REVIEW

Occupational risk of Lyme disease: an epidemiological review

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Lyme disease is the most common vector borne disease in the United States. Since the early 1980s, a large body of literature has evaluated the occupational risk of Lyme disease. The availability of a new vaccine to prevent Lyme disease makes it necessary for occupational health professionals to make decisions regarding the occupational risk of the disease among employees.

A method has been developed to categorise published studies into four groups based on their use in the assessment of the occupational risk of the disease (high, moderate, low, and none). This categorisation was based on study design, the definition of the occupational group, the presence and definition of the comparison group without occupational risk, the diagnostic basis for Lyme disease, and the method of laboratory confirmation. Four sources were used to obtain published articles (Medline, NIOSHTIC, Science Citation Index, and the European Union Concerted Action on Lyme Borreliosis website).

A total of 91 unique articles were reviewed for possible relevance to the occupational risk of Lyme disease, and 41 unique articles with primary data about occupational Lyme borreliosis were selected for detailed analysis. After applying the use for assessment method, 10 studies met criteria for high or moderate use; all but one were from European study populations.

Overall, the published literature suggested that outdoor workers may be at an increased risk of seropositivity for antibodies to *Borrellia burgdorferi*, mainly assessed in cross sectional studies with enzyme linked immunosorbent assay (ELISA) or indirect fluorescent antibody (IFA) only. However, many of these studies compared outdoor workers with groups that may have had lower risk of Lyme disease from residential and recreational exposure to ticks, limiting the inferences that can be made about occupational risk. Also, most of the studied seropositive workers did not have any symptoms compatible with Lyme disease, suggesting that the increased risk may be for asymptomatic infection.

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Lyme disease is the most common vector borne illness in the United States.[1] It is caused by infection with the bacterium *Borrelia burgdorferi* and transmitted by ticks of the *Ixodes ricinus* complex.[1] Between 1992 and 1998, 88 967 cases of Lyme disease were reported to the Center for Disease Control, with a mean annual incidence of 5.1 cases/100 000 population.[2] During this period, there was a 70% increase in the annual number of reported cases, from 9909 in 1992 to 16 802 in 1998. This is likely to represent both a true increase in the incidence of the disease, and an increase in the proportion of diagnosed cases that were reported.[2] However, it is estimated that for every reported case of Lyme disease, there are 7–12 cases that are unreported.[3 4] Between 1992 and 1998, 10 states accounted for 92% of all reported cases of Lyme disease: New York (32.8%), Connecticut (17.4), Pennsylvania (14.6), New Jersey (12.2), Wisconsin (3.6), Rhode Island (3.5), Maryland (3.1), Massachusetts (2.4), Minnesota (1.7), and Delaware (1.0).[2]

The risk of Lyme disease would seem to be an important concern to outdoor workers in endemic areas. To date, Lyme disease has been documented in many occupational groups, including forestry workers, farmers, veterinarians, military recruits, orienteers, and outdoor workers in general. However, the risk of symptomatic infection in outdoor workers has not been well described and there are no recent systematic reviews of the topic. Published studies have mainly relied on measurement of the seroprevalence of antibodies to *Borrelia burgdorferi* among occupational groups compared with controls. Studies in the general population and outdoor workers have documented that the risk of the disease can decline over time, probably due to behavioural change and acquisition of immunity.[5 6] Also, studies of outdoor workers have suggested that knowledge about Lyme disease, use of personal protective behaviour, and the development of pruritic reactions to tick bites may mitigate the risk of the disease among such workers.[7–10] The result is an overall uncertainty about the potential occupational risk of Lyme disease in outdoor workers.

Before 1998, prevention of Lyme disease in outdoor workers was mainly limited to the use of personal preventive behaviour, including protective clothing, insect repellent, and tick checks and early tick removal.[8 9] Environmental control methods are also available—such as control of grass and brush and application of insecticides. However, these methods have limited practicality for the prevention of Lyme disease in outdoor workers.[11 12] The

Abbreviations: EUCALB, European Union Concerted Action on Lyme Borreliosis; ELISA, enzyme linked immunosorbent assay; IFA, indirect fluorescent antibody; PCR, polymerase chain reaction

Table 1 Distribution of published articles by geographical location and author among 41 articles with primary data on the occupational epidemiology of Lyme disease

Country	n (%)*	Author
Argentina	1 (2.4)	Stanchi and Balague 1993[17]
Austria	1 (2.4)	Schmutzhard *et al* 1988[18]
Croatia	1 (2.4)	Golubic *et al* 1998[19]
Finland	1 (2.4)	Oksi and Viljanen 1995[20]
France	2 (4.9)	Christiann *et al* 1996[21]†; Zhioua *et al* 1997[22]
Germany	2 (4.9)	Hauser *et al* 1998[23]; Rath *et al* 1996[24]
Ireland	1 (2.4)	Robertson *et al* 1998[25]
Italy	2 (4.9)	Nuti *et al* 1993[26]; Santino *et al* 1998[27]
Japan	2 (4.9)	Ikushima *et al* 1999[28]; Nakama *et al* 1994[29]
Lithuania	1 (2.4)	Montejunas *et al* 1994[30]
Netherlands	5 (12.2)	Kuiper *et al* 1993[31]; Kuiper *et al* 1991[32]; van Charante *et al* 1998[33]; van Charante *et al* 1994[34]; Vos *et al* 1994[35]
Poland	1 (2.4)	Chmielewska-Badora 1998[36]
Spain	2 (4.9)	Arteaga *et al* 1998[37]; Oteo *et al* 1992[38]
Sweden	1 (2.4)	Gustafson *et al* 1993[39]
Switzerland	2 (4.9)	Fahrer *et al* 1998[40]; Fahrer *et al* 1991[41]
United Kingdom	6 (14.6)	Baird *et al* 1989[42]; Gregory *et al* 1993[43]; Guy *et al* 1989[44]; Morgan *et al* 1989[45]; Reese and Axford 1994[46]; Thomas *et al* 1998[47]
United States of America	10 (24.4)	Bowen *et al* 1984[48]; Goldstein *et al* 1990[49]; Klein 1995[50]; Lane *et al* 1992[51]; Ley *et al* 1995[52]; Parrott *et al* 1993[7]; Schwartz and Goldstein 1990[9]; Schwartz *et al* 1993[53]; Schwartz *et al* 1994[54]; Smith *et al* 1988[55]
Total	41 (100)*	

*May not total 100% due to rounding; †control data supplied by Christiann *et al* 1997.[57]

approval of a Lyme disease vaccine by the Food and Drug Administration offers a new method of prevention, independent of current strategies. Despite proved safety and 90% efficacy after three doses in subjects under 65 years of age, the role of the vaccine has been the focus of considerable discussion.[1 13–16]

The Center for Disease Control has recommended that the vaccine be considered for "persons who reside, work, or play in areas of high or moderate risk".[1] Specifically, "Lyme disease vaccination should be considered for persons aged 15–70 years who engage in activities (for example, recreational, property maintenance, occupational, or leisure) that result in frequent or prolonged exposure to tick-infested habitat".[1] The current recommendation that the vaccine be considered for use in selected people at moderate to high risk, and an incomplete understanding of the occupational risk of Lyme disease, have led to indecision on the part of health care professionals, government agencies, and employers on the role of vaccination against Lyme disease in outdoor workers. In an effort to evaluate the need for Lyme vaccination in outdoor workers, we assessed the occupational risk of Lyme disease in the published, scientific literature.

