



BMJ Open Reactive arthritis incidence in a community cohort following a large waterborne campylobacteriosis outbreak in Havelock North, New Zealand

Tiffany A Walker ¹, Rebecca Grainger ², Terence Quirke,¹ Rebekah Roos,¹ Jill Sherwood,¹ Graham Mackereth,¹ Tomasz Kiedrzyński,³ Rachel Eyre,⁴ Shevaun Paine,¹ Tim Wood,¹ Anita Jagroop,⁵ Michael G Baker,⁶ Nicholas Jones⁴

To cite: Walker TA, Grainger R, Quirke T, *et al*. Reactive arthritis incidence in a community cohort following a large waterborne campylobacteriosis outbreak in Havelock North, New Zealand. *BMJ Open* 2022;**12**:e060173. doi:10.1136/bmjopen-2021-060173

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-060173>).

Received 14 December 2021
Accepted 16 May 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to
Dr Tiffany A Walker;
twalk25@emory.edu

ABSTRACT

Objectives In August 2016, *Campylobacter* spp contaminated an untreated reticulated water supply resulting in a large-scale gastroenteritis outbreak affecting an estimated 8320 people. We aimed to determine the incidence of probable reactive arthritis (ReA) cases in individuals with culture-confirmed campylobacteriosis (CC), self-reported probable campylobacteriosis (PC) and those reporting no diarrhoea (ND).

Design We conducted a retrospective cohort study to identify incidence of probable ReA cases. We identified cases with new ReA symptoms using an adapted acute ReA (AReA) telephone questionnaire. Those reporting ≥1 symptom underwent a telephone interview with the study rheumatologist. Probable ReA was defined as spontaneous onset of pain suggestive of inflammatory arthritis in ≥1 previously asymptomatic joint for ≥3 days occurring ≤12 weeks after outbreak onset.

Setting Population-based epidemiological study in Havelock North, New Zealand.

Participants We enrolled notified CC cases with gastroenteritis symptom onsets 5 August 2016–6 September 2016 and conducted a telephone survey of households supplied by the contaminated water source to enrol PC and ND cases.

Results One hundred and six (47.3%) CC, 47 (32.6%) PC and 113 (34.3%) ND cases completed the AReA telephone questionnaire. Of those reporting ≥1 new ReA symptom, 45 (75.0%) CC, 13 (68.4%) PC and 14 (82.4%) ND cases completed the rheumatologist telephone interview. Nineteen CC, 4 PC and 2 ND cases developed probable ReA, resulting in minimum incidences of 8.5%, 2.8% and 0.6% and maximum incidences of 23.9%, 12.4% and 2.15%.

Discussion We describe high probable ReA incidences among gastroenteritis case types during a very large *Campylobacter* gastroenteritis outbreak using a resource-efficient method that is feasible to employ in future outbreaks.

INTRODUCTION

Reactive arthritis (ReA) is a known post-infectious sequelae of campylobacter gastroenteritis with a clinical spectrum ranging

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Reported campylobacteria-associated reactive arthritis (ReA) rates vary due to different methodological approaches that limit inclusion to one gastroenteritis type (self-reported vs culture proven).
- ⇒ To address these limitations, we estimated the incidence and characterised the clinical presentations of probable ReA cases in three groups: individuals with culture-confirmed campylobacteriosis, those with self-reported gastroenteritis and those reporting no diarrhoea during a large campylobacteriosis outbreak.
- ⇒ We offer a comprehensive description of ReA rates based on gastroenteritis severity to guide practitioners.
- ⇒ Cases were not examined by a rheumatologist; classification of joint involvement was dependent on a patient's self-report, preventing definitive diagnosis of ReA.

from transient arthralgias to severe peripheral and/or axial arthritis with occasional extra-articular features.^{1 2} Estimates of ReA incidence following campylobacter infection vary widely from 1% to 26%.²⁻⁷ This wide variation is likely due, in part, to lack of a standard definition for ReA and varying methods for estimating ReA incidence.⁶ Population-based studies have estimated ReA incidence by sampling individuals with culture-proven bacterial gastroenteritis^{1 2 4}; however, it is estimated that less than a quarter of gastroenteritis cases seek medical consultation and only 50% of those have a faecal specimen cultured.⁸ This method likely underestimates ReA incidence. Furthermore, there is often a delay between gastroenteritis development and investigation for ReA,^{9 10} which may reduce capture of ReA cases.

Outbreak-based studies allow estimation of ReA incidence in a cohort of exposed

individuals; however, many studies use self-reported gastroenteritis because culture confirmation can exceed laboratory capacity during a large outbreak.^{3 11–13} Some outbreak-based studies have calculated ReA incidence exclusively in culture-positive gastroenteritis cases.^{14 15} Both approaches typically rely on data from exposed individuals who sought medical care, excluding cases with less severe presentations and thereby limiting not only ReA incidence estimates, but potentially narrowing the described clinical spectrum of ReA in the affected population.

