Epidemiol. Infect. (1995), **115**, 299–307

A serosurvey of water-borne pathogens amongst canoeists in South Africa

M. B. TAYLOR[1], P. J. BECKER[2], E. JANSE VAN RENSBURG[1]*, B. N. HARRIS[3], I. W. BAILEY[4] AND W. O. K. GRABOW[1]

[1] *Department of Medical Virology, University of Pretoria, PO Box 2034, Pretoria 0001, South Africa*

[2] *Centre for Epidemiological Research in Southern Africa, Medical Research Council, Private Bag X385, Pretoria 0001, South Africa*

[3] *Department of Community Health, University of Pretoria, PO Box 667, Pretoria 001, South Africa*

[4] *Umgeni Water, PO Box 9, Pietermaritzburg 3200, South Africa*

(*Accepted 1 June 1995*)

SUMMARY

Certain health risks have been associated with recreational exposure to faecally polluted water. Canoeing in certain South African waters is considered to be a high risk activity with regard to schistosomiasis, gastroenteritis and possibly hepatitis. In a cross-sectional study, a serosurvey was conducted amongst canoeists to ascertain whether or not they had a higher seroprevalence to hepatitis A virus, Norwalk virus and *Schistosoma* spp. than non-canoeists. In comparisons between the two groups, a significant association could not be demonstrated between canoeing and antibody response to hepatitis A and Norwalk viruses (P-values for age-adjusted χ^2 were 0·083 and 0·219 respectively), but a significant association could be demonstrated between canoeing and the antibody response to *Schistosoma* spp. ($P < 0{\cdot}001$; age-adjusted).

INTRODUCTION

Recreational exposure to faecally polluted waters has been implicated as a potential health hazard and is the cause of great concern to the public, authorities and researchers worldwide [1–5]. Epidemiological investigations have shown that a significant risk of acute gastroenteritis is associated with swimming and snorkelling in both fresh and marine waters contaminated with human faeces [6, 7]. Swimmers in virally polluted water are reportedly at risk of meningitis, respiratory infections and gastroenteritis [8], and lake water was implicated as the source of a Coxsackie B virus epidemic [9] and Coxsackie A infections [10]. Hepatitis A [11] and Norwalk virus (NV) gastroenteritis [12, 13] have also been associated with immersion in surface water and swimming in polluted water respectively. Windsurfers [14] and white-water canoeists [15] have been shown to

* Current address: Department of Medical Virology, University of Stellenbosch, PO Box 19063, Tygerberg 7505, South Africa.

be at risk of contracting similar infections to swimmers, with the relative risk increasing with the frequency of immersion [14].

Canoeing in certain South African waters can be regarded as a high-risk activity with respect to diseases such as schistosomiasis [16, 17], gastroenteritis [17, 18] and hepatitis A [19]. Although canoeists may not intentionally drink polluted water, they do come into contact with aerosols from splashing water, and probably swallow water when they capsize [17]. Bacteriological analyses of the Umsindusi and Umgeni Rivers, Kwazulu/Natal, where the prestigious 3-day Dusi Canoe Marathon is held annually, has shown faecal coliform counts of up to 10^5/100 ml during the race [17, 18]. These counts far exceed the generally accepted limits of 2×10^3 faecal coliforms/100 ml and accepted risk of infection for direct contact recreational waters [5, 17, 18]. Therefore there is a potential risk that canoeists may contract a number of water-borne infections in these and possibly other South African waters. However infections, e.g. hepatitis A and NV-associated gastroenteritis, may not be recognized or associated with watersport activities due to their mild or sub-clinical presentation and/or difficulties in the diagnosis. Consequently it is difficult to assess the relative risk of these infections associated with canoeing. The purpose of this investigation was to establish whether any infections contracted by the canoeists could reliably be attributed to exposure to waters containing dispersed sewage. In a cross-sectional study, a serosurvey was conducted amongst canoeists and healthy volunteers with limited water sport activities. The seroprevalence between the groups was compared to test the postulate that canoeists had a higher prevalence of antibodies to hepatitis A virus (HAV), Norwalk virus (NV) and *Schistosoma* spp., than those without such exposure.

