Review Article

Global Prevalence of *Yersinia enterocolitica* in Cases of Gastroenteritis: A Systematic Review and Meta-Analysis

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The prevalence of *Yersinia enterocolitica* in gastroenteritis is often underestimated. It relates considerably to morbidity and medical expenses around the world. Understanding the cause of gastroenteritis leads to making the appropriate treatment decisions. We systematically searched PubMed, Science Direct, Embase, and Scopus to identify all published studies between Jan. 1, 2000, and Dec. 31, 2019, to assess the prevalence of *Y. enterocolitica* in gastroenteritis patients. A total of 5039 articles were identified that lead to the extraction of data from 47 of them. The pooled prevalence of *Y. enterocolitica* in cases of gastroenteritis was estimated as 1.97% (1.32–2.74%) in the culture method and 2.41% (1.07–4.22%) in the molecular method. Among the biotypes of *Y. enterocolitica*, 1A (62.48%) and 1B (2.14%) had the most and least prevalence, respectively. Serotype O3 *Y. enterocolitica* with 39.46% had the highest and O5,27 with 0.0% had the least prevalence in gastroenteritis cases. In conclusion, the findings of this systematic review show that *Y. enterocolitica* is prevalent in gastroenteritis in all age groups. Serotypes O3 and O9 of *Y. enterocolitica* had the highest prevalence and O5,27 had the least prevalence in diarrheal patients. The prevalence of *Y. enterocolitica* was similar in both gender and different seasons. It should be noted that to determine the role of the organism, more studies are needed especially in food-borne diseases.

1. Background

Yersiniosis is caused by Gram-negative bacteria *Yersinia enterocolitica* (*Y. enterocolitica*) and *Y. pseudotuberculosis*. Although *Y. enterocolitica* is a frequent cause of human infection especially in developed countries of temperate zones, *Y. pseudotuberculosis* human infection is rare [1]. It mainly caused a gastrointestinal infection in humans. Additionally, *Y. enterocolitica* can cause other clinical manifestations including mesenteric lymphadenitis, endocarditis, and predominantly infects children [2]. Yersiniosis is the third cause of notifiable bacterial zoonosis in the European Union after campylobacteriosis and salmonellosis [3]. *Y. enterocolitica* is a psychrotrophic organism that can replicate at temperatures ranging from 0 to 44°C. As such, the organism can replicate in the refrigerator and survives in frozen foods and liquids for long periods. Peritrichous flagella causes the motility of *Y. enterocolitica*. Motility is temperature dependent, as the bacterium is motile at 25°C but is not motile when it grows at 37°C. Pathogenesis of *Y. enterocolitica* also depends on temperature. The invasive proteins of *Y. enterocolitica* produce at environmental temperatures of less than 28°C and under acidic conditions at 37°C. The expression of virulence factors necessary to infection initiates by the gradual increase of temperature within the host [2]. Infections caused by *Y. enterocolitica* pathogenic strains do not belong to a specific age group, but the clinical manifestation is frequently observed in children and younger adults. Adults can be asymptomatic carriers of infection [4]. Fever, abdominal pain, and diarrhea are the
common symptoms of yersiniosis in children [2]. The bacterium was isolated from domestic and wild animals. Pigs are regarded as the reservoir of the pathogen [5], but high titers of anti-Yersinia antibodies in domestic animals, such as cattle, goats, and sheep revealed that there are other possible sources [6]. The main method of human infection is through consumption of contaminated food especially raw or undercooked ones [2] though drinking of contaminated water, close exposure to pet animals, and blood transfusion have also been mentioned [2, 7]. Y. enterocolitica had several biotypes and serotypes. Virulent isolates of Y. enterocolitica are attributed to certain biotypes and serotypes. Among the six known biotypes (including 1A, 1B, 2, 3, 4, and 5), 1A is reported as a nonpathogenic biotype in healthy people. Y. enterocolitica serotypes O3, O8, O9, and O5. 27 were isolated from most cases of human yersiniosis [2]. The most serious disease is caused by serotype O8 with extensive ulceration of the gastrointestinal tract and sometimes death of the patients [8].

Patients may defecate Y. enterocolitica for 90 days after the recovery, which shows the importance of early detection of the bacterium in order to prevent transmission and possible outbreak [9]. In order to detect the Y. enterocolitica, a culture method and molecular assays were developed. The conventional culture method is time-consuming and has false-negative results while PCR is not only a sensitive and specific detection method but also is able to identify the pathogenic isolates and further characterization of the isolates [4]. Around the world, there is limited information about the prevalence of yersiniosis due to the clinical presentation of the disease as gastroenteritis so the diagnosis and treatment mainly depend on the clinicians and not on the microbiological culture. The aim of the present study was to estimate the global prevalence of yersiniosis in cases of gastroenteritis. Moreover, the main biotypes and serotypes were determined. The existing data and knowledge were synthesized through a systematic literature review and meta-analysis.

2. Methods

2.1. Search Strategy and Study Selection. A systematic review was performed in PubMed, Science Direct, Embase, and Scopus to identify all published studies between Jan 1, 2000, and Dec 31, 2019, with the search keywords of "gastroenteritis," “Yersinia enterocolitica,” and “yersiniosis” and related terms without any language restriction. The searched keywords were extracted from the Medical Subject Headings thesaurus. The search strategy was presented in the supplementary file. Titles and abstracts of relevant original articles after the removal of duplicates were screened by two independent reviewers (TZ and EA). The bibliographies of the included articles were hand-searched for additional references. Gray literature was searched by using Google Scholar. PRISMA guidelines were used to perform the systematic reviews.

Selection of studies was carried out by the following criteria: primary research studies including original article either published or in press; studies with a cross-sectional design; case group of case-control studies; studies including detection of Y. enterocolitica on the samples based on culture or PCR; patients having the symptoms of gastroenteritis; studies performed in a specified region or country; having a known number of sample size; and studies with available full texts. Studies with confusing text or incomprehensible analyses that did not report the sample size and number or percent of positive cases toward Y. enterocolitica were excluded. Reviews, letters, or editorial articles without original data were also excluded.