During 5 August 2016–12 August 2016, the untreated reticulated water supply to Havelock North, New Zealand became contaminated with sheep faecal matter following a heavy rainfall event. This resulted in a narrow exposure outbreak of *Campylobacter* spp gastrointestinal infections, affecting an up to 8320 people.¹⁶ To address the above-mentioned limitations of previous ReA epidemiological studies, we aimed to estimate the incidence and characterise the clinical presentations of probable ReA cases in three groups; individuals with culture-confirmed campylobacteriosis (CC), those with self-reported probable gastroenteritis, and those reporting no diarrhoea (ND) during the outbreak period.

METHODS

Cohort description

The Hawke's Bay District Health Board (HBDHB) provides medical care and public health services for approximately 164 000 people in a 14 000 km² area, including metropolitan and rural populations. The catchment area includes Havelock North, which has a population of 14 118 and its own reticulated drinking water derived from untreated ground water. Prospective, population-based surveillance for acute gastrointestinal illnesses was conducted among residents of the HBDHB catchment area during 13 August 2016–6 September 2016, and faecal specimens were submitted to local laboratories for culture.¹⁶ Additionally, we conducted active surveillance through four rounds of telephone survey. We randomly sampled the same panel of 250 Havelock North households supplied by the contaminated municipal water source. The last survey occurring 7 weeks following the outbreak onset to identify additional gastroenteritis infections among residents who did not seek healthcare as well as identify exposed individuals who did not develop diarrhoea.

Patient and public involvement

Local community leaders were consulted in the design of this study to ensure outcomes met the priorities of the community. Preliminary communication about this study were distributed by the local media to the public to inform the population of the impact of this outbreak.

Campylobacter gastroenteritis outbreak case definitions

The study population included three groups. A CC case was defined as an individual who consumed reticulated

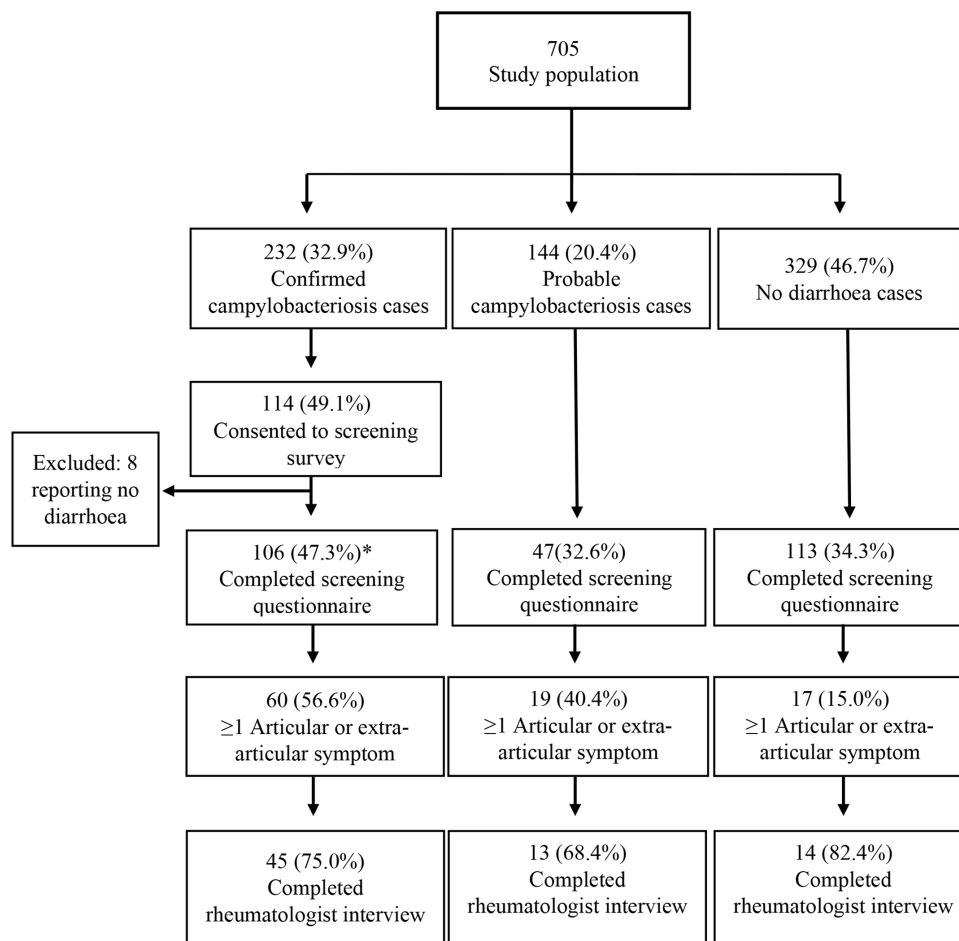
water from Havelock North, New Zealand from 5 August 2016 to 12 August 2016 with clinician-confirmed diarrhoea between 5 August 2016 and 6 September 2016 with a positive faecal specimen for *Campylobacter* spp. A probable campylobacteriosis (PC) case was defined as an individual from the household telephone survey with the same exposure as a CC case who developed diarrhoea between 5 August 2016 and 6 September 2016 without presentation to healthcare or provision of faecal specimen. ND participants (ND cases) were also identified by the household telephone survey and had the same exposure to contaminated water as a PC case but did not develop diarrhoea between 5 August 2016 and 6 September 2016. Seven weeks after the outbreak onset, all eligible cases were contacted by telephone to consent for enrolment into ReA surveillance.

