Giardiasis notifications are associated with socioeconomic status in Sydney, Australia: a spatial analysis

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Abstract

Objective: In developed countries prolonged symptoms due to, or following, *Giardia intestinalis* infection can have a significant impact on the quality of life. In this research, we investigate the presence of a socioeconomic status (SES) gradient in the reporting of giardiasis in South West Sydney Local Health District (SWSLHD), New South Wales (NSW), Australia, across geographic scales.

Methods: We used a large database, spatial-cluster analysis and a linear model.

Results: Firstly, we found one spatial cluster of giardiasis in one of the most advantaged neighbourhoods of SWSLHD. Secondly, rates of giardiasis notifications were significantly and consistently lower in SWSLHD compared to an unnamed advantaged Local Health District and NSW over multiple years. Finally, we found an overall significant positive dose–response relationship between counts of giardiasis and area-level SES.

Conclusions: Lower reporting in disadvantaged areas may represent true differences in incidence across SES groups or may result from differential use of health services and reporting.

Implications for public health: If the disparities result from differential use of health services, research should be directed toward identifying barriers and facilitators of use. If disparities result from a true difference in incidence, then the behavioural mediators between SES and giardiasis should be identified and addressed.

Key words: giardiasis notifications, SES, Sydney, diagnosis, spatial clusters, disparities, access

Giardiasis is one of the most important non-viral causes of human diarrhoeal disease, with an estimated 280 million people being infected each year around the world.[1] Giardiasis is a gastrointestinal illness caused by the enteric protozoan parasite *Giardia intestinalis* (also referred to as *G. lamblia* or *G. duodenalis*). It is a major and neglected cause of acute and chronic diarrhoea, particularly among children in underprivileged communities, with a prevalence between 10% and 50% in developing countries where hygiene and socioeconomic conditions drive the prevalence.[2,3]

In New South Wales (NSW), Australia, there are approximately 3.75 giardiasis notifications per 10,000 people annually.[4] While developed countries, in general, have low incidence and prevalence of giardiasis, notifications show marked geographic disparities with greater notifications from rural areas[5] being associated with livestock handling.[6-9] Geographic disparities may also be seen across socioeconomic status (SES) strata, although there is very little research in this area.[10] For the remainder of this paper, we use the terms 'advantaged' to indicate high SES, and 'disadvantaged' to indicate low SES.

There are three reasons why investigating SES disparities in giardiasis notifications in a developed country like Australia is important. First, the presence of excess and/or unreported giardiasis cases among the disadvantaged may cause disproportionate harm through loss of school or work days.[11] In the longer term, this may contribute to exacerbating already widening inequities, which is of concern in cities with existing geographic-SES disparities such as Sydney.[12] Second, the existence of unreported giardiasis among disadvantaged communities may imply the presence of similar inequities in other more serious conditions such as cancer and heart disease, especially in their early detection, since the underlying health behaviours that drive the help-seeking and diagnostic processes are similar.[13-15] For instance, an inability to access health services has been shown to lead to higher rates of comorbid conditions.[13,16] Finally, if there is an SES patterning to giardiasis reporting, it may systematically bias existing notifiable disease surveillance systems. In NSW, giardiasis is a laboratory-notifiable disease.[17] A person may be tested for free by a primary care provider (PCP) on presentation with symptoms. If *Giardia* is confirmed by the testing laboratory, the

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laboratory is legally mandated to notify the case to the state-wide confidential Notifiable Conditions Information Management System (NCIMS) infectious disease surveillance database, which is maintained by the NSW Ministry of Health.[17]

In NSW, there is a long pathway between a person developing giardiasis and being diagnosed, and then the subsequent notification and registration to a state-wide database. There are multiple points in this incidence-notification pathway that may be affected by SES. SES may affect the likelihood of contracting giardiasis, although the evidence in this regard is mixed.[17] Furthermore, the SES of the patient may influence the decision to see a doctor since a lack of knowledge, time, financial and other resource constraints may predispose disadvantaged patients from not visiting the local general practitioner (GP) or PCP.[18] Not all individuals or parents of children with gastrointestinal conditions may seek medical attention, particularly because giardiasis is usually self-limiting and symptoms may be considered a minor hindrance.[19,20] Even if a patient does visit a PCP, the PCP may not deem it necessary to order a diagnostic test.[21] Several factors may influence a PCP's decision to order a test including the age of the patient, or the severity of the condition and travel history. There is also evidence that the SES of the patient is a strong driver of PCP-ordered diagnostic tests,[18,22] operating independently of patient assertiveness.[23] Other studies have also observed that doctors are significantly more likely to prescribe drugs to disadvantaged patients than to order diagnostic tests.[24,25] Additionally, advantaged areas may attract better trained PCPs with greater diagnostic proficiency than PCPs in disadvantaged areas.[26]

