



RESEARCH ARTICLE

Shift in parasitic infections during the Corona pandemic: a hospital-based retrospective study

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ABSTRACT

The Corona pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) calls on the Saudi government to take action to control the infection. The government closed borders, prohibited travel, limited outdoor movements, and told primary and secondary care facilities to reduce all regular non-urgent health services. It is not known whether these measures have impacted the prevalence of parasitic intestinal infections. This study has therefore been carried out to investigate this issue. Dataset of 217 stool samples submitted to the King Faisal Medical Complex (KFMC) Microbiology Laboratory in Taif, Saudi Arabia for parasitological examination during the pandemic (January-June 2020) and 649 samples submitted during the corresponding months of the previous year (January-June 2019) were extracted and analyzed. Overall, 24.1% (209/866) of samples were parasites-positives; 26.6% (173/649) before and 16.5% (36/217) during the pandemic, with 79% reduction. There was a significant difference in gender-parasitism between the two periods where the majority of parasitism were for males ($p < 0.001$). Infections were frequent in patients aged 5-14 years both before (84/649; 12.9%) and during (12/217; 5.5%) the pandemic, with significant difference observed between the two cohorts ($p < 0.002$). Moreover, the majority of infected patients were non-Saudi (67.9%; 142/209), with a significant difference in nationality reported, ($p = 0.024$). Protozoa were identified in 21.8% (189) of all samples investigated, of which, *Blastocystis hominis*, *Entamoeba coli*, *Giardia lamblia*, *Entamoeba histolytica/dispar* and *Cryptosporidium* species were identified in 6.1% (53), 5.4% (47), 5.0% (44), 2.8% (25), and 2.3% (20), respectively. Helminths were diagnosed in 2.3% (20/866) of samples. Eggs of hookworm, *Ascaris*, *Taenia* spp, and *Hymenolepis nana* were detected in 0.9% (8), 0.5% (5), 0.3% (3) and 0.4% (4), respectively. In parallel with our research hypothesis, a substantial decrease in the burden of intestinal parasitic infections was recorded with the lock-down measures taken during the Corona pandemic.

Keywords: Corona pandemic; intestinal parasites; prevalence; retrospective study.

INTRODUCTION

Enteric parasites, a diverse group of pathogens affecting the gastrointestinal tract, are distributed worldwide (Rayan *et al.*, 2020). The poor infrastructure, political instability, insufficient supply of clean water, illiteracy, overpopulation, malnutrition, civil unrest, poor sanitation, and the climate changes have all contributed as risk factors for intestinal parasitic infections in the low-income group of developing countries (Kotloff, 2017). In developed countries, enteric parasites are frequently ignored as a major cause of gastrointestinal complaints in high-income groups due to over-confidence in public hygiene, municipal sanitization systems, and good agriculture and livestock practice (Fletcher *et al.*, 2012).

One of the developing countries in the Middle East is Saudi Arabia (Alrouh *et al.*, 2013). Because of water scarcity, low water quality, desertification and overuse of ground-water sources for personal consumption, the risk of parasitic infection has been estimated to be high in the country (DeNicola *et al.*, 2015; Abd El-Salam & Elham, 2016). The burden of parasitic intestinal infections in Saudi Arabia has been discussed in a number of studies (Zaglool *et al.*, 2011; Hawash *et al.*, 2017; Amer *et al.*, 2018; Bakarman *et al.*, 2019).

The new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as Corona virus disease of 2019 (COVID-19), appeared in December 2019, and rapidly spread worldwide (Meo, 2020). A growing number of cases has been reported in Saudi Arabia, prompting the health authorities to take measures on time to contain the infection. The

government closed the borders, prohibited traveling, limited the outdoor movements, and told the primary and secondary care facilities to decrease all regular non-urgent health care services. Reduced access to the health facilities, especially in developing countries, may cause a delay in the diagnosis, treatment and of other infections, including parasitic infections.

On this view, we aimed to estimate the prevalence of parasites that commonly affect the gastrointestinal tract and to address the impact of measures taken by the Saudi government during the Corona pandemic on the prevalence of these infections.

MATERIAL AND METHODS

The study area

The study was conducted at King Faisal Medical Complex (KFMC) located in Al-Taif district, Western Saudi Arabia. The hospital serves as a referral center for tertiary specialist care for a catchment population of approximately one million people. With a capacity of 500 beds, this hospital is considered one of the largest government hospitals in the Al-Taif Governorate. Both medical and remedial specializations are included, along with advanced medical cadres working at this big hospital.

