International Journal of Health Systems and Medical Sciences
ISSN: 2833-7433
Volume 05 Number 01 (2026)
Impact Factor: 10.87
SJIF (2023): 3.656

www.inter-publishing.com

Article

Impact of Ascaris lumbricoides Infection on Inflammatory and Immune Biomarkers Among the Elderly Population

Qahtan Adnan Rasheed

1. Department of Medical Laboratory Techniques, College of Health and Medical Techniques, Middle Technical University, Baghdad, Iraq
* Correspondence: qahtan.adnan@mtu.edu.iq

Abstract: Background: Ascaris lumbricoides infestation is a common helminthic infection in endemic areas and can lead to a major effect on the inflammatory and immune biomarker status of the aging population, which already exhibits impaired immunosenescence and low-grade chronic inflammation. Aims of the study: This study aimed to evaluate the impact of Ascaris lumbricoides infection on inflammatory and immune biomarkers among the elderly population and to determine the association between parasitic load and systemic immune response alterations. Methodology: This case–control study was conducted from June 10, 2025, to January 2, 2026, to assess the impact of Ascaris lumbricoides infection on inflammatory and immune biomarkers in individuals aged ≥60 years. Seventy-five infected patients and 40 age-matched healthy controls were enrolled. Diagnosis was confirmed by stool microscopy and Kato–Katz quantification. Blood samples were collected for hematological analysis and measurement of CRP, ESR, cytokines (IL-6, TNF-α, IL-4, IL-10), and total IgE using ELISA and standard laboratory methods. Result: Baseline characteristics were comparable between groups, with no significant differences in age, BMI, sex distribution, hypertension, or diabetes. Infected elderly individuals showed significantly higher inflammatory markers (CRP, IL-6, TNF-α, ESR) and elevated immune biomarkers, including IgE, eosinophils, IL-4, and IL-10 ($p < 0.001$). Hematological changes included leukocytosis, lymphocytosis, reduced neutrophils, and mild anemia. Parasitic load positively correlated with CRP, IL-6, IgE, and eosinophils, indicating infection-intensity–dependent inflammatory and Th2 immune activation. Conclusions: Ascaris lumbricoides infection in the elderly significantly enhances systemic inflammation and Th2-mediated immune activation, likely due to persistent antigenic stimulation and age-related immune dysregulation, contributing to leukocytosis, eosinophilia, and mild anemia in an already vulnerable aging immune system.

Keywords: Ascaris lumbricoides, Elderly population, Inflammatory biomarkers, Th2 immune response, Parasitic load

Citation: Rasheed, Q. A. Impact of Ascaris lumbricoides Infection on Inflammatory and Immune Biomarkers Among the Elderly Population. International Journal of Health Systems and Medical Sciences 2026, 5(1), 95-102

Received: 10th Nov 2025
Revised: 21th Dec 2025
Accepted: 14th Jan 2026
Published: 21th Feb 2026

1. Introduction

Ascaris lumbricoides is among the most common soil-borne helminths in the world and a serious health issue to the people especially in developing countries where sanitation is substandard and access to clean drinking water is limited [1]. The number of people infected around the world is estimated to be hundreds of millions of people, with the greatest concentration being witnessed in the tropical and subtropical regions. Despite the common belief that the infection is a childhood morbidity factor, there is growing evidence that an older population, in endemic areas, is susceptible to the infection because of continuous exposure to the environment, impaired immune system, and physiological deterioration. This notwithstanding, the literature on helminth studies has traditionally included pediatric cohort studies, so there are critical knowledge gaps on the immunological effects of Ascaris infection among adults [2],[3].

A. lumbricoides life cycle constitutes ingestion of eggs of embryones, larvae development through the lungs, and maturation in the small intestine. This complicated migratory action subjects the host immune system to habitual antigenic stimulation leading to localized and systemic immune response [3]. A T helper 2 (Th2)-type immune response, characterized by elevated secretion of interleukin-4 (IL-4), interleukin-5 (IL-5), interleukin-13 (IL-13), immunoglobulin E (IgE), and eosinophilia is the classical response to helminth infections. Such responses play critical roles in the expulsion of parasites as well as repair of tissues but can also play a role in long term immune control and inflammatory changes [4].

