Epidemiol. Infect. (2003), **131**, 655–662.
DOI: 10.1017/S0950268803008598 Printed in the United Kingdom

Children at risk of giardiasis in Auckland: a case–control analysis

M. E. HOQUE[1*], V. T. HOPE[1,2], R. SCRAGG[1] AND T. KJELLSTRÖM[1,3]

[1] *Division of Community Health, Faculty of Medical and Health Sciences, The University of Auckland, Private Bag 92019, Auckland, New Zealand*
[2] *Manager, Environmental Health, Auckland Regional Public Health Service, Auckland District Health Board, Private Bag 92605, Auckland, New Zealand*
[3] *Currently: National Centre for Epidemiology and Population Health, The Australian National University, Canberra ACT 0200, Australia*

(*Accepted 14 February 2003*)

SUMMARY

The incidence rate of giardiasis in New Zealand is one of the highest among developed countries, peaking in the 1–4 year age group. A case–control study was undertaken to identify risk factors for giardiasis among Auckland children under 5 years of age. The exposure history of 69 cases and 98 controls were analysed. Ninety-five per cent cases and 86% controls used water from the Auckland Metropolitan mains (AMM) supply for domestic purpose, 44 cases and 42 controls swam and 59 cases and 54 controls wore nappies. Children wearing nappies were at significantly increased risk of the disease (OR = 3·0, 95% CI = 1·01–8·9), as were those from households which had more than one child wearing a nappy (6·5, 1·8–23·4). The Auckland metropolitan mains water supply was associated with a reduced risk compared to other drinking water sources. Significantly increased risks were also associated with drinking water consumed away from home (4·7, 2·2–10·1), swimming at least once a week (2·4, 1·1–5·3) and travelling domestically (2·5, 1·03–6·0). The study identified vulnerable groups and modifiable risk factors for diarrhoeal diseases, particularly *Giardia* infection. Nappy wearing was an independent risk factor for infection. Further study is advocated to ensure better protection of public health, especially for children.

INTRODUCTION

Giardia is a leading cause of human gastrointestinal illnesses [1]. It is prevalent in both developed and developing countries. The transmission of *Giardia* sp. is common in certain high-risk groups, such as children, especially those who attend childcare centres [2, 3]. The major reservoir for the organism is infected humans. Other reservoirs are fresh surface water, and wild and domestic animals. Giardiasis became a notifiable disease in New Zealand in July 1996. Nearly 2000 giardia positive cases are reported in New Zealand annually. Currently, it is the third most commonly notified communicable disease in New Zealand after campylobacteriosis and salmonellosis and the most commonly notified potentially waterborne disease. The reported incidence rate of *Giardia* infection in New Zealand is 46·6 per 100 000 population [4], thought to be one of the highest among developed countries [5]. A bimodal pattern of infection is observed peaking in the 1–4 and 25–44 year age groups [2, 3, 6, 7]. Children aged 1–4 years have double the infection rate of the 25–44 year age group and had a tenfold higher rate than the 10–19 year age group [5].

* Author for correspondence.

Giardia transmission generally occurs through the faecal–oral route or via suitable vehicles of transmission, such as contaminated water. Ingestion of as few as ten cysts may cause infection [8]. Apart from water contact, person-to-person transmission plays a major role in spreading the disease possibly facilitated by situations of close contact such as nappy changing, childcare facilities or within households [3, 6, 9]. Overseas travel and water sports are other important factors associated with infection [2, 10]. A systematic study of these risk factors in the occurrence of *Giardia* infection in children has not been made in New Zealand to date.

We undertook a case–control study to identify the modifiable risk factors for giardiasis in children in Auckland. In particular, we wished to confirm (or refute), in pre-school children, our previous findings of the importance of exposure to nappies and childcare centres in the transmission of *Giardia* infection in adults 15 years and over [6].

