



Estimates of global and regional prevalence of *Helicobacter pylori* infection among individuals with obesity: a systematic review and meta-analysis

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Abstract

Purpose The prevalence of obesity is an escalating concern in modern populations, predominantly attributed to the widespread adoption of sedentary lifestyles observed globally. Extensive research has established a significant association between obesity and *Helicobacter pylori* (*H. pylori*). Nonetheless, a comprehensive assessment of the global prevalence of *H. pylori* among individuals with obesity remains undetermined.

Methods A systematic search strategy was applied to PubMed, Scopus, and Web of Science. The resulting records were screened using the Rayyan online tool for the management of systematic reviews. Freeman–Tukey double arcsine transformation was used. Subgroup analyses (continent, regional classifications, developmental status, religion, global hemisphere, income, access to international waters, and *H. pylori* eradication) and multivariate meta-regression (latitude, longitude, male-to-all ratio, mean age, and body mass index) were done to estimate the effects of the moderators. Risk of bias assessment was done using JBI checklist for prevalence studies.

Results A total of 472,511 individuals with obesity from 208 studies were included. The global estimation of *H. pylori* prevalence among individuals with obesity was 32.3% (95% CI 26.9%, 38.0%). South America had the highest prevalence. Based on the different classifications of countries, resource-rich, low-/middle-income, developing, and Islamic countries had the highest prevalence. Lower pooled prevalence was observed in the studies with adequate sample sizes ($n \geq 270$).

Conclusion The findings have the potential to influence future health policies for preventing and treating *H. pylori* infection. However, there is variability among the included studies, indicating the need for more population-based research.

Keywords Obesity · *Helicobacter pylori* · Prevalence · Meta-analysis · Systematic review

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Abbreviations

<i>H. pylori</i>	<i>Helicobacter pylori</i>
GI	Gastrointestinal
JBI	Joanna Briggs institute
BMI	Body mass index
COVID-19	Coronavirus disease of 2019
RoB	Risk of bias

Introduction

Given the potential for transmission and the significant complications that can arise, particularly in individuals with chronic infections, the prevalence of *Helicobacter pylori* (*H. pylori*) infection and its association with host and environmental factors have become a subject of scientific interest. In this regard, obesity represents one such host factor that is

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prevalent worldwide, and understanding its association with *H. pylori* infection poses a complex challenge. Mostly due to sedentary lifestyles and dietary changes, the global prevalence of obesity has multiplied in recent decades and become a growing public health concern throughout the world [1]. In this regard, the association between obesity and several gastrointestinal (GI) complications has been quantified [2]. However, the mutual relationship between obesity and *H. pylori* infection is complex. Extensive research efforts have been dedicated to examining the prevalence of *H. pylori* infection among the general population, both on a global and regional scale [3–5]. However, an important knowledge gap still exists regarding the estimation of *H. pylori* prevalence among individuals with obesity.

A recent meta-analysis has provided conclusive evidence that individuals infected with *H. pylori* are more prone to obesity and, conversely, individuals who are obese present an elevated risk of acquiring *H. pylori* infection [6]. The mutual relationship between *H. pylori* and obesity is intricate and the simultaneous coexistence of *H. pylori* infection and obesity can lead to a heightened susceptibility to complications. For instance, individuals may experience elevated levels of glycosylated hemoglobin in diabetes as well as an increased risk of developing gastric cancer [7, 8]. Moreover, due to the similarities in GI pathologies and subsequent clinical presentations, it is feasible that individuals with obesity experiencing heartburn and indigestion be erroneously diagnosed with *H. pylori*-associated symptoms and consequently receive excessive treatment.

An estimation of *H. pylori* infection prevalence among individuals with obesity can provide valuable guidance to health policymakers and clinicians in devising efficient diagnostic and eradication strategies for *H. pylori* infection among individuals with obesity. These clinical ramifications become particularly salient in the preoperative evaluation of bariatric surgeries, where healthcare teams must carefully factor in the endemic nature of the infection to delineate optimal screening methodologies.

In this study, our objective was to conduct a systematic review of relevant studies and assess the prevalence of *H. pylori* in individuals with obesity. Additionally, we aimed to analyze the distribution of *H. pylori* prevalence across different geographical regions and investigate temporal trends in its prevalence.

Materials and methods

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline, which is widely recognized as the standard for transparent reporting of systematic reviews and meta-analyses [9]. Also, widely endorsed methodological

guidelines were utilized to improve the quality of the study [10, 11]. The protocol of the systematic review was priorly published in a peer-reviewed scientific journal [12].

Search and data sources

The reviewers systematically searched PubMed, Scopus, and Web of Science for relevant studies, published since the inception of databases until May 19th, 2023. The search keywords included *H. pylori*, obesity, and relevant keywords. The syntax developed for each online database is provided in Supplementary Material 1.