Inequities in incidence and reporting would become explicit not only through traditional analyses of statistical relationships but also in spatial patterns of giardiasis notifications across geographic scales.[27]

Study area and research questions

Our study area is the South Western Sydney Local Health District (SWSLHD), which is one of the 17 independent Local Health Districts (LHDs) in NSW that are responsible for the management and delivery of tertiary and community-based health services. SWSLHD encompasses an area of 6,248km^2 and has a population of 966,450 (2016 data). It is also one of the most demographically and geographically diverse districts. Moreover, SWSLHD has one of the most disadvantaged populations as reported by the Australian Bureau of Statistics (ABS) Socio-economic Indexes for Areas (SEIFA).[28] Around half of the population speak a language other than English at home and more than 40% of all refugee humanitarian arrivals in recent years have settled in SWSLHD.[29] A significantly greater per cent – 46.1% (95%CI: 46, 46.3) – earn less than \$600/week (less than the lowest 10% of average Australian household income[12]) in comparison to an advantaged LHD (henceforward called *a*LHD) – 34.2% (95%CI: 34.1, 34.3). This *a*LHD (which will be kept unnamed) will be used as the comparison for this study. The two LHDs (SWSLHD and *a*LHD) were chosen as they are on opposite ends of the SES spectrum in Sydney and therefore form an appropriate pair of contrasting LHDs. Figure 1A demonstrates the often discussed North East–South West geographic trend of SES in Sydney with *a*LHD being located in the advantaged areas. Some commentators associate this SES trend with similar geographic trends in poorer health outcomes and behaviours in the South West.[30] Nevertheless, there are also advantaged areas within SWSLHD. While one of the Local Government Areas (LGAs) within SWSLHD is within the top 15% of advantaged LGAs (Camden) in NSW, another LGA (Fairfield) is within the bottom 5% of most disadvantaged.[29]

This study has three research questions that encompass geographic scales. First: 'Are there small local areas with significantly (statistically) higher rates of giardiasis notifications in SWSLHD, where do they persist across age groups, and how advantaged or disadvantaged are these areas relative to other areas in the LHD?' Second: 'Are rates of giardiasis notifications higher in SWSLHD as a whole, compared to *a*LHD or NSW?' Third: 'Is there a significant global relationship between SES and giardiasis notifications in SWSLHD?'

This research was completed as part of an exploratory analysis of the data for a project investigating the risk factors of giardiasis.[7] It was approved by the NSW Health Population Health Ethics Committee (HE16/079 LNR).

Methods

Giardiasis notifications data (n=944) from 1 January 2011 to 15 July 2016 for SWSLHD, along with age, were obtained from the NCIMS database through a special request and aggregated to the Statistical Area Level 1 (SA1) geography (small areas with ~400 people). Other information such as language spoken at home or ethnicity was not available. We generated four sets of SA1-level giardiasis notification data; one for each age group: 0–4 years, 5–14 years, 15–64 years, and 65 years or older. Each group had exposures specific to their own group, and this categorisation has been previously used.[31] It was also based on our observation of the age distribution of giardiasis.

Area-level SES was from the 2011 Index of Relative Advantage and Disadvantage (IRSAD) at the SA1 geographic level. The IRSAD is an ordinal ranking of areas published by the ABS. It is a composite weighted index with neighbourhood-level metrics such as per cent renting and area-level income. The IRSAD ranks small areas from the most disadvantaged to the most advantaged, with the most advantaged areas having higher ranks. IRSAD is used extensively as a measure of area-level SES in Australia, and especially to measure SES disparities in access.[32,33] Population counts at SA1s in NSW for the four age groups described above were obtained from the ABS.[34] We validated the use of 2011 population data by repeating some analyses with 2016 data (see Results section). Australian Statistical Geographic Standard (ASGS) rurality indices were obtained from ABS, which categorises SA1s into five categories ranging with increasing rurality from metropolitan to very remote. SWSLHD encompasses only two of these categories: metropolitan and inner-regional. We also obtained publicly available annual data (aggregated from NCIMS) on giardiasis notifications and population counts at the LHD and state level (2011–2016).[4,35]

