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Modulation of circulating cytokine production in alcoholic patients infected with *Strongyloides stercoralis*

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Abstract

Strongyloidiasis control is associated with a Th2 immune response. However, alcohol ingestion plays an important role in modulating the immune system. The aim of this study is to evaluate the occurrence of *Strongyloides stercoralis* infection in alcoholic patients, the levels of circulating cytokines (IFN-γ, IL-2, IL-4, IL-5, IL-10, IL-15 and IL-17), and its correlation with modulation of parasitic load in alcoholic individuals infected with *S. stercoralis*. A total of 336 alcoholic patients, treated at the Alcoholic Care and Treatment Center were included in this study. The cytokine levels were measured by a commercial ELISA in 80 sera divided into four groups with 20 individuals each: alcoholics infected (ASs+) and not infected (ASs-) with *S. stercoralis* and non-alcoholics infected (NASs+) and not infected (NASs-) with the helminth. *S. stercoralis* frequency in alcoholic patients was 16.1% (54/336). The parasitic load varied from 1 to 546 larvae/g of faeces, median and interquartile range (IQR) of 9 and 1.0–62.5 larvae/g of faeces, while in non-alcoholic individuals the parasitic load was less than 10 larvae/g of faeces. Levels of circulating IL-4 were significantly higher in ASs+ when compared with NASs- group ($p < .05$). An inverse correlation between serum levels of IFN-γ and parasitic load in alcoholic patients infected with *S. stercoralis* was observed ($r = -601$; $p < 0.01$). These results suggest that modulation of IFN-γ production occurs in alcoholic individuals with high parasitic burden.

KEYWORDS
alcoholics, cytokin, *Strongyloides stercoralis*

1 | INTRODUCTION

Strongyloides stercoralis infection is more prevalent in tropical and subtropical countries and affects approximately 600 million people worldwide.[1] However, this number is underestimated, due to the low sensitivity of the diagnostic methods used. Generally, *S. stercoralis* infection is asymptomatic or presents mild gastrointestinal symptoms. However, in immunocompromised patients, the infection can develop into a severe form, hyperinfection and dissemination, which can potentially be fatal.[2] Conditions associated with alteration in the immune response, such as high dose of corticosteroids, alcoholism, and HTLV-1 coinfection can lead to severe strongyloidiasis.[2–5] Alcohol has an important role in modulating the immune system, both in the innate and adaptive response. The effects of alcohol vary according to acute or chronic exposure.[6] Prolonged alcohol consumption results in an increased production of TNF-α by macrophages and the activation of the inflammatory cascade.[6,7] However, moderate alcohol intake has no significant effect on the serum levels of these cytokines.[8]

The prevalence of *S. stercoralis* infection in alcoholic patients varies from 14.5% to 40.2%.[3–5,9–11] In Latin America, alcoholism is higher than in the rest of the world. In major Brazilian cities it reaches 9.4% of the population, being one of the main causes of morbidity and mortality.[12,13] The alcoholism pathogenesis is complex, with several harmful consequences for the human body and, generally, it is associated with hepatic alterations, from moderate to severe, and other comorbidities, such as anaemia and malnutrition[5,14,15] Moreover, the association of *S. stercoralis* infection and alcoholism increases endogenous cortisol and parasitic load, as observed by our research group.[16] The social vulnerability of alcoholics possibly increases the exposure to *S. stercoralis* infection and, once infected, the endogenus cortisol and its metabolites stimulates the transformation of rhabditiform (L1) larvae into filariform (L3) larvae, leading to internal autoinfection and the consequent increase in the parasitic burden,[4,5,17] by mimetizing the effect of ecdysone, a parasitic hormone that stimulates the transformation of rhabditiform to filariform infective larvae, producing hyperinfection and parasite dissemination. We have recently demonstrated that alcoholic patients infected with *S. stercoralis* present a lower production of specific IgE and IgG1, compared to non-alcoholic individuals.[3] IgE is an important immunoglobulin in the immune response to *S. stercoralis* infection, as it is thought to mediate mast cell and eosinophil degranulation, which may lead to parasite expulsion.[18]