Study selection and eligibility criteria

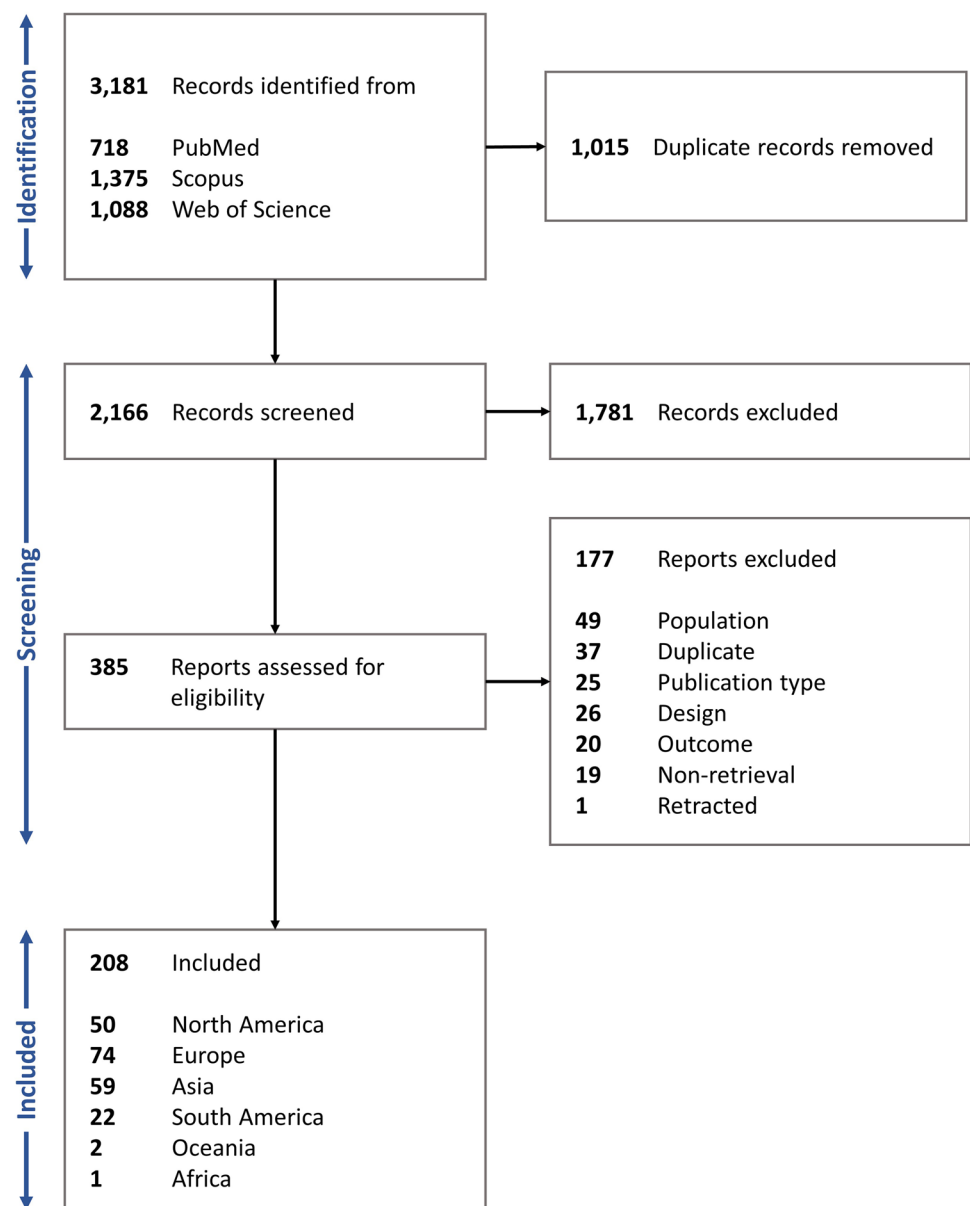
After automatic duplicate detection, the records were uploaded to the Rayyan online tool for management of systematic reviews where two reviewers (AS and NDE) independently screened them by titles and abstracts [13]. Controversial decisions were discussed to reach a consensus. In the next step, the full texts were assessed for eligibility. Observational and experimental studies were eligible for inclusion if they provided the statistics needed for the estimation of *H. pylori* prevalence (condition) among individuals with obesity (population) and had at least 30 sample participants from a representative population. Considering the variable definitions of obesity among the studies, the body mass index (BMI) of more than 30 kg/m², generally, and more than 25 kg/m², for Asian populations were acceptable [14]. To maximize the power of the analyses and avoid language and publication bias, we did not restrict the eligibility criteria to English papers [15]. Original articles, conference abstracts, and letters to editors were eligible for inclusion [16]. To avoid over-representation, when more than one study was available on a common series of patients, only the report with the largest sample size was included in the meta-analysis. A detailed PRISMA flow diagram presents the selection process in Fig. 1.

Data extraction and risk of bias assessment

Data were extracted into Excel spreadsheets by two independent reviewers (NDE and FN). The extracted data were later rechecked by a third reviewer (AS) for mistakes. The following data were extracted: study characteristics (first author, publication year, year(s) study conducted, language, and country), population characteristics (sample size, mean age, mean BMI, and male (%)), methodological considerations (detection methods, definition of the obesity, prior endoscopy, prior eradication, and definition of obesity), and the number of cases with *H. pylori*.

Risk of Bias (RoB) assessment was done by two independent reviewers (MAS and ET) using Joanna Briggs

Fig. 1 PRISMA flow chart of the literature screening. *PRISMA* preferred reporting items for systematic reviews and meta-analyses



Institute (JBI) Critical Appraisal Checklist [17, 18]. For each domain, studies scored one point if they were assessed as low risk (“yes”). Overall risk assessment for each study was done using the sum of scores; if scored five or more they were considered low risk, otherwise high risk.

Statistical analyses

Stata MP Version 16 (StataCorp, College Station, TX, USA) was utilized for analyses. A p value < 0.05 was considered statistically significant. The DerSimonian–Laird random-effects model was used to pool the Freeman–Tukey double arcsine transformed effect sizes [19]. With reliable results, the Freeman–Tukey method is the preferred transformation in meta-analyses of proportions [20]. An I^2 value $> 75\%$

indicated a statistically significant degree of heterogeneity [21].

Several subgroup analyses were applied to examine the potential sources of heterogeneity. WHO regional classification, geographical access to international waters, continents, global hemispheres, developed/developing condition, world bank income grouping, resource-richness of the countries, study periods, before/after the coronavirus disease of 2019 pandemic study period, mean age, mean BMI, prior eradication, overall RoB assessment, validity of the methods used for identification of the condition, and adequacy of the sample size were considered as potential moderators. Further subgroup analyses based on the peer-reviewed/non-peer-reviewed reports, the language of the report, and countries are available in Supplementary Material 2.