Rea screening questionnaire and rheumatologist interview

Using an adapted version of the previously validated Acute ReA (AReA) questionnaire¹⁴ (online supplemental appendix 1), we administered a 10-question telephone survey through a commercial survey provider to ReA surveillance enrollees 8 weeks after the outbreak onset. To comply with case definitions, we excluded 7 CC cases from the survey who denied a history of diarrhoea during the outbreak. All ages were included; parents or guardians provided proxy responses for children aged <15 years. Approximately 12 weeks after outbreak onset, respondees reporting ≥ 1 symptom on the AReA questionnaire underwent a telephone interview with the study rheumatologist, RG, who has 15 years' experience in rheumatology practice. Participants were asked about the inflammatory nature and onset of joint symptoms (online supplemental appendix 2). The study rheumatologist defined a probable ReA case as spontaneous onset of pain suggestive of inflammatory arthritis in ≥ 1 previously asymptomatic joint for ≥ 3 consecutive days occurring ≤ 12 weeks after outbreak onset in a CC, PC or ND cases.

Data analysis

Differences in baseline characteristics between outbreak case types were assessed using chi-square or Fisher's exact test for categorical variables and one-way analysis of variance for continuous variables. Minimum ReA rates are reported as the proportion of probable ReA cases occurring out of the total number of residents eligible for enrolment for each outbreak case type. Maximum ReA rates were estimated by applying the proportion of probable ReA cases occurring in residents who reported ≥ 1 ReA symptoms on the screening survey that completed the rheumatologist interview to those who reported ≥ 1 ReA symptoms but failed to complete the rheumatologist interview, then dividing the sum by the population that completed the screening survey. This was calculated for each outbreak case type individually. Relative risk (RR) and 95% CIs were calculated to assess the risk of developing probable ReA among outbreak case types and among adults compared with children. P values ≤ 0.05



*Percent calculated from confirmed campylobacteriosis cases reporting diarrhoea (N=224)

Figure 1 Reactive arthritis surveillance following Havelock North campylobacter gastroenteritis outbreak: screening questionnaire and rheumatologist interview enrolment.

were considered significant. Data were analysed using SAS V.9.4.

RESULTS

A total of 232 CC cases were notified to HBDHB. Of these, 114 (49.1%) participated in the AReA screening telephone questionnaire at 8 weeks; however, 8 responders reported no history of diarrhoea and were excluded from the remainder of the questionnaire, leaving 106 (47.3%) of 224 eligible CC cases completing the AReA questionnaire (figure 1). A total of 144 PC and 329 ND cases were identified from the randomly sampled household survey of which 47 (32.6%) PC and 113 (34.3%) ND cases completed the AReA questionnaire. Forty-three (40.6%) CC, 16 (34.0%) PC and 11 (9.73%) ND cases reported new joint symptoms after outbreak onset. New extra-articular symptoms including heel pain, eye symptoms, mouth ulcers, genital rash or discharge, or palm or sole rash were reported by 42 (39.6%) CC, 12 (25.5%) PC and 12 (10.6%) ND cases.

PC and ND cases were older ($p<0.001$) and more likely to be female ($p<0.001$) compared with CC cases (table 1).

CC cases were more likely to be of Maori or Pacific ethnicities than PC and ND cases ($p<0.01$). CC cases had longer duration of gastroenteritis symptoms (fever, nausea, vomiting, abdominal pain) (median=10 days) compared with PC (median=7 days) and ND cases (median=3 days) ($p=0.0014$). More CC cases had new joint ($p<0.001$) and extra-articular symptoms ($p<0.001$) compared with ND cases. There were no differences between CC and PC cases for joint or extra-articular symptoms.