Data collection

In this retrospective study, we relied on medical records of stool samples submitted to the microbiology laboratory at KFMC within two given time-periods: one during the Corona pandemic (from January 2020 to June 2020) and one long before the pandemic (from January 2019 to June 2019). Samples belonged to hospitalized or non-hospitalized patients presenting with or without gastrointestinal complaints. The datasets of samples included basic demographic features of patients (age, sex, and nationality) and the parasitological tests results. Data were extracted, tabulated, evaluated, compared and discussed. Samples that missing records for the laboratory tests results and/or the essential demographic data of patients were excluded from this analysis. Mainly two methods are used to diagnose common enteric parasites; the first includes wet mount microscopy, formol-ether concentrated smear microscopy, and the second includes special additional slides stained with Lugol's iodine, trichrome, and/or acid-fast stain (Garcia *et al.*, 2018).

Data analysis

Variations in distribution patterns of positive stool samples between sex and age were determined. The prevalence of infections was reported in proportions. Chi-square test (χ^2) was used to compare relative frequencies between groups (sex and age). Data analysis was conducted using SPSS version 20 (SPSS Inc, Chicago, Illinois). P-value <0.05 was considered as significant.

Ethical considerations

Ethical clearance to conduct this study was obtained from the KFMC Ethical Committee (Ref: KFMC-02-T-067). Informed consents from the study participants was not necessary for the purposes of this study.

RESULTS

In the current study, datasets of 866 fecal samples were obtained, extracted, tabulated and analyzed. Table 1 describes the demographic characters and the descriptive results of patients, both pre- and during the pandemic time

periods. Out of 649 stool samples submitted to the laboratory prior the pandemic time period, 378 were for male patients and 271 were for female patients. Of these patients, 273 were Saudi and 376 were non-Saudi residents. On the other hand, out of 217 patients submitted their feces during the pandemic time period, 103 were males and 114 were females. Of these patients, 98 were Saudi and 119 were non-Saudi. The patients' ages ranged between 3 and 71 years, each was allocated into one of four age groups.

Out of 649 samples examined before the pandemic, 173 (26.6%) were found to be positive for one or more intestinal parasites. In comparison, out of 217 specimens tested during the pandemic, 36 (16.5%) were positive for one or more intestinal parasites. In other mean, there was a reduction in the number and proportion of positive samples "parasitism or parasitosis" between the two cohorts, calculated to be 79%. In addition, there was a highly significant parasitism-gender relationship between the two cohorts ($p < 0.001$), where the majority of positive samples were for males. Before the Corona, intestinal parasites were identified in 14.1% (92/649) of male patients and in 12.4% (81/649) of female patients. In contrast, during the Corona pandemic, male patients were found to be positives in 10.1% (22/217) of samples while the female patients were positives in 6.4% (14/217) of samples.

Figure 1 shows the age and sex distribution of the positive patients, both pre and during the COVID-19 pandemic time period. The majority of parasitosis was recorded for patients aged 5-14 years both before (84/649; 12.9%) and during (12/217; 5.5%) the pandemic time periods. Moreover, as shown in Figure 2, the majority of patients found infected by parasites were non-Saudi residents. In the pre-pandemic time period, out of 376 non-Saudi patients tested, 117 (31.1%) were found positives for one or more enteric parasites. On the other hand, 25 out of 119 Saudi patients, submitted their stool during the pandemic period, were positives for enteric parasite(s). The difference between the two cohorts regarding the nationality of patients were significant ($p = 0.024$), (Table 1).

Enteric protozoa, including all detected species, were described more frequently in the 5 - 14 year age group, followed by the 0 - 4 year age group, and less frequently in patients ≥ 45 years of age, with a highly significant difference recorded ($p < 0.001$). The age-specific prevalence of helminth infections, on the other hand, was highest in patients over 15 years of age and lowest in the 0 - 4 year age group, with no significant difference reported, ($p = 0.660$).

Table 2 shows the distribution of intestinal parasites species, identified in the stool specimen of patients based on their ages and genders, both pre-and during the pandemic time periods. Out of 173 samples submitted prior the pandemic and found positive for gut parasites, 158 (91.3%) were positive for protozoa and 15 (8.6%) positives for helminths. The protozoan species identified were *Blastocystis hominis* (6.9%; 45/649) followed by, *Entamoeba coli* (5.8%; 38/649), *Giardia lamblia*, (5.7%; 37/649), *Entamoeba histolytica/dispar* (3.2%; 21/649) and, *Cryptosporidium* spp. (2.6%; 17/649). Among the intestinal helminths described in the pre-pandemic period, the hookworm was identified in 0.9% (6/649) of patients, followed by *Ascaris lumbricoides* (0.6%; 4/649), *Hymenolepis nana* (0.4%; 3/649) and *Taenia* spp. (0.3%; 2/649).