Multivariate meta-regression was applied considering the geographical coordinates of the country capitals of the studies (longitude and latitude), resource-richness, income, development, global hemisphere, prior *H. pylori* eradication, validity of the methods used, study year, overall RoB score, and male (%) as potential moderators. To reduce the bias caused by small studies, only studies with adequate samples sizes were included in the meta-regression. In this regard, the adequate sample sizes for examination of the association between potential covariate moderators and *H. pylori* prevalence among individuals with obesity was estimated at 370 using the method proposed by Naing et al. and the data provided by Lender et al. [22, 23]. Publication bias was not evaluated in this study, as it is not deemed pertinent to prevalence studies [24].

The robustness of the findings was examined using the leave-one-out method and subgroup analyses based on the overall RoB score, adequacy of the sample size, validity of the methods used to identify the condition, and peer-reviewed/non-peer-reviewed studies [16, 25].

Results

Study selection and characteristics

The search process generated 3138 records, 208 of which were included in the synthesis. Studies were from 53 countries (Fig. 2) of Europe ($n = 74$), North America ($n = 50$), Asia ($n = 59$), South America ($n = 22$), Oceania ($n = 2$), and Africa ($n = 1$). A total number of 472,511 individuals with obesity were evaluated for the presence of *H. pylori*. The included studies are cited in Supplementary Material 3. Supplementary Material 4 provides a summary of the study characteristics and settings. Supplementary Material 5 summarizes the identification methods used by each study to detect *H. pylori* infection. Definitions, findings, and overall RoB scores are provided in Supplementary Material 6.

Overall prevalence and geographical trends

As demonstrated in Table 1 and Fig. 3, the overall prevalence of *H. pylori* among individuals with obesity was 32.3% [95% CI 26.9%, 38.0%]. A detailed table demonstrating the meta-analysis of the overall pooled estimate is provided in Supplementary Material 7. Significant between-group differences were detected when classifying the studies based on the continent and WHO regional classification (p value < 0.01). Divided by the continents, South America had the highest prevalence of *H. pylori* infection with 46.9% [95% CI 40.3%, 53.6%], followed by Africa 38.5% [95% CI 31.5%, 45.8%], Asia 38.3% [95% CI 34.0%, 42.7%], Europe 36.9% [95% CI 32.4%, 41.5%], North America 15.2% [95% CI 10.9%,

19.9%], and Oceania 7.6% [95% CI 6.0%, 9.5%]. Divided by WHO regional classification, the prevalence of *H. pylori* among individuals with obesity was 47.1% [95% CI 40.0%, 54.3%] in Latin America and Caribbean, 43.8% [95% CI 23.6%, 65.2%] in South Asia, 40.3% [95% CI 34.4%, 46.4%] in Middle East and North Africa, 36.9% [95% CI 32.4%, 41.5%] in Europe and Central Asia, 30.3% [95% CI 23.5%, 37.5%] in East Asia and Pacific, and 13.4% [95% CI 9.5%, 17.9%] in North America. The difference between the prevalence of *H. pylori* among individuals with obesity in the global South and North, separated by Brandt Line [26, 27], was statistically significant with the global North 26.4% [95% CI 20.0%, 33.3%] and South 43.7% [95% CI 40.5%, 46.9%] (p value < 0.01). Also, significant between-group differences were observed when classifying the studies based on their access to international waters (p value < 0.01).

According to the multivariate meta-regression (Table 2), geographical latitude was negatively associated with the prevalence of *H. pylori* among individuals with obesity with β -0.008 [95% CI - 0.015, - 0.002] (p value 0.014). Geographical longitude was not significantly correlated with *H. pylori* prevalence with β 0.001 [95% CI - 0.001, 0.003] (p value 0.139).

Sociodemographic trends

Islamic countries had the highest prevalence of *H. pylori* among the individuals with obesity with 45.1% [95% CI 39.9%, 50.4%], followed by folk religions 44.9% [95% CI 37.4%, 52.6%], Judaism 33.7% [95% CI 22.9%, 45.4%], Hinduism 33.1% [95% CI 16.9%, 51.7%], Christianity 26.3% [95% CI 22.1%, 30.7%], and Buddhism 17.2% [95% CI 14.3%, 20.2%] (p value < 0.01). When classified by developmental status, studies from developed countries had a prevalence of 22.7% [95% CI 16.0%, 30.1%], whereas developing countries demonstrated a significantly higher prevalence of 43.9% [95% CI 41.0%, 46.8%] (p value < 0.01). Based on the world bank income classification of countries, studies from countries with a high income had 25.3% [95% CI 19.0%, 32.2%], whereas, studies from countries with a low and middle income had significantly higher prevalence 45.3% [95% CI 42.4%, 48.1%] (p value < 0.01). Figure 4 demonstrates Voronoi treemaps presenting the relative prevalence for each country classified based on geographical and sociodemographic classifications. The area of the polygon allocated to each country represents the relative estimated prevalence of *H. pylori* infection among individuals with obesity in that country. By employing a sequential process of dividing convex polygons, a Voronoi treemap is an exceptional means of visually representing hierarchical information. The area of the polygons within the Voronoi treemap is directly linked to the weights assigned to their respective nodes in the hierarchical structure [28].