It has been suggested that molecules secreted by helminths can modulate the immune response to autoimmune and inflammatory diseases.[16] The *S. stercoralis* infection usually stimulates a Th2 cellular response resulting in a predominance of cytokines, such as IL-4, IL-5 and IL-13[19] and increased levels of IL-10, which are crucial in the host defence against *S. stercoralis* infection. However, there is little scientific evidence associating the control of *S. stercoralis* infection by cytokines circulating response. In this way, the aim of this study was to evaluate the occurrence of *S. stercoralis* infection in alcoholic patients, the levels of circulating cytokines (IFN-γ, IL-2, IL-4, IL-5, IL-10, IL-15 and IL- 17) and its correlation with the parasitic load.

2 | MATERIALS AND METHODS

2.1 | Sampling

This was a cross-sectional study conducted with 336 male patients, aged 20–65 years-old, clinically diagnosed as alcoholics, and treated at the Alcoholic Care and Treatment Center (Centro de Acolhimento e Tratamento de Alcoolistas–CATA) of the Charitable Works Foundation of Sister Dulce (Obras Sociais Irmã Dulce–OSID), Salvador, Bahia, Brazil, from April 2017 to August 2018. Non-alcoholic male patients, in the same age range as the alcoholic group, were selected among the individuals attended at the Laboratory of Clinical and Toxicological Analysis of the Faculty of Pharmacy, Federal University of Bahia, Brazil, in the same period. Cytokine evaluation was conducted on 80 individuals who were divided into four groups and paired by age as follows: (1) 20 alcoholic patients infected with *S. stercoralis* (ASs+) and (2) 20 alcoholic patients non-infected with *S. stercoralis* (ASs-). In the same way, infected and non-infected non-alcoholic individuals were matched: (3) 20 non-alcoholics infected with *S. stercoralis* (NASs+) and 20 non-infected (NASs-).

Patients with diabetes, autoimmune diseases and infected with viral hepatitis B and C, HIV and HTLV and/or using immunosuppressive drugs were excluded from the study.

This study was approved by the Research Ethics Committee of the Nursing School at the Federal University of Bahia, Brazil, number 367.464. All study participants signed an informed consent form.

2.2 | Parasitological diagnosis and quantification of the parasitic burden in *S. stercoralis* infection

The parasitological diagnosis was performed using three different methods (spontaneous sedimentation, Baermann-Moraes and agar plate culture).[20–22] Three stool samples from each patient were

TABLE 1 Serum levels of cytokines in alcoholic and non-alcoholic patients infected and non-infected with *Strongyloides stercoralis*.

	Serum levels of cytokines (*g*-mean [95% CI])			
	Alcoholics *S. stercoralis* infection		Non-alcoholics *S. stercoralis* infection	
Cytokines (pg/ml)	Positive (ASs+) ($n = 20$)	Negative (ASs−) ($n = 20$)	Positive (NASs+) ($n = 20$)	Negative (NASs−) ($n = 20$)
IFN-γ	36.2 (22.7–57.7)	40.9 (30.2–55.4)	42.7 (30.9–58.9)	27.1 (16.5–44.6)
IL-2	25.2 (20.0–31.7)	23.0 (18.7–28.3)	22.4 (16.9–29.8)	27.8 (17.8–43.4)
IL-17	19.2 (14.2–25.8)	19.2 (14.2–25.9)	17.7 (14.3–21.8)	28.2 (17.2–46.1)
IL-15	47.0 (37.5–59.1)	34.3 (27.8–42.3)	43.8 (33.9–56.4)	42.6 (31.8–57.1)
IL-10	268.0 (186.1–385.9)	297.4 (272.5–324.6)	200.0 (135.6–294.9)	292.6 (252.0–339.6)
IL-4*	33.3 (31.4–35.2)	32.4 (30.8–34.0)	31.2 (31.2–31.2)	39.1 (33.2–46.0)
IL-5	43.9 (27.5–70.1)	57.5 (35.5–93.1)	70.7 (41.2–121.3)	47.9 (29.8–77.0)

*$p < .05$, Kruskall-Wallis test (ASs+ vs. NASs−).

collected on alternate days. *S. stercoralis* parasitic load was quantified with the Baerman-Moraes method using 1 g of faeces.