METHODS

A case–control study was carried out to identify potentially modifiable risk factors for giardiasis in children under 5 years of age in the Auckland region. Cases were identified from notifications of giardiasis received by Auckland Healthcare (now Auckland District Health Board) where giardia had been isolated from faeces. All cases were residents of the Auckland (telephone) region aged under 5 years with caregivers who could be contacted at home on a telephone number listed in the Auckland Telephone Book (ATB). Data were collected from cases diagnosed between November 1999 and June 2000. Upon receipt of a notification, a Health Protection Officer (HPO) from Auckland Healthcare contacted the main caregiver of the child and requested consent for the investigator to contact the caregiver directly. An information sheet describing the nature of study was forwarded at the same time. The HPO also organised an interview with the main caregiver of the case if consent was given. This was conducted within 72 h of initial contact by the HPO. Controls, from the same age range as cases, were identified from a random list of telephone numbers in the ATB. One child under 5 years of age in a household contacted by phone was included in the study if consent was given. If more than one child was in the house, the child with date of birth closest to the initial contact day was selected. Controls did not have a recent history of confirmed *Giardia* infection but were not tested for *Giardia* sp. The caregivers of controls were interviewed, over the same period as cases.

Interviews were conducted by telephone using a structured questionnaire. Telephone Marketing Research (TMR) conducted interviews for cases and controls following training by the researcher. Information on exposures was gathered for the 3 weeks preceding the date of onset of symptoms which corresponds to the usual maximum incubation period for *Giardia* infection. To maintain a similar study period for controls, a single digit random number ranging between 3 and 8 was generated for each control; this number was a proxy for days usually taken between the development of symptoms and pathological diagnosis. So, for controls, information on exposures was gathered for the 3 weeks preceding an estimated date [simulated date of 'onset' had they been a case = (date of referral) minus (a randomly assigned number of days between 3 and 8 to simulate time to diagnosis and referral in cases)]. Interviewers were not informed of the disease status of participants in order to minimize bias during data collection.

The occupation of main caregivers of children was categorized into six groups using the New Zealand Socio-economic Index (NZSEI) [11] and those not employed were categorized according to the nature of the unpaid work with which they were involved or their status as unemployed or retired. The age of children was grouped into 12 month bands.

The SAS (version 8.2, SAS Institute, Cary, NC) statistical computer program was employed for data analysis. Initial univariate analysis used Mantel-Haenszel (MH) odds ratios. Unconditional logistic regression was then undertaken, initially for each set of risk factors, and finally for various combinations of those sets, in a series of models to determine the individual effect of each risk factor controlling for other risk factors and potential confounding. The population attributable risk (PAR) of disease occurring was calculated using the proportion of cases exposed to risk factors (pd) and corresponding adjusted odds ratios [$pd\{(OR-1)/OR\}$] [12].

RESULTS

Eighty-four cases were notified during the study period. Seventy-four were referred to the study, resulting in 69 interviews (response rate 82·1%). Ninety-eight randomly selected controls were interviewed

https://doi.org/10.1017/S0950268803008598 Published online by Cambridge University Press

Table 1. *Demographic information*

Demography	Cases n (%)	Controls n (%)	χ^2 (P-value)
Gender			
Male	46 (66·7)	58 (59·2)	0·96 (0·33)
Female	23 (33·3)	40 (40·8)	
Ethnicity			
Polynesian	12 (17·4)	14 (14·3)	
European	48 (69·6)	77 (78·6)	2·1 (0·14)
Asian/others	9 (13·0)	7 (7·1)	
Age (months)			
1–12	7 (10·1)	14 (14·3)	
13–24	36 (52·2)	18 (18·4)	
25–36	12 (17·4)	22 (22·4)	10·2 (0·001)
37–48	9 (13·0)	23 (23·5)	
49–60	5 (7·3)	21 (21·4)	

(response rate 75%). Forty-six cases (67%) and 58 (59%) controls were male (Table 1). The mean age for cases and controls was 25·4(S.E. ±1·5) and 33·1(S.E. ±1·6) months respectively. The age distribution of cases and controls were significantly different ($\chi^2 = 10{\cdot}2$, $P < 0{\cdot}01$) (Table 1). More than 50% of cases were aged 13–24 months. They had a significant risk of infection (OR = 8·4, 95% CI = 2·7–25·8; $P < 0{\cdot}0001$) compared to 49–60 months age group.