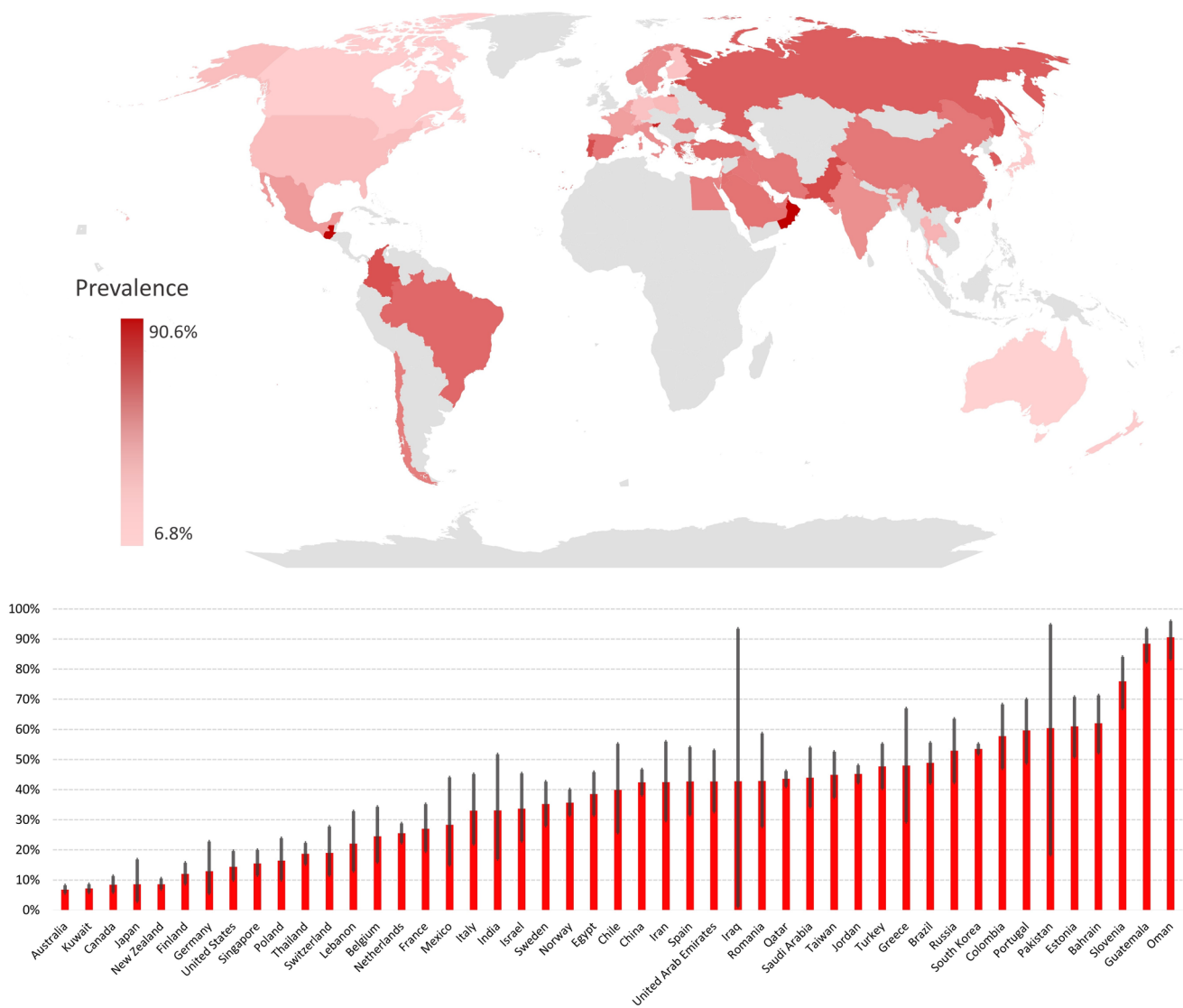


Fig. 2 (Top) World map of *H. pylori* prevalence. Countries filled with denser red color have higher prevalence. *H. pylori*, *Helicobacter pylori*. (Bottom) Bar chart demonstrating the estimated prevalence

of *H. pylori* infection among individuals with obesity in each country. Detailed estimates are provided in Supplementary Material 2. *H. pylori*, *Helicobacter pylori*

The meta-regression model of potential moderating factors of *H. pylori* prevalence is presented in Table 2 to explain the sources of heterogeneity in the effect estimates. Multivariate meta-regression showed that the prevalence is significantly influenced by geographical latitude.

Study characteristics and temporal trends

Studies with inadequate sample size demonstrated significantly higher prevalence than studies with adequate sample size with 36.0% [95% CI 31.8%, 40.3%] and 26.3% [95% CI 22.0%, 30.8%], respectively (*p* value < 0.01). On the other hand, studies that failed to employ validated identification methods for *H. pylori* infection demonstrated significantly

lower prevalence than those that employed validated tools 24.4% [95% CI 16.8%, 32.8%] and 33.2% [95% CI 29.8%, 36.7%], respectively (*p* value 0.04).

Meta-regression and subgroup analysis based on the study period failed to demonstrate a statistically significant temporal trend for the prevalence of *H. pylori* among individuals with obesity (*p* values 0.769 and 0.130, respectively). Also, the between-group differences were not statistically significant between English and non-English, peer-reviewed and non-peer-reviewed, and high- and low-risk studies (*p* values 0.75, 0.33, and 0.05, respectively). Bubble plots demonstrating the distribution of studies based on their estimated effect size and study period are available in Supplementary Material 8.