On the contrary, out of 36 samples submitted during the pandemic time period and found positive for gut parasites, 31 (86.1%) were protozoa-positive and 5 (13.8%) positives for helminths. Regarding protozoa, *E. coli* were identified in 0.2% (9/217), followed by *B. hominis* in 3.6% (8/217), *G. lamblia* in 3.2% (7/217), *E. histolytica/dispar* in 1.8% (4/217) and,

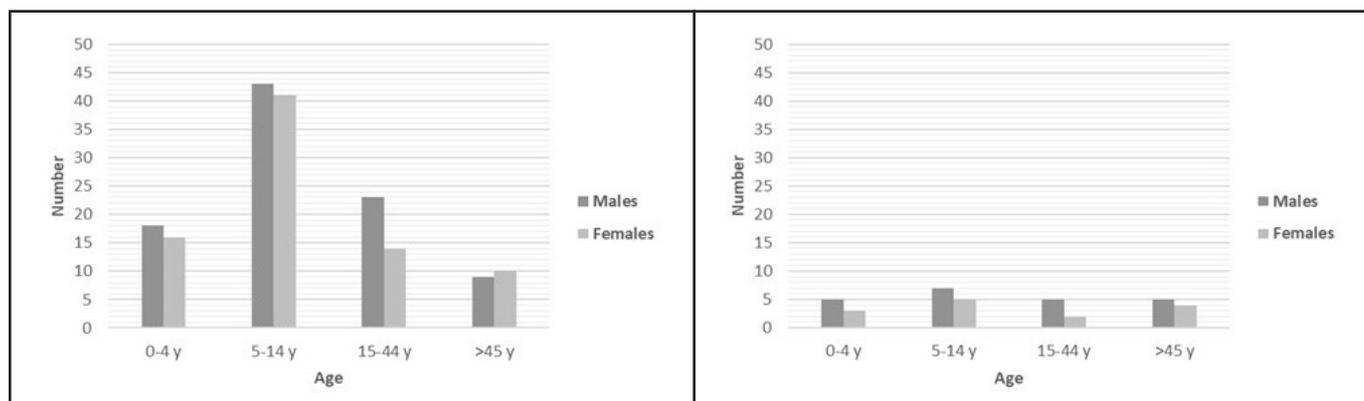


Figure 1. Age and gender distribution of parasites-positive patients before (right) and during (left) the COVID-19 pandemic time periods.

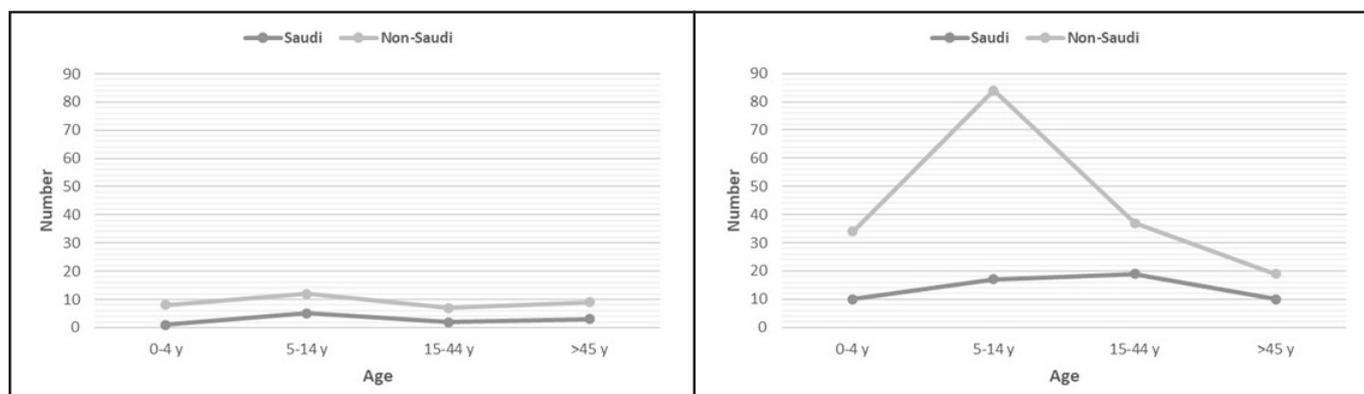


Figure 2. Distribution of age and nationality of parasites-positive patients before (right) and during (left) the COVID-19 pandemic time periods.