MATERIALS AND METHODS

Subjects

Canoeists/exposed group

Canoeists registering for the 1992 Dusi canoe marathon were invited to participate in the study. Five hundred and ninety-four volunteers, all from the higher socio-economic and predominantly white population, were asked to complete a short questionnaire to determine their exposure to potentially polluted waters through canoeing. Demographic data indicating the canoeist's residential province, and river or dam most frequently used for canoeing practice, and number of previous Dusi marathons were recorded. Data with regard to previous episodes of gastroenteritis ('Dusi-guts'), hepatitis and schistosomiasis, as well as other infections perceived to have been associated with the Dusi canoe marathon, were recorded. Prior to or during the 1992 Dusi canoe marathon, approximately 10 ml of blood was drawn from each subject to evaluate their antibody status.

Non-canoeists/unexposed group

Two hundred and seven non-canoeists, healthy students and laboratory staff with little or no water-sporting activity were invited to participate in the study. Volunteers, also all from the higher socio-economic population, completed a questionnaire to determine their exposure to polluted water through occupational and recreational activities. Data with regard to known previous or current

episodes of hepatitis or schistosomiasis were recorded. Serum samples were also obtained to determine antibody status.

Serological methods

Serum samples were screened, and the presence of antibodies was considered indicative of recent or previous infection.

Norwalk virus

Antibodies to NV were demonstrated in an enzyme immunoassay (EIA) system, using recombinant Norwalk virus antigen (rNV) expressed by baculovirus [20], described by Graham and colleagues [21] and adapted by Parker and colleagues [22]. Samples were tested at a dilution of 1/1000 and wells giving an o.d. value $> 0{\cdot}1$ and at least double the negative control were considered to be positive. A titre of $\leqslant 1000$ in the rNV EIA has, after extensive evaluation using reference sera from volunteers experimentally infected with NV, been found to be equivalent to a titre of < 50 in the radio-immunoassay (RIA), and can therefore be considered to be negative [22].

Hepatitis A virus

Antibodies to HAV were detected using a commercial EIA for the detection of total antibody to HAV (Wellcozyme anti-HAV, Wellcome Diagnostics, Dartford, UK). Tests were performed according to the manufacturer's specifications.

Schistosoma spp.

A commercial EIA for determining the level of *Schistosoma*-specific IgG in serum specimens (Schisto Stat IgG, Delta Bioproducts, Kempton Park, South Africa) was used to determine the presence of antibodies to *Schistosoma* spp. Tests were carried out according to the manufacturer's recommendations.

Statistical methods

Demographic data were summarized using descriptive statistics. Exposure groups were compared with respect to seropositivity in a χ^2 test while a relative comparison was based on the prevalence odds ratio (POR) [23] which approximates the incidence rate ratio (RR). As age can be a confounder, and with 184/207 (88·9%) of the control group $\leqslant 30$ years old, the $\leqslant 30$-year-old group was considered, where age was categorized into $\leqslant 21$ and > 21 years of age, with 21 being the median age of the $\leqslant 30$ group. Age adjustment was done with the Mantel–Haenszel technique.

RESULTS

The demographic data and serological results of both the canoeists and controls are summarized in Table 1.

Demographic data

Of the 1165 canoeists (1103 male: 62 female) who participated in the 1992 Dusi canoe marathon, data and serum specimens were available from 577 (549 male: 28 female) of the 594 canoeists who volunteered to take part in the study. From the available data it was evident that many of the subjects had not participated in

Table 1. *Demographic data and serological profiles of canoeists and non-canoeists collected in conjunction with the 1992 Dusi canoe marathon*

		Demographic data Age (years)			Prevalence of seropositive subjects		
Group	*n**	Range	Mean	(S.D.)†	HAV‡	NV§	*Schistosoma* spp.
Canoeists							
Male	549	15–53	31·3	(9·2)	205 (37·3%)	241 (43·9%)	281 (51·2%)
Female	28	15–47	28·3	(8·8)	8 (28·6%)	10 (35·7%)	6 (21·4%)
Total	577	15–33	31·1	(9·2)	213 (37·2%)	251 (43·5%)	287 (49·7%)
Prevalence odds ratio (POR)‖					2·4	1·8	13·6
95% Confidence interval					(1·64–3·66)	(1·29–2·63)	(7·54–25·12)
Non-canoeists							
Male	137	18–54	23·8	(7·2)	30 (22·1%)	36 (26·5%)	10 (7·4%)
Female	70	18–49	20·8	(3·9)	10 (14·3%)	25 (36·2%)	4 (5·8%)
Total	207	18–54	22·8	(6·4)	40 (19·4%)	61 (29·8%)	14 (6·8%)