Table 1 Overall prevalence of *H. pylori* among the individuals with obesity and subgroup analyses

Subgroups		Number of studies	Number of participants	Prevalence [95% CI %]	P value for subgroup analysis	<i>I</i> ² (%)
Overall		208	472,511	32.3 [26.9, 38.0]		99.91
WHO Regions	East Asia & Pacific	21	37,728	30.3 [23.5, 37.5]	< 0.01	99.35
	Europe & Central Asia	74	22,993	36.9 [32.4, 41.5]		98.01
	Latin America & Caribbean	25	5003	47.1 [40.0, 54.3]		95.73
	Middle East & North Africa	36	89,928	40.3 [34.4, 46.4]		99.51
	North America	47	315,463	13.4 [9.5, 17.9]		99.76
	South Asia	5	1396	43.8 [23.6, 65.2]		98.25
Continents	Africa	1	179	38.5 [31.5, 45.8]	< 0.01	-
	Asia	59	126,434	38.3 [34.0, 42.7]		99.48
	Europe	74	22,993	36.9 [32.4, 41.5]		98.01
	North America	50	316,963	15.2 [10.9, 19.9]		99.77
	Oceania	2	2439	7.6 [6.0, 9.5]		61.74
	South America	22	3503	46.9 [40.3, 53.6]		93
Religion by majority	Islam	53	789	45.1 [39.9, 50.4]	< 0.01	98.11
	Folk Religions	4	337,975	44.9 [37.4, 52.6]		90.5
	Unaffiliated	14	1889	37.4 [30.9, 44.1]		98.88
	Judaism	7	1058	33.7 [22.9, 45.4]		99.83
	Hinduism	3	19,193	33.1 [16.9, 51.7]		96.62
	Christianity	124	78,863	26.3 [22.1, 30.7]		99.71
	Buddhism	3	32,744	17.2 [14.3, 20.2]		15.31
Global hemisphere	North	135	420,976	26.4 [20.0, 33.3]	< 0.01	99.93
	South	73	51,535	43.7 [40.5, 46.9]		97.66
Developed/Developing	Developed regions	111	412,858	22.7 [16.0, 30.1]	< 0.01	99.94
	Developing regions	97	59,653	43.9 [41.0, 46.8]		97.66
World Bank Income	High	133	424,673	25.3 [19.0, 32.2]	< 0.01	99.94
	Low and middle	75	47,838	45.3 [42.4, 48.1]		96.55
Resource-rich countries	No	179	461,916	30.8 [25.0, 36.9]	0.03	99.92
	Yes	29	10,595	41.8 [34.2, 49.5]		98.39
Geographic access	Coastal	193	466,994	33.5 [27.8, 39.5]	< 0.01	99.92
	Island	7	2294	16.5 [8.1, 27.1]		96.83
	Landlocked	8	3223	19.0 [11.5, 27.8]		96.85
Study period	1993–2000	8	5197	39.4 [25.9, 53.7]	0.13	97.67
	2001–2010	53	76,071	25.9 [16.4, 36.6]		99.86
	2011–2020	122	386,129	33.1 [25.4, 41.3]		99.94
	2021–2023	3	1042	32.0 [19.3, 46.2]		94.35
Study after/before pandemic	After COVID-19	10	3656	43.6 [33.4, 54.1]	0.02	97.38
	Before COVID-19	176	464,783	30.6 [24.8, 36.7]		99.93
Adequacy of sample size	No	129	156,324	36.0 [31.8, 40.3]	< 0.01	99.62
	Yes	77	315,510	26.3 [22.0, 30.8]		99.63
Validity of the identification method	No	28	43,912	24.4 [16.8, 32.8]	0.04	99.33
	Yes	175	427,156	33.2 [29.8, 36.7]		99.72
RoB score ≥ 5	No	10	4387	20.8 [11.6, 31.9]	0.05	98.53
	Yes	198	468,124	32.9 [27.3, 38.8]		99.92
Eradication before testing	No	138	133,879	34.6 [30.4, 38.8]	0.14	99.54
	Yes	70	338,632	27.8 [20.2, 36.0]		99.91