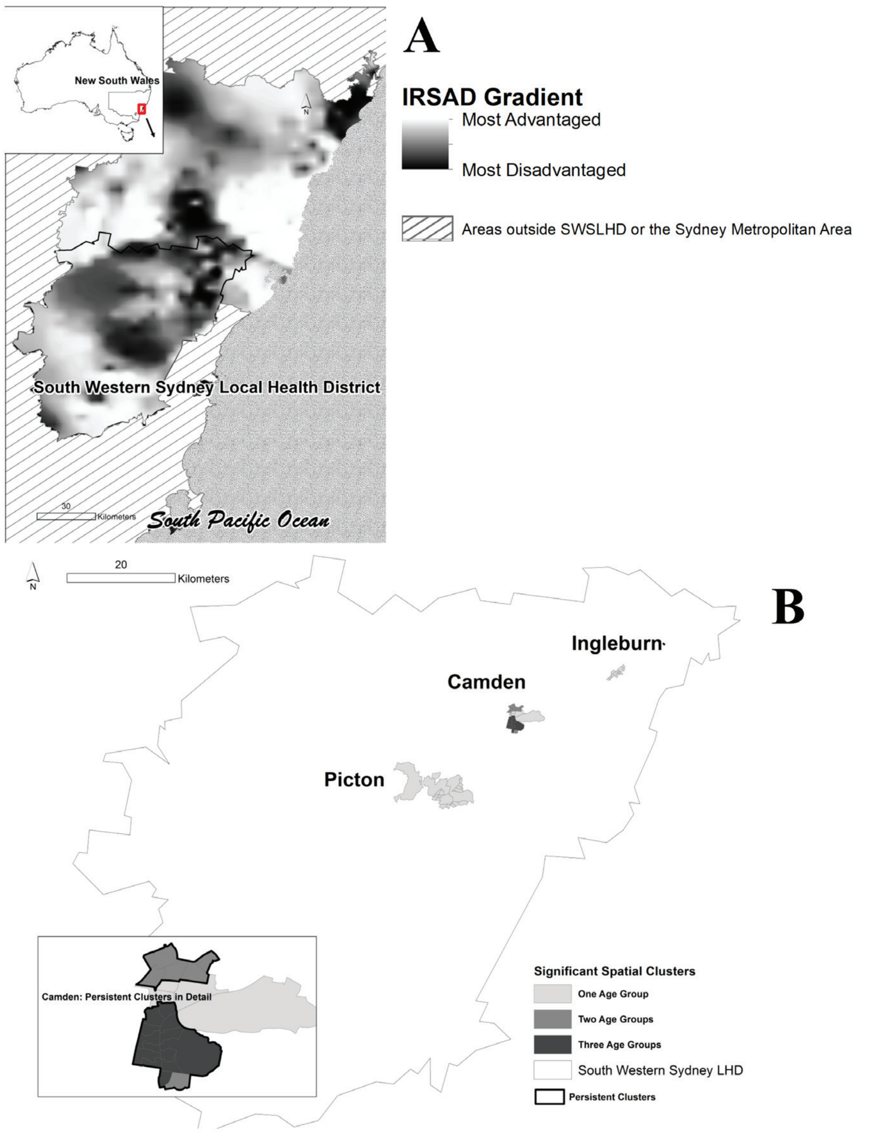
Statistical methods

To investigate if there were local spatial clusters of giardiasis in NSW, we used the validated and robust Spatial Scan Statistic to investigate significant spatial patterns. This method asks: "What area or what combination of areas is most likely to have a statistically significant 'high' or a significant 'low' risk relative to areas outside the combination of areas?" This would be framed as a "cluster detection problem" in the spatial epidemiology literature.[36] The Spatial Scan Statistic was implemented using the SaTScan software. While the details of the method can be seen elsewhere,[27,36] it essentially overlays multiple circular 'spatial filters'[37] over the SA1 centroids that grow to a pre-set maximum population threshold radius (set to 1% of the population in these analyses, to detect fine localised clusters), and determines which of these many circles are most likely to be clusters. Hypothesis testing is through the assumption of a Poisson distribution and 999 Monte Carlo randomisations to generate reference distributions. One primary cluster and multiple secondary clusters may be reported along with the relative risks at the clusters.