METHODS

Identification and selection of published articles

An attempt was made to collect every article published in English in the scientific literature that contained any primary data on occupational risk factors for Lyme borreliosis. The following databases were searched: Medline, NIOSHTIC (NIOSHTIC was produced by the National Institute of Occupational Safety and Health (NIOSH) and was distributed as OSH-ROM; the July 1998 version, from Silverplatter Information, Norwood, MA, was used), Science Citation Index, and the EUCALB (European Union Concerted Action on Lyme Borreliosis) website. A general search of Medline in October 1999 conducted on "keyword = Lyme disease" found 4917 published articles. In an effort to select only those articles with occupational relevance, "keyword = Lyme disease" was then combined with multiple other keywords including: agriculture (n=3 articles), work(er) (n=67), employee (n=4), outdoor (n=28), occupation(al exposure) (n=9), park (n=58), exposure (n=187), military (n=18), vaccine (n=220), forest(er) (n=66) and farm(er) (n=11). A general search of NIOSHTIC for "Lyme" also yielded 25 articles for potential review. Additionally, all of the articles referenced on the EUCALB website as of January 2000 (n=260) were assessed for occupational relevance. Finally, the Science Citation Index was used to cross reference any article that had cited any of the following authors in its references: Arteaga F, Christiann F, Fahrer H, Gustafson R, Guy E, Kuiper H, Nuti M, Rath P, Santino I, Schwartz B, and Zhioua E. These authors were selected because they were most often cited in articles of occupational risk of Lyme disease.

Each database yielded multiple articles, many of which were cross referenced between and within databases. Through these techniques, 91 unique articles were preliminarily reviewed for possible relevance to the occupational risk of Lyme disease. Only articles which contained primary data on occupational populations were considered for further analysis. Data were considered primary if they were collected by the researchers and referenced to an occupational population or exposure. The 50 rejected papers made no connection between the study data and an occupational population or exposure. Ultimately, 41 unique articles with primary data on occupational Lyme borreliosis were selected for detailed analysis, representing a broad range of geographic locations and 36 unique authors (table 1).[7 9 17–55] One additional article by Zhioua *et al*,[56] was identified but was not reviewed separately because the data were derived from another included article (Fahrer *et al*).[41] Control data for Christiann *et al* were obtained from a subsequent publication by Christiann *et al*.[21 57]

Evaluation of use of articles

Initial criteria were established to categorise articles according to their use in assessing the occupational risk of Lyme disease (table 2). In developing these criteria, the primary motivation was the recent approval of a vaccine to prevent Lyme disease by the Food and Drug Administration and its impact on the occupational health care environment.[1] Current Occupational Safety and Health Administration requirements for vaccination of workers are limited to vaccination for hepatitis B virus in its bloodborne pathogens standard (29 CFR Part 1910.1030). This standard is designed to protect workers from a symptomatic, often serious, and sometimes fatal, illness. In evaluating the occupational risk of Lyme disease, similar attention was given to the morbidity associated with Lyme disease. Risk of symptomatic, clinically and laboratory confirmed infection was thus the primary outcome of interest.

Five major factors were evaluated in defining the use of the published articles for assessing the occupational risk of Lyme disease (table 2):

Table 2 Criteria used to stratify articles according to their use in assessment of occupational risk of Lyme disease

Use	Criteria	
High	Design	Prospective study design Clearly defined occupational group Clearly defined comparison group without occupational risk
	Diagnosis	Clinical diagnosis of Lyme borreliosis (generally by physician) Laboratory confirmation (by western blot*)
Moderate	Design	Cross sectional or case-control study design Clearly defined occupational group Clearly defined comparison group without occupational risk
	Diagnosis	Clinical diagnosis of Lyme borreliosis (generally by physician) Positive ELISA or IFA serology
Low	Design	Any design Clearly defined occupational group Clearly defined comparison group without occupational risk
	Diagnosis	Diagnosis based on self reported symptoms or serology only Positive ELISA or IFA serology
None	Design	Any design No defined occupational group No defined comparison group without occupational risk
	Diagnosis	Diagnosis based on self report Positive ELISA or IFA serology

*Although other methods of laboratory confirmation were acceptable (culture, polymerase chain reaction), no studies used any method more definitive than western blot.

(1) Study design - prospective studies had higher utility than did case-control or cross-sectional studies;

(2) The occupational group had to be clearly defined;

(3) A comparison group without occupational risk had to be included;

(4) Definition of Lyme disease, with symptomatic, clinically confirmed infection of primary interest, by contrast with definition of cases on the basis of self reported symptoms ascertained by questionnaire or asymptomatic seropositivity only;

(5) Laboratory confirmation had to be included, with western blot and the definition of the Centers for Disease Control considered to be better documentation than enzyme linked immunosorbent assay (ELISA) or indirect fluorescent antibody (IFA) only.[58] No previous studies of the occupational epidemiology of Lyme disease used more rigorous definitions of laboratory confirmation—such as culture or polymerase chain reaction (PCR) of skin tissue from *erythema migrans* lesions.