Cryptosporidium spp. in 1.3% (3/217). Concerning helminths, the hookworm, was identified in 0.9% (2/217) followed by *A. lumbricoides*, *H. nana* and *Taenia* spp. each was diagnosed in one sample (0.4%; 1/217). As shown in Table 1, protozoa were identified more in samples submitted before the pandemic than during the pandemic, with a highly significant difference observed, ($p < 0.001$).

Similarly, the gut helminths were detected more in pre-pandemic samples than in the pandemic samples as absolute numbers, without statistically-reported significant difference ($p = 0.798$).

As seen in Table 2, overall, the enteric parasite species were identified more in males (53%; 92/173) than in females (46.8%; 81/173) in the pre-pandemic period. Also in samples submitted during the pandemic, the enteric parasites species were more in males (58.3%; 21/36) than in females (38.8%; 14/36). Apart from *E. histolytica/dispar* that detected more in females, all other enteric protozoan species were predominant in males, for both pre-and during the pandemic time periods, with highly significant difference observed between the two cohorts for all the species, ($p < 0.05$).

DISCUSSION

The current study acknowledges the effect of the Corona pandemic and its related lockdown measures on the prevalence of intestinal parasites in Saudi Arabia. To increase the importance of the study, we compared results obtained for fecal samples submitted during the pandemic

with the matching time-period long before the pandemic. We chose the same months of the preceding year for comparison to avoid seasonal and climate change impacts on the prevalence of such infectious agents.

Our results suggest that during the pandemic, there was a marked decline in the total number and proportion of positive cases of intestinal parasites relative to the previous year's matching cohort. It is unclear whether this reduction may be due to steps taken by the local health authority to slow the spread of the Corona virus or due to the reluctance of patients to visit hospitals for fear of being able to catch the virus. Travel prohibitions, daily washing of hands, and frequent use of disinfectants can play a role in reducing other infections, especially those that are faeco-orally transmitted, such as intestinal parasites.

The intestinal parasites were found in 24.1% of all samples recorded during the two periods in the current study. Inconsistent with this result, community-based studies conducted in various geographical areas in Saudi Arabia have recorded higher prevalence estimates implying that intestinal parasite infection is a major public health problem in Saudi Arabia (Al Shammari *et al.*, 2001; Al-Mohammed *et al.*, 2010). Far lower prevalence rates have also been seen in prospective research conducted in different Saudi cities like Makkah, Riyadh, and Jeddah (Zaglool *et al.*, 2011; Amer *et al.*, 2018; Bakarman *et al.*, 2019). Intestinal parasites with a prevalence rate of 0.5% - 6.2% have been reported in these studies. Very high rates of prevalence have been reported globally in less developing countries. In a survey study

Table 1. Patients' demographic and descriptive results, both pre- and during the pandemic

Demographic character	Pre-COVID-19 (n=649; 173 positives and 476 negatives)										During COVID-19 (n=217; 36 positives and 181 negatives)										p-value
	0-4y		5-14y		15-44y		>45y		Total		0-4y		5-14y		15-44y		>45y		Total		
	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	
Gender:																					
Males	18 (2.7)	12 (1.8)	43 (6.6)	60 (9.2)	23 (3.5)	113 (17.4)	9 (1.3)	101 (15.5)	92 (14.1)	286 (44)	5 (2.3)	4 (1.8)	7 (3.2)	3 (1.3)	5 (2.3)	63 (29)	5 (2.3)	11 (10.1)	22 (10.1)	81 (37.3)	
Females	16 (2.4)	32 (4.9)	41 (6.3)	54 (8.3)	14 (2.1)	39 (6.0)	10 (1.5)	64 (9.8)	81 (12.4)	190 (29.2)	3 (1.3)	4 (1.8)	5 (2.3)	6 (2.7)	2 (0.9)	36 (16.5)	4 (1.8)	54 (24.8)	14 (6.4)	100 (46)	
Nationality:																					
Saudi	10 (1.5)	3 (0.4)	17 (2.6)	69 (10.6)	19 (2.9)	48 (7.3)	10 (1.5)	97 (14.9)	56 (8.6)	217 (33.4)	1 (0.4)	4 (1.8)	5 (2.3)	4 (1.8)	2 (0.9)	50 (23)	3 (1.3)	29 (13.3)	11 (5)	87 (40)	
Non-Saudi	24 (3.6)	41 (6.3)	67 (10.3)	45 (6.9)	18 (2.7)	104 (16)	9 (1.3)	68 (10.4)	117 (18)	259 (39.9)	7 (3.2)	4 (1.8)	7 (3.2)	5 (2.3)	5 (2.3)	49 (22.5)	6 (2.6)	36 (16.5)	25 (11.5)	94 (43.3)	
Total	34 (5.2)	44 (6.7)	84 (12.9)	114 (17.5)	37 (5.7)	152 (23.4)	19 (2.9)	165 (25.4)	173 (26.6)	476 (73.3)	8 (3.6)	8 (3.6)	12 (5.5)	9 (4.1)	7 (3.2)	99 (45.6)	9 (4.1)	65 (29.9)	36 (16.5)	181 (83.4)	