Alongside Th2 polarization, helminth infections may trigger regulatory immune pathways that relate to interleukin-10 (IL-10) and transforming growth factor-beta (TGF-2) that restrain excessive inflammation and avoid tissue damage [5]. This immunomodulatory property has given rise to the hygiene hypothesis and autoimmune and allergic diseases may be suppressed by helminthic therapy. However, the immunity against Ascaris lumbricides is not suppressive consistently [6]. There may also be considerable systemic inflammation of the infection, which is manifested by high levels of acute-phase proteins including C-reactive protein (CRP), high erythrocyte sedimentation rate (ESR), and high levels of pro-inflammatory cytokines as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-alpha), depending on the severity of the infection, its chronology, and the nutritional status of the host, and genetic predisposition [7].

The immunology of the elderly population is unique. Immunosenescence is linked with aging, which is less adaptive and less naive T-cells generation, and the inability to clear pathogens. At the same time, older adults develop a persistent low-grade inflammatory condition known as inflammaging due to the constantly high levels of pro-inflammatory cytokines [8]. Such a dual phenomenon can change the host-parasite interactions, possibly increasing inflammatory reactions or disrupting the successful regulation of an immune response in helminth infection. Consequently, Ascaris infection in older individuals may not be immunologically tracked by the same patterns as it occurs in the younger population [9],[10].

In addition, the helminth infections may also cause hematological changes, including eosinophilia, leukocyte, and anemia. Although less so with blood-feeding parasites like hookworms, chronic intestinal inflammation, nutritional competition, and impaired micronutrient absorption caused by Ascaris may increase the severity of anemia in older people who already have a higher risk of it due to comorbidities and nutritional deficiencies in old age. Such changes can also have an additional effect on systemic inflammatory biomarkers and general immune homeostasis [11],[12].

The knowledge of the connection between infection with Ascaris lumbricoides and inflammatory and immune biomarkers in the elderly is especially significant due to a number of reasons. To begin with, chronic inflammation among elderly people is closely associated with heart diseases, metabolic illnesses, weakness, and mortality [13]. Second, immune dysregulation can have an impact on the predisposition to secondary infections and vaccine responses. Third, proper characterization of biomarker patterns may be used to differentiate between parasite-induced immune response and other chronic inflammatory diseases that occur in aging populations [14].

Although helminth infection is relatively common in endemic areas, little study has been done specifically on the cumulative inflammatory and immunological effect of the Ascaris lumbricoides infection in aging people. The bulk of available data are those based on children or mixed age groups, and it is hard to make extrapolation to older people [15]. As such, the current study was geared towards exploring the effects of Ascaris lumbricoides infection against major inflammatory and immune biomarkers in elderly population and specifically pro-inflammatory cytokines, Th2-related biomarkers, immunoglobulin E concentrations and hematological measurements. By clarifying these relationships, this research will contribute to a cumulatively improved comprehension of the hemodendosymbiotic immune modulation of helminths in elderly individuals as well as the direction of particular public health and clinical intervention in endemic localities.

2. Materials and Methods

The case-control analytical study was done between June 10, 2025, and January 2, 2026, to determine the effects of the Ascaris lumbricoides infection on inflammatory and immune biomarkers in the elderly population of 60 years and above. One hundred and fifty subjects were recruited and were split into two groups: 75 elderly patients with laboratory-proven Ascaris lumbricoides infection and 40 seemingly healthy age matching controls with negative stool analyses. The infection diagnosis was based on direct stool microscopy with saline and iodine wet mounts, then on formalin-ether concentration technique, and evaluation and quantification of the egg burden using the concentration technique, and the results were presented in the form of egg per gram (EPG) of stool to determine the extent of parasitic load. The inclusion criteria included: age (at least 60 years), patient group confirmed infection, and controls had negative parasitological findings; and exclusion criteria included coinfection with other intestinal parasites, recent acute infections, chronic inflammatory or autoimmune disease, malignancy, immunosuppressive treatment, and severe hepatic/renal dysfunction, and recent anti-helminthic treatment (last three months) to control confounding factors. Each participant had around 5-7 mL of venous blood aseptically collected; 2 mL of this sample was put in theory EDTA tubes to be subjected to the complete blood count test and the rest of the sample was collected in plain tubes where the serum was allowed to clot and then centrifuged at 3000 rpm and 10 minutes after which the separated serum was stored at -20 degrees Celsius awaiting analysis. Hematological parameters were measured on automated hematology analyzer and inflammatory biomarkers such as C-reactive protein (CRP) were measured on immunoturbidimetric methods, erythrocyte sedimentation rate (ESR) was measured by the Westerngren method and cytokines (IL- 6, TNF- alpha, IL-4 and IL-10) and total IgE were measured using standardized enzyme-linked immunosorbent assay (ELISA) kits as per the manufacturers protocols