Separate scans for significantly high rates were implemented for the four age groups. Next, we overlaid the significant ($p<0.05$) spatial-clusters (irrespective of their primary or secondary status) of each of the four age groups over each other to investigate if there were any persistent spatial-clusters common to more than one age group. We retained SA1s that were significant spatial clusters for two or more age groups or 'persistent clusters'. While occasional hotspots or significant rates in small areas may arise by chance, overlapping spatial clusters of giardiasis in multiple age groups or persistent clusters would point towards a systematic excess in giardiasis notifications. We compared the distribution of IRSAD scores in the persistent cluster areas with other areas using histograms and the Wilcoxon Signed Rank (WSR) test.

We plotted the rates of giardiasis notifications with binomial confidence intervals (95%) from 2011 to 2016 for SWSLHD, *a*LHD and NSW. To test the global relationship between giardiasis notifications and SES, we implemented a Poisson Generalised Estimating Equation (GEE) model with an exchangeable correlation matrix to account for spatial autocorrelation, and predicted the total number of giardiasis notifications from each SA1 as a function of the total number of people in each of the four age groups described earlier, the IRSAD score of the SA1 categorised in tertiles, and the two rurality index categories in SWSLHD.

Figure 1: A: IRSAD Gradient in the Sydney metropolitan area presented as a heat map. The IRSAD index at SA1s has been smoothed using an Inverse Distance Weighing Algorithm and eight nearest neighbours.; B: Spatial clusters of giardiasis notifications in SWSLHD.



Results

Giardiasis notification rates (per 100,000 population) were as follows, 0–4 years: 41.9; 5–14 years: 15.0; 15–64 years: 10.8; and 65 and older: 7.9. The highest number of reported cases were in the 15–64-year age group (509) followed by the toddler group (204), while the rates otherwise decreased with age. Two significant clusters each were found for the three age groups younger than 65 years, while no clusters were found for the 65 years and older group. The three groups younger than age 65 had one cluster each that overlapped each other. These three groups also had one cluster each that did not overlap with any other clusters and were located elsewhere (Supplementary File A and Figure 1). Thus, the three groups had a total of two clusters each. When the overlapping of clusters was mapped, the persistent clusters were located in one of the few advantaged areas in SWSLHD, the neighbourhoods/ suburbs of Camden, Camden Park and Camden South (Figure 1B). Single-age group clusters were located in a peri-urban area and in a suburb situated north west of the persistent cluster. The strongest clustering, in terms of risk elevation and number of cases, was in the toddler group with a relative risk of 12 and 7 in the two clusters, respectively. Cluster details are provided in Supplementary File A and Table 1.

While SA1s in persistent spatial-cluster areas had a median IRSAD of 1001 (80^{th} percentile in SWSLHD), non-spatial-cluster areas had a median IRSAD of 949 (50^{th} Decile in SWSLHD). A WSR test of difference of means of IRSAD at the SA1s in the spatial-clusters versus at SA1s in areas that were not spatial-clusters was significant at $W = 18303$ ($p<0.05$). Histograms of IRSAD values at SA1s show that the entire distribution is shifted towards the more advantaged (higher IRSAD) in the persistent clusters group (Figure 2A). To validate our use of 2011 base population data, the spatial scan was re-run using 2016 population data as denominators. This resulted in one spatial cluster consisting of 15 postcodes, all of which were a subset of the 2011 data-based clusters. In addition, this cluster had a more advantaged population than the 2011 data-based clusters with, for example, the mean IRSAD being 11 points higher and the minimum 50 points higher. This underscores the validity and robustness of the spatial clustering–SES relationship.

Rates of giardiasis notifications remained consistently and significantly higher than NSW in *a*LHD, and it remained consistently significantly lower in SWSLHD from 2011 through 2016 (Figure 2B). For example, in 2013 the notification rates were: 4.1 (3.7, 4.5) in *a*LHD, 1.6 (1.3, 1.9) in SWSLHD and 3.0 (2.9, 3.1) in NSW.

The global GEE regression analysis demonstrated a significant dose–response relationship between IRSAD and giardiasis notifications (Table 1). Compared to the first tertile of IRSAD, areas at the second tertile had a 38% elevated risk of registering giardiasis notifications, while those living at the third tertile had around double the risk. There was also a 56% elevated risk of giardiasis notifications from inner-regional areas compared to metropolitan areas.

