Water Use And Giardiasis In Aucklanders: A Statistical and Spatial Analysis

ME Hoque,[1] VT Hope,[1,2] J Graham,[2] TE Kjellström,[1] RKR Scragg.[1]

[1] Department of Community Health
The University of Auckland

[2] Public Health Protection
Auckland Healthcare

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ABSTRACT

Giardia is now one of the leading protozoal causes of human gastrointestinal illnesses. The World Health Organisation estimates around 200 million people are infected with this parasite. Over 2000 *Giardia* positive cases are reported in New Zealand annually and it is the second most common notifiable disease. Up to 41 percent of cases are notified from the Auckland region. The organism is ubiquitous and has been identified in the water supplies of 97 countries worldwide. The port of entry of the parasite is oro-faecal and water acts as an important vehicle for its spread. The current study investigated a modifiable risk factor for *Giardia* infection (drinking water use) and attempted to quantify the problem in Auckland in particular and New Zealand in general.

The study involved 200 laboratory positive *Giardia* cases and 400 controls, selected from a randomised list of phone numbers, aged 15 years and over and had their contact number in the Auckland Telephone Book. Cases were referred by GPs and randomly selected controls were then identified for interview. The telephone interview collected information on relevant exposures within 21 days preceding the onset of symptoms (cases) or an allocated date representing the same time period (controls).

The area of residence of cases and controls along with those of 413 notified patients to Auckland Healthcare, during the study period, were geo-coded and mapped. Water supply attributes were overlaid using the *ArcView* GIS programme. Age-specific rates for study and notified patients were calculated and compared.

The rate of notified patients was 51.9/100,000 in Auckland reticulated water zones supplying 90.1 percent of the population and 72.4/100,000 in un-reticulated zones. The proportion of notified cases living in reticulated water zones (86.7 percent) was nearly the same as that for study cases (83.1 percent). When data on notified patients and study cases was overlaid, a portion of study cases were found to reside in areas other than those in which notified patients were found.

Gender ratios were more or less identical for all groups, with female participants were higher in proportion than the males. The largest group was those 35-44 years of age for both genders and both groups of cases, and for female controls. The

combination of two age groups (25-34 and 35-44 years) represented 63 percent for both notified and study cases respectively.

Rain/roof-tank water used for drinking purposes and the use of water for other than mains had a significantly higher risk of the disease in the statistical analysis of the study. However, these risks are not immediately evident from the mapping of cases without water zones.

Most of the significant risk factors were consistent with the findings of overseas studies. Further studies are required to verify some of the risk factors and investigate solutions. The information obtained may suggest hypotheses for future research particularly in the form of intervention studies.

1.0 BACKGROUND

Giardia has been established as a human pathogen for just over a decade. Prior to that it was regarded as commensal organism. *Giardia* is now one of the leading protozoal causes of human gastrointestinal illnesses. According to the World Health Organisation, around 200 million people are infected with this parasite.[1] It is prevalent in both developed and developing countries. Over 2000 *Giardia* positive cases are reported from laboratories in New Zealand annually.[2] Of them, up to 41 percent are notified from the Auckland region. Giardiasis is the second most commonly notified notifiable disease in New Zealand. The rate of *Giardia* infection in New Zealand, as notified in July 1998, was 59.2 per 100,000 population. Despite extensive study, several fundamental questions concerning *Giardia* and giardiasis remain unsolved. The organism is ubiquitous and has been identified in the water supplies of 97 countries worldwide.[3] The parasite mainly gets entry through oro-faecal route. Transmission of *Giardia* is common in certain high-risk groups. Children, workers in day-care centres and/or sewage/irrigation processes, those who are exposed to contaminated water and/or certain animals, travellers, and the immuno-compromised, are known to be more susceptible to infection. The current study sought information on modifiable risk factors for *Giardia* infection related to water use and demographic variables. The aim was to quantifying the problem in Aucklanders in particular and New Zealanders in general. The findings will be helpful in formulating future measures to reduce the rate of the infection. The data are presented using both spatial and statistical methods of analysis. The spatial method was used to investigate the distribution of the study samples in relation to territorial and water distribution zones, and the comparability of study data with notification data held by Auckland Healthcare.

