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Research article

Intestinal parasite infection in the Augustinian friars and general population of medieval Cambridge, UK

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ABSTRACT

Objective: To investigate how lifestyle may have impacted the risk of contracting intestinal parasites in medieval England . Regular clergy (such as those living in monasteries) and the lay population form interesting groups for comparison as diet and lifestyle varied significantly. Monasteries were built with latrine blocks and hand washing facilities, unlike houses of the poor.
Materials: Sediment samples from the pelvis, along with control samples from feet and skull, of 19 burials of Augustinian Friars (13th-16th century), and 25 burials from All Saints by the Castle parish cemetery (10th-14th century), Cambridge.
Methods: We analysed the sediment using micro-sieving and digital light microscopy to identify the eggs of intestinal parasites.
Results: Parasite prevalence (roundworm and whipworm) in the Augustinian friars was 58%, and in the All Saints by the Castle parishioners just 32% (Barnards Test score statistic 1.7176, p-value 0.092).
Conclusions: It is interesting that the friars had nearly double the infection rate of parasites spread by poor hygiene, compared with the general population. We consider options that might explain this difference, and discuss descriptions and treatment of intestinal worms in medical texts circulating in Cambridge during the medieval period.
Significance: This is the first study to compare prevalence of parasite infection between groups with different socioeconomic status from the same location.
Limitations: Quality of egg preservation was suboptimal, so our data may under-represent the true prevalence.
Suggestions for further research: Larger studies with greater statistical power, covering different time periods and regions.

1. Introduction

While parasites were widespread in medieval Europe, very little work has been undertaken to compare how the risk of contracting different species may vary with a person's lifestyle. A range of intestinal parasites have been identified from medieval and early modern excavations in northern Europe including whipworm, roundworm, beef tapeworm, pork tapeworm, fish tapeworm, liver flukes, and protozoa

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that cause dysentery (Mitchell, 2015). Some types of parasitic worm are contracted by the contamination of food and drink by faeces (Ziegelbauer et al., 2012), but other parasites are caught by eating raw, smoked, pickled or salted meats or fish (Ledger and Mitchell, 2019). If we study parasites in the general population and compare with those leading specific lifestyles with different diets and occupation, such as the clergy, we can start to investigate this topic in a meaningful way. Similar comparison of the human skeletal remains of monasteries with the general population has found significant differences. For example, analysis of human remains from medieval monasteries has shown the clergy had a longer life expectancy than those in nearby parish cemeteries (De Witte et al., 2013), potentially from their more nourishing diet.