The rate of new ReA symptoms was higher among CC (RR 3.76; 95% CI 2.35 to 6.01) and PC cases (RR 2.26; 95% CI 1.25 to 4.09) compared with ND cases, but there were no significant differences between CC and PC cases (table 2). Of those reporting ≥ 1 new ReA symptom on the AReA questionnaire, 45 (75.0%) CC, 13 (68.4%) PC and 14 (82.4%) ND cases completed the rheumatologist telephone interview (figure 1). Non-participation at each stage of surveys was due to inability to contact participants after three attempts. Nineteen CC cases met the probable ReA case definition. Assuming no other cases occurred in the eligible population (N=224), then a minimum of 8.5% of CC cases experienced ReA. Similarly, 4 (2.8%) of

Table 1 Demographic and clinical characteristics of reactive arthritis (ReA) surveillance enrolees and probable ReA cases by outbreak case type

Participant characteristics	All ReA surveillance enrolees				Probable ReA cases		
	CC (N=106)	PC (N=47)	ND (N=113)	P value	CC (N=19)	PC (N=4)	ND (N=2)
Female	48 (45%)	31 (66%)	74 (65%)	<0.001	8 (42%)	2 (50%)	2 (100%)
Age, median (range)	47 (1–96)	55 (15–85)	62 (16–99)	<0.001	43 (10–73)	69 (54–78)	68 (49–86)
≤18 years	28 (26%)	1 (2%)	1 (1%)		5 (26%)	0	0
>18 years	78 (74%)	46 (98%)	112 (99%)		14 (74%)	4 (100%)	2 (100%)
Race/ethnicity	<0.001						
Maori	7 (7%)	2 (4%)	0		1 (5%)	0	0
Pacific Islander	2 (%)	0	0		1 (5%)	0	0
NZ European	85 (80%)	38 (81%)	97 (86%)		17 (89%)	4 (100%)	1 (50%)
Other European	8 (8%)	6 (13%)	16 (14%)		0	0	1 (50%)
Asian	3 (3%)	1 (2%)	0		0	0	0
Other	1 (1%)	0	0		0	0	0
Gastroenteritis symptoms*	<0.001						
0	13 (12%)	8 (17%)	101 (89%)		1 (5%)	2 (50%)	0
1	14 (13%)	10 (21%)	6 (5%)		0	1 (25%)	0
2	17 (16%)	15 (32%)	3 (3%)		2 (11%)	1 (25%)	2 (100%)
3	39 (37%)	9 (19%)	3 (3%)		7 (37%)	0	0
4	23 (22%)	5 (11%)	0		9 (47%)	0	0
Gastroenteritis duration, median (range)†	10 (2–62)	7 (1–31)	3 (1–17)	0.0014	14 (3–62)	10 (4–28)	2 (2)

*Includes fever, nausea, vomiting, abdominal pain.
†Missing gastroenteritis duration for five confirmed campylobacter and one probable campylobacter case from all ReA enrolees; missing gastroenteritis duration for one probable and one no diarrhoea probable ReA case.
CC, confirmed campylobacteriosis; ND, no diarrhoea; NZ, New Zealand; PC, probable campylobacteriosis.

144 PC and 2 (0.6%) of 329 ND cases met the probable ReA case definition. Assuming persons reporting new ReA symptoms on the screening questionnaire who did not complete the rheumatologist interview experienced ReA at the same rate as those interviewed, an estimated maximum of 23.9% of CC cases, 12.4% of PC cases and 2.15% of ND cases who completed the screening questionnaire developed probable ReA (table 2). Calculation can be referenced in online supplemental appendix 3. The maximum ReA rates were higher among CC (RR 11.4; 95% CI 3.13 to 41.2) and PC cases (RR 4.87; 95% CI 1.09 to 21.8) than ND cases. There was no significant

difference in maximum ReA rates between CC and PC cases.

No probable ReA cases were identified in children (aged ≤18 years) among PC and ND cases. Of CC cases, adults were not at higher risk for probable ReA compared with children (RR 1.18; 95% CI 0.464 to 3.02). There was no sex predominance for probable ReA cases compared with those who did not develop ReA, even when comparing within outbreak case types. Probable ReA cases reported gastroenteritis duration lasted twice as long compared with those who did not develop ReA (median 14 vs 7 days; $p<0.001$). There were insufficient responses to calculate

Table 2 New ReA symptom and probable ReA (pReA) incidence among outbreak case types following Havelock North campylobacter gastroenteritis outbreak

Case type	≥1 New ReA symptom	RR (95% CI)	RR (95% CI)†	Maximum pReA rate	RR (95% CI)*	RR (95% CI)†
CC	56.6%	3.76 (2.35 to 6.01)	1.40 (0.95 to 2.06)	23.9%	11.4 (3.13 to 41.2)	2.22 (0.90 to 5.43)
PC	40.4%	2.26 (1.25 to 4.09)		12.4%	4.87 (1.09 to 21.8)	
ND	15.0%			2.15%		

*Compared with ND cases.
†Compared with PC cases.
CC, confirmed campylobacteriosis; ND, no diarrhoea; PC, probable campylobacteriosis; RR, relative risk.