* Number of volunteers.
† Standard deviation.
‡ Hepatitis A virus.
§ Norwalk virus.
‖ Prevalence odds ratio of canoeists versus non-canoeists.

previous Dusi canoe marathons, but had trained in the Umsindusi or Umgeni rivers or other Natal waters. In addition, many canoeists had trained in waters outside Natal, but had competed in previous Dusi canoe marathons.

Serology

The percentage seropositivity to HAV was higher in the canoeists (37·2%) compared to the non-canoeists (19·4%) (POR = 2·4), which suggests that the chance of HAV seropositivity amongst canoeists is 2·4 times higher than amongst the non-canoeists. Similarly the seropositivity to NV was higher in the canoeists (43·5%) than the non-canoeists (28·8%) (POR = 1·8). A difference of 42·9% in seropositivity to *Schistosoma* spp., with a POR of 13·6, was evident when comparing the canoeists (49·7%) and non-canoeists (6·8%). However, when the serological results and age-adjusted POR for the $\leqslant$ 30-year-old group are considered, it is evident that age was a confounder and that for canoeists, the chance of being seropositive in this age group is 1·58, 1·34 and 7·87 times higher with respect to HAV, NV and *Schistosoma* spp., than that for the non-canoeists (Table 2). The exposure was marginally not significantly associated with HAV ($P = 0{\cdot}083$), not significantly associated with NV ($P = 0{\cdot}219$), but was highly significantly associated with *Schistosoma* spp. ($P < 0{\cdot}001$). As the POR approximates the RR, the approximate attributable proportions [24] of the seropositive canoeists for whom the seropositivity can be attributed to canoeing is 37% (HAV), 25% (NV) and 87% (*Schistosoma* spp.).

Infections associated with the Dusi marathon

Of the 577 volunteers participating in the study 149 (25·8%) had not previously participated in the event. Two hundred and seventy-seven (48·0%) respondents attributed a number of clinical conditions to exposure to the river water during

Table 2. *Serological data and prevalence odds ratios for canoeists and non-canoeists ⩽ 30 years of age*

		Number of subjects*					
		Hepatitis A virus		Norwalk virus		*Schistosoma* spp.	
Age (years)	Group	+ve	−ve	+ve	−ve	+ve	−ve
⩽ 21	Canoeists	26 (23·9%)	83 (76·1%)	37 (33·9%)	72 (66·1%)	39 (35·8%)	70 (64·2%)
	Non-canoeists	21 (14·8%)	121 (85·2%)	41 (29·1%)	100 (70·9%)	7 (5·0%)	134 (95·0%)
> 21–⩽ 30	Canoeists	55 (34·0%)	107 (66·0%)	68 (42·0%)	94 (58·0%)	77 (47·8%)	84 (52·2%)
	Non-canoeists	12 (27·9%)	31 (72·1%)	14 (32·6%)	29 (67·4%)	6 (14·0%)	37 (86·0%)
Mantel–Haenszel χ^2		$P = 0·083$		$P = 0·219$		$P < 0·001$	
Crude prevalence odds ratio		1·96		1·48		9·91	
Mantel–Haenszel age-adjusted POR†		1·58		1·34		7·87	
(95% confidence interval)		(0·95–2·67)		(0·85–2·10)		(4·20–16·15)	

* +ve, seropositive; −ve, seronegative.
† Prevalence odds ratio.