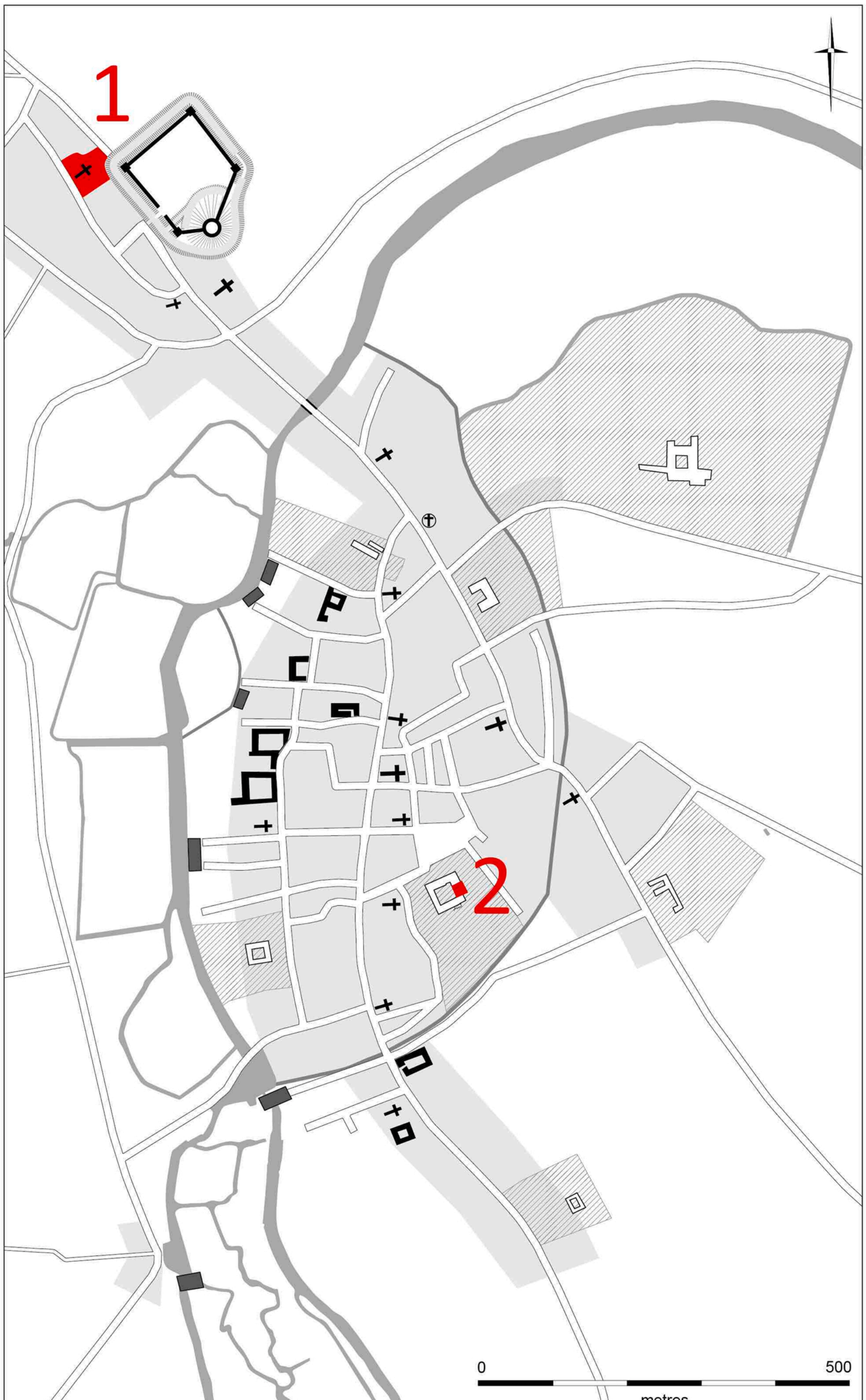

Fig. 1. Map showing locations of excavated burial grounds of All Saints by the Castle parish church (1) and the Augustinian friary (2) in medieval Cambridge c. 1350. Image credit: modified from an original figure produced by Vicki Herring for the After the Plague project.

1.1. Medieval sanitation in England

Sanitation in medieval towns in England was based upon the cesspit toilet. These holes dug into the ground were used for human faeces and other household waste (Magnusson, 2013), with numerous examples identified from excavations in Cambridge (Cessford and Dickens 2019). While they did not have a network of underground sewers as used by the Romans, that also meant the sewers could not flood or get blocked sending sewage back into people's houses (Hall and Kenward, 2015; Murray, 2000; Taylor, 2015). The sanitation system of monasteries, in comparison with its contemporaries, was typically better planned. At a time when even the aristocratic households did not usually possess running water systems, it was a common feature of monastery design (Singman, 1999). A raised cistern was typical, from which water drawn by gravity ran through channels diverting water through all the working areas in the monastery, including the latrine (Bond, 2017). However, urban monasteries such as the friary of the Augustinians in Cambridge did not always have access to such a flowing fresh water supply, and the latrines of the friary have not yet been identified as only part of the site has been excavated. Nevertheless, it would be expected that the Augustinian friars might have been more sanitary than the general public as the role of water and hygiene was regarded as necessary in the rule of Saint Benedict, which regulated all aspects of monastic life (Kerr, 2009; Winchester and Riyeff, 2017). The Cambridge friars followed the 1290 rule of the Augustinian mendicant order, known as the Ratisbon Constitutions (Cendoya, 1966), which incorporated the 13th-century mendicant practices of other orders of friars.