Statistical analysis:

Data analysis was done by using the SPSS version 26. Continuous variables were reported as the mean standard deviation (SD), but categorical ones were reported in the form of frequencies and percentages. Normally distributed variables were tested through independent samples t-test and Pearson correlation analysis was carried out to determine the relationship between parasitic load and biomarkers. The statistical significance was taken as p-value less than 0.05.

Ethical approval:

The study was approved by the human ethics committee of Thi-qar health directorate, Alhabbobi teaching hospital, Everyone who took part in the study was told about it and asked to sign a consent form. The patient was also guaranteed that his information would be kept private.

3. Results and Discussion

Results

Baseline comparison between infected patients (n=75) and healthy controls (n=40)

Table 1 demonstrates that there were no statistically significant differences between Ascaris lumbricoides–infected elderly patients and healthy controls regarding age (67.4 ± 5.8 vs. 66.9 ± 6.1 years, $p = 0.648$) or BMI (26.1 ± 3.9 vs. 25.8 ± 4.2 kg/m^2, $p = 0.712$). The distribution of males and females was comparable between groups ($p = 0.821$). Similarly, the prevalence of hypertension (52.0% vs. 47.5%, $p = 0.657$) and diabetes mellitus (37.3% vs. 32.5%, $p = 0.604$) did not differ significantly. These findings indicate appropriate baseline matching between the two study groups.

Table 1. Sociodemographic and Clinical Characteristics of Elderly Participants with and without Ascaris lumbricoides Infection

Variable	Ascaris Patients (n=75)	Controls (n=40)	p-value
Age (years)	67.4 ± 5.8	66.9 ± 6.1	0.648
Male, n (%)	41 (54.7%)	21 (52.5%)	0.821
Female, n (%)	34 (45.3%)	19 (47.5%)	0.821
BMI (kg/m²)	26.1 ± 3.9	25.8 ± 4.2	0.712
Hypertension, n (%)	39 (52.0%)	19 (47.5%)	0.657
Diabetes Mellitus, n (%)	28 (37.3%)	13 (32.5%)	0.604

Serum inflammatory markers presented as mean ± standard deviation (SD)

As shown in Table 2, elderly patients infected with Ascaris lumbricoides exhibited significantly elevated inflammatory biomarkers compared to healthy controls. CRP levels were markedly higher in patients (14.8 ± 6.2 mg/L) than controls (4.9 ± 2.1 mg/L, $p < 0.001$). Similarly, IL-6 (22.5 ± 8.7 vs. 8.4 ± 3.6 pg/mL, $p < 0.001$) and TNF-α (18.3 ± 6.4 vs. 7.9 ± 2.8 pg/mL, $p < 0.001$) were significantly increased. ESR values were also substantially elevated in infected individuals (36.7 ± 11.2 vs. 15.6 ± 6.3 mm/hr, $p < 0.001$), indicating a pronounced systemic inflammatory response associated with parasitic infection.