2.0 METHODS AND MATERIALS

The study undertaken was a case-control study focused on those aged 15 years and over. It aimed to obtain information on relevant exposures from 200 cases and 400 controls. This paper presents the preliminary results of the study. Cases were residents of the Auckland Telephone Book region who had *Giardia* isolated from faecal specimen by a pathological laboratory and who had access to a home telephone number, is listed in the telephone directory. Controls were selected from a randomised list of numbers in the Auckland Telephone Book region. The listing was confirmed before inclusion in the study.

Laboratories informed General Practitioners about *Giardia* positive cases with a request to approach cases regarding their possible participation in the study. Cases initially giving consent were then contacted for interview. Two controls were simultaneously located for each case identified and approached regarding possible participation in the study.

Information was collected by telephone interview using a structured questionnaire on the frequency of relevant exposures within the 21 days preceding the date of onset of symptoms (cases) or of a randomly allocated day between 3 and 8 days prior to the initial contact (controls). Blinding procedures were applied to ensure that the hypotheses of the study and the status of participants remained unknown to interviewers. The same questionnaire was used to interview both the cases and controls.

All *Giardia* notifications of patients aged 15 years or over from the Auckland Region located for the period of 1st July 1998 to 30th June 1999 were accessed from the Public Health Protection notified disease database. The total number of cases was 413. These notifications were then auto-geocoded using the residential address of the patients and *ArcView* GIS software. This gave x,y co-ordinates allowing a point of address to be marked on a map of the Auckland Region. The same auto-geocoding procedure was used for study cases and controls. Addresses that did not automatically geocode were done manually. From this information, an *ArcView* Shape file was created which allowed markers for notifications, of cases and controls to be marked on the same map of the Auckland Region. These were then overlaid on a map of reticulated drinking water zones. Using an estimated population for each zone and the number of notified patients, a rate of illness was calculated. Age-specific rates for study cases and notified patients were also calculated and compared.

3.0 RESULTS

Information was collected for 12 months between July 1998 and June 1999. Over 200 laboratory diagnosed giardiasis cases were referred to the study by GPs where subjects met the entry criterion of age (≥15 years) and all were interviewed. Simultaneously, 400 controls were also identified and interviewed. Nine cases, whose telephone numbers were not listed in the reference telephone book, and one case and 2 controls, for whom the questionnaire was incomplete, were excluded. Data on the 190 cases and 398 controls interviewed were analysed to estimate risk. In the same time period 413 cases aged 15 years or more were notified to Auckland Healthcare.

Table no. 1. Age distribution of study subjects and notified cases by gender

Age group (year)	**Cases (n=67)**			**Controls (n=123)**			**Total N=597**	**Notified cases**		**Total N=413**
	Male	**Female**	**Total**	**Male**	**Female**	**Total**		**Male**	**Female**	
	n (%)	**n (%)**	**N (%)**	**n (%)**	**n (%)**	**N (%)**	**No (%)**	n(%)	n(%)	**N(%)**
15–24	7(8.5)	5(4.3)	12(6.0	14(7.6)	20(9.3)	34(8.5)	46(7.7)	10(5.1	20(9.2)	30(7.3)
25–34	17(20.7)	37(31.6)	54(27.1)	45(24.6)	39(18.1)	84(21.1)	138(23.1)	58(29.6	62(28.6)	120(29.1)
35–44	31(37.8)	43(36.7)	74(37.2)	32(17.5)	65(30.2)	97(24.4)	171(28.6)	73(37.2	68(31.3)	141(34.1)
45–54	18(22.0)	17(14.5)	35(17.6)	36(19.7)	29(13.5)	65(16.3)	100(16.8)	36(18.4)	26(12.0)	62(15.0)
55–64	6(7.3)	13(11.1)	19(9.6)	25(13.7)	31(14.5)	56(14.1)	75(12.6)	12(6.1)	24(11.1)	36(8.7)
65–74	3(3.7)	1(0.9)	4(2.0)	14(7.6)	22(10.2)	36(9.1)	40(6.7)	4(2.1)	13(6.0)	17(4.1)
75+	0(0.0)	1(0.9)	1(0.5)	17(9.3)	9(4.2)	26(6.5)	27(4.5)	3(1.5)	4(1.8)	7(1.7)
Total	82(41.2)	117(58.8)	**199(33.3)**	183(46.0)	215(54.0)	**398(66.7)**	**597(100.0)**	196(47.5)	217(52.5)	**413(100.0)**