1.2. Aims

The aim of this study is to compare the prevalence of intestinal parasite infection in the general townsfolk and Augustinian friars to see if their differing lifestyle might have resulted in altered risk of infection by intestinal parasites.

2. Materials

Pelvic sediment collected from soil adherent to the sacrum bones of adult individuals excavated from two cemeteries in Cambridge (Fig. 1) were analysed for this study using our published sampling protocol (Mitchell, 2017). The cemetery of All Saints by the Castle parish church is thought to have been in use from c. 940–1150, and was abandoned in 1365/6 following the drop in population from the effects of the early outbreaks of the Second Plague Pandemic. Most of the burials in the cemetery date from the 12th-14th century. This parish was socio-economically mixed and likely poorer than Cambridge as a whole, with a significant proportion involved in agriculture (Cam, 1959, p.123; Casson, et al., 2020, pp. 64–5, 143–44). Twenty five individuals were available for sediment sampling of the sacrum, with control samples obtained from the cranium where intestinal parasites should not be present during life.

The Augustinian friary was founded in the 1280s, and functioned

Fig. 2. Excavation of an Augustinian friar with remains of his metal belt buckle in situ (left) and closeup of buckle (right). Image credit: Cambridge Archaeological Unit.

until its dissolution in 1538. Excavation recovered 32 burials from a cemetery dating from c. 1290–1380/1420, and 6 burials from within the chapter house, dating from c. 1380/1420–1538 (Roth, 1966; Cessford, 2017). Overall, two thirds of the friars died before 1349, and so date to the 13th-14th centuries. Not all 38 burials were suitable for analysis, as adequately preserved pelvises were required for sampling. Nineteen members of the Augustinian order were identified by the presence of their belt buckles indicating clothed burial, in contrast to the lay individuals buried in the cemetery who had been interred in shrouds without belt buckles (Cessford et al., 2022) (Fig. 2). We did not include the lay burials in this study as the sample size (seven) was too small to allow statistical comparison. All nineteen friars underwent sampling of sediment from their sacrum and control samples from the cranium and/or feet, where intestinal parasites should not have been present during life.

3. Methods

Samples of pelvic sediment weighed at 0.2 g were prepared for microscopy. Disaggregation was performed in a 15 ml test tube containing 8mls of 0.5% trisodium phosphate for at least two hours to create a liquid suspension. Gentle shaking and use of a vortex were employed to facilitate the separation of any aggregated particles. Once the samples were fully disaggregated, the mixture was poured through a stack of microsieves in order to separate out particles of a size too large or too small to be the eggs of parasites that typically infect humans in northern Europe (Garcia, 2016). The microsieves are composed of three sieves, having a mesh of 300 μm, 160 μm, and 20 μm, respectively, and a catchment container at the bottom. Material was washed through each sieve using distilled water, and that trapped on 20 μm sieve should contain the eggs of any intestinal helminths present. The sieves were thoroughly cleaned between samples using an ultrasonicator containing Decon 90 detergent. The material on the 20 μm sieve was collected and placed in 15 ml test tubes, centrifuged at 4000 rpm (3100 x g) for 5 min to concentrate the eggs and other similar sized particles at the base. The supernatant fluid was removed using a pipette, a few drops of glycerol added, and microscope slides made (Anastasiou and Mitchell, 2013). Each slide was viewed using digital light microscopy at x400 magnification (Olympus BX40F microscope with GXCAM-9 digital camera). Egg counts per gram (epg) were calculated by examining the entire 0.2 g sample, and multiplying the egg count by five. Species of parasite were identified based on the size, shape, colour, and special characteristics of the eggs (Garcia, 2016).

Our criteria for determining genuine infection in an individual at the time of their death were:

a) Pelvic sediment was positive for parasite eggs, while control samples were negative.
b) If control samples contained parasite eggs, then the egg count of the pelvic sediment was at least four times higher than that of the control sample.