2.2. Data Extraction and Risk of Bias Assessment. A standard dedicated data extraction form was designed in Excel software. Two authors (TZ and SMR) extracted data independently. If provided, the following data were extracted from each study: bibliographic characteristics, including first author, year of publication, start and end year of the study, study design (cross-sectional or case-control), and country (income, HDI and WHO region); population characteristics, including the age of the participants (mean ± standard deviation (SD), minimum and maximum), gender, and total number of tested patients; methodological information, including diagnostic method, number of patients positive for Y. enterocolitica in culture and PCR separately, season of sampling, biotypes and some prevalent pathogenic serotypes of isolated Y. enterocolitica, and geographic location (latitude and longitude). We included samples with both Y. enterocolitica and another pathogen detected (e.g., E. coli or viruses).

Data were stratified by the diagnostic method and age. Regarding age, data were stratified into four categories: younger than 6 years, 6 to 18 years old, 18 to 59 years old, and more than 60 years old. As an indicator of development and epidemiological context, income, WHO region, and human development index were used to categorize the data on the basis of the country in which the study was performed. The eligible studies were qualified independently by two authors (TZ and EA) according to the Joanna Briggs Institute [10].

2.3. Statistical Analysis. In the current study, random-effect models were used for estimating pooled prevalence and 95% confidence intervals (95% CI). Metaprop command was used in Stata software. Pooled prevalence was calculated using a Freeman–Tukey double arcsine transformation [11, 12]. Heterogeneity among studies was examined by $I^2$, Cochran’s Q. 12 index ranges between 0 and 100 percent and $I^2$ > 70% was considered heterogeneous [13, 14]. A Forest plot in the random-effects model was applied to show pooled prevalence. Subgroup analysis and metaregression were done to identify the sources of heterogeneity [15]. Univariate metaregression analysis was used for assessing the effect of publication year, human development index, geographical location (longitude/latitude), and quality score on the prevalence of Y. enterocolitica. In a subgroup analysis, we estimated the prevalence of Y. enterocolitica in different age groups, type of diagnostic method, study’s type, income, and WHO regions. Publication bias was not examined because
the aim of the study is not to determine the association between exposures and outcome [15]. The significance level was considered 0.05 in all analyses. All analyses were done by using STATA 13 (STATA Corp., College Station, Texas). In the metaregression, $p$ value $< 0.1$ was considered as a significant level due to the little range of prevalence of Y. enterocolitica and the rare nature of the organism.

3. Results

3.1. Study Characteristics. A total of 5039 articles were identified of which 4845 were not duplicates. According to the title and abstract, 202 articles were included and assessed for eligibility by full texts (Figure 1). From these, 49 articles passed the quality assessment and data were extracted from 47 of them. The final extracted data included 25 countries from all WHO regions (eight from the Americas, 17 from Europe, ten from Eastern Mediterranean, five from Africa, and seven from Western Pacific) except for the South-East Asia region. From these 47 studies, the prevalence of Y. enterocolitica by culture diagnosis method in cases of gastroenteritis was estimated as 1.97% (95% CI 1.32–2.74; $I^2 = 99.19%$; $p < 0.09$ test for heterogeneity) (Figure 2(a)). However, by the PCR method the estimate of pooled prevalence for Y. enterocolitica was 2.41 (95% CI 1.07–4.22; $I^2 = 98.39%$; $p < 0.00$ test for heterogeneity) (Figure 2(b)). There was significant heterogeneity among the included studies. Table 1 shows the pooled prevalence of Y. enterocolitica by culture and PCR method according to the countries. The highest prevalence of Y. enterocolitica in culture and PCR method was in Madagascar (16.56%). The lowest prevalence of Y. enterocolitica in culture and PCR method was in Australia (0.00%) and Brazil (0.00%), respectively. Table 2 shows the main characteristics of the included studies.

3.2. Subgroup Analysis. The type of study did not change the pooled prevalence of Y. enterocolitica, as in the culture method, the pooled prevalence in the cross-sectional and case-control studies is 2.20 and 1.22, respectively (random test for heterogeneity $p < 0.12$) (Figure 3(a)). The pooled prevalence of Y. enterocolitica by the PCR method in the cross-sectional and case-control studies is 2.28 and 4.44, respectively ($p < 0.05$) (Figure 3(b)). The pooled prevalence of Y. enterocolitica was decreased by the increase in the income of the countries ($p < 0.001$). The pooled prevalence of Y. enterocolitica in low- and high-income countries was

![Flowchart of identification and selection of studies for inclusion in the review.](image-url)
Heterogeneity between groups: $p = 0.089$

Overall ($I^2 = 99.19\%, p = 0.00$)

- Torres, M.E. (2001, Uruguay)
- Subtotal ($I^2 = 94.85\%, p = 0.00$)
  - Fiedoruk, K. (2015, Poland)
  - Maltezou, H.C. (2001, Greece)
  - Svenungsson, B. (2000, Sweden)
  - Hilmarsdttir, I. (2012, Iceland)
  - GASCO´ N, J. (2000, Tanzania)
  - Soltan Dallal, M.M. (2004, Iran)
  - Vernacchio, L. (2006, USA)
  - Wang, X. (2015, China)
  - Ehara, A. (2000, Japan)
  - Sinclare, M.I. (2005, Australia)
  - Zheng, H. (2008, China)
  - Wang, X. (2010, China)
  - Wang, X. (2015, China)
  - Duan, R. (2017, China)
  - Abdel-Haq, N.M. (2006, USA)
  - Rees, J.R. (2004, USA)

Subtotal ($I^2 = 99.64\%, p = 0.00$)
- Americas
- Subtotal ($I^2 = 90.42\%, p = 0.00$)
  - Americas
  - Subtotal ($I^2 = 97.96\%, p = 0.00$)
    - Africa
- Europe
- Eastern Mediterranean
- Subtotal ($I^2 = 94.85\%, p = 0.00$)
  - Western Pacific
- Subtotal ($I^2 = 98.38\%, p = 0.00$)