Measurement of occupational risk

After application of the criteria of usefulness to the 41 published articles with primary data on the occupational epidemiology of Lyme disease, two were defined as of high use, eight as moderate, 14 as low, and 17 had no use (table 3). For the 10 studies in the high or moderate categories, three epidemiological effect measures are reported and calculated, when possible, from the published data. These were, in order of least useful to most useful measure:

(1) Seroprevalence (odds) ratio—the prevalence of positive serological test results in the defined occupational group under study compared with the prevalence in a defined control group without occupational risk;

Table 3 Categorisation of articles according to criteria for use in assessing occupational risk of Lyme disease

Use	n (%*)	Study design	Author
High	2 (4.9)	Prospective	Kuiper *et al* 1993[31]; Vos *et al* 1994[35]
Moderate	8 (19.5)	Case-control	Hauser *et al* 1998[23]
		Cross sectional	Chmielewska-Badora 1998[36]; Gustafson *et al* 1993[39]; Kuiper *et al* 1991[32]; Zhioua *et al* 1997[22]
		Prospective	Bowen *et al* 1984[48]†; Fahrer *et al* 1998[40]‡; Fahrer *et al* 1991[41]
Low	14 (34.1)	Case-control	Stanchi and Balague 1993[17]; Christiann *et al* 1996[21]§
		Cross sectional	Arteaga *et al* 1998[37]; Baird *et al* 1989[42]; Reese and Axford 1994[46]; Robertson *et al* 1998[25]; Smith *et al* 1988[55]; Goldstein *et al* 1990[49]; Schwartz *et al* 1993[53]; Schwartz and Goldstein 1990[9]
		Prospective	van Charante *et al* 1998[33]; van Charante *et al* 1994[34]; Oksi and Viljanen 1995[20]; Rath *et al* 1996[24]
None	17 (41.5)	Case-control	Ley *et al* 1995[52]
		Case series	Gregory *et al* 1993[43]; Golubic *et al* 1998[19]; Klein 1995[50];
		Cross sectional	Guy *et al* 1989[44]; Ikushima *et al* 1999[28]; Morgan *et al* 1989[45]; Nakama *et al* 1994[29]; Nuti *et al* 1993[26]; Oteo *et al* 1992[38]; Santino *et al* 1998[27]; Schmutzhard *et al* 1988[28];
		Prospective	Lane *et al* 1992[51]; Montejunas *et al* 1994[30]; Parrott *et al* 1993[7]; Schwartz *et al* 1994[54]; Thomas *et al* 1998[47]

*Of total of 41 reviewed studies; †retrospective cohort included with prospective group for analysis; ‡follow up study for Fahrer *et al* 1991; §control data supplied by Christiann *et al* 1997.[57]

Table 4 Summary of published research with relevance to occupational risk of Lyme disease*

Reference (first author)	Study design, dates	Location	Study population *v* comparison group	Definition of Lyme disease or seroprevalence	Results of relevance to occupational risk
Arteaga 1998[37]	Cross sectional, 1998†	Vizcaya, Spain	302 Outdoor workers (117 forestry, 52 large animal vets, 18 shepherds, 27 apiculturists, 74 mushroom and truffle gatherers, 14 other) *v* none	ELISA, WB (CDC criteria for serological reactivity), and self reported clinical questionnaire.	Seroprevalence outdoor workers = 15% (44/302) by WB Cumulative clinical prevalence, outdoor workers = 15% (11/44) by WB
Baird 1989[42]	Cross sectional, 1989†	Wigtownshire, UK	101Samples from farmers, foresters, and gamekeepers and seven samples from patients with potential LD *v* none	IFA, ELISA and physician diagnosis	Seroprevalence = 11% (12/108) Cumulative clinical prevalence = 91% (11/12)
Bowen 1984[48]	Prospective, 1978–82	Monmouth County, NJ, USA	366 Outdoor workers at naval weapons station *v* 766 indoor workers at naval weapons station	IFA, clinical interview and medical record review	Incidence outdoor workers = 3.8% (14/366) Incidence indoor workers = 0.8% (6/766), p<0.001
Chmielewska-Badora 1998[36]	Cross sectional, 1998†	Lublin, Poland	1153 Workers exposed to ticks (880 forestry workers and 273 farmers), 458 patients suspected of LD (362 from neurological clinic and 96 from dermatologic clinic) *v* 100 healthy blood donors	IFA, ELISA and physician diagnosis	Seroprevalence farmers = 38.6% Seroprevalence foresters = 28.1% Seroprevalence blood donors = 6%, p<0.001 Cumulative clinical prevalence farmers/foresters = 0.0% (1/1153)
Christiann 1996[21] and Christiann 1997[57]	Case-control with control data supplemented from Christiann 1997	Berry, France	59 Cases of Lyme disease among the residents of Berry Sud (Christiann 1996); 170 recreational hunters *v* 182 blood donors (Christiann 1997)	IFA or ELISA until Nov 1993 and then ELISA only; clinical examination and WHO recommendations 1993 and CDC criteria 1990	58% (34/59) Of LD cases were among farmers Seroprevalence hunters = 15% (25/170) Relative risk of seroreactivity hunters *v* blood donors = 1.79, p=0.00001
Fahrer 1998[40]	Phase II, prospective, 1986–88 and 1993	Switzerland	Phase II, 305 seropositive orienteers reexamined *v* phase I, 950 orienteers	ELISA, self reported clinical questionnaire, physician diagnosis and medical record review.	Annual clinical incidence phase II orienteers = 0.8% 6 Month clinical incidence phase I orienteers = 0.8% Cumulative clinical prevalence phase II orienteers = 4.9% (15/305)