Table 2. Comparison of Inflammatory Biomarkers between Elderly Patients with Ascaris lumbricoides Infection and Healthy Controls

Parameter	Patients (n=75)	Controls (n=40)	p-value
CRP (mg/L)	14.8 ± 6.2	4.9 ± 2.1	<0.001
IL-6 (pg/mL)	22.5 ± 8.7	8.4 ± 3.6	<0.001
TNF-α (pg/mL)	18.3 ± 6.4	7.9 ± 2.8	<0.001
ESR (mm/hr)	36.7 ± 11.2	15.6 ± 6.3	<0.001

Th2-associated cytokines and immunoglobulin levels expressed as mean ± standard deviation (SD)

Table 3 shows a marked elevation in immune response biomarkers among elderly patients infected with Ascaris lumbricoides compared to controls. Total IgE levels were significantly higher in patients (328.4 ± 115.7 IU/mL) than in healthy individuals (92.6 ± 41.3 IU/mL, $p < 0.001$). Eosinophil percentages were also substantially increased (8.9 ± 3.2% vs. 2.1 ± 1.0%, $p < 0.001$). Moreover, Th2-related cytokines IL-4 (16.2 ± 5.4 vs. 6.7 ± 2.3 pg/mL, $p < 0.001$) and IL-10 (12.4 ± 4.1 vs. 7.2 ± 2.6 pg/mL, $p < 0.001$) were significantly elevated, indicating a strong type-2 immune activation associated with helminth infection.

Table 3. Comparison of Immune Response Biomarkers in Elderly Individuals with Ascaris lumbricoides Infection and Healthy Controls

Parameter	Patients (n=75)	Controls (n=40)	p-value
Total IgE (IU/mL)	328.4 ± 115.7	92.6 ± 41.3	<0.001
Eosinophils (%)	8.9 ± 3.2	2.1 ± 1.0	<0.001
IL-4 (pg/mL)	16.2 ± 5.4	6.7 ± 2.3	<0.001
IL-10 (pg/mL)	12.4 ± 4.1	7.2 ± 2.6	<0.001

Complete blood count parameters expressed as mean ± standard deviation (SD)

Table 4 demonstrates significant hematological alterations among elderly individuals infected with Ascaris lumbricoides. Total WBC count was significantly higher in patients compared to controls (9.6 ± 2.3 vs. 6.8 ± 1.7 $\times 10^3/\mu L$, $p < 0.001$). In contrast, hemoglobin levels were significantly lower in infected participants (11.8 ± 1.4 vs. 13.2 ± 1.1 g/dL, $p < 0.001$), indicating mild anemia. Lymphocyte percentages were elevated in patients (34.5 ± 7.6% vs. 28.2 ± 6.9%, $p = 0.002$), whereas neutrophil percentages were significantly reduced

(51.2 ± 8.4% vs. 60.7 ± 7.5%, $p < 0.001$). These findings reflect infection-associated leukocytosis and immune modulation in the elderly population.

Table 4. Hematological Profile of Elderly Patients with Ascaris lumbricoides Infection Compared to Healthy Controls

Parameter	Patients (n=75)	Controls (n=40)	p-value
WBC (×10³/µL)	9.6 ± 2.3	6.8 ± 1.7	<0.001
Hemoglobin (g/dL)	11.8 ± 1.4	13.2 ± 1.1	<0.001
Lymphocytes (%)	34.5 ± 7.6	28.2 ± 6.9	0.002
Neutrophils (%)	51.2 ± 8.4	60.7 ± 7.5	<0.001

Pearson correlation analysis among infected participants (n = 75)

Table 5 reveals significant positive correlations between parasitic load and major inflammatory and immune biomarkers among infected elderly patients. Parasitic burden showed a moderate positive correlation with CRP ($r = 0.58$, $p < 0.001$) and IL-6 ($r = 0.49$, $p < 0.001$). A stronger association was observed with total IgE levels ($r = 0.71$, $p < 0.001$) and eosinophil percentage ($r = 0.64$, $p < 0.001$). These findings indicate that increasing infection intensity is directly associated with amplified systemic inflammation and enhanced Th2-mediated immune activation.

Table 5. Correlation between Parasitic Load and Key Inflammatory and Immune Biomarkers in Elderly Patients with Ascaris lumbricoides Infection

Parameter	r-value	p-value
Parasitic Load vs CRP	0.58	<0.001
Parasitic Load vs IgE	0.71	<0.001
Parasitic Load vs IL-6	0.49	<0.001
Parasitic Load vs Eosinophils	0.64	<0.001

Discussion:

The current paper has shown that the elderly patients with Ascaris lumbricoides showed a strong systemic inflammatory and Th2-biased immune response as compared to the healthy controls. Notably, sociodemographic and clinical characteristics (age, sex ratio, BMI, hypertension, and diabetes) at baseline were too similar between groups, which limited the effects of confounding bias and enhanced the internal validity of reported biomarker differences. This similarity of baselines makes it possible to suggest that occurrence of helminth infection in the first place and lack of demographic/metabolic variations could be considered to explain the presence of the identified immunological and hematological changes [16].