Heterogeneity between groups: $p = 0.089$

Overall ($I^2 = 99.19\%, p = 0.00$);
Heterogeneity between groups: $p = 0.000$

Overall ($I^2 = 98.39\%$, $p = 0.00$);

- Calderaro, A. (2018, Italy)
- Duan, R. (2017, China)
- Assis, F.E.A. (2014, Brazil)
- Zheng, H. (2007, China)
- Vernacchio, L. (2006, USA)
- Fiedoruk, K. (2015, Poland)
- Calderaro, A. (2018, Italy)
- Subtotal ($I^2 = 91.90\%$, $p = 0.00$)
- Bublitz, D.C. (2014, Madagascar)
- Americas
- Europe
- Western Pacific
- Subtotal ($I^2 = 91.59\%$, $p = 0.00$)
- Eastern Mediterranean
- Africa
- Subtotal ($I^2 = 83.18\%$, $p = 0.00$)
- Subtotal ($I^2 = 99.87\%$, $p = 0.00$)
- Subtotal ($I^2 = 99.32\%$, $p = 0.00$)
- Nimri, L.F. and Meqdam (2004, Jordan)
- Ghassmikebria, F. (2010, Iran)
- Hawash, Y.A. (2017, Saudi Arabia)
- Subtotal ($I^2 = 91.59\%$, $p = 0.00$)
- Okwori, A.E.J. (2009, Nigeria)
- Bublitz, D.C. (2014, Madagascar)
- Nimri, L.F. and Meqdam (2004, Jordan)
- Ghasemikebria, F. (2010, Iran)
- Hawash, Y.A. (2017, Saudi Arabia)
- Subtotal ($I^2 = 99.32\%$, $p = 0.00$)
- Studen ($I^2 = 99.32\%$, $p = 0.00$)

**Table 1:** A pooled prevalence of *Y. enterocolitica* by culture and PCR method according to the countries.

| Country       | Culture | PCR          |
|---------------|---------|--------------|
|               | Number  | Pooled prevalence (95% confidence interval) | Number | Pooled prevalence (95% confidence interval) |
| Global        | 45      | 1.97 (1.32–2.74) | 13     | 2.41 (1.07–4.22) |
| USA           | 5       | 2.09 (0.23–5.62) | 1      | 0.23 (0.01–1.25) |
| Brazil        | 2       | 0.03 (0.00–0.53) | 1      | 0.00 (0.00–0.92) |
| Uruguay       | 1       | 0.45 (0.01–2.46) | —      | — |
| Sweden        | 2       | 4.95 (4.82–5.08) | —      | — |
| Greece        | 2       | 0.50 (0.32–0.69) | —      | — |
| Netherlands   | 2       | 0.60 (0.19–1.20) | —      | — |
| Denmark       | 1       | 2.36 (1.14–4.29) | —      | — |
| Austria       | 1       | 0.33 (0.01–1.81) | —      | — |
| Germany       | 3       | 1.09 (0.05–3.11) | 1      | 0.20 (0.15–0.27) |
| Finland       | 2       | 1.05 (0.98–1.12) | —      | — |
| Iceland       | 1       | 0.65 (0.13–1.88) | —      | — |
| Switzerland   | 1       | 1.11 (0.51–2.10) | —      | — |
| Poland        | 1       | 2 (0.24–7.04)    | 1      | 2 (0.24–7.04) |
| Italy         | 1       | 0.64 (0.32–1.14) | 1      | 0.99 (0.58–1.58) |
| Jordan        | 1       | 4.44 (1.94–8.57) | 1      | 4.44 (1.94–8.57) |

**Figure 2:** Forest plots for random-effects meta-analysis of the prevalence of *Y. enterocolitica* by (a) culture method and (b) PCR method in WHO regions.
7.17 and 1.35 in culture (\(p < 0.001\)) (Figure 4(a)) and 16.56 and 0.36 in PCR method (\(p < 0.02\)) (Figure 4(b)), respectively. The source of heterogeneity of included studies is income. According to age, the prevalence was not significantly different in younger than six years, 6–18 years, and 18–59 years (1.75%; 0.96–2.54; \(p < 0.05\) for culture and 1.84%; 0.49–3.19; \(p < 0.01\) for PCR) (Figure 4(c)). By gender of participants and season of sampling, the prevalence was similar (\(p < 0.05\) and \(p < 0.89\), respectively) (Figure 4(d)). According to the biotype of \(Y.\) enterocolitica isolates, 1A (62.48%; 95% CI 27.56–91.77) and 1B (2.14%; 95% CI 0.04–6.14) had the most and least prevalence, respectively. Among the investigated serotypes of \(Y.\) enterocolitica isolates, O3 with 39.46% had the highest and O5,27 with 0.0% had the least prevalence (Figure 5(b)).

3.3. Metaregression. According to Figures 6(a) and 6(b), by the increase of publication year, the prevalence did not have any significant change (\(p < 0.51\) for culture and \(p < 0.38\) for PCR). Countries with higher HDI had a lower prevalence of \(Y.\) enterocolitica (\(p < 0.39\) for culture and \(p < 0.01\) for PCR) (Figures 6(c) and 6(d)). Latitude had no any significant effect on the prevalence of \(Y.\) enterocolitica \(p < 0.7\) for culture and \(p < 0.24\) for PCR) (Figures 6(e) and 6(f)). The prevalence of \(Y.\) enterocolitica increased slightly with increasing latitude but was not statistically significant (\(p < 0.12\)) in the culture method; in contrast, its prevalence was decreased with the increasing latitude in the PCR method (\(p < 0.01\)) (Figures 6(g) and 6(h)). Metaregression for quality assessment and prevalence was carried out and no relation was observed (\(p < 0.74\) for culture and \(p < 0.33\) for PCR).