Table no. 2. Area of residence of study cases, controls and notified cases

AREA OF RESIDENCE	**Population**π	**Notified Cases**λ			**Study Cases**			**Participat'n rate***	**Controls**	
	N (≥15 Yr)	**n**	**%**	**Rates/10^5**	**n**	**%**	**Rates/10^5**	**%**	**n**	**%**
Central Auckland	270,195	162	39.2	60.0	69	34.7	25.5	43	133	33.4
North Auckland	160,881	105	25.4	65.3	57	28.6	35.4	54	92	23.1
West Auckland	120,168	45	10.9	37.5	25	12.6	20.8	56	67	16.9
South Auckland	214,542	101	24.5	47.1	48	24.1	22.4	48	106	26.6
Total	**765,786**	**413**	**100.0**	**53.9**	**199**	**100.0**	**26.0**	**48**	**398**	**100.0**

π Stat NZ λ Auckland Healthcare * Study Cases/Notified Cases

Table no. 3. Exposure to drinking water for study subjects

Variables	Cases	Controls	Effect Estimation	
	n (%)	n (%)	Crude (95% CI)	Adjusted (95% CI) #
Sources of water for domestic use (2 cases & 2 controls had common bore and rain/roof tank water)				
Mains supply *	155(82.5)	356(89.5)	1.00	1.00
Bore water	5(3.1)	6(1.7)	1.91(0.59-6.25)	1.90(0.59-6.14)
River water	2(1.3)	2(0.6)	2.30(0.34-15.61)	2.32(0.34-15.76)
Rain/roof tanks water	28(15.3)	36(9.2)	1.79(1.06-3.02)†	1.81(1.07-3.06)†
USE OF WATER FROM OTHER SOURCES (MULTIPLE RESPONSES)				
Exposure No *	53(28.2)	218(54.8)	1.00	1.00
Exposure Yes	135(71.8)	180(45.2)	3.09(2.14-4.45)¥	3.11(2.15-4.49)¥
Bore water	8(13.1)	12(5.2)	2.74(1.10-6.84)†	2.92(1.16-7.33)†
River water	8(13.1)	7(3.1)	4.70(1.77-12.49)‡	5.75(2.10-15.75)¥
Rain/roof tank water	36(40.5)	58(21.0)	2.55(1.54-4.23)¥	2.60(1.56-4.31)¥
Bottle water	51(49.0)	55(20.2)	3.81(2.38-6.11)¥	3.69(2.33-5.84)¥
Mains elsewhere in NZ	47(47.0)	68(23.8)	2.84(1.78-4.55)¥	2.90(1.81-4.64)¥
Water/ice-cubes overseas	43(44.8)	19(8.0)	9.31(5.31-16.31)¥	9.46(5.40-16.58)¥
WATER USE FROM OTHER SOURCES EXCLUDING OVERSEAS TRAVELLERS (MULTIPLE RESPONSES)				
Exposure No *	53(36.5)	218(57.5)	1.00	1.00
Exposure Yes	92(63.5)	161(42.5)	2.35(1.59-3.47)¥	2.37(1.60-3.51)¥
Bore water	8(13.1)	11(4.8)	2.99(1.19-7.53)†	3.26(1.28-8.30)†
River water	5(8.6)	7(3.1)	2.94(0.94-9.18)	3.59(1.11-11.55)†
Rain/roof tank water	33(38.4)	58(21.0)	2.34(1.40-3.92)¥	2.38(1.42-3.99)¥
Bottled water	33(38.4)	48(18.1)	2.83(1.67-4.78)¥	2.74(1.64-4.57)¥
Mains elsewhere in NZ	41(43.6)	66(23.2)	2.56(1.57-4.15)¥	2.59(1.59-4.21)¥
Comparison between water used from other sources in NZ and in overseas				
Exposure No *	53(28.2)	218(54.8)	1.00	1.00
Exposure Yes	135(71.8)	180(45.2)	3.09(2.14-4.45)¥	3.11(2.15-4.49)¥
Water drunk inside NZ	92(63.5)	161(42.5)	2.35(1.59-3.47)¥	2.37(1.60-3.51)¥
Water drunk overseas	43(44.8)	19(8.0)	9.31(5.31-16.31)¥	9.46(5.40-16.58)¥