Infected elderly subjects had a high increased inflammatory biomarker (CRP, IL-6, TNF-a, and ESR). These findings are in accordance with the current researches that have indicated that helminth infections can cause systemic inflammatory responses, particularly in case of chronic or heavy infections [17]. In spite of the conventionally recognized anti-inflammatory or immunomodulatory effects of helminths, in particular, through IL-10 production, multiple studies have demonstrated that A. lumbricoides larvae can stimulate acute-phase reactants and pro-inflammatory cytokines during tissue migration [18]. The high levels of IL-6 and TNF-a in our research could be a result of continuous intestinal mucosal irritation and immune stimulation, particularly in older persons with the characteristics of inflammaging inflammation state chronic low-grade inflammation [19]. Such baseline of age-related inflammation may enhance a response of cytokines to parasitic antigens, which can be attributed to the vastness of the differences between this condition and controls [19].

On the other hand, other reports indicate that chronic helminth infections subdue the systemic inflammation by regulation pathways and can actually decrease autoimmune or allergic diseases [20]. This difference between our study and those studies could be connected with age groups differences, infection severity, chronicity, and comorbidity.

Numerous immunosuppressive observations in young adult or pediatric groups were observed, but the immune system of the elderly is an immunosenescence state with dysregulated cytokine secretions. Hence, rather than an exclusively regulatory phenotype, older patients can have a combination of inflammatory-regulatory phenotype [21].

We also found significant increases in total IgE and eosinophil percentages and Th2-related cytokines (IL-4 and IL-10) in infected patients. This is much in line with already established immunological paradigms of helminth infection, in which Th2 polarization is predominant [22]. B-cell class switching to IgE is stimulated by IL-4, whereas eosinophil activation and survival is generally facilitated by IL-5 (which was not measured in this case). The typical responses to A. lumbricoides include elevated IgE and eosinophilia which have been repeatedly observed in endemic populations [23]. This close positive relationship between parasitic load and IgE ($r = 0.71$) also supports the idea that the response of humoral hypersensitivity to antigenic burden is dose-dependent, which is further supported by the close positive relationship between parasitic load and IgE ($r = 0.71$).

Interestingly, IL-10 was much-increased as well. Although the IL-10 is traditionally anti-inflammatory, its rise during helminth infection is viewed as a regulating response that supports tissue damage due to excessive tissue inflammation by Th2 [24,25]. According to some studies, there is an increase in the levels of IL-10 that are reported to be related to chronic stages of infection and indicate an adaptive immune tolerance phenomenon [26]. Disagreements in studies can be based on the type of infection and its acute, chronic, or repetitive occurrence, genetic and environmental exposures.

Hematological evidence showed the presence of leukocytosis, lymphocytosis and low hemoglobin in the infected people. WBC count is higher which is consistent with immune activation caused by infection [27], and higher percentages of lymphocytes indicate adaptive immune activities. The lower percentage of neutrophils relative to the controls might be an indication of lymphocyte and eosinophil responses characteristic in parasitic and not bacterial infections. Subclinical blood loss (helminth burden) may be associated with mild anemia in patients (reduced hemoglobin) and may be caused by chronic inflammation of the intestine or nutrient malabsorption [28]. Though A. lumbricoides is not a blood-feeding parasite such as hookworm, chronic gastrointestinal inflammation and micronutrient (e.g. iron, vitamin A) competition could also lead to anemia in older adults with marginal nutritional reserves [29].

The biological plausibility of these findings is further proven by the correlation analysis. Strong positive correlations between parasitic load and CRP, IL-6, IgE, and eosinophils point to these specific correlations as being dependent on the intensity of infection. This is a similar dose-response pattern that has been observed in the epidemiology of helminth whereby an increasing number of egg counts has been related to an increasing magnitude of Th2 cytokine response and an increasing magnitude of IgE titers [30,31]. The support of these correlations to the causal relationship between parasite burden and immunomodulation is possible on the systemic scale [31].