Significant *p*-values (less than 0.05) were presented in bold

H. pylori Helicobacter pylori, *RoB* risk of bias, *COVID-19* coronavirus disease of 2019

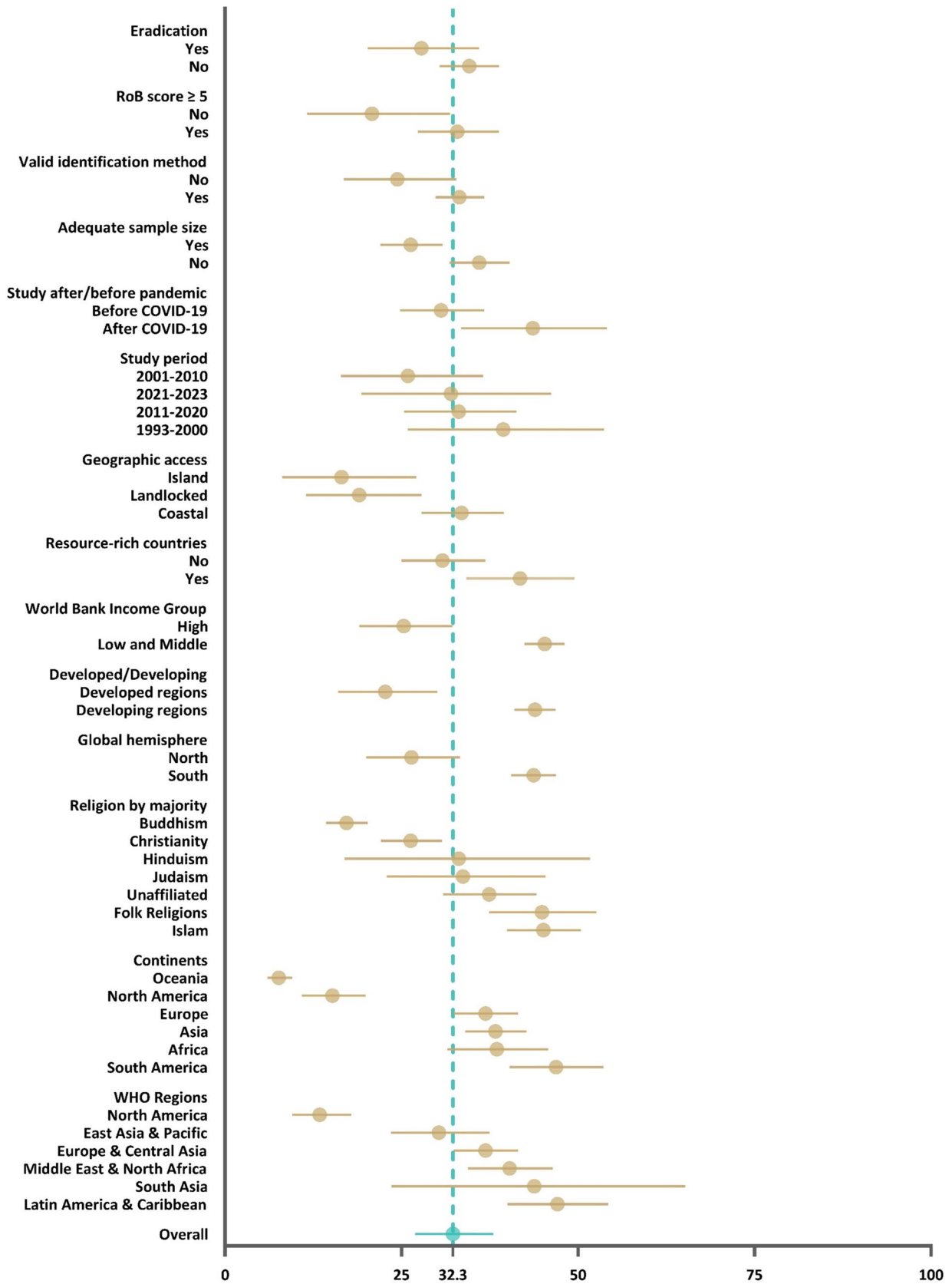


Fig. 3 Forest plot demonstrating the overall estimated prevalence and subgroup analyses

Table 2 Multivariate meta-regression*

Moderator	Categories	β (95% CI)	P value
Resource	Rich	-0.439 [-1.067, 0.190]	0.171
	Not rich	1	-
Income	High	0.134 [-0.403, 0.671]	0.624
	Low and middle	1	-
Development	Developed	-0.055 [-0.749, 0.640]	0.877
	Developing	1	-
Hemisphere	North	-0.329 [-0.848, 0.190]	0.214
	South	1	-
Longitude		0.002 [-0.001, 0.004]	0.139
Latitude		-0.008 [-0.015, -0.002]	0.014
Male (%)		-0.003 [-0.018, 0.011]	0.655
Mean age		-0.005 [-0.021, 0.011]	0.544
Study year		0.005 [-0.021, 0.030]	0.714
Mean BMI		0.012 [-0.030, 0.055]	0.567
<i>H. pylori</i> eradication	Yes	-0.132 [-0.390, 0.125]	0.313
	No	1	-
Valid identification method	Yes	0.671 [-0.402, 1.744]	0.22
	No	1	-
RoB score		-0.285 [-0.758, 0.188]	0.237

Significant *p*-values (less than 0.05) were presented in bold

$R^2 = 21.08\%$, *p* value = 0.012

RoB risk of bias, BMI body mass index, *H. pylori Helicobacter pylori*

*Studies with adequate sample size ($n \geq 370$), estimated by the method proposed by Naing et al. and data provided by Lender et al. were included in the meta-regression [22, 23]

