobacteria (Heise, 1949; Cohen and Reif, 1953); others describe more serious acute illnesses (Dillenberg and Dehnel, 1960; Carmichael *et al.,* 1985; Turner *et al.,* 1990; Codd and Beattie, 1991). The main public health concern with exposure to freshwater cyanobacteria relates to the understanding that some blooms can produce toxins that specifically target the liver or the central nervous system. The route of exposure for these toxins is oral, from accidental or deliberate ingestion of recreational water, and possibly by inhalation. However, observations by cyanobacteria researchers and others who use recreational waters reveal that many individuals can be exposed to high levels of cyanobacteria with no apparent acute effects.

Reports of illness following recreational exposure to cyanobacteria in the medical and scientific literature are sparse. Significant under-reporting, especially of minor, self-limiting illnesses, and a knowledge gap about cyanobacteria amongst many primary health care providers may explain this. Epidemiological studies are few in number (Philipp, 1992; Philipp and Bates, 1992; Philipp *et al.,* 1992; El Saadi *et al.,* 1995; Pilotto *et al.,* 1997). UK studies and a smaller Australian study did not find any significant hazard from exposure to cyanobacterial blooms in recreational waters, but Pilotto *et al.* (1997) reported an increase in illness amongst those exposed to fairly low levels of cyanobacteria (>5,000 cells per mL) compared to unexposed individuals.

The World Health Organization and the Agriculture and Resource Management Council of Australia and New Zealand have both published guideline levels for recreational exposure to cyanobacteria (Johnstone, 1995; WHO, 2003), yet there is concern that the current management practice in some countries of warning all users or closing access to waterbodies is overly proscriptive. Such practices cause concern among regular users of recreational waters that are affected by cyanobacteria, and can impact communities surrounding such important social and economic water resources. There is general agreement that further epidemiological studies are required to advance the understanding of acute cyanobacteria-related illnesses, so that advice and guidelines for recreational exposure can be revised and refined. Therefore we sought to conduct a prospective study of recreational water users in Australia and in the United States to compare the frequency of acute health problems among cohorts of people exposed to recreational waters with differing levels of cyanobacteria. In a prospective cohort study, participants are enrolled based on their potential to be exposed to the agent of interest. Exposure is measured prior to disease outcome, which is determined at a follow-up procedure. Subjects were initially recruited in eastern Australia; the study was expanded to include Florida because of the broad similarities in geographic latitude, climate, nuisance cyanobacteria and recreational activities across the two regions.

Materials and Methods

Members of the public were approached at various recreational water sites in southern and southeast Queensland, the Myall Lakes area in New South Wales (Australia), and central Florida (USA); those who were engaging or planning to engage in recreational activities that involved water contact were invited to participate in the study. Typical recreational activities were swimming, skiing, jet skiing

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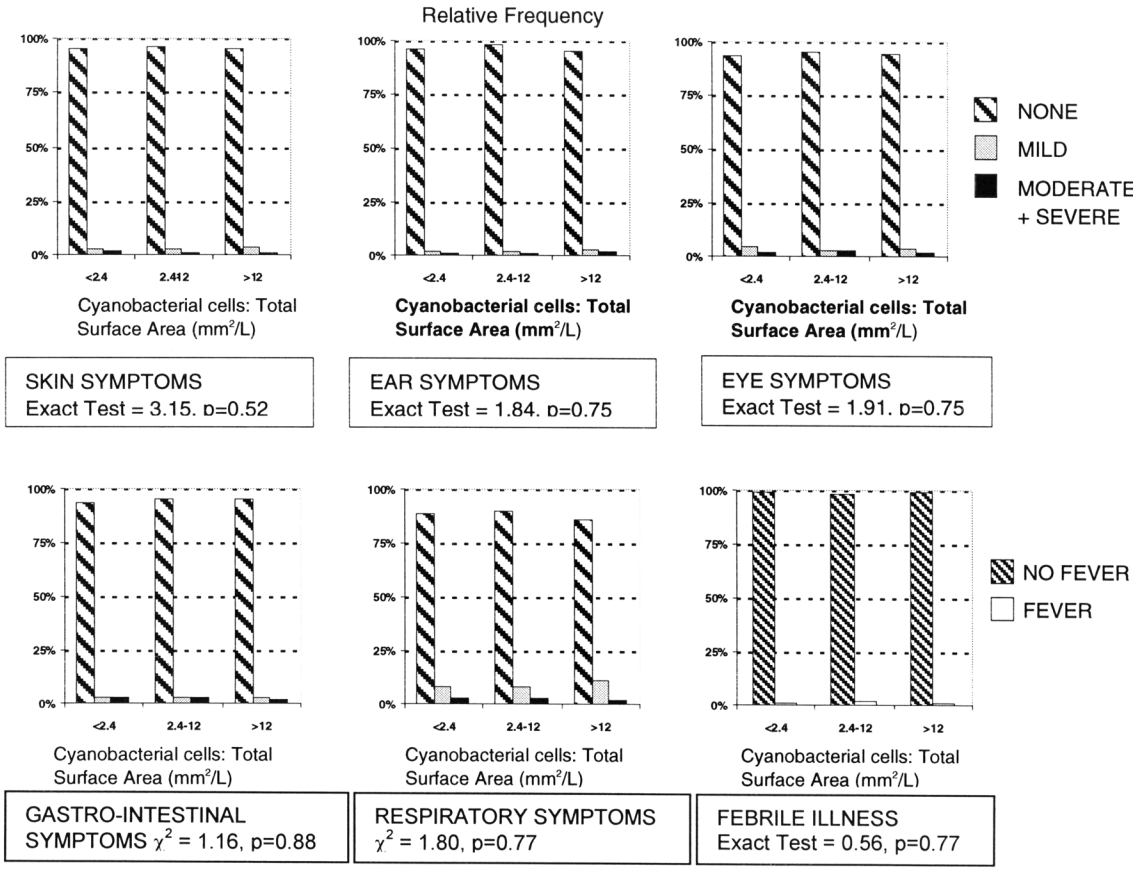