Study participants were allocated to one of three broad ethnic groups. The largest group of study participants was those of European origin (74·8%) (Table 1), consistent with the national pattern. Other ethnic groups included were Polynesian (15·6%) and Asian/others (9·6%) (Table 1). Ethnic distribution was the same for cases and controls.

Water used for drinking purposes was categorized into that 'used at home' and 'away from home'. About 90% participants used water from Auckland metropolitan mains (AMM) supplies and the remainder used roof-collected rainwater for domestic purposes. There were no overseas water users in the control group, so we excluded cases who had used water overseas ($n = 6$) from the water analysis. Consumption of drinking water other than home sources was associated with a significantly increased risk (OR = 4·7, $P < 0{\cdot}0001$), especially for roof-collected rainwater (OR = 8·3, $P < 0{\cdot}0001$) and mains supply other than AMM (OR = 8·6, $P < 0{\cdot}0001$) (Table 2). River water was also found to be significantly associated with notified disease in logit estimation (OR = 10·4, $P < 0{\cdot}001$). Analysis of risk associated with drinking water sources was repeated by taking overseas cases into account, leaving outcomes the same.

The role of recreational exposure to water was examined (Table 3). Swimming, the most popular water sport, has an increased risk for infection significantly for those who swam at least once a week (OR = 2·4, $P < 0{\cdot}05$) (Table 3) although the risk of giardiasis associated with increased frequency of swimming could not be analysed by location due to small numbers. Swimming in rivers (OR = 4·7) showed a significant association in logistic analysis (OR = 19·7, 1·9–200·3). Those who reportedly swallowed water during water activities had a significantly higher risk of infection (OR = 2·3, 1·1–4·7; $P < 0{\cdot}01$), which remained an independent risk factor (OR = 4·4, 1·2–15·7) in logistic regression analysis after controlling for place and frequency of swimming.

A significant risk of infection was associated with children wearing a nappy (OR = 3·0, $P < 0{\cdot}05$) (Table 4). The risk was significantly higher for child in households where more than one children wore a nappy (OR = 6·5, $P < 0{\cdot}01$) and for those who attended and ate at early childhood centres (OR = 2·3, $P < 0{\cdot}05$) (Table 4). Toilet-trained children were less at risk of infection than their non-toilet-trained or partially-trained counterparts (OR = 3·8, 1·8–7·8; $P < 0{\cdot}001$) when controlled for gender only. However, this association was not significant when adjusted for gender and age-group (OR = 2·1) (Table 4). The risk analysis for toilet training was repeated by restricting to 13–48 month age groups to control overestimation but the results remained the same.

Children staying away from their usual home anytime during the 3-week exposure period bore a significant risk of *Giardia* infection (OR = 2·5, 1·2–5·2; $P < 0{\cdot}05$). The risk increased with travelling in general (OR = 4·9, 2·3–10·4; $P < 0{\cdot}0001$) and also with travelling inside New Zealand (OR = 4·4, 2·1–9·5; $P < 0{\cdot}0001$). Choice of accommodation during travel was variably associated with infection. Staying in a holiday chalet and/or private houses was associated with a higher risk of infection (OR = 3·4, 1·4–8·5; $P < 0{\cdot}01$). The risk of infection also increased by contact with other giardiasis cases (OR = 11·3, 2·6–35·7; $P < 0{\cdot}001$). Contact with pets showed no increased risk of *Giardia* infection (OR = 0·49, 0·24–0·97).

Logistic regression analyses were carried out to see if the main variables in this study had independent effects on giardia risk (Table 5). A number of logistic regression models using various combinations of significant risk variables were applied where consumption of water from sources other than AMM (OR = 4·5), having more than one nappy-wearing child

Table 2. *Drinking water sources and risk of giardiasis during 3 week exposure period*

Water sources	Case $n=63$	Control $n=98$	Adjusted OR (95% CI)*
Water consumed from home sources only†	16	59	1·00
Water consumed away from usual home	47	39	4·7 (2·2–10·1)
(Participants could be exposed to more than one of the following sources)			
Roof collected rain-water	19	12	8·3 (2·6–26·7)
River	5	1	10·4 (1·9–55·8)‡
Bore	3	1	9·9 (0·62–158·3)
Bottle	7	14	2·4 (0·74–8·1)
Mains other than AMM§	38	18	8·6 (3·5–21·2)

* Adjusted for gender and age-group.
† Reference group.
‡ Logit estimation.
§ AMM, Auckland Metropolitan Mains supply.