Discussion

This study investigated the role of SES in giardiasis notifications across geographic scales. We found significant positive associations between area-level advantage and an increased likelihood of giardiasis notifications. Three findings support this association. Firstly, local spatial clusters of giardiasis that persisted across age groups were from a neighbourhood with significantly higher SES than the rest of the study area. Secondly, the study area itself, one of the most disadvantaged LHDs in NSW, was found to have significantly lower giardiasis notification rates than NSW and an advantaged LHD in NSW. Thirdly, there was a significant dose–response global relationship between SES at small areas and giardiasis notifications. Overall, this study provides convergent evidence of a robust relationship between area-level SES and giardiasis notifications. An additional finding was an increased risk of giardiasis notifications in non-metropolitan areas.

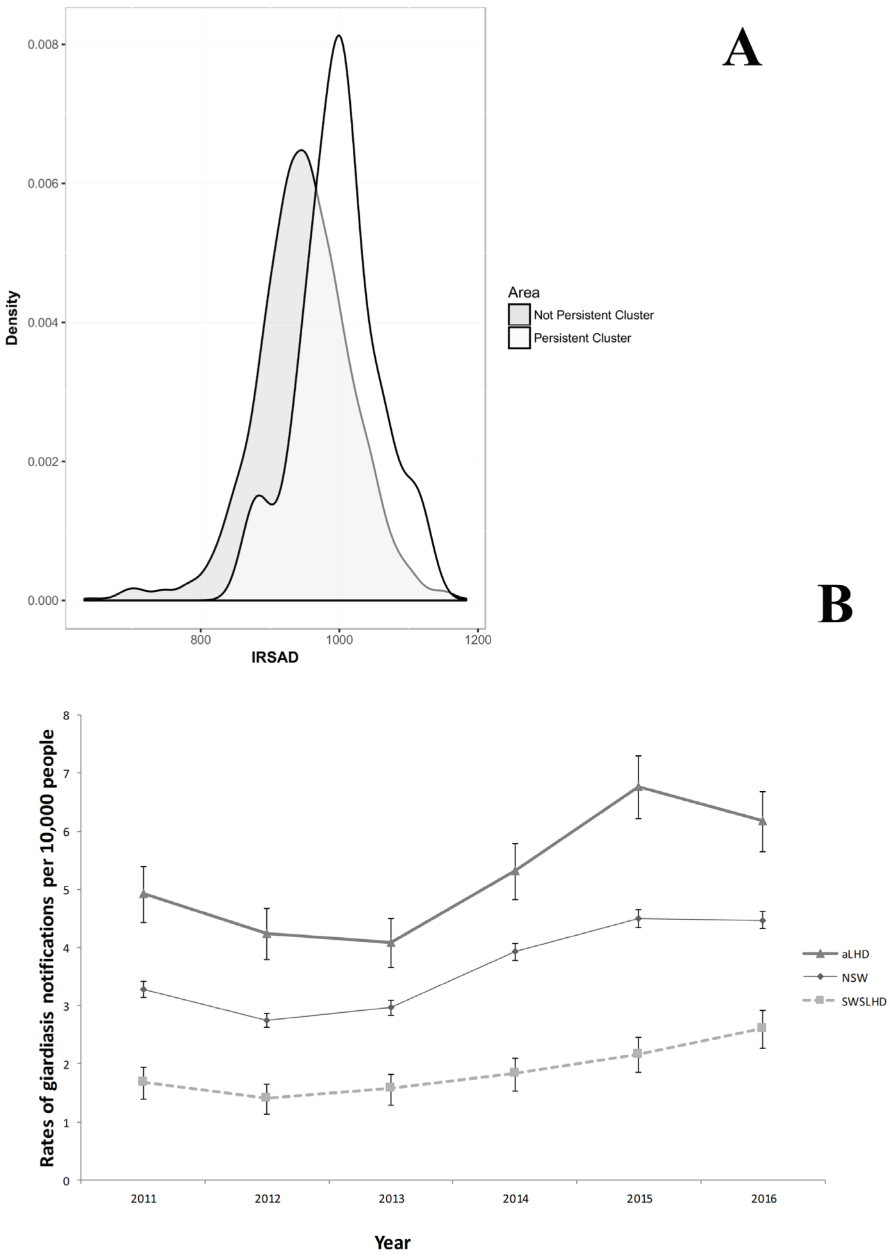
While a New Zealand study found that the highest rates of giardiasis cases were reported from a high-income region – Auckland,[38] research from Canada has shown lower rates of giardiasis notifications in advantaged areas.[10] A recent systematic review analysing mostly laboratory-based surveillance data reported a positive SES-foodborne illness relationship in developed countries.[20]