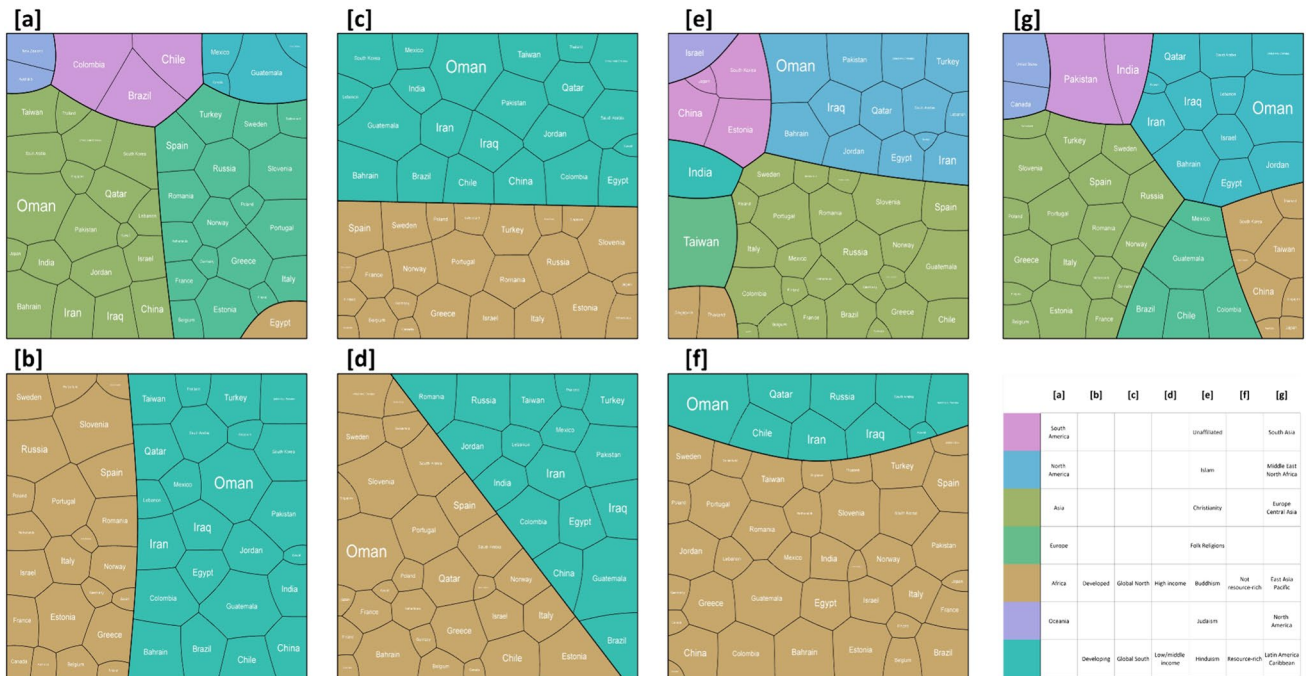


Fig. 4 Voronoi treemaps present the relative prevalence for each country classified based on geographical and sociodemographic classifications. The area of the polygon allocated to each country represents the relative estimated prevalence of *H. pylori* infection among individuals with obesity in that country. Classifications of the coun-

tries based on **a** continent, **b** developed versus developing, **c** global hemispheres, **d** world bank income groups, **e** the religion held by the majority of the population of the country, **f** resource-richness, and **g** WHO regional classification. *H. pylori Helicobacter pylori*, WHO world health organization

RoB assessment and sensitivity analyses

The median RoB score was 8 points for the included studies. Assuming a score less than 5 as high risk, 10 studies were high risk for bias, whereas 198 studies were low risk for bias. Sensitivity analyses based on the overall risk of bias and leave-one-out demonstrated the robustness of our findings (Supplementary Material 9). However, assuming adequacy of sample size and validity of identification methods as the major component of bias, the findings differed significantly between the respective low- and high-risk studies. Furthermore, sensitivity analysis was done based on the peer-review status of studies (Supplementary Material 2). The proportional evaluation of the quality score in each JBI domain is presented in Fig. 5. A detailed evaluation of each study for RoB is presented in Supplementary Material 10.

Discussion

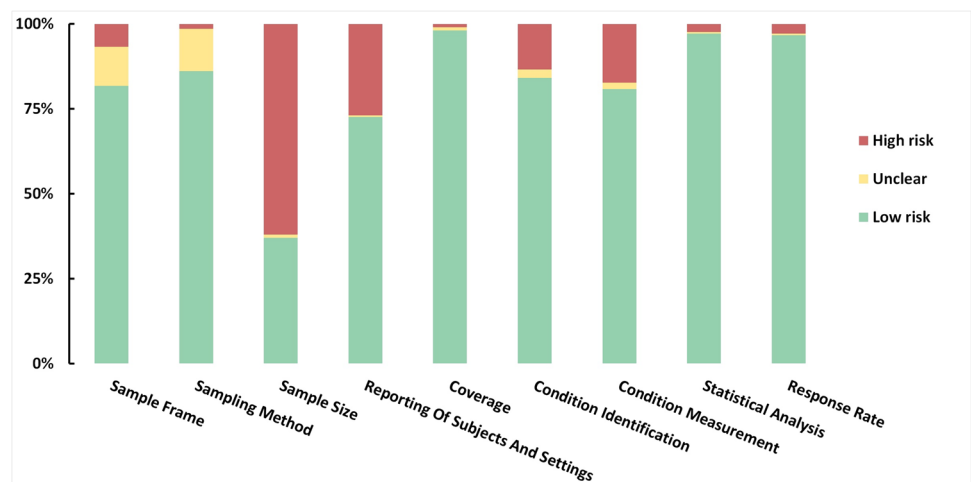
H. pylori infection is still one of the most common infections worldwide. The most recent evidence estimates that almost 48.9% of the global general population are infected with *H. pylori* [3]. To further extend the knowledge, several studies have been undertaken to investigate the prevalence of *H. pylori* infection in individuals with obesity. However, these studies have produced a wide range of estimates leading to inconclusive results. Moreover, the absence of a systematic review that comprehensively gathers and evaluates all the available evidence further contributes to the inconclusive nature of these estimations. The current study addresses the prevalence of *H. pylori* among people with obesity and associated study-level geographical, temporal, and sociodemographic factors by systemically reviewing the literature and pooling the eligible reports.

H. pylori prevalence in individuals with obesity versus general population

Our analyses showed that the global estimation of *H. pylori* prevalence among individuals with obesity was 32.3% (95% CI of 26.9%, 38.0%). In comparison with recent evidence [3], our findings suggest a lower prevalence of *H. pylori* infection among individuals with obesity than the general population. However, it seems that our findings replicate the previous findings from the general population regarding geographical and sociodemographic trends [3, 4]. In this regard, consensual evidence suggests that North America and Latin America have the lowest and highest regional prevalence, respectively. However, our findings do not necessarily replicate the temporal trends proposed by Li et al. [3]. They found that the prevalence of *H. pylori* decreased during the past decades in the general population, while our meta-regression and subgroup analyses suggest that the prevalence of *H. pylori* infection among individuals with obesity does not follow a statistically significant linear temporal trend.

A possible justification for the lower prevalence of *H. pylori* infection among the population with obesity than the general population is the heightened postprandial gastric acid secretion observed in individuals with obesity. It has been shown that hypergastrinemia can occur in individuals with obesity due to vagal dysfunction, even if it is not necessarily related to achlorhydria [29]. Transient gastric achlorhydria has been shown to be associated with primary *H. pylori* infection and increased survival and colonization of *H. pylori* in the stomach [30, 31]. Therefore, increased gastric acid production can decrease *H. pylori* virulence and its inoculation. Furthermore, in those with obesity, it has been reported that they have a more prominent maximal gastric acid response to intravenous gastrin administration and, also, a lesser stimulatory requirement to reach the secretory plateau. Consequently, the increased sensitivity to blood gastrin levels and accentuated postprandial gastric acid secretion

Fig. 5 Proportional evaluation of quality score in each JBI domain. *JBI* Joanna Briggs institute



may affect *H. pylori* colonization [32]. In addition, previous studies have shown that gastric emptying and proximal small intestine transit are accelerated in overweight and obese individuals [33]. This, in turn, may help in the clearance of *H. pylori* from the stomach by peristalsis and decrease its acquisition [34]. In addition, we propose that different gastric pre-*H. pylori* infection microbiota, gastric secretion of proteolytic enzymes, and mucosal environment immune activity in individuals with obesity may have a role in the *H. pylori* infection rate, compared to the general population.