Table 3. *Clinical symptoms associated with previous Dusi canoe marathons*

Number of volunteer canoeists		
No previous marathons		149 (25·8%)
Reporting symptoms		277 (48·0%)
No symptoms		151 (26·2%)
Symptoms recorded		
Gastroenteritis		205/277 (74·0%)
> 1 week	60/205 (29·3%)	
⩽ 1 week	55/205 (26·8%)	
Bilharzia		82/277 (29·6%)
Infected cuts		47/277 (17·0%)
Jaundice		9/277 (3·2%)
Tick bite fever		5/277 (1·8%)

previous Dusi canoe marathons, although in most instances no clinicians were consulted or definitive diagnoses made. The infections attributed to exposure to the river water, during and after 1–24 previous marathons, are summarized in Table 3. From Table 3 it is evident that gastroenteritis accounted for 74% of infections associated with previous marathons, and *Shigella* spp. and amoebic dysentery were implicated in three cases where a definitive diagnosis was made. Of the 205 respondents who reported episodes of gastroenteritis, 60 (29·3%) indicated that the gastroenteritis had continued longer than 1 week and in some cases up to 6 months, while 55 (26·8%) indicated that their episode of gastroenteritis had lasted only a few days. Bilharzia was the second most common infection reported although in most instances the method of diagnosis was not given. Forty-seven respondents (16·9%) reported they had had cuts which had become infected and only nine respondents (3·2%) associated jaundice with the canoeing event. None of the latter respondents gave any details with regard to time of onset of the jaundice, or what the definitive diagnosis was.

DISCUSSION

Schistosoma haematobium, *S. mansoni* and *S. mattheei* are endemic in certain areas of the Transvaal, Natal and eastern Cape coastal regions of South Africa [25]. Consequently all people using natural streams, rivers and man-made collections of water in these areas for domestic or recreational activities are at risk of becoming infected [16, 26]. Although Appleton and Bailey [17] reported a low prevalence of urinary schistosomiasis in canoeists participating in the 1988 and 1989 Dusi canoe marathons, results from concurrent questionnaires indicated that 70·6 and 48·7% of the respondents who had been tested for schistosomiasis prior to the 1988 and 1989 Dusi canoe marathons respectively, were positive [17]. Whether the crude POR or age-adjusted POR for *Schistosoma* spp. are considered, it is evident that the canoeists have a significantly greater chance of contracting bilharzia than the non-canoeists. Although canoeists as a group had a relatively high seroprevalence rate to *Schistosoma* spp., the canoeists from the Natal region were shown to have only a slightly greater chance of contracting bilharzia than

those from other regions, predominantly the Transvaal (POR 1·2; results not shown). This is in contrast to Appleton and Bailey's results [17], but is not unexpected as both *S. haematobium* and *S. mansoni* are endemic in areas of the Transvaal. These results therefore confirm previous observations that canoeing in waters in areas endemic for *Schistosoma* spp. poses a meaningful risk for infection. South African canoeists are well aware of this risk and many take anti-schistosomal drugs regularly [17].

Few data are available on the epidemiology of HAV infection in South Africa. Seroprevalence data from limited investigations indicate that all of the lower socio-economic and predominantly black community have been infected by 6–10 years of age [27, 28], while in the higher socio-economic and predominantly white community 40–60% of adults have been infected [29, 30]. In one report [27], 44·9% of white subjects aged 10–19 years were reportedly immune while 76·1% were immune by 30–39 years of age. This suggests an increase in HAV seroprevalence with age and consequent lifestyle, an observation confirmed by our investigation. Furthermore the results from this investigation indicate that there is an increased chance, albeit small (age-adjusted POR = 1·58), of canoeists exposed to sewage-polluted waters contracting hepatitis A. These findings are supported by the fact that after the 1991 Dusi marathon a 33-year-old participant developed hepatitis A 4 weeks after the marathon, and two other canoeists who developed clinical jaundice after the race were serologically diagnosed as having hepatitis A [19].