4. Discussion

In the current meta-analysis, we provided the first estimates of the global prevalence of yersiniosis in cases of gastroenteritis. Based on the culture isolation of \(Y.\) enterocolitica, Africa [1, 26, 39, 40, 44] and Eastern Mediterranean [17, 22, 42, 46, 48, 53, 56–58] WHO regions had the first and second rank of prevalence of the bacterium, while Europe [4, 16, 19, 21, 24–26, 28, 29, 33–36, 38, 45, 49, 50, 54] had the least prevalence of \(Y.\) enterocolitica in gastroenteritis cases. Yersiniosis had a global prevalence and is a reportable disease in some countries, such as Denmark, Norway, and 38 states of USA [59, 60]. According to PCR detection, Africa and Western Pacific [3, 9, 18, 23, 27, 37] had the most, and the Americas [20, 30–32, 41, 51, 52, 55] had the least prevalence of \(Y.\) enterocolitica. In the present study, the highest prevalence of \(Y.\) enterocolitica in culture and PCR method was in Madagascar (16.56%). The lowest prevalence of \(Y.\) enterocolitica in culture and PCR method was in Australia (0.00%) and Brazil (0.00%), respectively, in the current study. Bublitz et al. (2014) reported that the prevalence of \(Y.\) enterocolitica is 16.56% in Madagascar and Assiss et al. (2014) reported it is 0.0% in Brazil. In the United States (US), 0.33 per 100000 individuals were infected by Yersinia during 1996 to 2012 in the general population according to Food-borne Diseases Active Surveillance Network, 2012 [61]. In Denmark, \(Y.\) enterocolitica was reported as a common cause of bacterial diarrheal disease with 4.9 cases per 100,000 inhabitants in 2016 [62]. Among developed countries, food-borne yersiniosis was higher in most European countries than US [63, 64]. The prevalence of \(Y.\) enterocolitica was higher in gastroenteritis patients than in the general healthy population. In the present study, income was the origin of heterogeneity among included studies. As, in the low-income countries, \(Y.\) enterocolitica was more prevalent than high-income ones. This can be related to considering hygiene principles. Human yersiniosis is commonly caused by \(Y.\) enterocolitica [59]. Yersiniosis caused self-limiting diarrhea that sometimes may be bloody in children younger than four years old. However, fever and abdominal pain accompanied by diarrhea and/or vomiting were reported in older children and adults [9]. The clinical presentation of gastrointestinal disease can be different based on the age and immune status of the host [2]. Diagnosis of yersiniosis is done by isolation of the microbe from human feces or blood or following removal of the appendix, mistakenly [59], although the culture of the bacterium is not a usual procedure for gastrointestinal patients in most hospitals that may lead to underestimates of yersiniosis [59].

Age was not a significant factor regarding gastroenteritis caused by \(Y.\) enterocolitica in the current study. Some studies reported that younger children are more susceptible to diarrhea caused by \(Y.\) enterocolitica [9, 27, 39, 40]. Al Jarousha