* : highly significant difference observed
 † : significant difference observed
 Symbols: (+) enteric parasite(s)-positives; (-) enteric parasite(s)-negatives

conducted in Bahir Dar, Ethiopia, 65.5% (235/359) of primary school students were found infected with one or more enteric parasites (Hailegebriel, 2017). A prevalence rate of 57.5% was shown by a cross-sectional epidemiological study done in a primary health unit in São Paulo, Brazil. (Fonseca et al., 2017). The higher rates can be due to unsuitable hygiene and agricultural backgrounds in these regions.

Furthermore, in the current research, there was a highly important patient-gender relationship between the two cohorts, where the majority of parasitosis was observed in males, consistent with the previous study (Al Shammari et al., 2001). In our study, males were considered more vulnerable to infection than females. This sex-based disparity may be attributed to behavior and culture variation between the two the two sexes in Saudi Arabia. In this highly-conservative country, males are more likely to come into contact with sources of infection than females. In contrast to this result, Ahmed et al. found more intestinal parasites in women (57.4%) than in men (42.6%) who were subjected to stool examination at a tertiary health center in Makkah as a pre-employment requirement (Ahmed et al., 2015). In that research, more women than men have filled out applications for nursing work, and this is the cause of this predominance. The predominance of the female gender over the male gender towards parasitosis has also been seen outside Saudi Arabia (Baral et al., 2017). Such gender predominance is likely to indicate different behavior between the two sexes. In a study conducted in Cameroon, the higher prevalence of human intestinal protozoa in women was found to be due to the fact that women commonly eat unwashed fruits and vegetables or salads that may be contaminated (Taha, 2013). Similarly, there was a substantial relationship between the two time-periods and the nationality of the patients in the current study, where the majority of parasitosis occurred in non-Saudi expatriate workers in line with previous reports (Mohammad & Koshak, 2011; Taha, 2013). Expatriate workers come primarily from Bangladesh, the Philippines, India, Indonesia, Pakistan, Sri Lanka, and Egypt which are endemic countries for intestinal parasites (Hussain et al., 2019; Wakid, 2020). This population's group, i.e. the non-Saudi expatriate workers, needs special attention because they are a significant source of transmission of parasitic infections in the region.

The enteric protozoan infections remain the most common parasitic infection, consistent with previous studies in the same community (Hawash et al., 2017) or in other communities (Amer et al., 2018; Bakarman et al., 2019). A 20.8% prevalence rate of intestinal protozoa in diarrheal feces of patients was documented in a previous study in AL-Taif, identical to the figure reported in the current study (Hawash et al., 2017). In contrast, Hegazi et al have reported enteric protozoa in 5.3% schoolchildren in Jeddah (Bakarman et al., 2019). In the same sense, Amer and his colleagues have recorded only 0.5% of children under 5 years living in King Fahd Medical City, Riyadh, with intestinal protozoa (Amer et al., 2018). Outside the Kingdom, enteric protozoa have been reported with prevalence rates exceeding 50% in Pakistan, Ethiopia, Cuba, Nigeria, and Malaysia (Mehraj et al., 2008; Cañete et al., 2012; Ngui et al., 2012; Tyoalumun et al., 2016; Wasihun et al., 2020). The differences between the study populations, parasitological methods adopted, geographical location, level of environmental sanitation, drinking water resources, timing of research and cultural differences may be linked to these reported variations in the prevalence of enteric protozoa among the studies.

In the current study, samples recorded prior the pandemic were found to have more enteric protozoa than those examined during the pandemic period. The explanation behind this difference is most effectively due to the action taken to contain the viral pandemic by the health authority. Considering previous reports, *Blastocystis hominis*, *Giardia*, and *Cryptosporidium* were the most common protozoan species found in the study site (Hawash et al., 2014; Hawash et al., 2020) and in other Saudi regions (Mohamed et al., 2017; Wakid, 2020). Also in our study, with respect to the intestinal helminths, the species found in the study population with an overall prevalence rate of 2.3% were the hookworm, followed by *Ascaris lumbricoides*, *Hymenolepis nana* and *Taenia* spp. According to one study (Wakid, 2020), *Hymenolepis nana*, *Ascaris* and *Trichuris trichiura* were the predominant helminthic species found in stool samples of middle-school boys in Jeddah. According to another study (Makki et al., 2010), among the apparently healthy immigrant workers at Dammam, Saudi Arabia, the major helminths that have been the pinworms, *Trichuris trichiura* and *Hymenolepis nana*.