Table 3. *Water recreation and risk of giardiasis during 3 week exposure period*

Water sport	Case $n=69$	Control $n=98$	Adjusted OR (95% CI)*
No†	24	51	1·00
Yes	45	47	1·8 (0·92–3·6)
Sailing‡	4	5	2·3 (0·45–11·5)
Swimming‡	44	42	1·9 (0·97–3·9)
Swam less than weekly	10	15	1·3 (0·49–3·7)
Swam weekly or more frequently	34	27	2·4 (1·1–5·3)
Swimming pool	29	36	1·6 (0·74–3·2)
River	6	1	4·7 (0·98–22·3)§
Sea	9	5	2·3 (0·59–9·0)

* Adjusted for gender and age-group.
† Reference group.
‡ Not mutually exclusive, participants could be exposed to more than one.
§ Logit estimation.

in a family (OR = 5·3), and travelling in New Zealand (OR = 2·5) were found to be independently associated with the risk of infection. However, frequent swimming was also associated with infection when travelling was removed from the model (OR = 2·6).

Population attributable risk (PAR) percentages calculated for significant risk factors using adjusted ORs from Table 5. There were exposure to: drinking water sources other than usual home supply (PAR = 57·8%), household having more than one child wearing nappy (PAR = 66·2%), travelling in New Zealand (PAR = 33·2%) and frequent swimming (PAR = 36·4%).

Eight per cent of cases ($n=6$) were asymptomatic. Analyses were repeated without asymptomatic cases and the results were unchanged.

DISCUSSION

The *Giardia* infection rate among children under 5 years of age is almost double the rate for other age groups in the Auckland region [5] and there is evidence of person-to-person transmission of infection in which children under 5 years play a pivotal role [10]. This study aimed to identify modifiable risk factors among giardia infected children under 5 years of age in Auckland. The study targeted cases from the notification records of what is now Auckland District Health Board (ADHB) which receives notifications from general practitioners. These cases were mostly symptomatic. Overseas studies, however, found no association between clinical manifestations and infection [13] and a high proportion of infected children

Table 4. *Risk related to nappy, toilet training and childhood centres during 3-week exposure period*

Child activities	Case $n=69$	Control $n=98$	Adjusted OR (95% CI)*
Wore nappy			
No†	10	44	1·00
Yes	59	54	3·0 (1·01–8·9)
Number of children wearing nappies in the family			
None†	5	30	1·00
One child wear nappy in family	38	47	1·9 (0·46–8·0)
More than one child wear nappy in family	22	9	6·5 (1·8–23·4)
Level of toilet training			
Toilet trained†	12	45	1·00
Not fully trained	57	53	2·1 (0·73–5·9)
Partially trained	12	19	1·9 (0·64–5·7)
Not trained at all	45	34	3·5 (0·54–22·7)
Attended early childhood centre			
Not attended†	27	38	1·00
Attended, not eat meal	10	43	0·48 (0·19–1·2)
Attended, eat meal	32	17	2·3 (1·01–5·0)

* Adjusted for gender and age-group.
† Reference group.

Table 5. *Logistic regression models for potential risk factors of* Giardia *infection in children during 3-week study period*

Risk variables	Model A OR (95% CI)*	Model B OR (95% CI)*	Model C OR (95% CI)*
Water consumed at home only†	1·00	1·00	1·00
Water consumed away from home	5·3 (2·4–12·0)	4·31 (1·9–10·0)	4·5 (1·9–10·4)
No nappy wear child†	1·00	1·00	1·00
One nappy child family	1·7 (0·42–6·6)	1·7 (0·4–6·6)	1·7 (0·41–6·8)
More than one nappy child family	6·0 (1·6–21·9)	4·8 (1·3–17·4)	5·3 (1·4–19·8)
Did not swim†	1·00		1·00
Swam less than weekly	1·2 (0·38–3·6)		0·88 (0·28–2·8)
Swam weekly or more frequently	2·6 (1·1–6·4)		2·0 (0·75–5·0)
Did not travel†		1·00	1·00
Travel inside New Zealand		2·9 (1·3–6·6)	2·5 (1·03–6·0)