Fahrer 1991[41]	Phase I of Fahrer 1998, prospective, 1986	Switzerland	950 Swiss orienteers *v* 51 healthy volunteers who had spent most of their life at altitudes >1000 m and 50 inhabitants of Berne at altitude 500 m‡	ELISA, self reported questionnaire, physician diagnosis and medical record review.	Cumulative clinical prevalence orienteers = 1.9%–3.1% Seroprevalence orienteers = 26.1% Seroprevalence high altitude = 3.9% (2/51) Seroprevalence Berne = 6.0% (3/50) Six month clinical incidence orienteers = 0.8%
Goldstein 1990[49]	Cross sectional, Oct 1998	New Jersey, USA	689 Employees from the NJ Natural and Historic Resources Section from 12 different sites *v* none	IFA, ELISA, and self reported clinical questionnaire	Seroprevalence = 5.7% (39/689) by IFA or ELISA There was no association between seropositivity and job title or job habitat
Golubic 1998[19]	Case series, 1998†	Croatia	218 Cases of LB in NW Croatia *v* none	IFA, self reported questionnaire, physician diagnosis and medical record review.	Clinical prevalence according to occupation: student 15% (33/218), agricultural worker 30% (30/218), agricultural clerk 14% (32/218), pensioner 12.5% (27/218) and housewife 14% (30/218)
Gregory 1993[43]	Case series, 1987–91	UK	Two cases of neuroborreliosis and 6 more reports of clinical LD with positive ELISA *v* none	ELISA and physician diagnosis	2 Case reports of neuroborelliosis and six case reports of LD among military personnel in the UK
Gustafson 1993[39]	Cross sectional, Oct 1990	Stockholm, Sweden	362 Orienteers from the county of Stockholm during a large relay race in October 1990 A - 50 Blood donors B - 150 People living in Sweden (no orienteers) C - 74 Hospital patients D - 378 People from Iceland (no Ixodes ticks)	ELISA, self reported clinical questionnaire and physician diagnosis	Seroprevalence orienteers = 9% (31/362) Seroprevalence controls = 2% (A-1/50), 9% (B-13/150), 1% (C-1/74), 2% (D-9/378) Seroprevalence OR orienteers *v* control B = 0.9 (95% CI 0.5 to 1.8) Seroprevalence OR orienteers *v* control C = 9.3 (95% CI 3.6 to 24.2) Cumulative clinical prevalence orienteers = 6% (22/362) Cumulative clinical prevalence controls-B = 1% (2/150), OR = 4.8 (95% CI 1.1 to 20.6)
Guy 1989[44]	Cross sectional, 1989†	Southampton, UK	41 Forestry Commission workers (11 keepers, 30 other) *v* none	ELISA, WB and self reported clinical questionnaire	Seroprevalence = 25% (10/40) by WB Cumulative clinical prevalence = 5% (2/40)
Hauser 1998[23]	Case control, 1989–95	Germany	222 Patients with clinically defined LB and 458 asymptomatic forestry workers *v* 133 blood donors	ELISA and physician diagnosis	Seroprevalence foresters = 41–44.8%, depending on ELISA antigen. Seroprevalence blood donors = 8%, OR = 8.4 (95% CI 4.4 to 15.9)
Ikushima 1999[28]	Cross sectional, 1999†	Japan	80 Forestry workers *v* none	ELISA and WB	Seroprevalence foresters = 22.5% (18/80) by WB
Klein 1995[50]	Case series, 1995	Wilmington, DE, USA	Five physicians among 83 employed pediatricians and 55 pediatric residents *v* none	Physician diagnosis	One year clinical prevalence physicians = 3.6% (5/138)
Kuiper 1993[32]	Prospective, 1989–90	Netherlands	151 Dutch forestry workers *v* 151 male office workers matched for age and residence	ELISA, WB, and physician diagnosis with reference to CDC case definition, 1990	Seroprevalence forestry = 28% (43/151) by ELISA Seroprevalence office = 5% (8/151) by ELISA, p<0.01 Clinical incidence forestry = 0.0% Seroconversion forestry = 5% by ELISA/WB 18% (7/39) Of seropositive forestry workers or 5.5% (7/127) of all forestry workers in 1989 met the case definition criteria for LB.
Kuiper 1991[31]	Cross sectional, 1989	Netherlands	127 Dutch forestry workers *v* 127 male office workers, matched for age and region	IFA, WB and physician diagnosis (adapted CDC classification)	Seroprevalence foresters = 19.7% (25/127) Seroprevalence office = 6.3% (8/127), OR = 3.7, 95% CI 1.5 to 9.7. Cumulative clinical prevalence foresters = 6% (7/127)
Lane 1992[51]	Prospective, 1988–89	Northwest California	119 Residents of Mendocino County at entry (99 current and 20 former residents) and 59 at follow up *v* none	IFA, WB and physician diagnosis	Seropositivity was associated with greater years of residence in the area (p=0.032), decreased hiking (p=0.006), and woodcutting (p=0.048). Time spent working outdoors was not identified as a risk factor for probable LD.
Ley 1995[52]	Case control, June 1991–Dec 1992	California	All cases of EM reported to CA Department of Health Services *v* age and sex matched controls	Physician diagnosis	Diagnosis of LD was not associated with work outdoors, OR = 1.04 (p=0.87) or total number of hours spent outside during leisure activities per month.
Montejunas 1994[30]	Prospective, 1988–91	Lithuania	Three occupational groups: foresters (n=268), outside field workers (n=115), and veterinarians (n=68) *v* 163 urban industrial workers	IFA	Seroprevalence foresters = 14% (37/268) Seroprevalence field = 22% (25/115) Seroprevalence vets = 32% (22/68) Seroprevalence urban = 4% (6/163), OR = 2.5, p<0.001