Table 3 Clinical characteristics among probable reactive arthritis (ReA) cases by outbreak case type

Rheumatological symptoms	CC (N=19)	PC (N=4)	ND (N=2)	All probable ReA (N=25)
Initial symptom				
Joint	15 (79%)	4 (100%)	2 (100%)	21 (84%)
Eye	1 (7%)	0	0	1 (4%)
Oral	1 (7%)	0	0	1 (4%)
Joint symptoms				
Pain	18 (95%)	4 (100%)	2 (100%)	24 (96%)
Swelling	8 (42%)	2 (50%)	2 (100%)	11 (44%)
Pain or swelling	18 (95%)	4 (100%)	2 (100%)	24 (96%)
No of swollen joints*				
0	11 (58%)	2 (50%)	0	7 (28%)
1	2 (11%)	1 (25%)	1 (50%)	4 (16%)
2	3 (16%)	0	0	5 (20%)
3	0	1 (25%)	0	4 (16%)
4	1 (5%)	0	0	1 (4%)
5	0	0	0	0
6	0	0	1 (50%)	1 (4%)
Joint sites†				
Hand	4 (21%)	1 (25%)	0	5 (20%)
Wrist	3 (16%)	1 (25%)	0	4 (25%)
Elbow	4 (21%)	1 (25%)	0	5 (20%)
Shoulder	2 (11%)	1 (25%)	0	3 (12%)
Feet	5 (26%)	1 (25%)	1 (50%)	7 (28%)
Ankle	10 (53%)	0	2 (100%)	12 (48%)
Knee	6 (32%)	3 (75%)	1 (50%)	10 (40%)
Hip	5 (26%)	0	1 (50%)	6 (24%)
Back	4 (21%)	1 (25%)	1 (50%)	6 (24%)
Extra-articular symptoms				
Heel	2 (11%)	1 (25%)	0	3 (12%)
Other tendon	1 (5%)	0	1 (50%)	2 (8%)
Mouth ulcers	4 (21%)	0	0	4 (16%)
Sore eyes	6 (32%)	0	2 (100%)	8 (32%)
Conjunctivitis	3 (16%)	0	1 (50%)	4 (16%)
Morning stiffness	13 (68%)	4 (100%)	1 (50%)	18 (72%)
<1 hour	9	3	1	13 (52%)
≥1 hour	4	1	0	5 (20%)

*Missing number of joints affected in two CC cases reporting joint swelling.

†Includes joint pain or swelling.

CC, confirmed campylobacteriosis; ND, no diarrhoea; PC, probable campylobacteriosis.

the median interval between onset of gastroenteritis and development of ReA.

Based on the rheumatologist interview, joint symptoms were the most common initial symptom in probable ReA cases. All PC and ND ReA cases and 95% of CC ReA cases developed either joint pain or swelling during the course of their disease (table 3). Ankle (48%), knee (40%) and

feet (28%) were the most common joints involved across outbreak case types. Other than eye symptoms (32%), extra-articular symptoms were uncommon. Three CC cases requiring hospitalisation for severe gastroenteritis developed probable ReA. In addition, two probable ReA cases reported receiving a specialist physician diagnosis of ReA to the study rheumatologist.



DISCUSSION

We report probable ReA occurring in 8.5%–23.9% of CC and 2.15%–12.4% of PC cases in a large waterborne campylobacter gastroenteritis outbreak in Havelock North, New Zealand caused by ovine faecal contamination of the untreated reticulated ground water system following a heavy rainfall event.¹⁶ ReA incidence estimates following campylobacter infections vary widely. One meta-analysis reported incidences from 0% to 24% with a summary estimate of 2.9%.⁶ Larger surveillance platforms generally estimate lower ReA incidence, likely due less reporting of gastroenteritis cases to primary care than occurs in an outbreak setting where disease reporting is often enhanced.⁶ Additionally, prolonged latency between gastroenteritis onset and investigation for ReA often resulted in lower ReA incidence estimates. Achieving accurate ReA estimates is challenging in population-based studies using healthcare databases because there is insufficient standardisation of International Classification of Diseases 10th Revision (ICD-10) coding for ReA and inconsistent recording of related codes.⁸ Outbreak-based studies have the benefit of following a similarly exposed cohort to determine ReA incidence. However, many studies prospectively follow notified gastroenteritis cases of which few are culture-confirmed,^{3 11–13} weakening associations between ReA incidences and the suspected pathogen. Furthermore, some uncultured infections in these studies could be caused by pathogens not known to precipitate ReA, further diluting the ReA incidence estimates.^{8 12 13} Other outbreak-based studies only investigate culture-confirmed cases.^{13–15} In doing this, they limit the description of ReA to affected individuals who sought medical care.

Our study design has the advantage of addressing a number of these issues by comparing three case types typically encountered in an outbreak: culture-confirmed gastroenteritis, self-reported gastroenteritis and those exposed who do not develop diarrhoea. We found probable ReA was more common among CC and PC cases compared with ND cases with no difference in rates between CC and PC cases. Though small PC sample size may have precluded detection of differences between CC and PC cases. Garg *et al* investigated similar diarrhoeal presentations, including asymptomatic, self-reported gastroenteritis and gastroenteritis presenting to medical care and found higher incidences than we report; however, their outcome of interest was new arthritis, not specifically defined as ReA.⁷ They only report significant differences between medical care-seeking cases and asymptomatic cases. The trend towards higher probable ReA rates among CC cases may be associated with longer gastroenteritis duration, which may have increased the likelihood of seeking medical care and having the illness confirmed by faecal culture.