These rigorous criteria minimises the likelihood of mistakenly allocating an individual as infected when eggs had contaminated the burial soil at the time of interment. Such contamination can occur when burials are dug through earlier features that contain refuse, and that soil is used to backfill the graves. Until now, researchers have analysed control samples as well as pelvic sediment, but no one has put forward criteria for interpreting burials where eggs have been found in the control samples. Using these criteria there should be a low risk of false positives. However, if individuals with genuine infection were buried in soil that was already contaminated by human faeces, thecontamination noted in the control samples may result in our discounting an individual as infected when they genuinely were. This means there are likely to be some false negatives in our data. Barnards test was used to assess whether there was a significant difference in parasite infection prevalence between the two groups.

4. Results

Of the 19 Augustinians friars, 11 were positive for parasite infection (58%). In contrast, only 8 of the 25 individuals from All Saints by the Castle were found infected with parasites (32%). Roundworm (*Ascaris lumbricoides*) and whipworm (*Trichuris trichiura*) were identified in the pelvic sediment of these groups, with roundworm being much more common (Fig. 3, Table 1). All nineteen positive individuals had roundworm, while one friar also had whipworm. The roundworm egg dimensions at the All Saints site were mean length 59.4 μm (SD +/- 4.8), mean width 45.4 μm (SD +/- 3.9). The egg dimensions at the Augustinian friary were mean length 63.1 μm (SD +/- 6.0), mean width 44.8 μm (SD +/- 4.4). The egg numbers for whipworm (2) were not sufficient to calculate mean and standard deviation data. Statistical analysis using Barnards test showed the test score statistic was 1.717663, Nuisance parameter 0.5001, and p-value for two-sided test 0.092. This suggests a roughly 91% likelihood that the apparent difference between prevalence in the two groups was genuine, and a 9%

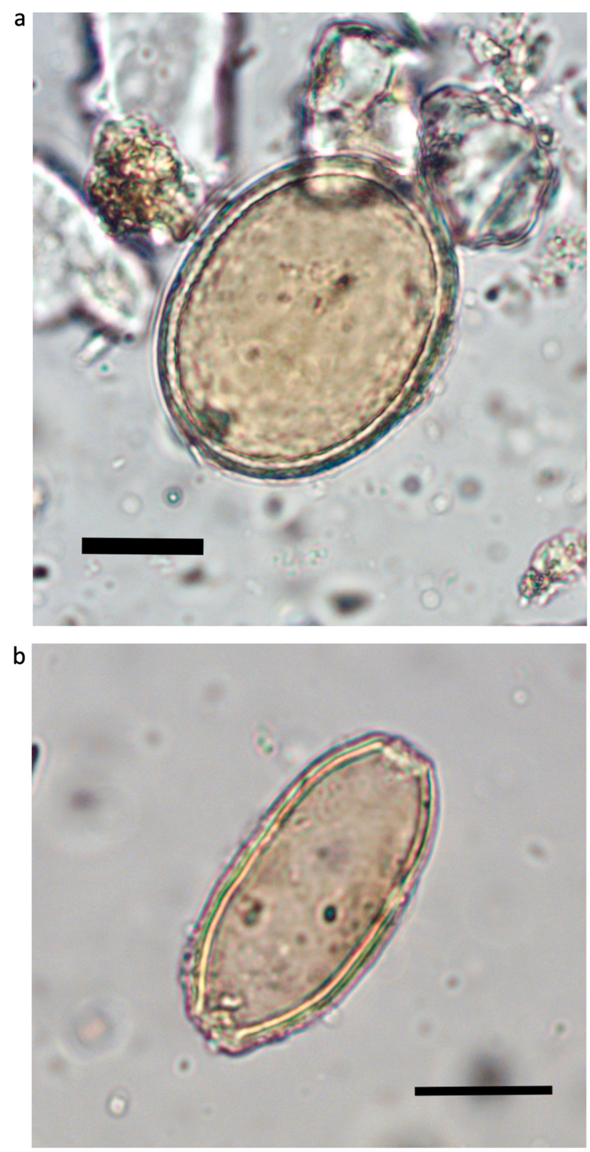

Fig. 3. Left: decorticated roundworm egg from burial at All Saints parish cemetery, with dimensions 59 × 45 μm; right: whipworm egg, with dimensions 52 × 24 μm (black bar indicates 20 μm).