Certainly, there is no particular age is immune from getting the infection since intestinal parasitic infection is mostly linked to food and drinking water hygiene, in addition, a good numbers of these parasites are transferred from animals to humans "zoonotic". Nonetheless, in the present study, the demographic characteristic review of positive cases also revealed that young ages (<24 years) had the highest percent distribution towards protozoan infections whereas older ages (≥ 45 years) had the highest percent distribution towards helminths, consistent with one report (Umar et al., 2016) and inconsistent with other (Abaka-Yawson et al., 2020). Since they are more vulnerable and prone to parasitic diseases, the two age groups need special care. Malnutrition, low immunity, poor sanitation, polluted food or water, unsafe waste disposal and poor hygiene can be associated with this high infection risk.

The present study was not free of constraints. First, because it is the first study concerned with investigation of parasitic infections in humans during the Corona pandemic, it was difficult for us to compare our findings with those of others. Second, because our study was medical records-based, we used the available patients data for the analysis. Data on the key clinical symptoms and the socio-demographic variables, such as the patient's residence, education, work, income, drinking water supply and wastewater disposal, have been missing from patients records. Such data, if was available, could provide a detailed explanation of the prevalence of intestinal parasites among the population. Third, being a hospital based, our findings do not reflect the true prevalence in the country. A large proportion of parasitic gut infections are not diagnosed as asymptomatic individuals who are aware of infection. Finally, our study focused on routine hospital diagnostic methods that lack sensitivity of parasite detection, especially for enteric protozoa. Such less sensitive techniques could underestimate the true prevalence of these parasites.

In conclusion, infections with intestinal parasites remain an important issue for the study population. A significant decrease in the prevalence of these parasites was reported during the COVID-19 pandemic time period, compared to pre-pandemic period. The lock-down measures taken by the Saudi government to control the pandemic could play a role in this reduction. This study will provide invaluable data needed to prepare meaningful public control programs aimed to reduce the prevalence and morbidity of parasitic infections in the study population.

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Conflict of interests

The authors declare that they have no conflict of interests.