* Adjusted for gender and age-group.
† Reference group.

may remain asymptomatic [14]. Assessment of the actual burden of this disease in the community is therefore difficult. Moreover, underreporting is a longstanding problem [1]. We used the same questionnaire and interview procedure for caregivers of cases and controls to minimize information bias. Since 96% of households in New Zealand have access to a telephone [15] this sampling criterion is likely to have had minimal effect on recruitment or data collection at a regional level. A significant risk of infection was found in the 1–2 year age group in our study, supporting a peak incidence among children of the same age reported elsewhere [5]. Although the mean age for controls was slightly higher than for cases, this difference should not influence the outcome as age was controlled for in analyses. The gender differences found in our study are supported by others [3]. Ethnic representation, though consistent with the national population pattern, could be biased against non-European groups due to possible under-diagnosis and/or underreporting [1, 5].

Water is a common transmission medium for *Giardia* parasites in the community. The parasite is abundant in New Zealand surface water contaminated by human and animal sources [14, 16]. We found consumption of water from Auckland metropolitan mains (AMM) at home resulted in a lower risk of infection in children, which supports our recent findings in adult cases [10] and from other studies [3]. Some studies have found a relationship between *Giardia* infection and the consumption of un-boiled municipal water [17]. The transmission of waterborne illnesses in the community depends on the efficiency of filtration techniques used [18] and the water quality monitoring system [19]. Small communities depend on locally or privately managed sources of drinking water using less efficient treatment methods. A significant association between giardiasis and consumption of river water in general found in our study could be the result of source water contamination. However, this finding should be interpreted with caution due to small sample size [2]. Roof water contamination with *Giardia* parasite was reported earlier [20] although a recent survey reported otherwise [21].

Toddlers or young children swim mostly under adult guidance in community pools, at home or in institutions such as childcare centres, as well as in natural waters such as beaches, rivers, harbours and estuaries. Most cases ($n=29$) swam in pools and were under 2 years of age, although swimming in a pool was not significantly associated with infection in our study after controlling for other confounders (Table 3). An overseas study and our previous study suggested a relationship between the transmission of giardiasis and the use of swimming pools [10, 22]. Pool water may be contaminated by faecal accidents from bathing children [23]. Chlorination is not always successful in killing *Giardia* parasites [24]. We did not collect information on the types of pool used and their chlorination status. However, no outbreaks of giardiasis among children under 5 years old were reported from Auckland swimming pools during the study period. The relationship between giardiasis and swimming in children has not been studied so far; however the dose–response relationship with frequency of swimming in this report is consistent with our adult giardisis study [10]. A review of health risk studies in swimmers suggests a dose-related increase in risk associated with an increase in indicator-bacteria count in recreational waters [25]. An increased risk of *Giardia* transmission from the swallowing of contaminated pool water has been reported earlier [22]. Risks are higher among children attending swimming classes [26]. The ingestion of water during swimming was an independent risk in our study. The Center for Disease Control and Prevention (CDC) recommends some preventive measures to limit the transmission of waterborne illnesses among children using water recreation facilities [27]. However, these recommendations may not be realistic.

Children in the first 2–3 years of life wear nappies until they are fully toilet trained. Thirty per cent of children under 5 years age attend licensed early childhood centres in Auckland and the attendance rate is higher among 2–4 year age group (personal communication, Data Management and Analysis Division, Ministry of Education, New Zealand). In New Zealand, children start to receive toilet training between 12 and 18 months and by the end of 48 months most of them do not wet their bed at night [28]. A relationship between nappy use and the transmission of infectious organisms has been speculated previously, mostly in early childhood settings [29]. We have identified a significant association between the incidence of giardiasis and the frequency of nappy changing among the adult population in our previous study [6]. A significant association between nappy wearing children and giardiasis in the present report supports our earlier findings and reinforces the need for further research in this area. We have demonstrated an increased risk of infection with an increase in the number of nappy-wearing children in a family. The exact mechanism of transmission is not clear, but person-to-person transmission seems the most likely explanation [7]. Previous studies have shown a relationship between giardiasis and children who are not toilet trained [30]. All these observations have been in childcare locations. The risk of *Giardia* infection among non-toilet trained children in our study was not significantly influenced by attendance at early childhood centres. Attending an early childhood centre increased risk of infection only those eating meals at the centre which supports other similar findings suggestive of transmission of disease through close interpersonal contact [9]. There is no international consistency on appropriate timeframes for toilet training [28, 31]. New Zealand studies in this regard are incomplete and may be dated [28].