Table 1
Data for parasite eggs count in the pelvic and control samples from 0.2 g sediment for the Augustinian friary and All Saints parish church. For egg count per g, multiply by five.

Cemetery	Sex	Pelvic Eggs	Parasite Species	Control Eggs	Infected or Not?
Friary					
SK1466. F191	M	1	Roundworm	0	Yes
SK1863. F260	M	0	–	–	No
SK1428. F216	M	4	Roundworm	0	Yes
SK1482. F230	M	0	–	–	No
SK1873. F331	M	4	Roundworm	0	Yes
SK1458. F190	M	0	–	–	No
SK1771. F310	M	0	–	–	No
SK1735. F302	M	0	–	–	No
SK1602. F265	M	0	–	–	No
SK1887. F334	M	4	Roundworm	1	Yes
SK1782. F311	M	1	Roundworm	0	Yes
SK1797. F314	M	8	Roundworm	0	Yes
SK1918. F343	M	23	Roundworm	0	Yes
SK1893. F336	M	4	Roundworm	1	Yes
SK1880. F332	M	2	Roundworm	3	No
SK1932. F344	M	2	Roundworm	0	Yes
SK1884. F333	M	7	Roundworm	0	Yes
SK1945. F347	M	3	Roundworm	0	Yes
		1	Whipworm		
SK2011. F367	M	2	Roundworm	2	No
All Saints Parish					
CP73 EU11309 SU177	F	0	–	–	No
CP73 EU11294 SH160	M	2	Roundworm	0	Yes
CP73 B48 PDN752	F	1	Roundworm	0	Yes
CP73 EU11288 SU152	M	4	Roundworm	0	Yes
CP73 EU1–1–276 PSN717(130)	F	0	–	–	No
CP73 EU11174 SK4	F	0	–	–	No
CP73 EU11247	F	1	Roundworm	0	Yes
CP73 EU11196 25	F	0	–	–	No
CP73 B41	F	0	–	–	No
CP73 EU11328 SU 204	M	0	–	–	No
CP73 EU11331 SK208	F	0	–	–	No
CP73 EU11320 SU193	M	1	Roundworm	0	Yes
CP73 EU11323 SK196	M	0	–	–	No
CP73 EU11281 SU141	M	0	–	–	No
CP73 EU11277	F	0	–	–	No
CP73 EU11244 84 PSN713	F	0	–	–	No
CP73 EU11203 G33	M	0	–	–	No
CP73 170 EU11302	M	2	Roundworm	0	Yes
CP73 EU1.1.187	M	0	–	–	No
CP73 B39	F	0	–	–	No
CP73 EU11314	M	0	–	–	No
CP73 B36	M	0	–	–	No
CP73 EU11278 SU132	F	0	–	–	No
CP73 EU11189 B18	F	1	Roundworm	0	Yes
CP73 EU11289 SK154	M	4	Roundworm	0	Yes

likelihood that the apparent difference was due to chance. If we focus on the individuals who were positive for parasite infection, the mean number of eggs recovered in the Augustinian friars group was 5.6 and for the All Saints parishioners was 2.0.