NV and other small round structured viruses (SRSVs) are a major cause of outbreaks of non-bacterial gastroenteritis affecting people of all age groups [31]. The infection is characterized by a short incubation period, acute onset and benign course of illness [32]. Common source outbreaks, with a high attack rate, have been ascribed to the ingestion of faecally contaminated water and ice [33, 34], as well as swimming in polluted waters [12, 13]. The results of NV seroprevalence studies in this investigation suggest that the canoeists only have a slightly increased chance (age-adjusted POR = 1·34) of acquiring NV gastroenteritis in comparison to the non-canoeists. These findings are supported by the fact that only 106/205 (51·7%) respondents who associated gastroenteritis with the canoeing event had antibodies to NV. After the 1988 and 1989 Dusi canoe marathons approximately 18·2 and 13·3% of the respondents to questionnaires indicated that they had suffered from gastroenteritis during or immediately after the race [17]. During the 1991 Dusi marathon 65% of the canoeists reportedly contracted gastroenteritis, possibly attributable to a major sewage leak into the river prior to the race, and the clinical symptoms were suggestive of a predominantly viral aetiology [18]. However no data are available with regard to gastroenteritis in an appropriate control group, i.e. seconds and supporting services, associated with the 1991 Dusi marathon. In this investigation the responses to the questionnaire were, however, suggestive of a varied aetiology, as in some cases the episodes of gastroenteritis continued longer than a week, with amoebic dysentery and *Shigella* spp. implicated in the diagnoses. In addition pre-existing antibodies to NV may not necessarily confer protective immunity to subsequent NV infections, and infection with one strain of SRSV does not confer protection against infection with another strain [32, 35].

In this study a significant association between canoeing and antibody response to *Schistosoma* spp., but not HAV and NV, has been demonstrated. This does not preclude the possibility of other enteric viruses or microbial causes of water-borne infections posing a meaningful risk for the canoeists in faecally polluted waters in South Africa.

ACKNOWLEDGEMENTS

We wish to thank Mrs C. Schildhauer for technical assistance; the Water Research Commission, the Medical Research Council and the Faculty of Medicine, University of Pretoria, South Africa for financial support; Professor Mary K. Estes and Dr Xi Jiang from the Division of Molecular Virology, Baylor College of Medicine, Texas Medical Center, Houston, Texas for the reagents for the rNV EIA; Dr I. Walters and staff of the Pietermaritzburg City Health Department for assisting with the collection of blood samples from the canoeists, and Umgeni Water for facilitating the study and their laboratory staff for processing the canoeists' blood samples. A special word of thanks goes to the Natal Canoe Club for their co-operation and to all canoeists, students and laboratory staff members who volunteered to participate in the study.

REFERENCES

1. Cabelli VJ. Public health and water quality significance of viral diseases transmitted by drinking water and recreational water. Wat Sci Tech 1983; **15**: 1–15.
2. Godfree A, Jones F, Kay D. Recreational water quality. The management of environmental health risks associated with sewage discharges. Marine Pollution Bull 1990; **21**: 414–22.
3. Fewtrell L. Freshwater recreation: a cause for concern? Appl Geogr 1991; **11**: 215–26.
4. Kay D, Jones F. Recreational water quality. PHLS Microbiol Dig 1992; **9**: 125–8.
5. Department of Water Affairs and Forestry. South African water quality guidelines, 1993, Vol 2: Recreational use.
6. Cabelli VJ. Swimming-associated illness and recreational water quality criteria. Wat Sci Tech 1989; **21**: 13–21.
7. Philipp R, Evans EJ, Hughes AO, Grisdale SK, Enticott RG, Jephcott AE. Health risks of snorkel swimming in untreated water. Int J Epidemiol 1985; **14**: 624–7.
8. Feachem R, Garelick H, Slade J. Enteroviruses in the environment. World Health Forum 1982; **3**: 170–80.
9. Hawley HB, Morin DP, Geraghty ME, Tomkow J, Phillips A. Coxsackievirus B epidemic at a boys' summer camp. JAMA 1973; **226**: 33–6.
10. Denis FA, Blanchouin E, DeLignières A, Flamen P. Coxsackie A16 infection from lake water. JAMA 1974; **228**: 1370–1.
11. Philipp R, Waitkins S, Caul O, Roome A, McMahon S, Enticott R. Leptospiral and hepatitis A antibodies amongst windsurfers and waterskiers in Bristol City Docks. Public Health (Lon) 1989; **103**: 123–9.
12. Koopman JS, Eckert EA, Greenberg HB, Strohm BC, Isaacson RE, Monto AS. Norwalk virus enteric illness acquired by swimming exposure. Am J Epidemiol 1982; **115**: 173–7.
13. Baron RC, Murphy FD, Greenberg HB, et al. Norwalk gastrointestinal illness: an outbreak associated with swimming in a recreational lake and secondary person-to-person transmission. Am J Epidemiol 1982; **115**: 163–72.
14. Dewailly E, Poirier C, Meyer FM. Health hazards associated with windsurfing on polluted water. Am J Public Health 1986; **76**: 690–1.
15. Fewtrell L, Godfree AF, Jones F, Kay D, Salmon RL, Wyer MD. Health effects of white-water canoeing. Lancet 1992; **339**: 1587–9.
16. Gear JHS, Miller GB, Reid FP. Bilharzia contracted in small dams and while canoeing with special reference to its early stages. South Afr J Epidemiol Infect 1986; **1**: 38–43.