Travelling, especially, to giardia endemic regions has often caused giardiasis outbreaks [32]. In New

Zealand, a history of recent overseas travel prompts a general practitioner to request for stool tests for patients with gastroenteritis [33]. In our study, only six cases travelled overseas, but none among the controls. However, logit estimation suggested a tenfold increased risk for those travelled overseas. We have confined our detailed analysis to travel within New Zealand. A fourfold increased risk of infection for children who visited other places inside New Zealand other than their usual home is not surprising as the presence of *Giardia* parasites in New Zealand is widespread [16]. Moreover, without a higher quality filtration system it is hard to eliminate *Giardia* parasites from all community water supplies. Our previous study on adult Aucklanders also identified a significant risk associated with domestic travel [10]. National disease surveillance (www.moh.govt.nz/esr.nsf/ff53911...) has previously reported higher than average rates of giardiasis from some of the popular tourist destinations in New Zealand. It is not clear whether the risk in this study is due to direct contact with contaminated water or indirect contact with peers or elders. Swimming could have been confounded by travelling or vice versa, as risks weaken when both were in the same logistic model, suggestive of exposure to contaminated surface water [16] during travel.

This study demonstrates that giardiasis is a major communicable disease for children under 5 years of age in New Zealand and, more significantly, in the second year of their life. The quality of water consumed by these children is important in controlling the transmission of this disease. *Giardia* is a weak parasite which can be killed easily by boiling water for 1 min. Recreational or environmental exposure to this parasite remains a real public health challenge. Travelling in general should be regarded as a risk, while effective toilet training and increased hygiene may reduce the transmission of disease. This study also suggests areas of further research, especially on exposure to water. Nappy-wearing families in which there are two or more children are a sub-group at particular risk. Preventive activities should be targeted at these groups and/or activities which may lead to improvements in the control of all diarrhoeal diseases.

ACKNOWLEDGEMENTS

This study was funded by Auckland Healthcare Services Limited (now Auckland Regional Public Health Services, Auckland District Health Board), Auckland, New Zealand. We would like to thank all the participants, Richard Thornton, Emma York, John Whitmore from Auckland District Health Board (ADHB) and Dr Donald Campbell (now Mid-Central Health) and colleagues in the Division of Community Health, the University of Auckland, for their contribution to the study.

REFERENCES

1. Furness BW, Beach MJ, Roberts JM. Giardiasis surveillance – United States, 1992–1997. CDC Surveillance Summaries. MMWR 2000; **49**: 1–13.
2. Dennis DT, Smith RP, Welch JJ, et al. Endemic giardiasis in New Hampshire: a case–control study of environmental risks. J Infect Dis 1993; **167**: 1391–1395.
3. Birkhead G, Vogt RL. Epidemiologic surveillance for endemic *Giardia lamblia* infection in Vermont. The roles of waterborne and person-to-person transmission. Am J Epidemiol 1989; **129**: 762–768.
4. National surveillance data – December 2000. NZ Public Health Report 2001; **8**: 14.
5. Hoque ME, Hope VT, Scragg R. *Giardia* infection in Auckland and New Zealand: trends and international comparison. NZ Med J 2002; **115**: 121–123.
6. Hoque ME, Hope VT, Scragg R, Kjellström T, Lay-Yee R. Nappy handling and risk of giardiasis. Lancet 2001; **357**: 1017–1018.
7. Okell RS, Wright JM. *Giardia lamblia* – An assessment from the Eastern Bay of Plenty: September 1 1986–September 30 1989. NZ J Med Lab Technol 1990; **44**: 64–66.
8. Rendtorff RC. The experimental transmission of human intestinal protozoan parasites. II. *Giardia lamblia* ysts given in capsules. Am J Hyg 1954; **59**: 209–220.
9. Keystone JS, Krajden S, Warren MR. Person-to-person transmission of *Giardia lamblia* in day-care nurseries. Can Med Assoc J 1978; **119**: 241–248.
10. Hoque ME, Hope VT, Scragg R, Kjellström T, Lay-Yee R. Risk of giardiasis in Aucklanders: a case control analysis. Int J Infect Dis 2002; **6**: 191–197.
11. Davis P, McLeod K, Ransom M, Ongley P. The NZ Socioeconomic Index of Occupational Status (NZSEI). Wellington, NZ: Stats NZ, 1997.
12. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. Am J Public Health 1998; **88**: 15–19.
13. Lindo JF, Levy VA, Baum MK, Palmer CJ. Epidemiology of giardiasis and cryptosporidiosis in Jamaica. Am J Trop Med Hyg 1998; **59**: 717–721.
14. Lopez CE, Dykes AC, Juranek DD, et al. Waterborne giardiasis: a communitywide outbreak of disease and a high rate of asymptomatic infection. Am J Epidemiol 1980; **112**: 495–507.
15. Households. New Zealand Official Yearbook, 101st ed. Wellington: Statistics New Zealand, 1998: 105–111.