2.3 | Serum cytokine levels

The cytokines IFN-γ, IL-2, IL-4, IL-5, IL-10, IL-15 and IL-17 were measured using the ELISA method, according to the manufacturer's information (R&D Systems, Inc., USA).

2.4 | Statistical analysis

The data were analysed using the GraphPad Prism 5.0 program (GraphPad, San Diego, CA, USA). Fisher's test was used for comparisons between frequencies and proportions. Cytokine levels were expressed as geometric mean (*g*-mean) and a 95% of confidence interval (CI). A comparison between more than two groups was assessed by Kruskal-Wallis Test with Dunn's Multiple Comparison Test. The Mann–Whitney Test was used to compare levels of cytokines

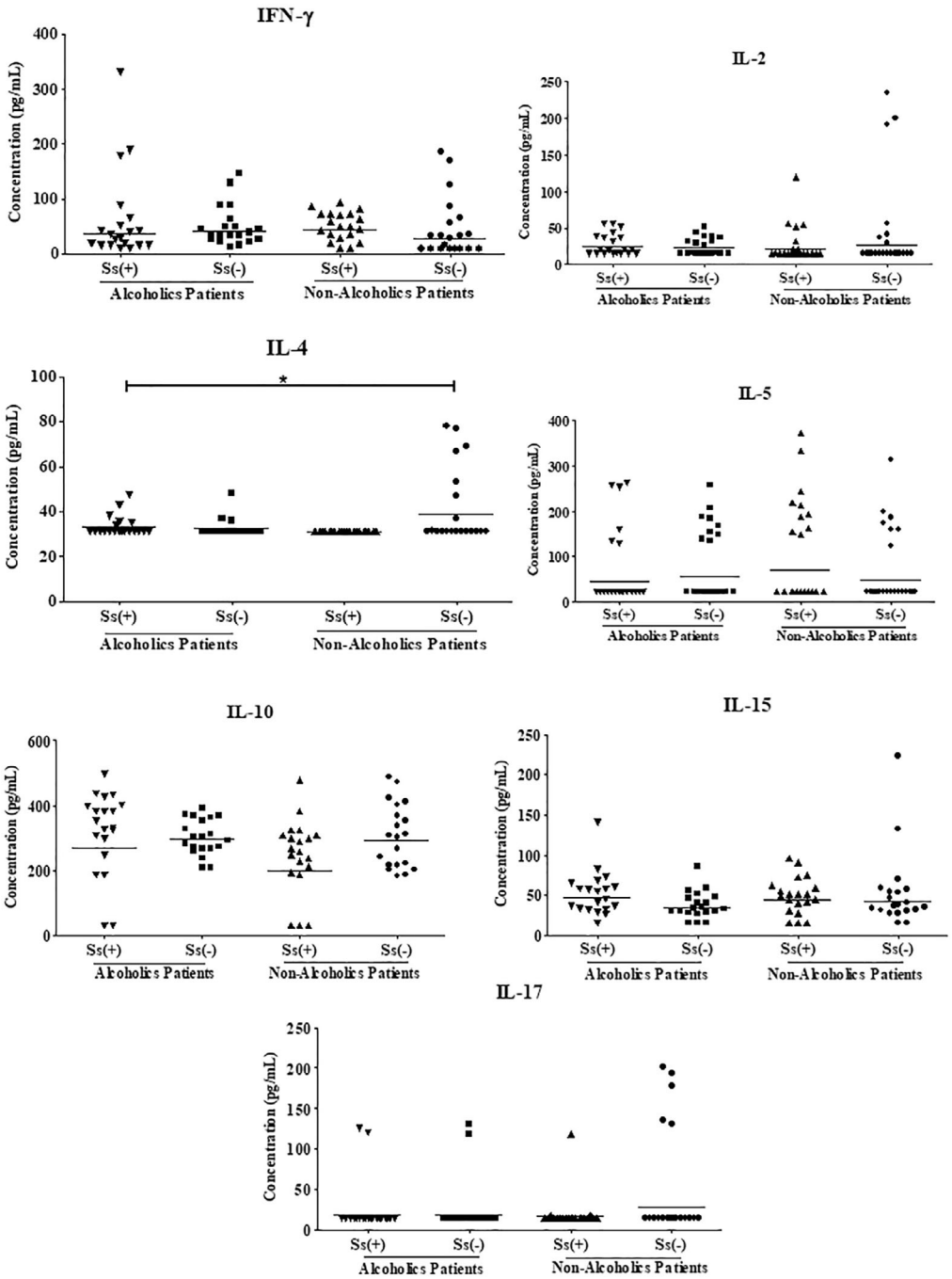

FIGURE 1 Cytokine levels (pg/ml) in serum samples from alcoholic patients, infected (ASs+, $n = 20$) and non-infected with *Strongyloides stercoralis* (Ass–, $n = 20$) and non-alcoholic patients infected (NASs+, $n = 20$) and non-infected with *S. stercoralis* (NASs-, $n = 20$). *p <.05, Mann–Whitney test. Horizontal bars (in the graph) represent the geometric means.

between individual infected with low or high parasite load. Spearmann's correlation was used to assess the correlation of parasitic load and cytokine concentration. All probabilities of the tests were performed to a 95% significance level. Statistically significant differences were considered when the *p*-value was less than .05.

Strongyloides stercoralis parasitic load was divided into two groups: <10 larvae/g of faeces and ≥10 larvae/g of faeces. This classification was based on our experience in the laboratory routine, where it was observed that 95% of asymptomatic immunocompetent patients had less than 10 larvae/g of faeces.

3 | RESULTS