A unique feature of our study is the inclusion of rheumatologist telephone interview to confirm joint and extra-articular symptoms, leading to more refined ReA incidence estimates. Rheumatologist review is more

commonly seen in population-based studies,^{1 4 17 18} which may be due to more available resources and less time constraints compared with outbreak-based studies. However, we demonstrate with a retention rate of 68%–82% for rheumatologist telephone interview that this is a feasible method for the outbreak setting. This retention rate is substantially higher than other outbreak studies using rheumatologist examination as the sole means to estimate ReA incidence,^{3 11} and timelier than others with high rheumatologist review rates,¹⁵ likely improving the precision of our incidence estimates. Additionally, our approach is a less resource-intensive and labour-intensive method than those requiring rheumatologist physical examination, making it a distinct and viable option for investigating ReA in future outbreaks.

ND cases may represent asymptomatic *Campylobacter* infections as opposed to uninfected residents,^{7 12 19} but case status remains unclear since no faecal specimens were tested in this population and some ND cases reported mild, non-diarrhoeal gastrointestinal symptoms. Multiple studies have shown that culture-confirmed infections can present without diarrhoea^{20 21} or can be asymptomatic in up to 15% of cases.^{22–25} In fact, findings from one outbreak demonstrated that asymptomatic individuals exposed to a contaminated water supply developed more joint symptoms than an unexposed population.¹⁹ Others have reported 8%–10% of asymptomatic individuals who consumed contaminated food during *Salmonella* outbreaks developed ReA.^{9 26} Although ND cases may represent outbreak-related infections, our results are consistent with previous findings that individuals without diarrhoea are at lower risk for developing ReA compared with those who experience diarrhoea.^{19 26}

Although PC and ND cases were more likely to be older and female, we found no sex or age differences in the probable ReA cases compared with those who did not develop ReA. This is in contrast with recent studies reporting a predominance of females^{1 4 11 18} and higher ReA incidence among adults compared with children.^{1 12} Most probable ReA cases presented with mild symptoms and few sought medical care, consistent with previous campylobacter outbreaks.^{4 11 13} As with previous studies, knee and ankle were the sites most commonly involved^{1–3 13} and extra-articular manifestations were rare.¹¹ Data on the association between gastroenteritis severity and development of ReA are conflicting. Probable ReA cases had longer duration than those without ReA. Similarly, many have shown higher severity^{1 2} and longer duration of gastroenteritis^{4 9 12 26} associated with higher risk of ReA development, whereas others have shown no association.^{2 4 13 14}

This study had several limitations. Postoutbreak whole genome sequencing revealed that outbreak-related campylobacteriosis cases likely had onset dates between 7 August 7 and 24 August.¹⁶ Given limitations in our enrolment design, we were unable to amend our outbreak period. This would have little impact on ReA rates attributed to CC cases because each is culture-CC; however, inclusion

of PC cases beyond the true outbreak period may have over attributed diarrhoeal cases to campylobacteriosis in 22 PC cases, including 2 cases with probable ReA. Our screening phone survey response rates were not as high as some studies using similar methods,^{9 12} and use of a land-line sampling frame may have reduced recruitment of younger and economically deprived households. These biases as well as willingness to participate could impact the comparison of minimum ReA rates between groups, so we chose to compare maximum ReA rates because this analysis would be primarily limited by participation bias.

Cases were not examined by a rheumatologist and classification of joint involvement was dependent on a patient's self-report, preventing definitive diagnosis of ReA. It is possible that individuals seeking medical care, such as CC cases, were more likely to report medical conditions and symptoms, including ReA symptoms. In the absence of physical examination by a rheumatologist, this bias could contribute to the trend towards higher ReA incidence seen in this population.⁷ Furthermore, these individuals may be more likely to report more gastroenteritis symptoms during the survey, potentially biasing the association between gastroenteritis severity and ReA development.¹⁸

Given resource limitations, we were unable to perform follow-up assessments of existing cases to assess disease remission and chronicity. Although the timeliness of our survey likely reduced recall bias compared with other studies,^{9 15} it also prohibited identification of incident cases occurring greater than 12 weeks following the outbreak. Ternhag *et al* demonstrated that initial ReA surveillance identified few cases at 3 months, but follow-up 1 year revealed new, associated cases.²⁷ Also, although we compared CC and PC cases with ND cases, we did not have the resources to study an unexposed, control group. As such, we have no ReA baseline incidence with which to compare our rates.¹⁹ We did not have resources to screen HLA-B27 prevalence, which has known association with ReA development and may have affected the rates seen in our cohort.⁴