REFERENCES

- Abaka-Yawson, A., Senoo, D., Aboagye, E.A., Hotorvi, C., Tawiah, P.A., Sosu, S.Q. & Kwadzokpui, P.K. (2020). High prevalence of intestinal helminthic infection among children under 5 years in a rural Ghanaian community: an urgent call for attention. *Journal of Parasitic Diseases* **44**: 625-632. <https://doi.org/10.1007/s12639-020-01239-z>
- Abd El-Salam, M.M. & Elhakem, A.H. (2016). Desertification and its effect on the erosion of vegetation in the south-western region of Saudi Arabia. *Environmental Monitoring and Assessment* **188**: 164. <https://doi.org/10.1007/s10661-016-5164-z>
- Ahmed, M.A., Alam-Eldin, Y.H., Eltaweel, N.A. & Elmorsy, S. (2015). Intestinal parasites detected during pre-employment stool examination at tertiary health care center in Makkah, Kingdom of Saudi Arabia. *Journal of the Egyptian Society of Parasitology* **45**: 367-373. <https://doi.org/10.12816/0017580>
- Al-Mohammed, H.I., Amin, T.T., Aboulmagd, E., Hablus, H.R. & Zaza, B.O. (2010). Prevalence of intestinal parasitic infections and its relationship with socio-demographics and hygienic habits among male primary schoolchildren in Al-Ahsa, Saudi Arabia. *Asian Pacific Journal of Tropical Medicine* **3**: 906-912. [https://doi.org/10.1016/S1995-7645\(10\)60218-0](https://doi.org/10.1016/S1995-7645(10)60218-0)
- Alrouh, H., Ismail, A. & Cheema, S. (2013). Demographic and health indicators in Gulf Cooperation Council nations with an emphasis on Qatar. *Journal of Local and Global Health Perspectives* **2013**: 3. <https://doi.org/10.5339/jlghp.2013.3>
- Al Shammari, S., Khoja, T., El Khwasky, F. & Gad, A. (2001). Intestinal parasitic diseases in Riyadh, Saudi Arabia: prevalence, sociodemographic and environmental associates. *Tropical Medicine & International Health* **6**: 184-189. <https://doi.org/10.1046/j.1365-3156.2001.00698.x>
- Amer, O.S., Al-Malki, E.S., Waly, M.I., AlAgeel, A. & Lubbad, M.Y. (2018). Prevalence of intestinal parasitic infections among patients of King Fahd Medical city in Riyadh Region, Saudi Arabia: A 5-year retrospective study. *Journal of Parasitology Research* **26**: 8076274. <https://doi.org/10.1155/2018/8076274>
- Bakarman, M.A., Hegazi, M.A. & Butt, N.S. (2019). Prevalence, characteristics, risk factors, and impact of intestinal parasitic infections on school children in Jeddah, Western Saudi Arabia. *Journal of Epidemiology and Global Health* **9**: 81-87. <https://doi.org/10.2991/jegh.k.190219.001>
- Baral, R., Jha, P., Amatya, R. & Khanal, B. (2017). Prevalence of intestinal parasitic infections among patients attending in a tertiary care hospital of eastern region of Nepal-A retrospective, laboratory based study. *Asian Journal of Medical Sciences* **8**: 55-59. <https://doi.org/10.3126/ajms.v8i3.16909>
- Cañete, R., Díaz, M.M., García, R.A., Martínez, P.M.L. & Ponce, F.M. (2012). Intestinal parasites in children from a day care centre in Matanzas City, Cuba. *PLoS ONE* **7**: e51394. <https://doi.org/10.1371/journal.pone.0051394>
- DeNicola, E., Aburizaiza, O.S., Siddique, A., Khwaja, H. & Carpenter, D.O. (2015). Climate change and water scarcity: The case of Saudi Arabia. *Annals of Global Health* **81**: 342-353. <https://doi.org/10.1016/j.aogh.2015.08.005>
- Fletcher, S.M., Stark, D., Harkness, J. & Ellis, J. (2012). Enteric protozoa in the developed world: a public health perspective. *Clinical Microbiology Reviews* **25**: 420-449. <https://doi.org/10.1128/CMR.05038-11>
- Fonseca, R.E., Barbosa, M.C. & Ferreira, B.R. (2017). High prevalence of enteroparasites in children from Ribeirão Preto, São Paulo, Brazil. *Revista Brasileira de Enfermagem* **70**: 566-571. <https://doi.org/10.1590/0034-7167-2016-0059>
- Garcia, L.S., Arrowood, M., Kokoskin, E., Paltridge, G.P., Pillai, D.R., Procop, G.W., Ryan, N., Shimizu, R.Y. & Visvesvara, G. (2018). Laboratory diagnosis of parasites from the gastrointestinal tract. *Clinical Microbiology Reviews* **31**: e00025-17 <https://doi.org/10.1128/CMR.00025-17>
- Hailegebriel, T. (2017). Prevalence of intestinal parasitic infections and associated risk factors among students at Dona Berber primary school, Bahir Dar, Ethiopia. *BMC Infectious Diseases* **17**: 362. <https://doi.org/10.1186/s12879-017-2466-x>
- Hawash, Y.A., Ismail, K.A. & Almeahadi, M. (2017). High frequency of enteric protozoan, viral, and bacterial potential pathogens in community-acquired acute diarrheal episodes: evidence based on results of Luminex gastrointestinal pathogen panel assay. *The Korean Journal of Parasitology* **55**: 513. <https://doi.org/10.3347/kjp.2017.55.5.513>
- Hawash, Y.A., Ismail, K.A., Saber, T., Eed, E.M., Khalifa, A.S., Alsharif, K.F., Alghamdi, S.A., Dahlawi, H.A., Alsanie, W. & Khalifa, A.M. (2020). Predominance of infection with *Blastocystis hominis* in patients with colorectal cancer and its association with high mucin content, infiltration of inflammatory cells and elevated serum tumor necrosis factor α . *Infectious Diseases in Clinical Practice* **20**: e32-e38. <https://doi.org/10.1097/IPC.0000000000000931>
- Hussain, A., Younis, E.Z., Elamami, A.H., Jelodar, M., Mishra, T. & Shivaramaiah, G. (2019). Prevalence of intestinal parasitic infestation among expatriate workers. *Cureus* **11**: e4849. <https://doi.org/10.7759/cureus.4894>
- Kotloff, K.L. (2017). The burden and etiology of diarrheal illness in developing countries. *Pediatric Clinics* **64**(4): 799-814. <https://doi.org/10.1016/j.pcl.2017.03.006>
- Makki, S.M. & Arafa, W.A.S. (2010). Parasitosis among apparently healthy immigrant workers at Dammam, Saudi Arabia. *Journal of the Egyptian Society of Parasitology* **40**: 311-320.
- Mehraj, V., Hatcher, J., Akhtar, S., Rafique, G. & Beg, M.A. (2008). Prevalence and factors associated with intestinal parasitic infection among children in an urban slum of Karachi. *PLoS ONE* **3**: e3680. <https://doi.org/10.1371/journal.pone.0003680>
- Meo, S.A. (2020). COVID-19 Pandemic: Saudi Arabia's role at national and international levels. *Journal of Diabetes Science and Technology* **14**: 758-759. <https://doi.org/10.1177/1932296820930068>
- Mohamed, R.T., El-Bali, M.A., Mohamed, A.A., Abdel-Fatah, M.A., El-Malky, M.A., Mowafy, N.M., Zaghlool, D.A., Bakri, R.A. & Al-Harhi, S.A. (2017). Subtyping of *Blastocystis* sp. isolated from symptomatic and asymptomatic individuals in Makkah, Saudi Arabia. *Parasites & Vectors* **10**: 174. <https://doi.org/10.1186/s13071-017-2114-8>
- Mohammad, K.A. & Koshak, E.A. (2011). A prospective study on parasites among expatriate workers in Al-Baha from 2009-2011, Saudi Arabia. *Journal of Egyptian Society of Parasitology* **41**: 423-432.