| Country       | Culture Number | Culture Pooled prevalence (95% confidence interval) | PCR Number | PCR Pooled prevalence (95% confidence interval) |
|---------------|----------------|---------------------------------------------------|------------|-----------------------------------------------|
| Iran          | 4              | 1.83 (0.75–3.33)                                   | 1          | 2.64 (1.37–4.56)                               |
| Crete         | 1              | 5.53 (4.34–6.92)                                   | —          | —                                             |
| Saudi Arabia  |                | —                                                  | 1          | 0.00 (0.00–2.24)                               |
| Palestine     | 2              | 2.65 (1.68–3.83)                                   | —          | —                                             |
| Tanzania      | 1              | 0.00 (0.00–3.52)                                   | —          | —                                             |
| Nigeria       | 3              | 9.29 (1.94–3.08)                                   | 1          | 5.62 (3.74–8.08)                               |
| Madagascar    | 1              | 16.56 (11.21–23.18)                                | 1          | 16.56 (11.21–23.18)                            |
| Japan         | 1              | 2.92 (1.88–4.32)                                   | —          | —                                             |
| Australia     | 1              | 0.00 (0.00–0.47)                                   | —          | —                                             |
| China         | 5              | 2.41 (0.61–5.35)                                   | 3          | 4.37 (0.54–11.54)                              |
| Study                  | Publication_year | Start_year | End_year | Type of study | Country     | Mean_age | Min_age | Max_age | Diagnosis_method | Total_sample_size | Total_PCR_positive | Total_culture_positive | Quality score |
|-----------------------|------------------|------------|----------|---------------|-------------|----------|---------|---------|------------------|-------------------|--------------------|----------------------|---------------|
| Calderaro et al. [16] | 2018             | 2016       | 2018     | Cross-sectional | Italy       | 3.6      | 0       | 14      | Culture + PCR     | 1716              | 17                 | 11                   | 9             |
| Hawash et al. [17]    | 2017             | 2016       | 2017     | Cross-sectional | Saudi Arabia | 29.9     | 0       | 60      | PCR              | 163               | 0                  | —                    | 10            |
| Wang et al. [18]      | 2015             | 2010       | 2014     | Cross-sectional | China       | —        | 0       | 65      | Culture           | 3224              | —                  | 9                    | 9             |
| Fiedoruk et al. [19]  | 2015             | 2010       | 2011     | Cross-sectional | Poland      | 0        | 4       | —       | Culture + PCR     | 100               | 2                  | 2                    | 9             |
| Assis et al. [20]     | 2014             | 2010       | 2011     | Cross-sectional | Brazil      | —        | —       | —       | Culture + PCR     | 400               | 0                  | 0                    | 9             |
| Hilmarsdóttir et al. [21] | 2012     | 2003       | 2007     | Cross-sectional | Iceland     | 0        | 83      | —       | Culture           | 464               | —                  | 3                    | 10            |
| El Qouqa et al. [22]  | 2011             | 2006       | 2007     | Case-control   | Palestine   | 5.01     | 0       | 12      | Culture           | 600               | —                  | 16                   | 9             |
| Wang et al. [23]      | 2010             | 2004       | 2008     | Cross-sectional | China       | —        | —       | —       | Culture           | 1152              | —                  | 14                   | 8             |
| Zheng et al. [9]      | 2008             | 2005       | 2008     | Cross-sectional | China       | —        | 0       | 83      | Culture + PCR     | 2600              | 178                | 160                  | 9             |
| Maltezou et al. [24]  | 2001             | 1999       | 1999     | Cross-sectional | Greece      | —        | 0       | 14      | Culture           | 132               | 2                  | —                    | 8             |
| Huhulescu et al. [25] | 2007             | 2007       | 2009     | Cross-sectional | Austria     | 37       | 0       | 89      | Culture           | 306               | —                  | 1                    | 10            |
| Okwori et al. [1]     | 2009             | 2002       | 2004     | Cross-sectional | Nigeria     | —        | 18      | —       | Culture + PCR     | 480               | 27                 | 27                   | 9             |
| Bucher et al. [4]     | 2008             | 2002       | 2002     | Cross-sectional | Germany     | —        | —       | —       | Culture + real time PCR | 22835            | 46                 | 46                   | 6             |
| Bublitz et al. [26]   | 2014             | 2011       | 2011     | Cross-sectional | Madagascar  | 0        | 15      | —       | Culture + PCR     | 163               | 27                 | 27                   | 10            |
| Duan et al. [3]       | 2017             | 2010       | 2015     | Cross-sectional | China       | —        | 0       | 59      | Culture + PCR     | 9208              | 80                 | 80                   | 10            |
| Ehara et al. [27]     | 2000             | 1997       | 1999     | Cross-sectional | Japan       | 3.56     | 0       | 14      | Culture           | 821               | —                  | 24                   | 7             |
| Ternhag et al. [28]   | 2008             | 1997       | 2004     | Cross-sectional | Sweden      | 36.5     | 0       | 100     | Culture           | 101855            | —                  | 5133                  | 7             |
| Giubbers et al. [29]  | 2011             | 2002       | 2004     | Cross-sectional | Netherlands | 8.8      | 4       | 16      | Culture           | 220               | —                  | 1                    | 6             |
| Rees et al. [30]      | 2004             | 1998       | 1999     | Cross-sectional | USA         | —        | —       | 72      | Culture           | 1454              | —                  | 26                   | 6             |
| Vernacchio et al. [31] | 2006             | 2001       | 2002     | Case-control   | USA         | —        | 0       | 3       | Culture + PCR     | 443               | 1                  | 1                    | 10            |
| Talan et al. [32]     | 2001             | 1997       | 1998     | Prospective case series | USA      | 2.9      | 4       | 41      | Culture           | 549               | —                  | 4                    | 9             |
| de Wit et al. [33]    | 2001             | 1996       | 1999     | Case-control   | Netherlands | —        | 0       | 80      | Culture           | 857               | —                  | 6                    | 10            |
| Karsten et al. [34]   | 2009             | 2004       | 2004     | Case-control   | Germany     | —        | 0       | 80      | Culture           | 1,046             | —                  | 10                   | 9             |
| Svenungs son et al. [35] | 2000     | 1996       | 1997     | Case-control   | Sweden      | 41       | 15      | 98      | Culture           | 851               | —                  | 2                    | 9             |
| Olesen et al. [36]    | 2005             | 2000       | 2001     | Case-control   | Denmark     | 1.2      | 0       | 4       | Culture           | 424               | —                  | 10                   | 9             |
| Study | Publication_year | Start_year | End_year | Type of study | Country | Mean_age | Min_age | Max_age | Diagnosis_method | Total_sample_size | Total_PCR_positive | Total_culture_positive | Quality_score |
|-------|------------------|------------|----------|---------------|---------|----------|---------|---------|------------------|-------------------|-------------------|----------------------|--------------|
| Sinclair et al. [37] | 2005 | 1997 | 1999 | Cross-sectional | Australia | — | 0 | 59 | Culture | 791 | — | 0 | 9 |
| Jansen et al. [38] | 2008 | 2005 | 2007 | Prospective cohort | Germany | 48 | 18 | 91 | Culture/serology | 104 | — | 6 | 9 |
| Okwori. et al. [39] | 2007 | 2005 | 2006 | Cross-sectional | Nigeria | — | 1 | 69 | Culture | 150 | — | 6 | 9 |
| Omoigberal and Abiodun [40] | 2002 | 2001 | 2001 | Cross-sectional | Nigeria | — | 1 | 59 | Culture | 215 | — | 47 | 9 |
| Abdel-Haq et al. [41] | 2006 | 1990 | 2002 | Cross-sectional | USA | 10.3 | 0 | 14 | Culture | 1920 | — | 201 | 10 |
| Perdikogianni et al. [42] | 2006 | 1993 | 2004 | Cross-sectional | Crete | — | 0 | 14 | Culture | 1285 | — | 71 | 5 |
| Zheng et al. [43] | 2007 | 2005 | 2006 | Cross-sectional | China | — | 2 | 83 | Culture + real time PCR | 700 | 52 | 52 | 10 |
| Gasco et al. [44] | 2000 | 1997 | 1997 | Case-control | Tanzania | — | 0 | 5 | Culture | 103 | — | 0 | 9 |
| Stephen et al. [45] | 2013 | 2011 | 2011 | Cross-sectional | Switzerland | — | 20 | 60 | Culture | 811 | — | 9 | 0 |
| Garverianiet al. [46] | 2007 | 2005 | 2006 | Cross-sectional | Iran | — | 0 | 5 | Culture | 405 | — | 13 | 9 |
| GhasemiKebriaet al. [47] | 2010 | 2005 | 2006 | Cross-sectional | Iran | 5.07 | 0 | 22 | PCR | 455 | 12 | — | 9 |
| Al Jarousha et al. [48] | 2011 | 2006 | 2007 | Case-control | Palestine | 5.01 | 0 | 12 | Culture | 300 | — | 8 | 9 |
| Huovinen et al. [49] | 2010 | 2006 | 2006 | Case-control | Finland | 46.66 | 0 | 99 | Culture | 41841 | — | 406 | 8 |
| Sihvonen et al. [50] | 2009 | 2006 | 2006 | Cross-sectional | Finland | — | — | — | Culture | 41848 | — | 473 | 7 |
| Orlandi et al. [51] | 2001 | 1998 | 1999 | Case-control | Brazil | 0.86 | 0 | 5 | Culture | 130 | — | 1 | 10 |
| Abdel-Haq et al. [52] | 2000 | 1990 | 1997 | Retrospective | USA | 0.75 | 0 | 12 | Culture | 10 570 | — | 142 | 9 |
| Nimmt and Meqdam [53] | 2004 | 2000 | 2002 | Case-control | Jordan | 48 | 12 | 84 | Culture + PCR | 180 | 8 | 8 | 10 |
| Maniki et al. [54] | 2003 | 1995 | 1999 | Cross-sectional | Greece | — | 0 | 59 | Culture | 7090 | — | 46 | 10 |
| Torres et al. [55] | 2001 | 1990 | 1994 | Case-control | Uruguay | 0.4 | 0 | 2 | Culture | 224 | — | 1 | 8 |
| Dallal et al. [56] | 2006 | 1998 | 1999 | Cross-sectional | Iran | — | 0 | 5 | Culture | 1600 | — | 11 | 10 |
| Soltan Dallal et al. [57] | 2004 | 2002 | 2002 | Cross-sectional | Iran | 3.24 | 0 | 12 | Culture | 300 | — | 8 | 10 |
| Soleymani-Rahbar et al. [58] | 2007 | — | — | Cross-sectional | Iran | — | 0 | 10 | Culture | 800 | — | 14 | 9 |
Heterogeneity between groups: \( p = 0.121 \)