Our findings have several important implications. They underscore the importance of advising populations affected by campylobacter outbreaks that delayed effects can occur. These individuals and doctors should be alerted to the risk of ReA following campylobacter outbreaks. As ReA impacts short-term and long-term health outcomes, outbreak-associated economic assessments should consider including costing for this sequela.²⁸

In summary, we present a high probable ReA incidence among a spectrum of gastroenteritis case types during a very large campylobacter gastroenteritis outbreak, providing a comprehensive characterisation of ReA in an exposed population. We describe a screening survey and rheumatologist review method that provides a more refined approach than use of a screening questionnaire alone. This method serves as a practical and resource-efficient alternative to in-person rheumatological exams and is a feasible option for estimation of ReA burden in future gastroenteritis outbreaks.

Author affiliations

¹Institute of Environmental Science and Research Ltd, Porirua, The New Zealand

²Department of Medicine, University of Otago, Wellington, The New Zealand

³Ministry of Health, Wellington, The New Zealand

⁴Hawke's Bay District Health Board, Napier, The New Zealand

⁵School of Health and Sport Science, Eastern Institute of Technology, Napier, The New Zealand

⁶Department of Public Health, University of Otago, Dunedin, The New Zealand

Twitter Rebecca Grainger @drbecky

Contributors TAW: led surveillance, assisted with study design, conducted analysis, performed literature review, drafted manuscript. TW serves as the guarantor. RG: assisted with literature review, assisted with study design, conducted rheumatologic interviews, assisted with interpretation of findings, reviewed manuscript. TQ: assisted with study design, assisted with data analysis, assisted with interpretation of findings, reviewed manuscript. RR: assisted with literature review, assisted with study design, assisted with interpretation of findings, reviewed manuscript. JS: assisted with study design, assisted with interpretation of findings, reviewed manuscript. GM: conducted household survey, assisted with study design, assisted with data analysis, assisted with interpretation of findings, reviewed manuscript. TK: assisted with household study design, assisted with study design, assisted with interpretation of findings, reviewed manuscript. RE: assisted with study design, assisted with interpretation of findings, reviewed manuscript. SP: assisted with household study design, assisted with study design, assisted with interpretation of findings, reviewed manuscript. TW: assisted with household study design, assisted with interpretation of findings, reviewed manuscript. AJ: assisted with interpretation of findings, reviewed manuscript. MGB: assisted with interpretation of findings, reviewed manuscript. NJ: provided project oversight, assisted with interpretation of findings, reviewed manuscript.

Funding This work was supported by the New Zealand Ministry of Health, Award Number: N/a, Health Research Council grant, Award Number: 17/911, ESR Strategic Science Investment Fund, Award Number: N/a, and Royal Society Te Aparangi grant, Award Number: RDF-MAU1701.

Disclaimer The funding resource has no role in study design, collection, analysis or interpretation of data, writing of reports, nor decision to submit papers for publication. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Institute for Environmental Science and Research.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval New Zealand Health and Disabilities Ethics Committee approval was obtained prior to study enrolment.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as online supplemental information.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Tiffany A Walker <http://orcid.org/0000-0002-9602-3754>