Strongyloides stercoralis was the most frequent pathogenic parasite in alcoholics patients treated at the Centro de Acolhimento e Tratamento de Alcoolistas (CATA), Salvador, Bahia, Brazil ($n = 336$), 16.1% (54/336), followed by helminhts such as, hookworm, 4.5% (15/336), *Schistosoma mansoni* 2.1%, (7/336) and *Ascaris lumbricoides* 1.2% (4/336). Among the potentially pathogenic intestinal protozoa, *Giardia duodenalis* was the most frequent, 1.5% (5/336) followed by *Entamoeba histolytica/dispar/moshkovskii*, 1.2% (4/336). The frequency of other pathogenic parasites was less than 1%. (Table S1).

The cytokines IFN-γ, IL-2, IL-15 IL-17 and IL-10 did not show significant differences between groups, although the levels of IL-17 and IL-10 were slightly lower in NASs+ group (Table 1). The IL-4 levels were higher in NASs- (39.1 pg/ml) when compared with ASs+ individuals (33.3 pg/ml, $p < .05$). IL-5 was higher in NASs + when compared to ASs+, although it was not significant (Table 1 and Figure 1). An inverse correlation between IFN-γ serum concentration (pg/ml) and parasitic load in alcoholic patients infected with *S. stercoralis* was observed (Table 2).

Strongyloides stercoralis parasitic load in alcoholic patients varied from 1 to 546 larvae/g of faeces, median and interquartile range (IQR) of 9 and 1.0–62.5 larvae/g of faeces, while in non-alcoholic individuals the parasitic load was less than 10 larvae/g of faeces. IFN-γ levels presented an inverse correlation with parasitic load ($r = -0.601$). In the groups of individuals with an excretion less than and greater than 10 larvae/g of faeces, the levels of IFN-γ were 56.7 and 18.5 pg/ml, respectively ($p < .05$) (Table 2). In two patients with a parasitic load of 171 and 546 larvae per g/faeces, the levels of IL-5 were elevated, 259 and 129 pg/ml, respectively, when compared with patients with a parasitic load of ≤124 larvae per g/faeces (63.3 ± 81.6 pg/ml).