Overall (\( I^2 = 99.19\%, \ p = 0.00 \)); Subtotal (\( I^2 = 99.37\%, \ p = 0.00 \))

GASCO´ N, J. (2000, Tanzania)
Gijsbers, C.F.M. (2011, Netherlands)
Maraki, S. (2003, Greece)
Soleymani-Rahbar, A.A. (2007, Iran)
Soltan Dallal, M.M. (2004, Iran)
Subtotal (\( I^2 = 77.15\%, \ p = 0.00 \))

Abdel-Haq, N.M. (2006, USA)
Ehara, A. (2000, Japan)
Okwori, A.E.J. (2009, Nigeria)
Garveriani, E. (2007, Iran)
Maltezou, H.C. (2001, Greece)
El Qouqa, I.A. (2011, Palestine)
Assis, F.E.A. (2014, Brazil)
Calderaro, A. (2018, Italy)
Wang, X. (2015, China)
Wang, X. (2010, China)
Zheng, H. (2008, China)
Olesen, B. (2005, Denmark)

Study | ES (95% CI) | Weight (%) |
--- | --- | --- |
Abdel-Haq, N.M. (2000, USA) | 1.34 (1.13, 1.58) | 2.42 |
Talan, D.A. (2001, USA) | 0.73 (0.20, 1.85) | 2.27 |
Rees, J.R. (2004, USA) | 1.79 (1.17, 2.61) | 2.36 |
Abdel-Haq, N.M. (2006, USA) | 10.47 (9.13, 11.93) | 2.38 |
Vernacchius, L. (2006, USA) | 0.23 (0.01, 1.25) | 2.23 |
Asis, F.E.A. (2014, Brazil) | 0.00 (0.00, 0.92) | 2.31 |
Maltezou, H.C. (2001, Greece) | 1.52 (0.18, 5.37) | 1.88 |
Maraki, S. (2003, Greece) | 0.65 (0.48, 0.86) | 2.41 |
Huhulescu, S. (2007, Austria) | 0.33 (0.01, 1.81) | 2.16 |
Ternhag, A. (2008, Sweden) | 5.04 (4.91, 5.18) | 2.45 |
Jansen, A. (2008, Germany) | 5.77 (2.15, 12.13) | 1.77 |
Bucher, M. (2008, Germany) | 0.20 (0.15, 0.27) | 2.42 |
Silvonen, L.M. (2009, Finland) | 1.13 (1.03, 1.24) | 2.42 |
Huovinen, E. (2010, Finland) | 0.97 (0.88, 1.07) | 2.42 |
Gjisbers, C.F.M. (2011, Netherlands) | 0.45 (0.01, 2.51) | 2.07 |
Hilmarsdttir, J. (2012, Iceland) | 0.65 (0.13, 1.88) | 2.24 |
Stephen, R. (2013, Switzerland) | 1.11 (0.51, 2.10) | 2.32 |
Fiedoruk, K. (2015, Poland) | 2.00 (0.24, 7.04) | 1.75 |
Calderaro, A. (2018, Italy) | 0.64 (0.32, 1.14) | 2.37 |
Solhan Dallal, M.M. (2004, Iran) | 2.67 (1.16, 5.19) | 2.15 |
Solhan Dallal, M.M. (2006, Iran) | 0.69 (0.34, 1.23) | 2.37 |
Perdikogianni, C. (2006, Crete) | 5.53 (4.34, 6.92) | 2.36 |
Soleymani-Rahbar, A.A. (2007, Iran) | 1.75 (0.96, 2.92) | 2.32 |
Garveriani, E. (2007, Iran) | 3.21 (1.72, 5.43) | 2.22 |
Omoiberale, A.I. (2002, Nigeria) | 21.86 (16.53, 27.99) | 2.06 |
Okwori, A.E.J. (2007, Nigeria) | 4.00 (1.48, 8.50) | 1.93 |
Okwori, A.E.J. (2009, Nigeria) | 5.63 (3.74, 8.08) | 2.25 |
Bublitz, D.C. (2014, Madagascar) | 16.56 (11.21, 23.18) | 1.96 |
Ebara, A. (2000, Japan) | 2.92 (1.88, 4.32) | 2.32 |
Sinclaire, M.I. (2005, Australia) | 0.00 (0.00, 0.47) | 2.31 |
Zheng, H. (2007, China) | 7.43 (5.60, 9.63) | 2.30 |
Zheng, H. (2008, China) | 6.15 (5.26, 7.15) | 2.39 |
Wang, X. (2010, China) | 1.22 (0.67, 2.03) | 2.35 |
Wang, X. (2015, China) | 0.28 (0.13, 0.53) | 2.40 |
Duan, R. (2017, China) | 0.87 (0.69, 1.08) | 2.42 |
Subtotal (\( I^2 = 99.37\%, \ p = 0.00 \)) | 2.20 (1.43, 3.11) | 78.64 |