Table 4 continued

Reference (first author)	Study design, dates	Location	Study population *v* comparison group	Definition of Lyme disease or seroprevalence	Results of relevance to occupational risk
Morgan 1989[45]	Cross sectional, 1989	UK	180 Farmers and their familes *v* 75 control patients who lived in the area, but who denied contact with farm animals	ELISA	Seroprevalence farmers/families = 14.4% (26/180) Seroprevalence control = 2.6% (2/75)
Nakama 1994[29]	Cross sectional, 1990–91	Nagano, Japan	222 Forestry workers *v* 760 residents of an agricultural town	IFA	Seroprevalence foresters = 1.1% (8/760) Seroprevalence residents = 5.9% (13/222), p<0.01
Nuti 1993[26]	Cross sectional, 1987–91	Italy	1146 Subjects subdivided into six categories: farmers (395), forestry workers (265), rangers (82), soldiers (299), hunters (75) and fishermen (30) *v* none	IFA	Seroprevalence farmers = 10.1% (40/395) Seroprevalence foresters = 19.6% (52/265) Seroprevalence rangers = 19.5% (16/82) Seroprevalence soldiers = 3.0% (9/299) Seroprevalence hunters = 8.0% (6/75) Seroprevalence fisherman = 16.6% (5/30)
Oksi 1995[20]	Prospective, Jun 1993–Dec 1993	Gylto, Finland	77 Military recruits in Lyme endemic area initially, 67 recruits completed the study at 6 months *v* 50 military recruits in nonendemic area, initially; 33 recruits completed the study at 6 months.	ELISA and self reported clinical questionnaire	No probable history of EM in either group. Seroprevalence military endemic = 16.9% (13/77) Seroprevalence military nonendemic = 4.0% (2/50) No change in IgG seroprevalence at 6 month follow up for either group.
Oteo 1992[38]	Cross sectional, Oct 1986–Mar 1988	La Rioja, Spain	500 Non-randomised individuals residing in Rioja, Spain *v* none	IFA and self reported clinical questionnaire	Seroprevalence outdoor worker = 20% *v* other 4.7%, p<0.001 Seroprevalence was associated with rural residence, p<0.001 Seroprevalence was associated with foresters, cattle raisers, and contact with domestic animals, p<0.001 28% of farmers/foresters showed clinical signs compatible with LD
Parrott 1993[7]	Prospective, May 1989–Oct 1989	Assateague Island, MD	99 Outdoor workers on Assateague Island initially with 86 workers continuing to post seasonal evaluation *v* None	ELISA and self reported clinical questionnaire	Seroprevalence = 0% Seroconversion 3 month follow up = 0% Clinical prevalence = 0%
Rath 1996[24]	Prospective, Feb–Sep 1992	Brandenburg, Germany	626 Foresters initially, 406 foresters at 6 month follow up *v* 200 blood donor controls	IFA, IBA, and self reported clinical questionnaire	Seroprevalence foresters = 8% by IBA Seroprevalence controls = 4% by IBA, p<0.05 Seroconversion foresters, 6 month follow up = 7.2% (IBA)
Reese 1994[46]	Cross sectional, 1993	London, UK	44 Outdoor park workers from Richmond and Bushey parks *v* 27 zoo keepers from Whipsnade wildlife park in Bedfordshire, who worked in a similar outdoor environment	ELISA, IBA and self reported clinical questionnaire	Seroprevalence park = 32% (14/42) by IBA (three bands) Seroprevalence zoo = 4% (1/27) by IBA (three bands), p<0.005
Robertson 1998[25]	Cross sectional, 1998†	Ireland	38 National park rangers *v* 1224 blood donors from the same location as the park rangers	ELISA and IBA (5 bands present)	Seroprevalence park rangers = 0% (0/22) by IBA Seroprevalence blood donors = 3.4% (42/1224) by IBA
Santino 1998[27]	Cross sectional, Jun–Aug 1995	Abruzzo, Italy	22 Park workers at an altitude of 750 to 1150 m *v* 50 park inhabitants at an altitude of 1150 m‡	ELISA, WB, and self reported clinical questionnaire	Seroprevalence park rangers = 9.1% (2/22) by ELISA, altitude = 800 m, 1080 m Seroprevalence park rangers = 4.5% (1/22) by WB (5 bands), altitude unknown Seroprevalence park inhabitants = 0.0% by ELISA, altitude = 1150 m None of the park workers or inhabitants showed signs compatible with LD.
Schmutzhard 1988[18]	Cross sectional, 1985	Tyrol, Austria	80 Austrian Federal Army soldiers intially, 50 soldiers at 4 week follow up (serology) and clinical observation for 14 weeks *v* none	ELISA and physician diagnosis	Seroprevalence initially = 11% (9/80) Seroprevalence at 4 week follow up = 38% (18/50) Seroconversion = 22% (11/50) Clinical prevalence at 14 week follow up = 4% (2/50)
Schwartz 1990[9]	Cross sectional, Sep–Oct 1988	NJ, USA	689 Employees of NJ State Dept. of Env. Protection, included both indoor and outdoor workers *v* subset of indoor workers	IFA, ELISA, and self reported clinical questionnaire	Seroprevalence indoor/outdoor workers = 5.7% (39/689) Crude OR associated with occupational tick exposure = 2.2 (95% CI 0.7 to 9.0). Adjusted OR associated with occupational tick exposure = 5.1 (95% CI =1.1 to 23.6).
Schwartz 1993[53]	Cross sectional, Oct 1990	NJ, USA	758 Employees of NJ State Dept. of Env. Protection Outdoor workers *v* none	ELISA and self reported clinical questionnaire	Seroprevalence outdoor, 1988 = 8.1% Seroprevalence outdoor, 1990 = 18.7% (142/758) LD incidence in the general population increased 30% from 1989 to 1991
Schwartz 1994[54]	Prospective, 1988–91	NJ, USA	NJ outdoor workers from Dept. of Env. Protection; 1519 workers for at least 1 y, 378 workers for 2 y, 228 for 3 yrs, and 192 for 4 years *v* none	IFA in 1988 and then ELISA from 1989 to 1991; and self reported clinical questionnaire	Seroprevalence outdoor = 4.4 to 18.7% Seroconversion outdoor = 0.6 to 16.7% Seroreversion outdoor = 23 to 53% Risk factors for seroconversion included years at residence, rural residence, pet ownership, and a history of medical problems.
Smith 1988[55]	Cross sectional, May–Nov 1986	NY, USA	414 State employees of the NY State Office of Parks, Recreation and Historic Preservation and of the NY State Department of Environmental Conservation *v* 362 NY State blood donors in Lyme endemic area and NY State blood donors in non Lyme endemic area, total number unknown	ELISA, WB and self reported clinical questionnaire	Seroprevalence state employees = 6.5% (27/414) Seroprevalence Lyme endemic controls = 1.1% (4/362) Seropositivity RR state employees *v* Lyme endemic controls = 5.9 (95% CI 2.4 to 14.6) RR seropositivity outdoor worker *v* indoor worker = 2.0 (95% CI 0.3 to 13.0). Seropositivity was associated with leisure time outdoor exposure, while the evidence for an association with work exposure was less consistent. Hours spent outdoors during work was not associated with seropositivity.

Table 4 continued

Reference (first author)	Study design, dates	Location	Study population *v* comparison group	Definition of Lyme disease or seroprevalence	Results of relevance to occupational risk
Stanchi 1993[17]	Case control, 1993	Argentina	28 Farmers referred by physicians for arthritis *v* 25 farmers without past or present arthritis	IFA	Seroprevalence farmers with arthritis = 11% (3/28) Seroprevalence farmers without arthritis = 0% (0/25)
Thomas 1998[47]	Prospective, 1991 to 96	UK	404 Farmers and their families at enrollment; 387 at 1 year; 345 at 2 years; and 336 at 3 years *v* None	ELISA, WB and self reported clinical questionnaire	Seroprevalence enrollment = 0.2% (1/404) by WB Seroreversion = 0.3% (1/387) Seroconversions = None
Van Charante 1998;[33] Follow up of Van Charante 1994[34]	Prospective, 1989 to 93	Netherlands	312 Forestry workers and muskrat catchers stratified according to high or low exposure *v* 356 office workers with no exposure	ELISA, WB self reported clinical questionnaire	Seroprevalence OR high exposure foresters/muskrat *v* office workers = 17 (95% CI 6.4 to 55) Seroprevalence OR low exposure foresters/muskrat *v* office workers = 6.1 (95% CI 2.9 to 13) Seroconversion = 0.23 year^{-1} (95% CI 0.12 to 0.34)
Van Charante 1994[34]	Prospective, 1989 to 90	Netherlands	151 Forestry workers *v* 151 office clerks	ELISA, self reported clinical questionnaire	Seroprevalence forester = 19.9% (30/151) Seroprevalence office = 6% (9/151) Seroprevalence OR foresters *v* office = 3.9 (95% CI 1.7 to 9.7)
Vos 1994[35]	Prospective, Jan to Dec 1991	Netherlands	Initially, 905 outdoor military recruits. After 1 year 469 recruits for second blood draw *v* Initially, 1253 indoor military recruits. After 1 year 463 for follow up	ELISA, WB, self reported clinical questionnaire and physician diagnosis	Seroconversion indoor = 0.9% (4/469) Seroconversion outdoor = 2.2% (10/463) Seroconversion RR outdoor *v* indoor = 0.4 (95% CI 0.1 to 1.2) Clinical incidence among seroconverted outdoor = 7.1% (1/14) Clinical incidence among seroconverted indoor = 0.0% (0/10)
Zhioua 1997[22]	Cross sectional, 1997	France	212 Forestry workers *v* 31 blood donors with no contact with the forest	IFA and physician diagnosis	Seroprevalence forester = 15.2% (32/211) Seroprevalence blood donor = 3.2% (1/31) Seropositivity OR forester *v* blood donor = 5.4 (95% CI 0.7 to 40.7) Cumulative clinical prevalence forester = 3.3% (7/211)