Geographical trends

Latitude and *H. pylori* prevalence in individuals with obesity

We have found compelling evidence supporting an inverse relationship between geographical latitude and the prevalence of *H. pylori* infection among the subjects included in our study. However, it is not fully investigated and there are inconsistent findings, here, we gathered some existent explanations in this regard. As one moves farther from the equator, the amount of daily sunlight and the average temperature decrease, which is contrary to the favorable conditions for the growth of *H. pylori*. The best temperature for the optimum growth of *H. pylori* is 30 to 37 °C and at temperatures around 25 degrees, the growth is barely possible [35]. In addition, in a review study on the relationship of *H. pylori* with environmental conditions and geographical latitude, increased average daily sunlight time was found to correlate with higher *H. pylori* infection rates; their analysis, however, showed a negative trend with average annual temperature and latitude. They hypothesized that this variation in the prevalence of different geographical areas, in part, results from differences in the level of vitamin D synthesis [36]. Vitamin D synthesis is dependent on the exposure to sun and plays an important role in immunoregulation [26]. Prior investigations have also found that vitamin D is a protective factor against *H. pylori* infection, and those with vitamin D deficiency had a higher probability of eradication failure [37].

Regional differences

In line with studies on the general population, there is a wide variation in the prevalence of *H. pylori* between geographical regions and even between countries in each region [3]. We found that South America had the highest pooled prevalence of *H. pylori* in individuals with obesity, followed by Africa, Asia, Europe, North America, and Oceania. This variation may reflect the presence of differences in socioeconomic status, the level of sanitary infrastructure, access to clean foodstuff, and crowded living conditions. In this regard, we found that the developing countries have significantly higher *H.*

pylori prevalence than the developed countries. The source of *H. pylori* infection can be contaminated drinking water, well water, seawater, and rivers [38]. This context may be the reason behind our finding that a positive correlation was found between higher *H. pylori* infection rates and access to international waters. In addition, using shared dishes and eating utensils could facilitate intrafamilial clustering of *H. pylori* infection. Therefore, with more crowded households, the possibility of its transmission from person to person increases as a result of close contact [39].

Other contributing factors

In bariatric surgery, prior eradication of *H. pylori* is a common practice. Many of the included studies were evaluations of the pre-, intra-, and postoperative prevalence of individuals who had undergone bariatric surgeries. Although not statistically significant in this study, prior eradication treatments can change the findings. This result may be due to low quality and variable of reporting among the studies. Therefore, further investigations should be done. In addition, we observed a significant difference in the prevalence of *H. pylori* in individuals with obesity based on the official religion of the countries. This variation could be attributable to the differences in cultural, religious, and sanitary practices. Studies with larger sample sizes tend to provide more representative and reliable results. In our review, we found that studies with sufficient sample sizes reported a notably lower prevalence of *H. pylori*. This observation suggests a greater gap between the general population and the population affected by obesity. Consequently, it is crucial to consider various evaluations and exercise caution when drawing conclusions from the available evidence.

Strengths and limitations

To the best of our knowledge, this is the first study that estimates a global prevalence of *H. pylori* among individuals with obesity. The present study attempts to minimize language and publication biases by not restricting the eligibility criteria to a specific language, time period, and publication type. Furthermore, sensitivity analyses are done to measure the effect of these characteristics on final estimation. However, some important limitations are present in the present study. Our study was only successful in detecting studies from almost 26% of the countries globally (53/200). The *H. pylori* infection prevalence among individuals with obesity from the rest of the countries remains unestimated. Therefore, the geographical representation is incomplete, especially for developing and underdeveloped countries. Moreover, the included studies varied significantly regarding the time period, methodology, sample population, definitions, and identification methods, resulting in considerable heterogeneity. Similar to other

meta-analyses of prevalence, our study indicated considerable heterogeneity, even between populations with close characteristics, suggesting local variations in risk factors of *H. pylori* infection. Our study fails to discover the sources of heterogeneity [11, 40–42].

Conclusion

To sum up, this systematic review and meta-analysis provides a comprehensive overview of *H. pylori* prevalence among individuals with obesity, *H. pylori* distribution based on geographical regions, and correlated sociodemographic trends. Our study confirmed that *H. pylori* prevalence in individuals with obesity is not greater than the prevalence among the general population. Failure to consider this point may cause overtreatment in obese people by physicians or arbitrary prescription of antibiotics, especially before bariatric surgeries. In addition, considering the higher prevalence of this infection in developing countries, the most important way to decrease this disease transmission is to provide sanitary distribution of water by governments. Also, educating people to avoid sharing eating utensils and encouraging them to personal hygiene issues will be effective in preventing infection. Conducting studies to evaluate the stomach microbiota in obese and overweight people before colonization with *H. pylori*, evaluating the effect of climatic conditions on the survival and growth of *H. pylori*, assessing worldwide and countries' temporal trends, and exploring host factors predisposing to higher acquisition rates are recommended for further investigations.

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Declarations

Conflict of interest The authors declare that the present study was done in the absence of any financial and personal competing interests.

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