17. Appleton CC, Bailey IW. Canoeists and waterborne diseases in South Africa. S Afr Med J 1990; **78**: 323–6.
18. Grabow WOK, Taylor MB, Bailey IW, Walters I. Dusi canoe marathon: risk of infection associated with polluted river water. In: Abridged papers, Proceedings of the third Biennial Conference and Exhibition of the Water Institute of Southern Africa. Johannesburg: Water Institute of Southern Africa, 1993: 166–7.
19. National Institute of Virology. Surveillance Bulletin: South African Virus Laboratories 1991; April **04**: 12.
20. Jiang X, Wang M, Graham DY, Estes MK. Expression, self assembly and antigenicity of the Norwalk virus capsid protein. J Virol 1992; **66**: 6527–32.
21. Graham DY, Jiang X, Tanaka T, Opekun A, Madore HP, Estes MK. Norwalk virus infection of volunteers: new insights based on improved assays. J Infect Dis 1994; **170**: 34–43.
22. Parker SP, Cubitt WD, Jiang X, Estes MK. Efficacy of a recombinant Norwalk virus protein enzyme immunoassay for the diagnosis of infections with Norwalk virus and other human 'candidate' caliciviruses. J Med Virol 1993; **41**: 179–84.
23. Ahlbom A, Norell S. Introduction to modern epidemiology. 2nd ed. Chestnut Hill, MA: Epidemiology Resources Inc., 1990: 34.
24. Rothman KJ. Modern epidemiology. Boston: Little, Brown and Company, 1986: 38.
25. Gear JHS, Pitchford RJ, van Eeden JA. Atlas of bilharzia in Southern Africa. Joint publication by the South African Institute for Medical Research, South African Medical Research Council, and Department of Health, Johannesburg, 1980.
26. Kvalsvig JD, Schutte CHJ. The role of human water-contact patterns in the transmission of schistosomiasis in an informal settlement in a major industrial area. Ann Trop Med Parasitol 1986; **80**: 13–26.
27. Prozesky OW. Onlangse vordering in virushepatitis. S Afr J Continuing Med Education 1984; **2**: 31–9.
28. Abdool Karim SS, Coutsoudis A. Sero-epidemiology of hepatitis A in black South African children. S Afr Med J 1993; **83**: 748–50.
29. Martin DJ. Hepatitis A vaccination – an option for South Africa? S Afr Med J 1992; **82**: 5–6.
30. Prozesky OW, Whitcutt JM, Coppin A, Rossouw E. Diagnosis of viral hepatitis. Experience in a South African laboratory. S Afr Med J 1984; **65**: 591–4.
31. Cubitt WD. Diagnosis, occurrence and clinical significance of human 'candidate' caliciviruses. Prog Med Virol 1989; **36**: 103–19.
32. Cubitt WD. Human, small round structured viruses, caliciviruses and astroviruses. In: Farthing MJ, ed. Virus infections of the gut and liver. Baillières Clin Gastroenterol 1990; **4**: 643–56.
33. Kaplan JE, Goodman RA, Schonberger LB, Lippy EC, Gary GW. Gastroenteritis due to Norwalk virus: an outbreak associated with a municipal water system. J Infect Dis 1982; **146**: 190–7.
34. Cannon RO, Poliner JR, Hirschhorn RB, et al. A multistate outbreak of Norwalkvirus gastroenteritis associated with the consumption of commercial ice. J Infect Dis 1991; **164**: 860–3.
35. Taylor MB, Schildhauer CI, Parker S, et al. Two successive outbreaks of SRSV-associated gastroenteritis in South Africa. J Med Virol 1993; **41**: 18–23.