*Abbreviations as in table 1; CDC, Centers for Disease Control; ELISA, enzyme linked immunosorbent assay; EM, erythema migrans; IBA, immunoblot assay; IFA, immunoflourescent antibodies; LB, Lyme borreliosis; LD, Lyme disease; OD, optical density; OR, odds ratio; RR, relative risk; WB, western blot; †indicate date of publication, no information provided regarding dates for collection of data; ‡altitudes >1000 m represent non-endemic areas for Lyme disease.

(2) Clinical prevalence (odds) ratio—the prevalence of symptomatic, clinically confirmed Lyme disease with laboratory confirmation in the defined occupational group compared with the prevalence in the control group;

(3) Clinical incidence ratio—the incidence of symptomatic, clinically confirmed Lyme disease with laboratory confirmation in the defined occupational group compared with the incidence in the control group. When calculated by the author of the published study, these data were reported directly. When sufficient data were included in the article to calculate a desired epidemiological effect measure, but not reported by the author, the effect measure was calculated using Intercooled Stata™, version 6 (Stata Corporation, College Station, TX).

RESULTS

Descriptive summary of published literature

The published literature on the occupational epidemiology of Lyme disease included 41 articles with a mean (SD) occupational group sample size of 367 (378) and a mean (SD) comparison group sample size of 196 (333) (table 4). Of these studies, two (4.9%) were conducted (or initiated) before 1985; 23 (56.1%) were conducted from 1986 to 1990; 10 (24.3%) were conducted from 1991 to 1995; and six (14.6%) were conducted from 1996 to 1999. A total of 14 (34.2%) used a prospective study design (including one study with a retrospective cohort design, by Bowen *et al* (1984)[48]); 20 (48.8%) were cross sectional in design; four (9.8%) were case-control studies; and three (7.3%) were case series. Sixteen (39%) studies presented data only for occupationally exposed subjects without reference to a control group, and 25 studies (61%) presented data for both occupational and comparison groups.

The definition of Lyme disease varied among the studies. Twenty three (56.1%) studies solely relied on serological assessment. Sixteen (39.0%) studies used both serological assessment and clinical evaluation by a physician and two (4.9%) studies used only clinical evaluation by a physician without any laboratory confirmation. Of the 39 studies with serological data, 15 (38.5%) confirmed positive results by ELISA or IFA with western blot.

Evaluation of occupational risk in studies of high and moderate use

Of the 10 studies with high and moderate use, seven reported the prevalence of seropositivity among the occupational group under study, which ranged from 1.0% to 44.8%. When compared with the seroprevalence among controls, six of the seven studies documented a significantly increased relative odds of seropositivity ranging from 3.7 to 9.9 (table 5), whereas the association found in one study (Zhioua *et al*[22]) did not reach statistical significance. However, only two of the seven studies (Kuiper *et al*[31 32]) matched the comparison subjects to the occupationally exposed subjects for age and residence. The other studies did not reach an important goal of the comparison group, which would be the ability to separate occupational risk from residential and recreational risk, because it seemed that comparison subjects also had a lower risk of residential and recreational tick exposure. Of these seven studies, only two studies (Kuiper *et al*[31 32]) performed western blots as confirmatory evidence in subjects with positive ELISA or IFA test results according to current standards recommended by the Centers for Disease Control.[58] It should be noted that all seven studies were performed in Europe where confirmatory western blots are not standardised and four of the seven studies predated the 1995 Centers for Disease Control criteria for Lyme disease serological testing.

Of the 10 studies with high and moderate use, six presented data on the prevalence of clinically confirmed Lyme disease in the occupational group under study, ranging from 0.4% to

Table 5 Summary of epidemiological effect measures on occupational risk of Lyme disease from 10 published studies of high or moderate use*

Study	Seroprevalence: Study group (%)	Seroprevalence: Control group (%)	Seroprevalence: OR (95% CI)	Clinical prevalence: Study group (%)	Clinical prevalence: Control group (%)	Clinical prevalence: OR (95% CI)	Clinical incidence: Study group (%)	Clinical incidence: Control group (%)	Clinical incidence: RR (95% CI)
High use studies (n=2)									
Kuiper *et al* 1993[31]	28	5.0	7.1 (3.2 to 15.8)†	5.5	NR	NA	0.0	NR	NA
Vos *et al* 1994[35]	NR	NR	NA	NR	NR	NA	0.9‡	2.2‡	0.4 (0.1 to 1.2)†
Moderate use studies (n=8)									
Bowen *et al* 1984[48]	NR	NR	NA	NA	NA	NA	3.8§	0.8§	4.9 (1.9 to 12.6)†
Chmielewska-Badora 1998[36]	38.6	6	9.9 (2.6 to 36.8)†	0.4	0.0	NC	NA	NA	NA
	28.1		6.1 (1.8 to 20.4)†						
Fahrer *et al* 1998[40]	NR	NR	NA	NR	NR	NA	0.8	0.8¶	1.0
Fahrer *et al* 1991[41]	26.1	3.9	8.6 (2.1 to 35.8)†	1.9–3.1**	NR	NA	0.8	NR	NA
		6.0	5.5 (1.7 to 17.9)†						
Gustafson *et al* 1993[39]	9	1	9.3 (3.6 to 24.2)†	6.0§§	1.3§§	4.8 (1.1 to 20.6)†	NA	NA	NA
		9	0.9 (0.5 to 1.8)†						
Hauser *et al* 1998[23]	41.0 to 44.8††	8‡‡	8.4 (4.4 to 15.9)†	NR	NR	NA	NA	NA	NA
Kuiper *et al* 1991[32]	19.7	6.3	3.7 (1.5 to 9.7)	6.0	NR	NA	NA	NA	NA
Zhioua *et al* 1997[22]	15.2	3.2	5.4 (0.7 to 40.7)†	3.3§§	NR	NA	NA	NA	NA

*NR, not reported; NA, not applicable; NC, not calculable; OR, odds ratio; RR, relative risk; †calculated with Intercooled Stata, version 6; ‡Data represents reported seroconversion. During the study, one case of Lyme disease was reported in the comparison group; §data were reported for two years, and thus represents a two-year cumulative incidence; ¶historical comparison group; **the prevalence of symptomatic disease was 1.9% for definite disease and 3.1% for probable disease; ††IgG and IgM activity to four different antigens were used, range reported is IgG only; ‡‡control data using IgG reactivity only, derived from Hauser *et al* 1998, table 1[23]; §§lifetime prevalence; for Zhioua *et al*,[22] the prevalence was for probable disease only.