- Ngui, R., Lim, Y.A.L., Kin, L.C., Chuen, C.S. & Jaffar, S. (2012). Association between anaemia, iron deficiency anaemia, neglected parasitic infections and socioeconomic factors in rural children of West Malaysia. *PLoS Neglected Tropical Diseases* **6**: e1550. <https://doi.org/10.1371/journal.pntd.0001550>
- Ryan, E.T., Hill, D.R., Solomon, T., Endy, T.P. & Aronson, N. (2020). Hunter's tropical medicine and emerging infectious diseases. 10th edition. Amsterdam: Elsevier. <https://doi.org/10.1016/C2016-0-01879-X>
- Saaed, F.M. & Ongerth, J.E. (2019). *Giardia* and *Cryptosporidium* in children with diarrhea, Kufra, Libya, a North African migration route city. *International Journal of Hygiene and Environmental Health* **222**: 840-846. <https://doi.org/10.1016/j.ijheh.2019.04.006>
- Taha, H.A. (2013). Intestinal parasitic infections among expatriate workers in Al-madina Al-munawarah, Kingdom of Saudi Arabia. *Tropical Biomedicine* **30**: 78-88.
- Tyoalumun, K., Abubakar, S. & Christopher, N. (2016). Prevalence of intestinal parasitic infections and their association with nutritional status of rural and urban pre-school children in Benue State, Nigeria. *International Journal of MCH and AIDS* **5**: 146.
- Umar, M., Chen, X.Y., Osman, Y., Simayi, A., Hou, Y.Y., Maimaitiyiming, Y. & Xiao, N. (2016). Epidemiological survey on human intestinal protozoa in Xinjiang Uygur Autonomous Region in 2015. *Chinese Journal of Parasitology & Parasitic Diseases* **34**: 361-365.
- Wakid, M. (2020). Intestinal parasitic infection among middle school boy students in Jeddah, Saudi Arabia. *Parasitologists United Journal* **13**: 46-51. <https://doi.org/10.21608/puj.2020.24313.1061>
- Wakid, M.H. (2020). Prevalence of enteroparasites among non-Saudis in Bahrah, Saudi Arabia. *Cureus* **12**. <https://doi.org/10.7759/cureus.9253>
- Wasihun, A.G., Teferi, M., Negash, L., Marugán, J., Yemane, D., McGuigan, K.G., Conroy, R.M., Abebe, H.T. & Dejene, T.A. (2020). Intestinal parasitosis, anaemia and risk factors among pre-school children in Tigray region, northern Ethiopia. *BMC Infectious Diseases* **20**: 379. <https://doi.org/10.1186/s12879-020-05101-8>
- Yousry Hawash, L.S., Dorgham, A.S. & Mohammed, S. (2014). Prevalence of *Cryptosporidium*-associated diarrhea in a high altitude-community of Saudi Arabia detected by conventional and molecular methods. *The Korean Journal of Parasitology* **52**: 479-485. <https://doi.org/10.3347/kjp.2014.52.5.479>
- Zagloul, D.A., Khodari, Y.A., Gazzaz, Z.J., Dhafar, K.O., Shaker, H.A. & Farooq, M.U. (2011). Prevalence of intestinal parasites among patients of Al-Noor specialist hospital, Makkah, Saudi Arabia. *Oman Medical Journal* **26**: 182-185. <https://doi.org/10.5001/omj.2011.44>