Case-control

Orlandi, P.P. (2001, Brazil) | 0.77 (0.02, 4.21) | 1.87 |
Torres, M.E. (2001, Uruguay) | 0.45 (0.01, 2.46) | 2.07 |
Svenungsson, B. (2000, Sweden) | 0.24 (0.03, 0.85) | 2.32 |
de Wit, M.A.S. (2001, Netherlands) | 0.70 (0.26, 1.52) | 2.32 |
Olesen, B. (2003, Denmark) | 2.36 (1.14, 4.29) | 2.22 |
Karsten, C. (2009, Germany) | 0.96 (0.46, 1.75) | 2.34 |
Nimri, L.F. and Meqdam (2004, Jordan) | 4.44 (1.94, 8.57) | 2.00 |
Al Jarousha, A.M.Kh. (2011, Palestine) | 2.67 (1.16, 5.19) | 2.15 |
El Quizza, I.A. (2011, Palestine) | 2.67 (1.53, 4.29) | 2.28 |
GASCO´ N, J. (2000, Tanzania) | 0.00 (0.00, 3.52) | 1.77 |
Subtotal (\( I^2 = 77.15\%, \ p = 0.00 \)) | 1.22 (0.57, 2.08) | 21.36 |

Heterogeneity between groups: \( p = 0.121 \)
Overall (\( I^2 = 99.19\%, \ p = 0.00 \)):

Prevalence

(a) Figure 3: Continued.
et al. reported higher isolation of *Y. enterocolitica* from diarrheic children with the age of one to six years than children less than one year and more than 6 years [48]. *Y. enterocolitica* had different biotypes and serotypes. The insignificant effect of age may be due to infection of children, adults, and the elderly with different serotypes that may not necessarily create immunity to other serotypes [65]. Furthermore, limited studies were performed on older ages. Gender difference was not seen in the current study. Men and women did not show different symptoms in yersiniosis [40, 49]. A seasonal variation was not seen in the present study. Some studies reported more cases during the cooler season [46, 66], but according to the report of the European Centre for Disease Prevention and Control, no seasonal pattern was observed for yersiniosis for a period of three years [67]. Some other studies did not also report a significant difference between seasons [9, 47, 68], which may support the hypothesis that the infection is transmitted via food items that are consumed consistently throughout the year, such as meat and meat products [65].

Among the six biotypes of *Y. enterocolitica*, 1A was the most prevalent biotype. As biotype 1A is a nonpathogenic biotype mostly found in the environment, it had a higher prevalence in most studies and was isolated from human, animals, and gastroenteritis [49, 50, 69]. Among the virulent biotypes, biotypes II and III had a prevalence of 33.06% and 12.89%, respectively. In the current study, serotypes O3 and O9 had the most prevalence. They were reported in other studies as the main serotypes of *Y. enterocolitica* in diarrheal patients [4, 39, 43]. Serotype O8 was the third serotype in gastroenteritis patients of the current study. It was observed as the most pathogenic serotype in biotype 1B that was correlated to four of six food poisoning outbreaks in the US [41]. A total of 18% of the patients were infected with pathogenic *Y. enterocolitica* [49]. A total of 0.6% of acute diarrhea cases were because of *Y. enterocolitica* and all of them were serotype O3 [54]. In Nigeria, *Y. enterocolitica* bioserotype 2/O9 was the only isolated pathogenic in human samples. Bioserotype 4/O3 of *Y. enterocolitica* is the major isolated one from humans globally [63] and was isolated in some European countries, including Denmark, Italy, Belgium, Spain, Finland, and Sweden [50, 64]. According to Stephen et al., biotypes II and IV were only diagnosed in diarrheal patients, but strains of biotype 1A were isolated from both asymptomatic and diarrheal patients which shows the biotype 1A is not the etiologic agent of gastroenteritis [45]. *Y. enterocolitica* serotype O3 was commonly isolated.

### Figure 3: Forest plots for random-effects meta-analysis of the prevalence of *Y. enterocolitica* by (a) culture method and (b) PCR method according to the type of studies.

| Study                          | ES (95% CI)   | Weight (%) |
|-------------------------------|--------------|------------|
| Case-control                  |              |            |
| Nimri, L.F. and Meqdam (2004, Jordan) | 4.44 (1.94, 8.57) | 7.11       |
| Cross sectional               |              |            |
| Vernacchio, L. (2006, USA)    | 0.23 (0.01, 1.25) | 7.82       |
| Zheng, H. (2007, China)       | 7.43 (5.60, 9.63) | 8.02       |
| Bucher, M. (2008, Germany)    | 0.20 (0.15, 0.27) | 8.38       |
| Zheng, H. (2008, China)       | 6.85 (5.91, 7.89) | 8.29       |
| Okworni, A.E.J. (2009, Nigeria) | 5.63 (3.74, 8.08) | 7.86       |
| Ghiesemikibria, F. (2010, Iran) | 2.64 (1.37, 4.56) | 7.83       |
| Assis, F.E.A. (2014, Brazil)  | 0.00 (0.00, 0.92) | 7.76       |
| Bublitz, D.C. (2014, Madagascar) | 16.56 (11.21, 23.18) | 7.00       |
| Feidruck, K. (2015, Poland)   | 2.00 (0.24, 7.04) | 6.34       |
| Duan, R. (2017, China)        | 0.87 (0.69, 1.08) | 8.36       |
| Hawash, Y.A. (2017, Saudi Arabia) | 0.00 (0.00, 2.24) | 7.00       |
| Calderaro, A. (2018, Italy)   | 0.99 (0.58, 1.58) | 8.23       |
| Subtotal (*I² = 98.50%, *p = 0.00*) | 2.28 (0.95, 4.11) | 92.89       |
| Heterogeneity between groups: *p = 0.048* | 2.41 (1.07, 4.22) | 100.00     |
| Overall (*I² = 98.39%, *p = 0.00*) |              |            |