16. Brown T, Ionas G, Learmonth J, Keys L, McLenachan T. The distribution of *Giardia* and *Cryptosporidium* in New Zealand waters – a nationwide survey. NZ Water & Wastes 1998: 60–63.
17. Navin TR, Juranek DD, Ford M, Minedew DJ, Lippy EC, Pollard RA. Case–control study of waterborne giardiasis in Reno, Nevada. Am J Epidemiol 1985; **122**: 269–275.
18. Fraser GG, Cooke KR. Endemic giardiasis and municipal water supply. Am J Public Health 1991; **81**: 760–762.
19. Clancy JL. Sydney's 1998 water quality crisis. J Am Water Works Assoc 2000; **92**: 55–66.
20. Ramsay CN, Marsh J. Giardiasis due to deliberate contamination of water supply. Lancet 1990; **336**: 880–881.
21. Simmons G, Hope V, Lewis G, Whitmore J, Gao W. Contamination of potable roof-collected rainwater in Auckland, New Zealand. Water Res 2001; **35**: 1518–1524.
22. Porter JD, Ragazzoni HP, Buchanon JD, Waskin HA, Juranek DD, Parkin WE. Giardia transmission in a swimming pool. Am J Public Health 1988; **78**: 659–662.
23. Greensmith CT, Stanwick RS, Elliot BE, Fast MV. Giardiasis associated with the use of a water slide. Pediatr Infect Dis J 1988; **7**: 91–94.
24. Jarroll EL, Bingham AK, Meyer EA. Effect of chlorine on *Giardia lamblia* cyst viability. Appl Environ Microbiol 1981; **41**: 483–487.
25. Prüss A. Review of epidemiological studies on health effects from exposure to recreational water. Int J Epidemiol 1998; **27**: 1–9.
26. Harter L, Frost F, Grunenfelder G, Perkins-Jones K, Libby J. Giardiasis in an infant and toddler swim class. Am J Public Health 1984; **74**: 155–156.
27. News. CDC says there are ways to reduce enteric pathogen transmission in swimming pools. Clin Infect Dis 2001; **33**: i.
28. Stenhouse G. Toilet training in children. NZ Med J 1988; **101**: 150–151.
29. Petersen NJ, Bressler GK. Design and modification of the day care environment. Rev Infect Dis 1986; **8**: 618–621.
30. Thompson SC. *Giardia lamblia* in children and the child care setting: a review of the literature. J Paediatr Child Health 1994; **30**: 202–209.
31. Berk LB, Friman PC. Epidemiologic aspects of toilet training. Clin Pediatr 1990; **29**: 278–282.
32. Hardie RM, Bardham M, Wall PG. Unwanted holiday souvenirs: who should pay? Lancet 1997; **350**: 964.
33. Sarfati D, Bates MN, Garrett N, Baker MG. Acute gastroenteritis diagnostic practices of New Zealand general practitioners. NZ Med J 1997; **110**: 354–356.