However, there are some conflicting results that indicate the low level of systemic inflammation in steady helminthiasis [32]. These discrepancies may be explained by variations in the species of parasites, host age, nutritional status, microbiome composition and coinfections. Additionally, helminth immunology research to date has underrepresented the use of older populations and the immune system remodelling during old age may significantly alter the host-parasite relationship compared to younger populations [33].

4. Conclusion

On the whole, the current results suggest that the Ascaris lumbricoides infection in older patients could be viewed as a combination of pro-inflammatory and Th2-regulatory immune responses, accompanied by a hematological change and the increase in the level of biomarkers depending on the level of the infection. This effect of helminth-induced immune polarization on immune dysregulation in old age is likely the reason behind the scale and trend of these alterations. These findings improve the comprehension of the immunobiology of helminth in older patients and accentuate the necessity of age-stratified immunological monitoring in the endemic areas.

REFERENCES

[1] S. M. Fletcher, J. M. Stark, J. Harkness, and J. Ellis, "Enteric protozoa in the developed world: A public health perspective," Clinical Microbiology Reviews, vol. 25, no. 3, pp. 420–449, 2012.
[2] S. Maharjan, "Closing the nutrient loop with ecological sanitation in Nepal," 2020.
[3] A. F. R. Neto et al., "Why are we still a worm world in the 2020s? An overview of risk factors and endemicity for soil-transmitted helminthiasis," Acta Parasitologica, vol. 68, no. 3, pp. 481–495, 2023.
[4] F. H. Stewart, "On the life-history of Ascaris lumbricoides," British Medical Journal, vol. 2, no. 2896, p. 5, 1916.
[5] A. L. Willingham and U. Kishore, "Innate immune response," in Innate Immunity: Pattern Recognition and Effector Mechanisms, 2025, p. 251.
[6] B. Ayelign et al., "Helminth induced immunoregulation and novel therapeutic avenue of allergy," Journal of Asthma and Allergy, vol. 13, pp. 439–451, 2020.
[7] A. Rajamanickam and S. Babu, "Monocytes/macrophages in helminth infections: Key players in host defence, inflammation, and tissue repair," in Monocytes and Macrophages in Development, Regeneration, and Disease, 2024, pp. 315–340.
[8] C. Aranzamendi, L. Sofronic-Milosavljevic, and E. Pinelli, "Helminths: Immunoregulation and inflammatory diseases—Which side are Trichinella spp. and Toxocara spp. on?," in Immunoregulation by Trichinella spiralis: Benefits for Parasite and Host, vol. 12, 2012, p. 9.
[9] L. J. Wammes et al., "Helminth therapy or elimination: Epidemiological, immunological, and clinical considerations," The Lancet Infectious Diseases, vol. 14, no. 11, pp. 1150–1162, 2014.
[10] M. Alghanmi et al., "Helminth-derived proteins as immune system regulators: A systematic review of their promise in alleviating colitis," BMC Immunology, vol. 25, no. 1, p. 21, 2024.
[11] R. T. M. Alam, E. A. A. Hassanen, and S. A. M. El-Mandrawy, "Heamonchus contortus infection in sheep and goats: Alterations in haematological, biochemical, immunological, trace element and oxidative stress markers," Journal of Applied Animal Research, vol. 48, no. 1, pp. 357–364, 2020.
[12] E. C. Ngetich, "Haematological parameters by age and sex of asymptomatic indigenous cattle and sheep infected with gastrointestinal parasites in Kerio Valley, Kenya," 2019.
[13] S. Zaman et al., "Measurement of Ascaris lumbricoides IgG antibody, associated risk factors and identification of serum biochemical parameters as biomarkers of pathogenicity: Among patients with gastrointestinal complains in Pakistan," pp. 10–25, 2018.
[14] B. Zhang and D. Gems, "Gross ways to live long: Parasitic worms as an anti-inflammaging therapy?," eLife, vol. 10, e65180, 2021.
[15] L. Magalhães et al., "Immunological underpinnings of Ascaris infection, reinfection and co-infection and their associated co-morbidities," Parasitology, vol. 148, no. 14, pp. 1764–1773, 2021.
[16] C. Rennie et al., "The impact of helminth infection on the incidence of metabolic syndrome: A systematic review and meta-analysis," Frontiers in Endocrinology, vol. 12, Art. no. 728396, 2021.
[17] J. A. Khan, "Role of CRP in monitoring of acute pancreatitis," in Clinical Significance of C-Reactive Protein. Singapore: Springer, 2020, pp. 117–173.
[18] C. Gau and C. Wu, "Sunday, 2 June 2019 TPS 01 clinical immunology from autoimmunity to cancer," Allergy, vol. 74, pp. 376–853, 2019.
[19] A. Gherasim, A. Dao, and J. A. Bernstein, "Confounders of severe asthma: Diagnoses to consider when asthma symptoms persist despite optimal therapy," World Allergy Organization Journal, vol. 11, no. 1, p. 29, 2018.
[20] R. M. Maizels, "Regulation of immunity and allergy by helminth parasites," Allergy, vol. 75, no. 3, pp. 524–534, 2020.
[21] L. Magalhães et al., "Immunological underpinnings of Ascaris infection, reinfection and co-infection and their associated co-morbidities," Parasitology, vol. 148, no. 14, pp. 1764–1773, 2021.
[22] C. N. Bock, Identification and Characterization of Murine and Human Th2/1 Hybrid Cells in Th2-Driven Diseases. Dissertation, 2019.