* Reference Group; # Adjusted for sex; † $P<0.05$; ‡ $P<0.01$; ¥ $P<0.001$;

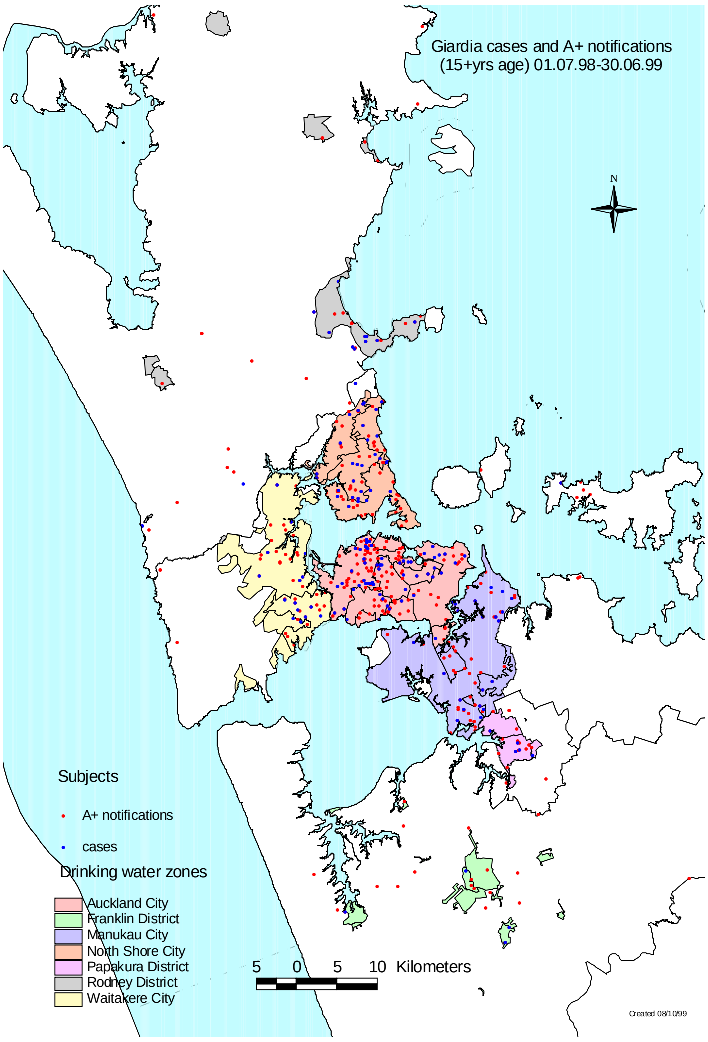
The gender ratios for cases and controls were similar for both groups ($P=0.27$). Study participants were more than 1.3 times higher for female than for the males whereas, the frequency of notified female patients was 1.1 times higher than males. About 52 percent notified cases, 59 percent study cases and 54 percent controls were females as compared with 48 percent, 41 percent and 46 percent respectively for males. Data on age were collapsed into 10-year age groups and compared by gender. The largest group was those 35-44 years of age for both genders of notified and study cases, and for female controls. The combined age groups of 25-34 and 35-44 years accounted for more than 63 percent for both notified and study cases respectively. Controls of this combined age group represented less than 50 percent of the total.