4 | DISCUSSION

A high frequency of parasitic infections is associated with inadequate sanitary conditions and low socioeconomic status, mainly in underdeveloped and developing countries, where the temperature and humidity provide a suitable environment for the transmission of enteroparasites. *S. stercoralis* infection in immunocompromised patients can lead to severe hyperinfection and/or dissemination of strongyloidiasis.[4,9,17]

TABLE 2 Correlation between serum cytokine concentration (pg/ml) and parasitic load in alcoholic patients infected with *S. stercoralis* ($n = 20$).

Parasitic load	Patients, *n* (%)	Cytokines serum levels (*g*-mean [95% CI])						
		IFN-γ*	IL-2	IL-17	IL-15	IL-10	IL-4	IL-5
≤10	12 (60%)	56.7 (30.9–103.8)	23.2 (16.6–32.3)	22.7 (13.0–39.9)	52.6 (39.6–70.0)	228.0 (115.2–451.0)	33.2 (30.4–36.2)	42.5 (21.2–85.1)
>10	8 (40%)	18.5 (10.9–31.4)	29.9 (19.9–44.8)	15.6 (15.6–15.6)	41.5 (25.5–67.5)	326.4 (257.1–414.3)	33.7 (30.4–37.4)	49.7 (20.5–120.3)
r[a]		−0.601**	0.327	−0.410	−0.054	−0.100	0.148	0.129

*$p < .01$, Mann–Whitney test (low vs. high parasite load). [a]Spearmann's correlation test (**$p < .01$).

Studies from our laboratory reported a frequency of *S. stercoralis* infection in alcoholic patients varying from 14.5% to 23.5%.[3,4,9,17] Also, our research demonstrated that alcoholics excrete a higher number of parasites in the faeces when compared to non-alcoholic patients.[17] In this study, the frequency of *S. stercoralis* infection was 16.1% (54/336). In addition, in agreement with previous data, a high parasitic burden in several patients was observed. One possible mechanism in the enhancement of *S. stercoralis* excretion is the increased level of endogenous cortisol and its metabolites in chronic alcohol abusers. Cortisol presents an effect similar to ecdysone, a parasitic hormone that stimulates the transformation of rhabditiform to filariform infective larvae, leading to internal autoinfection and the consequent increase in the parasitic burden.[5]

Alcohol plays an important role in the modulation of the immune system, in both innate and adaptive responses. The effects vary according to acute or chronic exposure.[6] Our results demonstrate that the median levels of IFN-γ, IL-2, IL-5, IL-10, IL-15 and IL-17 were similar between all groups of alcoholics and non-alcoholics, infected or not, with *S. stercoralis*. Although, there were no differences in the IFN-γ levels among the groups, it is interesting to note the inverse correlation between IFN-γ concentrations and parasitic load in ASs+, described here for the first time, to our knowledge. This result suggests that a high parasitic load (>10 larvae g/faeces) may be required to down-regulate IFN-γ production. Indeed, a level about three times higher of serum IFN-γ was observed in patients with lower parasitic load (≤10 larvae g/faeces; 56.7 pg/ml), when compared with higher parasitic load individuals (>10 larvae g/faeces; 18.5 pg/ml). A higher number of patients is required to verify this finding. Neupane et al. showed that patients with alcoholism and depression comorbidity had high levels of IL-6, IFN-γ and TNF, but not IL-10, when compared with alcoholic individuals without depression, which suggests the depression factor may contribute to an increase of these cytokines through stress.[23] Although it is not statistically significant, IL-17 also presented a inverse correlation tendency with the excretion of *S. stercoralis* ($r = -0.410$). We have previously observed that among the cytokines analysed, only IL-17 increased 19 times after the treatment of strongyloidiasis in a hyperinfected patient with HTLV-1.[24] The stimulator-regulatory balance of the cytokine production network in comorbidities must be analysed by taking into consideration multiple factors that may interfere with the fine regulation of immune responses.