[23] D. S. Mandlik and S. K. Mandlik, “New perspectives in bronchial asthma: Pathological, immunological alterations, biological targets, and pharmacotherapy,” Immunopharmacology and Immunotoxicology, vol. 42, no. 6, pp. 521–544, 2020.
[24] N. P. M’bondoukwé et al., “Circulating IL-6, IL-10, and TNF-alpha and IL-10/IL-6 and IL-10/TNF-alpha ratio profiles of polyparasitized individuals in rural and urban areas of Gabon,” PLoS Neglected Tropical Diseases, vol. 16, no. 4, e0010308, 2022.
[25] P. Arora et al., “Body fluid from the parasitic worm Ascaris suum inhibits broad-acting pro-inflammatory programs in dendritic cells,” Immunology, vol. 159, no. 3, pp. 322–334, 2020.
[26] S. Almeida, P. Nejsum, and A. R. Williams, “Modulation of human macrophage activity by Ascaris antigens is dependent on macrophage polarization state,” Immunobiology, vol. 223, no. 4–5, pp. 405–412, 2018.
[27] S. H. Mohammed, A. S. Jabbr, and N. K. Ibrahim, “Impact of parasitic infection with Ascaris lumbricoides on pulmonary function tests in asthmatic and non-asthmatic children,” Respiratory Medicine Case Reports, vol. 34, Art. no. 101552, 2021.
[28] V. Luber et al., “Excretion of Ascaris lumbricoides following reduced-intensity allogeneic hematopoietic stem cell transplantation and consecutive treatment with mebendazole,” Transplant Infectious Disease, vol. 22, no. 1, e13224, 2020.
[29] V. Mehta et al., “Bronchial mucus plug mimicking fragmented Ascaris worm: An ambiguous case presentation,” Journal of Family Medicine and Primary Care, vol. 11, no. 7, pp. 4019–4022, 2022.
[30] J. Mamum, Investigating Systemic Immune Biomarkers in a Controlled Human Hookworm Infection Model. Dissertation, Open Access Te Herenga Waka–Victoria University of Wellington, 2022.
[31] M. A. Abo-Zaid and A. A. Hamdi, “Evaluation of immune response and haematological parameters in infected male albino rats by giardiasis,” Parasite Immunology, vol. 44, no. 4–5, e12908, 2022.
[32] G. A. Zavala et al., “Intestinal parasites: Associations with intestinal and systemic inflammation,” Parasite Immunology, vol. 40, no. 4, e12518, 2018.
[33] B. de Gier et al., “Soil-transmitted helminth infections and intestinal and systemic inflammation in schoolchildren,” Acta Tropica, vol. 182, pp. 124–127, 2018.