5. Discussion

While a number of studies have investigated the prevalence of intestinal parasite infection in past European populations using the pelvic sediment from burials (Anastasiou et al., 2018; Flammer et al., 2020; Ledger et al., 2021; Roche et al., 2019; Ryan et al., 2022), as far as we are aware this is the first study to compare individuals living different lifestyles in the same settlement. A study of 589 medieval burials from 7 sites in 3 European countries (Britain, Germany, Czech Republic) found a prevalence of 9–43% for roundworm, 1.5–28% for whipworm, 0–10% for *Taenia* tapeworm, and 0–6% for fish tapeworm (Flammer et al., 2020). Further work on high and late medieval British burials from York, Ipswich, Christchurch and Southampton found a mean prevalence of 31% roundworm infection, but much lower prevalence for other parasite species (Ryan et al., 2022). The 32% prevalence of parasites in the Cambridge All Saints parish cemetery is comparable with both these studies.

The previous work noted above assessing prevalence of parasite infection in past populations has typically employed an approach of presence or absence of eggs in the pelvic sediment. While this seems reasonable if the control samples are negative, if there is environmental contamination and control samples are positive then we need some clear criteria for deciding how to interpret that data. In the method we here describe, a new set of criteria for interpreting whether an individual was infected by parasites at the time of their death, regardless of whether environmental contamination of the burial ground with human faeces had occurred, is offered. We hope others will consider our proposed criteria, employ them in their own future studies, and improve them where possible.

Our results suggest that infection by intestinal helminths was relatively common in Medieval Cambridge. This is not an unexpected finding in pelvic sediment, as roundworm was recovered from the pelvic sediment of King Richard III who was buried in Leicester in 1485 (Mitchell et al., 2013). While we were able to recover intestinal parasite eggs from 32% of the socioeconomically mixed town folk buried at All Saints parish cemetery, there was a 58% prevalence among the Augustinian friars. Both these figures represent a minimum prevalence, as it is likely that actual number of infection was higher due to destruction of eggs in the sediment by fungi and insects (Morrow et al., 2016), and that we may have discounted some genuine infections if they happened to be buried in soil that was already contaminated by human faeces that contained parasite eggs. The fact that the mammillated coat of the roundworm eggs and the polar plugs of the whipworm eggs had not survived highlights the degree to which taphonomic change in the soil had degraded the eggs and likely reduced their number.

If the prevalence of helminth infection might be different in past populations with different lifestyles, might this be due to lifestyle or other reasons? The locations of the two cemeteries are not identical, but they are sufficiently close (within a km) and share the same soil type and climate that differences in egg survival over time would not be significantly different. The dates of use of the two cemeteries are not identical but do overlap (10th-14th century and 13th-16th century). Indeed, most of the individuals from All Saints are thought to date from the 12th-14th centuries, and two thirds of the friars died before 1349, and so date to the 13th-14th centuries. With this similarity in date of death it is unlikely that the amount of eggs destroyed over time by organisms in the soil would be dramatically different between the two groups. The population of Cambridge (c. 2500–4000 in the mid 13th century) was slowly increasing over time due to the expansion of the university, but the change in population would not have been of an order that would change the risk of geohelminth prevalence. All the individuals sampled were adults, so the known difference in risk of infection between children and adults would not be relevant to the individuals included in this study. The All Saints burials were excavated earlier than the friary burials, but the tough nature of roundworm and whipworm eggs mean that time in storage prior to analysis is unlikely to have had a major impact upon egg survival. In consequence, it seems unlikely that external confounding factors might explain the different prevalence in parasite infection we found of 32% and 58%.

In order to consider potential explanations, we need to understand the lifecycles of roundworm and whipworm (Garcia, 2016; Mejia et al., 2020). Adult roundworm and whipworm live in the intestines of the host. Roundworm can reach up to 30 cm in length, while whipworm are smaller, up to 5 cm in length. They have a lifespan of 1–2 years, and after mating their eggs are passed in the human faeces. These eggs are durable, surviving months and sometimes years in ideal soil conditions. The robust nature of these parasites promotes their survivability in harsh conditions, hence its transmission in all sorts of environments. The transmission takes a faecal-oral route. Larvae develop within fertilised eggs and become infective within a week or two. Once faecal material containing infective eggs are ingested on food or in water, larvae hatch out in the intestine. Whipworms mature in lining of the intestines, but immature roundworm migrate through the tissues to the lungs where they mature, crawl up the airways to the throat, and then are swallowed back into the intestines where they develop into adult worms and mate in the intestines to produce their own eggs.