IL-15 was discovered by its structural similarity to IL-2 and is produced by multiple tissues.[25] Rajamanickam et al. demonstrated that the levels of IL-15 decreased in the sera of patients infected with *S. stercoralis*.[26] Our results showed no differences in IL-15 production between all groups of alcoholics and non-alcoholics, infected or not, with *S. stercoralis*. In this context, it is possible that the consumed amount of alcohol that was not measured in the alcoholic patients may have modulated the immune response.

In our study, lower IL-4 levels were observed in alcoholic individuals infected with *S. stercoralis* when compared with non-alcoholic non-infected individuals. This suggests an alteration of IL-4 production only when both alcoholism and infection are present. In relation to IL-5 levels, no statically significant differences among groups were observed. However, in two alcoholic patients with a high parasitic load, 171 and 546 larvae/g of faeces, had the highest IL-5 levels observed, 259 and 129 pg/ml, respectively. This could indicate that alcohol does not necessarily suppress the production of IL-5 induced by *Strongyloides* infection, especially in high parasite load hosts. This finding will be a subject of further studies.

Ribeiro et al demonstrated an increase in T regulatory cells in alcoholic patients, both infected and non-infected, with *S. stercoralis*, as well as in non-alcoholic infected individuals,[27] which suggests that both alcoholism and *S. stercoralis* infection increase the frequency of these cells. In this study, the levels of IL-10 in alcoholic patients infected or non-infected with *S. stercoralis* did not show statistical differences when compared to non-alcoholic groups. The differences observed between studies is possibly due to the different methodologies applied, as the increase in the number of T regulatory cells does not necessarily reflect the levels of circulating IL-10.

In conclusion, our results suggest that a modulation of IFN-γ production occur in alcoholic individuals with high parasitic burden.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/pim.12977.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author and may be obtained upon request.

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REFERENCES

1. Buonfrate D, Bisanzio D, Giorli G, et al. The global prevalence of *Strongyloides stercoralis* infection. *Pathogens*. 2020;9:468.