The subjects of the case-control study and the notified data were grouped by their places of residence into four census zones in Greater Auckland; namely, Central, North, West and South Auckland. The highest proportion of cases (34.7 percent), controls (33.4 percent) and notified (39.2 percent) samples came from Central Auckland. West Auckland represented the lowest proportion for all three categories of subjects. When notified cases were compared with the study cases, the study cases were slightly higher in proportion in North and West and the opposite was true for Central. However, the South showed an almost identical proportion in all categories. While rates of notified and study cases were considered, highest rates were observed among both categories of population in North Auckland and lowest in West Auckland. More than 50 percent of cases participated in the study were from North and West Auckland. Overall participation rate of study cases compared to the notification was 48 percent

The areas of residence of cases and controls along with those of the 413 cases notified to Auckland Healthcare were geocoded and mapped and water supply attributes were overlaid. Eighty six point seven percent cases were resident in the reticulated water zone, supplying 90.1 percent of the population. The rates of giardiasis notification for reticulated and un-reticulated water zones respectively was 51.9/100,000 and 72.4/100,000.

When study cases and controls were compared, 83.1 percent of the cases lived in reticulated water supply zones; while, this was true for 89 percent of controls. When data for notified and study cases was overlaid, it was seen that a significant number of the study cases had not been notified.

Rain/roof-tank water used for drinking purposes was associated with a significantly increased risk of disease (*OR*=1.79, 1.06-3.02; *P*<0.05) and the association strengthened when adjusted for gender. Use of water other than a mains supply showed a significant association with disease in both crude estimates and when adjusted for gender. When water other than the domestic source was considered, users of river water (*OR*=4.70, 1.77-12.49; *P*<0.01), rain/roof tank water (*OR*=2.55, 1.54-4.23; *P*<0.001), mains water elsewhere in New Zealand (*OR*=2.84,1.78-4.55; *P*<0.001) and those who consumed water overseas (*OR*=9.31, 5.31-16.31; *P*<0.001) had a significantly higher risk of disease. All of these associations were strengthened when adjusted for gender; and, except for river water users, remained when overseas travellers were excluded from the analysis. Travellers to Australia (*OR*=4.53, 1.92-10.67; *P*<0.001) showed a positive association with disease. The study period coincided with the Sydney water crisis last year.



A parallel statistical analysis was done with age restricted to below 65 years since there were substantially more controls above 65 years than cases in that age group. This weakened odds ratio for most associations due to smaller sample size but did not reduce it to insignificance except for the use of rain/roof tanks water for domestic consumption (*OR*=1.66, 0.96-2.86).

4.0 DISCUSSION

The study aimed to identify modifiable risk factors in relation to water use among people 15 years and over with *Giardia* positive stool specimens in the Greater Auckland area. Information was sought retrospectively. After from a peak in children under 5, the second largest age peak for infection in the bimodal pattern of giardiasis incidence in New Zealand usually begins after 15 years of age,[4] when people are more independent and start taking control of their lives.

Recruitment of cases was dependent on referrals from GPs. Compared to the notified cases, the participation rate of the cases in the study was nearly 50 percent. This raises concerns about the generalisability of the study, particularly where the characteristics of non-participants are not known. The requirement to communicate in English and have a contact phone number for subjects may have resulted in some minor selection bias. All cases, except one teenager and one non-English speaker, were interviewed successfully irrespective of their ethnicity, so language was not a major barrier for data collection. Almost 96 percent of households in New Zealand have access to a telephone.[5] The present study estimated about 5.5 percent of the cases interviewed were not listed in the telephone book. They were excluded from the analysis.