Rebecca Grainger <http://orcid.org/0000-0001-9201-8678>



REFERENCES

- 1 Townes JM, Deodhar AA, Laine ES, *et al*. Reactive arthritis following culture-confirmed infections with bacterial enteric pathogens in minnesota and oregon: a population-based study. *Ann Rheum Dis* 2008;67:1689–96.
- 2 Schönberg-Norio D, Mattila L, Lauhio A, *et al*. Patient-reported complications associated with Campylobacter jejuni infection. *Epidemiol Infect* 2010;138:1004–11.
- 3 Hannu T, Kauppi M, Tuomala M, *et al*. Reactive arthritis following an outbreak of Campylobacter jejuni infection. *J Rheumatol* 2004;31:528–30.
- 4 Hannu T, Mattila L, Rautelin H, *et al*. Campylobacter-triggered reactive arthritis: a population-based study. *Rheumatology* 2002;41:312–8.
- 5 Ajene AN, Fischer Walker CL, Black RE. Enteric pathogens and reactive arthritis: a systematic review of Campylobacter, Salmonella and Shigella-associated reactive arthritis. *J Health Popul Nutr* 2013;31:299–307.
- 6 Keithlin J, Sargeant J, Thomas MK, *et al*. Systematic review and meta-analysis of the proportion of Campylobacter cases that develop chronic sequelae. *BMC Public Health* 2014;14:1203.
- 7 Garg AX, Pope JE, Thiessen-Philbrook H, *et al*. Arthritis risk after acute bacterial gastroenteritis. *Rheumatology* 2008;47:200–4.
- 8 Curry JA, Riddle MS, Gormley RP, *et al*. The epidemiology of infectious gastroenteritis related reactive arthritis in U.S. military personnel: a case-control study. *BMC Infect Dis* 2010;10:266.
- 9 Loch H, Krogfelt KA. Comparison of rheumatological and gastrointestinal symptoms after infection with Campylobacter jejuni/coli and enterotoxigenic Escherichia coli. *Ann Rheum Dis* 2002;61:448–52.
- 10 Buxton JA, Fyfe M, Berger S. Multiprovincial Salmonella typhimurium case-control study Group. reactive arthritis and other sequelae following sporadic Salmonella typhimurium infection in British Columbia, Canada: a case control study. *J Rheumatol* 2002;29:2154–8.
- 11 Uotila T, Antonen J, Laine J, *et al*. Reactive arthritis in a population exposed to an extensive waterborne gastroenteritis outbreak after sewage contamination in Pirkanmaa, Finland. *Scand J Rheumatol* 2011;40:358–62.
- 12 Arnedo-Pena A, Beltrán-Fabregat J, Vila-Pastor B, *et al*. Reactive arthritis and other musculoskeletal sequelae following an outbreak of Salmonella hadar in Castellon, Spain. *J Rheumatol* 2010;37:1735–42.
- 13 Loch H, Mølbak K, Krogfelt KA. High frequency of reactive joint symptoms after an outbreak of Salmonella enteritidis. *J Rheumatol* 2002;29:767–71.
- 14 Rohekar S, Tsui FWL, Tsui HW, *et al*. Symptomatic acute reactive arthritis after an outbreak of Salmonella. *J Rheumatol* 2008;35:1599–602.
- 15 Lee ATY, Hall RG, Pile KD. Reactive joint symptoms following an outbreak of Salmonella typhimurium phage type 135a. *J Rheumatol* 2005;32:524–7.
- 16 Gilpin BJ, Walker T, Paine S, *et al*. A large scale waterborne Campylobacteriosis outbreak, Havelock North, New Zealand. *J Infect* 2020;81:390–5.
- 17 Hannu T, Mattila L, Siitonen A, *et al*. Reactive arthritis attributable to shigella infection: a clinical and epidemiological nationwide study. *Ann Rheum Dis* 2005;64:594–8.
- 18 Schiellerup P, Krogfelt KA, Loch H. A comparison of self-reported joint symptoms following infection with different enteric pathogens: effect of HLA-B27. *J Rheumatol* 2008;35:480–7.
- 19 Laine J, Uotila T, Antonen J, *et al*. Joint symptoms after a large waterborne gastroenteritis outbreak—a controlled, population-based questionnaire study. *Rheumatology* 2012;51:513–8.
- 20 Amour C, Gratz J, Mduma E. Etiology, risk factors, and interactions of enteric infections and malnutrition and the consequences for child health and development project (MAL-ED) network investigators. epidemiology and impact of Campylobacter infection in children in 8 low-resource settings: results from the MAL-ED study. *Clin Infect Dis* 2016;63:1171–9.
- 21 Mason J, Iturriza-Gomara M, O'Brien SJ, *et al*. Campylobacter infection in children in Malawi is common and is frequently associated with enteric virus co-infections. *PLoS One* 2013;8:e59663.
- 22 Komba EVG, Mdegela RH, Msoffe PLM, *et al*. Prevalence, antimicrobial resistance and risk factors for thermophilic Campylobacter infections in symptomatic and asymptomatic humans in Tanzania. *Zoonoses Public Health* 2015;62:557–68.
- 23 Lääveri T, Antikainen J, Pakkanen SH, *et al*. Prospective study of pathogens in asymptomatic travellers and those with diarrhoea: aetiological agents revisited. *Clin Microbiol Infect* 2016;22:535–41.
- 24 Lindblom GB, Åhrén C, Changalucha J, *et al*. Campylobacter jejuni/coli and enterotoxigenic Escherichia coli (ETEC) in faeces from children and adults in Tanzania. *Scand J Infect Dis* 1995;27:589–93.
- 25 Zaidi MB, McDermott PF, Campos FD, *et al*. Antimicrobial-resistant Campylobacter in the food chain in Mexico. *Foodborne Pathog Dis* 2012;9:841–7.
- 26 Dworkin MS, Shoemaker PC, Goldoft MJ, *et al*. Reactive arthritis and Reiter's syndrome following an outbreak of gastroenteritis caused by Salmonella enteritidis. *Clin Infect Dis* 2001;33:1010–4.
- 27 Ternhag A, Törner A, Svensson A, *et al*. Short- and long-term effects of bacterial gastrointestinal infections. *Emerg Infect Dis* 2008;14:143–8.
- 28 Moore D, Drew R, Davies P. The economic costs of the Havelock North August 2016 waterborne disease outbreak, report prepared for the Ministry of health. Sapere Research Group Ltd., Wellington, NZ; 2020. <https://www.health.govt.nz/publication/economic-costs-havelock-north-august-2016-waterborne-disease-outbreak> [Accessed 05 Sep 2020].