2. Marcos LA, Terashima A, Canales M, Gotuzzo E. Update on Strongyloidiasis in the immunocompromised host. *Curr Infect Dis Rep*. 2011; 13:35-46.
3. De Souza JN, Cruz AV, Araújo WAC, et al. Alcohol consumption alters anti-*Strongyloides stercoralis* antibodies production. *Immunobiology*. 2019;225:151898. doi:10.1016/j.imbio.2019.151898
4. de Souza JN, Oliveira CL, Araújo WAC, et al. *Strongyloides stercoralis* in alcoholic patients: implications of alcohol intake in the frequency of infection and parasite load. *Pathogens*. 2020;9:422.
5. Teixeira MCA, Pacheco FTF, Souza JN, Silva MLS, Inês EJ, Soares NM. *Strongyloides stercoralis* infection in alcoholic patients. *Biomed Res Int*. 2016;2016:1-11.
6. Crews FT, Bechara R, Brown LA, et al. Cytokines and alcohol. *Alcohol Clin Exp Res*. 2006;30:720-730.
7. Mandrekar P, Catalano D, Dolganiuc A, Kodys K, Szabo G. Inhibition of myeloid dendritic cell accessory cell function and induction of T cell anergy by alcohol correlates with decreased IL-12 production. *J Immunol*. 2004;173:3398-3407.
8. Gonzalez-Quintela A, Campos J, Loidi L, Quinteiro C, Perez LF, Gude F. Serum TNF-α levels in relation to alcohol consumption and common TNF gene polymorphisms. *Alcohol*. 2008;42:513-518.
9. Silva MLS, Inês EJ, Souza JN, et al. Influence of parasite load on the diagnosis and occurrence of eosinophilia in alcoholic patients infected with *Strongyloides stercoralis*. *J Helminthol*. 2019;93:21-25.
10. Marques CC, Zago-Gomes M d P, Gonçalves CS, Pereira FEL. Alcoholism and *Strongyloides stercoralis*: daily ethanol ingestion has a positive correlation with the frequency of Strongyloides larvae in the stools. *PLoS Negl Trop Dis*. 2010;4:e717.
11. Zago-Gomes MP, Aikawa KF, Perazzio SF, Gonçalves CS, Pereira FEL. Prevalence of intestinal nematodes in alcoholic patients. *Rev Soc Bras Med Trop*. 2002;35:571-574.
12. Galduróz JCF, Caetano R. Epidemiology of alcohol use in Brazil. *Rev Bras Psiquiatr*. 2004;26:3-6.
13. Meloni JN, Laranjeira R. The social and health burden of alcohol abuse. *Rev Bras Psiquiatr*. 2004;26:7-10.
14. Leevy CB, Leevy CM. Alcoholic liver disease. *Compr Ther*. 1993;20:6-9.
15. Massey VL, Arteel GE. Acute alcohol-induced liver injury. *Front Physiol*. 2012;3:193.
16. Finlay CM, Walsh KP, Mills KHG. Induction of regulatory cells by helminth parasites: exploitation for the treatment of inflammatory diseases. *Immunol Rev*. 2014;259:206-230.
17. Silva MLS, De J. Inês E, Da S. Souza AB, et al. Association between *Strongyloides stercoralis* infection and cortisol secretion in alcoholic patients. *Acta Trop*. 2016;154:133-138.
18. Malpica L, White Jr AC, Leguia C, et al. Regulatory T cells and IgE expression in duodenal mucosa of *Strongyloides stercoralis* and human T lymphotropic virus type 1 co-infected patients. *PLoS Negl Trop Dis*. 2019;13:e0007415.
19. Anuradha R, Munisankar S, Bhootra Y, et al. Systemic cytokine profiles in *Strongyloides stercoralis* infection and alterations following treatment. *Infect Immun*. 2015;84:425-431.
20. Hoffman WA, Pons JA, Janer JL. The sedimentation-concentration method In schistosomiasis mansoni. *P R J Public Health Trop Med*. 1934;9: 283-291.
21. Koga K et al. A modified agar plate method for detection of *Strongyloides stercoralis*. *Am J Trop Med Hyg*. 1991;45:518-521.
22. Willcox HP, Coura JR. The efficiency of Lutz, Kato-Katz and Baermann-Moraes (adapted) techniques association to the diagnosis of intestinal helmints. *Mem Inst Oswaldo Cruz*. 1991;86:457-460.
23. Neupane SP, Lien L, Martinez P, et al. High frequency and intensity of drinking may attenuate increased inflammatory cytokine levels of major depression in alcohol-use disorders. *CNS Neurosci Ther*. 2014; 20:898-904.
24. De Souza JN et al. Case report: *Strongyloides stercoralis* Hyperinfection in a patient with HTLV-1: an infection with Filariform and Rhabditiform larvae, eggs, and free-living adult females output. *Am J Trop Med Hyg*. 2018;99:1583-1586.
25. Carson WE, Giri JG, Lindemann MJ, et al. Interleukin (IL) 15 is a novel cytokine that activates human natural killer cells via components of the IL-2 receptor. *J Exp Med*. 1994;180:1395-1403.
26. Rajamanickam A, Munisankar S, Bhootra Y, et al. Altered levels of memory T cell subsets and common γc cytokines in *Strongyloides stercoralis* infection and partial reversal following anthelmintic treatment. *PLoS Negl Trop Dis*. 2018;12:e0006481.
27. Ribeiro SR, Covre LP, Stringari LL, Da Penha Zago-Gomes M, Gomes DCO, Pereira FEL. Peripheral blood CD4+/CD25+ regulatory T cells in alcoholic patients with *Strongyloides stercoralis* infection. *Parasitol Res*. 2017;116:1071-1074.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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