Figures 1–6 Frequency of reporting within six different symptom groups by level of cyanobacteria exposure.

and tubing. Individuals who indicated they were engaging in non-or minimal water contact activities such as boating or fishing were excluded. After they had finished their recreational activity, potential recruits were asked to complete a self-administered questionnaire on the day of recruitment, and to participate in a telephone follow-up interview after three days. The questionnaire elicited basic demographic information, details of relevant chronic illnesses (*e.g.,* asthma, dermatitis), recent acute illnesses, type and duration of recreational activity, and details of any water recreation activities during the week prior to recruitment. The follow-up interview elicited information on the occurrence of a range of specific symptoms during the three-day period following the day of recruitment. Respondents were asked to rate any symptom occurrences as mild, moderate or severe. Water samples were collected on recruitment days for 1) total phytoplankton identification and enumeration by phase-contrast microscopy using a calibrated cell-chamber; 2) cyanobacterial toxin analysis by HPLC and HPLC-MS/MS, which was run on samples in which potentially toxic species were identified during total phytoplankton analysis; and 3) faecal coliform counts. Cyanobacterial cell surface areas were used as exposure estimates for this work; surface areas were derived from cell counts and measured or documented cell dimensions (cell and/or trichome diameters and lengths). Low exposure sites were defined by total surface area less than 2.4 mm^2/L; surface areas greater than 12 mm^2/L represented high exposures. An intermediate exposure level was given for sites with surface areas between 2.4–12 mm^2/L. Data were entered into a relational database (MS Access2000) for data handling and manipulation; statistical analysis was performed using SPSS v11.5. Reported symptoms were classified into six categories (skin, eye, ear, gastrointestinal, respiratory, and febrile illness) and as absent, mild, moderate or severe. Because small numbers of subjects reported moderate or severe symptoms, these two groups were combined for analysis. The proportions of people reporting symptoms at each cyanobacteria exposure level were compared using chi-squared tests. When the expected numbers were small, the Fisher-Freeman-Halton test was used (Garson, 2003; Norušis, 2002).

Results and Discussion

1,331 subjects completed the questionnaire and follow-up interview. This number represents 37% of those who met the initial inclusion criteria. The proportions of subjects reporting symptoms that occurred within three days of water exposure are shown below in relation to their level of exposure. Overall symptom reporting was low, although we found a wide range of cyanobacteria concentrations in study waters, with cyanobacterial surface areas greater

than 300 mm^2/L at one site. Cyanobacterial toxins, when present, were generally at low levels. The frequency of reported symptoms did not vary significantly across the different cyanobacteria groups suggesting that increasing cyanobacteria exposure was not associated with acute health effects. Measuring exposure to cyanobacteria is probably the most significant source of uncertainty in this type of study, given the heterogeneity of cells in time and space within a given waterbody, the inability to determine movement of individuals within a waterbody (some will ski over a wide area of a lake, others will bathe on a small section of the lake shore), and the sometimes diverse phytoplankton profile within and across study lakes. A subsequent publication will discuss these issues in more detail, and will present further statistical analysis using different exposure measures—cell counts, cell biovolumes and chlorophyll *a*. We also plan to conduct multivariate analyses to determine the impact of cyanobacterial toxins, salinity, and faecal coliforms, and to examine whether subjects who have a history of allergic illness were differentially reporting symptoms. Cyanobacteriologists, recreational water managers and public health workers are justifiably concerned about the potential for serious illness or death from recreational or occupational exposures to cyanobacterial exotoxins, given that most of these compounds are potent systemic or neurological poisons. A recent press report of a US coroner's finding is a reminder that freshwater cyanobacteria can be extremely hazardous organisms. A teenage boy apparently died as a result of ingesting cyanobacteria containing anatoxin-a from a golf course pond. This is the first report in the world of a human fatality related to recreational exposure to cyanobacteria (Behm 2003). However, one of the difficulties with this epidemiology work is that many cyanobacteria-related illnesses appear to be mild and self-limiting. Public health priorities in this field should in the future be directed toward the epidemiology of cyanobacterial exotoxins, which have a greater potential for harm in waters where sufficient exposures may occur, compared with waters containing non-toxic strains and species, or waters where toxic strains produce low levels of toxins.

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