Therefore, any apparent differences in prevalence between the friars and general population are likely to be related to the lifecycle of this parasite and how the population of Cambridge managed their sanitation. We can only speculate, but here we will consider some potential options. The Augustinians might have manured the crops in their friary gardens with the faeces from their own latrine block, and if the townspeople did not, then this might have caused disproportionate reinfection in the Augustinians. Similarly, if the Augustinians purchased manure from the town to fertilise their gardens that contained human faeces or pig faeces (pigs can be infected by roundworm), then this might have led to higher infection rates when they ate the crops from their gardens.

5.1. *The understanding of intestinal parasitic worms by medieval people*

To complement the archaeological evidence for parasites in the population, it can be helpful to integrate this with medieval textual records describing intestinal worms. Such texts were written by educated medical practitioners and friars, and not poor townspeople. Nevertheless, this helps us to understand the views of medieval people about their parasites, how they believed the worms were created, and the treatments they might have used to get rid of them.

John Stockton, a medical practitioner in Cambridge (died by 1361), left a medical manuscript to Peterhouse college (Peterhouse MS 52), written mostly in the 13th century in Italy and England. One of the texts in the manuscript is the *Practica brevis* (short Practica) of Johannes Platearius. The second chapter of the section on illnesses of the intestines is *De lumbricis* (on worms). "Different shapes of worms are generated there according to the varieties of the humour, phlegm. Long round worms form from an excess of salt phlegm, short round worms from sour phlegm, while short and broad worms came from natural or sweet phlegm. Bitter medicinal plants like aloe and wormwood kill these intestinal worms, but they need to be disguised with honey or other sweet things" (Platearius, 1497). Such evidence would indicate that those people of medieval Cambridge who were trained in medicine would have been aware of the existence of intestinal parasitic worms. The description of 'long round worms' seems to match the 30 cm long *Ascaris lumbricoides*, while 'short round worms' would match with the 5 cm long *Trichuris trichiura*, or 1 cm long *Enterobius vermicularis* (pinworm).

The Augustinian friars of Cambridge may well have had access to a medical text compiled by Franciscan friars in 1416–25, the *Tabula medicine* (table of medicine) (Jones and Edwards, 2008). This was organised alphabetically and there was an entry for *Vermes* (another term for worms) in the text. Some of the remedies were credited to individual Franciscans. Castel says that *bursa pastoris* (shepherd's purse) should be worn round the neck attached by a long thread, but not touching the flesh, and this will compel worms breeding in the intestines or womb to drop out. More orthodox medical use of herbs is prescribed in a plaster to be applied to the belly with colocynth, centaury and bull's gall as the main ingredients, all to be cooked in vinegar. Symon Welles has tested a powder made from a mole (but does not say how), to be given in a drink, and declares it effective against different types of worms in the intestines (Jones, 2011).

The *Tabula medicine* found favour with two famous Cambridge doctors of the 15th century: Roger Marchall who had been at Peterhouse, and John Argentein of King's College (Jones, 2011). So, whether the Augustinians looked to their own reading of the *Tabula medicine*, or took medical advice from the most eminent local physicians, they might have been prescribed the same remedies for intestinal worms.

6. Conclusion

This study investigated the types of parasites that infected the population of medieval Cambridge, and found that prevalence in the Augustinian friars was 58%, compared with 32% in the All Saints parishioners. We consider why infection seems to have been twice as common in the friars and feel it likely to be a consequence of the way the two groups approached sanitation. Medical texts available in medieval Cambridge show that doctors of the time were aware of intestinal worms of different shapes and sizes, and knew of medicines that they felt were helpful in treatment. Further studies comparing subgroups within populations that followed contrasting lifestyles would be expected to identify other examples where parasite infection prevalence differed within that population, so helping us to understand variation in risk for infectious diseases in past societies.

Declaration of Interest

None.

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