6.0%. Many of these studies reported lifetime prevalence—that is, diagnosis of disease compatible with Lyme disease at any time in the past. However, only two (Chmielewska-Badora[36] and Gustafson *et al*[39]) reported prevalence of symptomatic Lyme disease among the occupational group under study and a comparison group. Chmielewska-Badora[39] documented one case of Lyme disease among 261 farmers and foresters compared with no cases in 50 blood donor controls (odds ratio (OR) not calculable). Gustafson *et al*[39] documented a lifetime history of 17 definite and five probable cases of Lyme disease among 362 orienteers compared with two cases of Lyme disease among 150 controls (OR=4.8, 95% confidence interval (95% CI) 1.1 to 20.0). The conclusion of definite disease was based on a past diagnosis of *erythema migrans* made by a physician.

The highest quality epidemiological measure of effect in this review is that of incidence of symptomatic, clinically confirmed disease. Of the 10 studies with high and moderate use, five reported annual incidence of symptomatic, clinically confirmed Lyme disease in the occupational groups under study. Vos *et al*[35] reported both the clinical incidence and seroconversion rates. Overall, relatively few new cases of occupationally acquired Lyme disease were documented in these incidence studies. Both Kuiper *et al*[31] and Vos *et al*[35] found no new cases of symptomatic Lyme disease during their follow up period. Vos *et al*[35] found a risk of seroconversion among the occupational group that was lower than that of the comparison group, although the relative risk did not reach significance. Fahrer *et al*[40 41] documented 15 new cases of Lyme disease, equivalent to an annual incidence of 0.8% over the mean follow up interval of 6.5 years. This annual incidence was no different than that found among the non-exposed comparison group. Only Bowen *et al*[48] reported an increased 2 year cumulative incidence of clinical Lyme disease in an outdoor occupational group (3.8%), compared with an indoor occupational group (0.8%), with a relative risk (95% CI) of 4.9 (1.9 to 12.6). These cases were collected retrospectively from among cases reported to the state of New Jersey in 1981 and 1982; the cases that worked at the Naval Weapons Station in Monmouth County were then categorised by indoor and outdoor work.

An important and consistent finding among the studies was that most subjects found to be seropositive, in either prevalence or incidence studies, had no current or past symptoms compatible with Lyme disease. For example, among the studies with high and moderate use, Kuiper *et al*,[31–32] Chmielewska-Badora,[36] Hauser *et al*,[23] and Zhioua *et al*[22] reported that 82%, 83%, 99%, 100%, and 100% of seropositive subjects were asymptomatic, respectively. Similarly, Vos *et al*[35] and Fahrer *et al*[40] reported that 93% and 98% of people with incident seroconversion had no symptoms consistent with Lyme disease.

DISCUSSION

The goal of this exercise was to find if outdoor workers who live, pursue leisure activities, and work in areas endemic for Lyme disease have an increased risk of the disease compared with people who only live and pursue leisure activities in those same areas. Although Lyme disease would seem to be an obvious risk of outdoor work, the scientific literature has not clearly documented the magnitude of the risk of symptomatic, clinically confirmed disease. Many studies have documented the occurrence of Lyme disease in outdoor workers, but few have attempted to document the risk of confirmed, symptomatic disease comparing occupationally exposed people and controls using the current standards of diagnosis of the disease. Most published studies with primary occupational data were cross sectional in design and documented an increased risk of seropositivity among workers compared with controls. However, the use of these studies in guiding decisions about the need to vaccinate outdoor workers in the United

States is limited by: (*a*) lack of clinical evaluation of subjects; (*b*) reliance on serological evaluation with ELISA or IFA only, without confirmation by western blot[58]; (*c*) inadequate assessment of occupational exposure to ticks—for example, lack of measurement of the number of outdoor hours worked or years of service, lack of assessment of protective behaviour or clothing, and failure to adjust for non-occupational exposures; and (*d*) a predominance of data from European studies, where *Borrelia burgdorferi* strain differences may alter the clinical presentation of Lyme disease.

In this evaluation of the scientific literature on the occupational risk of Lyme disease, three epidemiological effect measures were evaluated, in order from lowest to highest inferential value: (*a*) odds ratios for seropositivity from cross sectional studies; (*b*) odds ratios for symptomatic, clinically confirmed Lyme disease from cross sectional studies; and (*c*) incidence ratios (relative risks) for symptomatic, clinically confirmed Lyme disease, from longitudinal studies.

Despite the apparent increased risk of seropositivity in occupationally exposed people compared with controls, it should be noted that the choice of an appropriate comparison group can influence the magnitude of this risk. Of the seven studies in table 5 that had an increased risk of seropositivity in the occupational groups under study, five used a comparison group with a decreased residential risk of Lyme disease. Comparing seroprevalence among occupationally exposed people, who generally live in areas endemic for Lyme disease, with controls, who live in areas where Lyme disease is lowest or absent, would bias estimations of occupational risk in the direction of increased risk. Thus, the increased risks of seropositivity for outdoor work presented in table 5 may over estimate the occupational risk.

One consistent deficiency is that less than half of the 41 published studies required clinical confirmation by a physician. What is perhaps most surprising about the published studies is that three studies published in the 1990s all document no increased incidence of symptomatic, clinically confirmed Lyme disease in outdoor workers (Kuiper *et al*[31]; Vos *et al*[35]; and Fahrer *et al*[40]). Although one of these studies,[31] did not report data from a comparison group, no cases of Lyme disease were found in the occupational group under study. Of the 41 studies, only Bowen *et al*[48] documented an increased incidence of symptomatic Lyme disease among a very specific group of outdoor workers and controls. However, all cases were diagnosed during 1981 and 1982, and thus may not represent either current standards for diagnosis of Lyme disease or current levels of risk after 20 years of experience with the disease among outdoor working populations. Thus, although we think that the findings of Bowen *et al*[48] are internally valid, they may not be generalisable, especially to current practice.