Table 1: Relationship between numbers of giardia cases in Statistical Area 1 geographies and various area level geodemographic characteristics

	IRR (95% CI)	*P* Value
Intercept	0.1 (0.1,0.2)*	<0.05
Age Groups		
0 to 4 Years	1 (1,1)	0.18
5 to 14 Years	1 (1,1)	0.3
15 to 64 Years	1 (1,1)	0.06
65 and Older	1 (1,1)	0.18
SES (Reference IRSAD Tertile 1)		
IRSAD Tertile 2	1.4 (1.1,1.7)*	<0.05
IRSAD Tertile 3	1.9 (1.5,2.4)*	<0.05
Rurality (Reference Metropolitan Areas)		
Inner Regional Areas	1.6 (1.3,1.9)*	<0.05

Notes:
IRR: Incidence Rate Ratio
SES: Socio Economic Status
IRSAD: Index of Socio Economic Advantage and Disadvantage
** Significant at the p<0.05 level*

Figure 2: A: Comparing density histograms of the IRSAD SES index in SA1s at persistent clusters with elsewhere; B: Rates of giardiasis notifications are consistently lower in SWSLHD compared to other areas.



An Australian survey of gastrointestinal illness symptoms found inconsistent relationships with SES,[39] as did a few other similar assessments in other regions.[20] While the relationship between SES and giardiasis incidence remains ambiguous, the relationship between SES and giardiasis reporting appears to be more consistent and generally in the positive direction.

The association between giardiasis and unhygienic behavioural practices (including infrequent handwashing, changing diapers, nail-biting and other hand-to-mouth contact) is well-documented, even in developed countries.[40-42] As such, an inverse relationship with SES may be expected.[10] Handling of farm animals in rural areas is a risk factor and this is evident in that inner-regional areas in our study area have significantly more notifications of giardiasis than metropolitan areas. While some risk factors such as overseas travel and swimming in recreational pools may be associated with a higher SES,[7] it is difficult to attribute the entire SES effect found in this study to such factors, and under-reporting and under-diagnosis among the disadvantaged may explain some of the uncovered relationships. In agreement with existing literature,[43,44] this study found that clustering is most pronounced (when both numbers of significant clusters and relative risk are considered) in the 0–4 age group and that clustering decreases with increasing age. However, this study found that 0–4-year-olds living in a less disadvantaged area were at higher risk, which, like the other age groups, could be an effect of true risk and real incidence, greater reporting, or both. Further research could be carried out to determine the level of under-reporting.

This study has two strengths. First, it attempted to unpack the SES-giardiasis notification relationship across three geographic scales, finding converging results. Second, it used a comprehensive dataset from a geographically and demographically diverse region of Sydney. There are some notable limitations to this study. In-depth information on giardiasis notifications (such as individual-level SES and health behaviours) is lacking. This prevented us from moving beyond association into causation and from addressing questions such as, "Do health-seeking behaviours or health literacy mediate the relationship between SES and giardiasis?" Subsequently, potential risk factors such as overseas travel, contact with animals or contaminated water and day-care enrolment could not be adjusted for.[7] Additionally, the use of area-level SES may have introduced elements of ecological fallacy into this research. Finally, a selection bias may have been introduced through using SWSLHD instead of any other LHD or region. This may affect the generalisability of this study, although the large size and degree of diversity of this LHD's population reduce this possibility. We believe it is likely that similar patterns would be found if these analyses were replicated elsewhere in NSW.

This research suggests that health-seeking behaviours and diagnosis of giardiasis symptoms within certain sociodemographic groups and geographic areas are associated with higher SES. Due to the possibility of chronic infections and the associated impact on the quality of life, health education campaigns targeting lower SES and disadvantaged communities are needed. In addition, PCPs in these areas could also be trained to proactively diagnose and treat persons presenting with giardiasis symptoms. While this research exposes an SES gradient in giardiasis notifications it remains, as explained earlier, an ecological study without an exposition of the causal mechanisms involved. Asking how this pattern is manifested, perhaps through differential health behaviours, remains an area for future enquiry.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary Figure 1: Significant clusters in different age groups.

Supplementary Table 1: Summary of significant clusters observed across different age groups.