Giardia infection shows a seasonal pattern of late summer and early autumn peaks both in New Zealand[6] and overseas.[7] This pattern had a positive influence on recruitment of cases during those seasons. However, a reported outbreak of notified cases from a junior school during the case recruitment did not noticeably increase the rate of notification of giardiasis.[8]

As expected, a higher proportion of *Giardia* cases came from Central Auckland (32.8 percent) consistent with other data from Auckland Healthcare Public Health Protection.[9] The rate of infection in Central Auckland ($60/10^5$) was lower compared to North Auckland ($65.3/10^5$). The central area is supplied by reticulated water, nonetheless, the notified infection rate was relatively higher. Factors other than local supply might be responsible. Given the relatively high proportion of people resident in South Auckland (the second highest population in Auckland behind Central Auckland), giardiasis notifications were comparatively low. This was also true for the present study. The reasons for such low notification are yet to be explored. However, factors such as, a patient's willingness or ability to seek medical advice, the practitioner's decision to request stool samples, a patient's compliance with the request for stool tests, and the practitioner's compliance with disease notification requirements, would all affect notification rates.[10] It is difficult to estimate the actual proportion of cases remaining unnotified without having access to laboratory data. When new diagnostic procedures with high sensitivity and specificity are available to identify incidence cases more convincingly, poor notification might still undermine efforts in the surveillance and control of the disease.

The present study investigated the type of water used for drinking and domestic purposes, and water consumed during travel. The study quantified giardiasis notified cases in reticulated and unreticulated water supply zones. Water is responsible for a quarter of endemic *Giardia* infections in the USA,[10] and the role of contaminated municipal water supplies in epidemic outbreaks of giardiasis is undeniable.[11,12] *Giardia* cysts are also reported to be abundant in New Zealand waters.[13] A recent investigation of a reported outbreak of giardiasis in a Central Auckland primary school did not implicate the mains water supply.[8] Mains water supply, in the present study, was found to be protective (OR=0.41, 0.18-0.91, P<0.029) among the Auckland population. During 1996, 97 percent of the bulk water monitored was found to have complied microbiologically with the DWSNZ: 1995.[14] Auckland's main water supply has been said by controlling authorities to be *Giardia*-free.[15] More than 90 percent of the current study area is serviced by reticulated water supply. However, routine water sampling may not detect the problem if sampling sites are not representative of the entire system or the fault affects a small part of the water system for a short period.[16] An increased incidence of *Giardia* has been found among users of the municipal water supply in Dunedin.[17] Mechanical microstrainers (screen size 23 μm) used there to filter surface catchment water were not expected to remove *Giardia* cysts.[18] Contamination may also occur at the reservoir or in the reticulation system as was suggested for 34 percent of cases in Bay of Plenty urban area supplied by filtered water.[10] A study in Christchurch found a slightly higher rate (RR=2.9) of *Giardia* infection among the users of water other than mains.[19] Contamination of roof tanks with *Giardia* cysts of faecal origin is not unlikely.[20] Small local water providers mostly use chlorine to purify drinking supplies. About half the giardiasis outbreaks in the USA had public water supplies treated by chlorination only.[16] Of the implicated community water supplies, 74 percent had chlorinated only or inadequately treated water, accounting for 91 percent of cases.[21] This indicates chlorination alone can not remove *Giardia* from the water system. Moreover, adequate concentrations of chlorine, temperature, pH and contact time are required to inactivate organisms like *Giardia*.

A strong association between overseas water consumption and giardiasis in the present study is consistent with previous observations on overseas travellers.[22,23] Oral use of water abroad was correlated significantly with subsequent passage of *Giardia* cysts (OR=9.31, 5.31-16.31; P<0.001). The significant association of the disease and travel to Australia in the present study coincided with reports of last year's Sydney water pollution. However, no increase in *Giardia* cases during the crisis was reported in Sydney itself by the Australian authorities.[24] A "Boil Water" alert was in place for local residents, but tourists were not necessarily in a position to observe that caution.

Further studies are required to verify some of the risk factors and investigate solutions. The information obtained may suggest hypotheses for future research particularly viewed in the context of surveillance and control, and the use of GIS in the investigation of the role of drinking water consumption in gastro-intestinal diseases.

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