Among cross sectional studies that evaluated symptomatic Lyme disease, only one (Gustafson *et al*[39]) reported the second most useful effect measure (OR for symptomatic disease); this study reported an increased relative odds for symptomatic Lyme disease over a lifetime, but the methods may raise concerns about recall bias. Many studies documented an increased risk of seropositivity, but most seropositive subjects were asymptomatic, and seropositivity was defined with ELISA or IFA only, which is not the current standard for serological testing. An important point is that, to our knowledge, there are no studies that suggest that asymptomatic seropositive subjects are at risk of developing symptomatic disease or late sequelae of infection. On the contrary, at least one study has reported that there is no increased risk for the development of symptomatic disease in such subjects over an average follow up interval of 6.5 years (Fahrer *et al*[40]). Serological studies also document significant seroreversion rates; asymptomatic seropositive subjects are seronegative, and still asymptomatic, on repeat testing (Fahrer *et al*[40]; Schwartz *et al*[54]). For example, Schwartz *et al*[54] reported annual seroreversion rates of 43%, 23%, and 53% from 1988–89, 1989–90, and 1990–91, respectively.

Assessment of occupational risk was further limited by the paucity of studies that attempted to define occupational risk factors more carefully (in terms of hours outdoors in specific tick infested habitats, specific high risk tasks, or controlling for use of preventive behaviour) or that controlled for non-occupational risk factors in the assessment of occupational risk. Hours of recreation outdoors, deer sightings near the home, pet ownership, rural residence, and personal preventive behaviour have all been shown to be risk or protective factors for Lyme disease or seropositivity for antibodies to *Borrelia burgdorferi*.[9 10 49 54]

Despite the limitations of the scientific literature, it would seem obvious that people who work outdoors in tick infested areas should be at increased risk of Lyme disease; however, an increased risk of symptomatic, clinically confirmed Lyme disease has not been documented in outdoor workers. Many of the studies were not specifically designed to evaluate the occupational risk of symptomatic, clinically confirmed Lyme disease, and the current serological testing guidelines were developed after most of these studies were published. However, the three best published epidemiological studies do not suggest that an occupational risk exists (Vos *et al*[35]; Kuiper *et al*[31]; Fahrer *et al*[40]). It may be that workers in tick infested habitat become knowledgeable about the disease and use personal preventive behaviour to minimise their risk.[9 55]

Several studies suggest that such personal protective behaviour as tick checks, tucking trousers into socks, or use of permethrin or DEET may decrease the risk of seropositivity or tick bites. Antitick saliva antibody (ATSA) and antirecombinant tick calreticulin antibody are two biomarkers of tick exposure that have been used in epidemiological studies of exposure to ticks.[8 59 60] For example, in a study of military personnel on manoeuvres in tick infested areas of Arkansas, people who tucked their trousers into their socks were significantly less likely to be ATSA seropositive than subjects who did not tuck in their trousers (OR 2.8 (95% CI 1.1 to 7.1, Schwartz 1996).[8] Similarly, outdoor workers in New Jersey who did not use insect repellants were more likely to be ATSA seropositive (OR (95% CI) = 2.0 (1.0-4.0), Schwartz and Goldstein).[9]

Environmental application of insecticides has been shown to decrease the abundance of ticks, but this is more likely to be useful in the prevention of residentially acquired Lyme disease than in the prevention of occupational disease.[11] It is also known that duration of tick feeding is an important determinant of the risk of infection, so tick checks and early tick removal are likely to be effective in the prevention of the disease.[61] It should be noted, however, that other studies have not shown that personal preventive behaviour is effective in disease prevention.[55] All of these strategies have been recommended by the Centers for Disease Control as effective measures to decrease the risk of acquiring Lyme disease.[1]

There are no other personal strategies to prevent Lyme disease that have been proved to prevent the disease as effectively as the Lyme disease vaccine. The Lyme vaccine efficacy study was a randomised, placebo controlled trial in 10 936 subjects aged 15–70 years.[62] Lyme disease was carefully documented with culture, polymerase chain reaction, or western blot seroconversion among subjects with symptoms compatible with Lyme disease. Among study subjects under the age of 65, after three doses the vaccine was 90% effective in preventing laboratory confirmed, symptomatic Lyme disease. The Centers for Disease Control, The Medical Letter, and other authors have all commented on use of the vaccine.[1 13 14]

Another important factor to consider is the natural history of Lyme disease compared with other diseases preventable by vaccine. Lyme disease is non-fatal, relatively easy to diagnose, and relatively easy to treat with oral antibiotics. By contrast, hepatitis B virus, for example, can be fatal, can have a chronic carrier state, and is not effectively treated. Although vaccination against Lyme disease may help to decrease morbidity, it would seem less imperative than for an organism such as hepatitis B virus.

When deciding whether or not to vaccinate a workforce against Lyme disease, the occupational physician should consider several factors—the strength of the scientific evidence presented here, the availability of resources, the history of risk of Lyme disease in the workforce under consideration, and the concerns of workers. The scientific literature shows an increased risk of occupational exposure to *Borrelia burgdorferi*, as assessed by the seroprevalence studies, but fails to document an increased risk of development of symptomatic Lyme disease. The lack of documented clinical risk makes it difficult to rely exclusively on the current scientific literature. Factors that may favour vaccination would include documented increased risk of Lyme disease in the workforce under consideration for vaccination; a high level of concern about the disease from workers; high level of outdoor activity in tick infested areas; poor compliance with personal protective clothing or behaviour; and availability of financial resources for occupational health programmes. Further studies that explicitly assess the risk of developing occupationally acquired Lyme disease are necessary to help guide the physician on whether or not to vaccinate.

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Answers to multiple choice questions on *Complementary and alternative medicine: what is it all about?* by E Ernst and A Fugh-Berman on pages 140–144

(1)(a) true;
(b) false—few therapies are whole systems, many are discrete treatments;
(c) false—it is "diagnosis, treatment and/or prevention which complements mainstream medicine by contributing to a common whole, by satisfying a demand not met by orthodoxy or by diversifying the conceptual frameworks of medicine";
(d) true

(2)(a) true;
(b) true;
(c) false—complementary therapist visits were more numerous by 70%;
(d) false: in the USA, 72% did not tell their physician

(3)(a) false—there is no evidence in support of this hypothesis;
(b) true;
(c) true—at least in breast cancer patients;
(d) true

(4)(a) false—the figure is 16%;
(b) true;
(c) false—there is clear evidence that the same evidence is required for complementary medicine as is required for conventional medicine;
(d) false—evidence exists

(5)(a) false—there is limited evidence that it is more effective;
(b) false—the evidence suggests the effects of homoeopathy are not completely due to placebo;
(c) false—the evidence is not convincing;
(d) true