(b)
Heterogeneity between groups: \( p = 0.000 \)

Overall (\( I^2 = 99.19\%, p = 0.00 \)); Subtotal (\( I^2 = 99.98\%, p = 0.00 \))

El Qouqa, I.A. (2011, Palestine)
Huovinen, E. (2010, Finland)
Bublitz, D.C. (2014, Madagascar)
Torres, M.E. (2001, Uruguay)
Hilmarsdóttir, I. (2012, Iceland)

Subtotal (\( I^2 = 99.48\%, p = 0.00 \))
Wang, X. (2010, China)
Omoigberale, A.I. (2002, Nigeria)
Perdikogianni, C. (2006, Crete)
Bucher, M. (2008, Germany)
Huhulescu, S. (2007, Austria)

Low

Subtotal (\( I^2 = 99.98\%, p = 0.00 \))
Duan, R. (2017, China)
Assis, F.E.A. (2014, Brazil)
Fu, X. (2008, China)
Talan, D.A. (2001, USA)
Rees, J.R. (2004, USA)
Jansen, A. (2008, Germany)
Ternhag, A. (2008, Sweden)
Zheng, H. (2008, China)

Upper_middle

Subtotal (\( I^2 = 94.46\%, p = 0.00 \))
Zheng, H. (2007, China)
Karsten, C. (2009, Germany)
Jansen, A. (2008, Germany)
Ternhag, A. (2008, Sweden)

High

Subtotal (\( I^2 = 97.02\%, p = 0.00 \))
Wang, X. (2010, China)
Assis, F.E.A. (2014, Brazil)
Duan, R. (2017, China)
Zheng, H. (2007, China)
Karsten, C. (2009, Germany)
Jansen, A. (2008, Germany)
Ternhag, A. (2008, Sweden)

Heterogeneity between groups: \( p = 0.000 \)
Overall (\( I^2 = 99.19\%, p = 0.00 \));
Heterogeneity between groups: \( p = 0.027 \)

Overall (\( I^2 = 98.39\% \), \( p = 0.00 \));

Hawash, Y.A. (2017, Saudi Arabia)

Study

Okwori, A.E.J. (2009, Nigeria)

Zheng, H. (2008, China)

Fiedoruk, K. (2015, Poland)

Duan, R. (2017, China)

Bucher, M. (2008, Germany)

Nimri, L.F. and Meqdam (2004, Jordan)

Calderaro, A. (2018, Italy)

Vernacchio, L. (2006, USA)

Zheng, H. (2007, China)

Ghasemikebria, F. (2010, Iran)

Bublitz, D.C. (2014, Madagascar)

Low

Prevalence

Diagnosis method, Culture

<6 years old (n=21, \( I^2=94.01 \))

6-18 years old (n=12, \( I^2=93.72 \))

18-59 years old (n=9, \( I^2=93.28 \))

Subtotal (\( I^2 = 0.0\% \), \( p = 0.932 \))

Diagnosis method, PCR

<6 years old (n=7, \( I^2=96.1 \))

6-18 years old (n=5, \( I^2=90.57 \))

18-59 years old (n=4, \( I^2=96.08 \))

Subtotal (\( I^2 = 0.0\% \), \( p = 0.932 \))

Gender

Female (n=7, \( I^2=95.63 \))

Male (n=7, \( I^2=90.44 \))

Subtotal (\( I^2 = 0.0\% \), \( p = 0.987 \))

Seasons

Spring (n=8, \( I^2=94.21 \))

Summer (n=7, \( I^2=94.54 \))

Autumns (n=8, \( I^2=92.06 \))

Winter (n=7, \( I^2=90.77 \))

Subtotal (\( I^2 = 0.0\% \), \( p = 0.989 \))

NOTE: Weights are from random effects analysis

Analysis of Prevalence (%) by Income of Countries

Study ID | ES (95% CI) | Weight (%)
---|---|---
Bublitz, D.C. (2014, Madagascar) | 16.56 (11.21, 23.18) | 7.00
Okwori, A.E.J. (2009, Nigeria) | 5.63 (3.74, 8.08) | 7.86
Nimri, L.F. and Meqdam (2004, Jordan) | 4.44 (1.94, 8.57) | 7.11
Zheng, H. (2007, China) | 7.43 (5.60, 9.63) | 8.02
Zheng, H. (2008, China) | 6.85 (5.91, 7.89) | 8.29
Ghasemikebria, F. (2010, Iran) | 2.64 (1.37, 4.56) | 7.83
Assis, F.E.A. (2014, Brazil) | 0.00 (0.00, 0.92) | 7.76
Duan, R. (2017, China) | 0.87 (0.69, 1.08) | 8.36
Bucher, M. (2008, Germany) | 4.44 (1.94, 8.57) | 7.00
Calderaro, A. (2018, Italy) | 0.99 (0.58, 1.58) | 8.23
Vernacchio, L. (2006, USA) | 0.20 (0.15, 0.27) | 8.38
Zheng, H. (2007, China) | 0.36 (0.01, 1.02) | 8.38
Ghasemikebria, F. (2010, Iran) | 0.20 (0.15, 0.27) | 8.38
Buch, M. (2008, Germany) | 2.00 (0.24, 7.04) | 6.34
Hawash, Y.A. (2017, Saudi Arabia) | 0.00 (0.00, 2.24) | 7.00
Fiedoruk, K. (2015, Poland) | 1.49 (0.14, 3.82) | 8.36
Fiedoruk, K. (2015, Poland) | 1.49 (0.14, 3.82) | 8.36
Fiedoruk, K. (2015, Poland) | 1.75 (0.96, 2.54) | 8.36

Figure 4: Forest plots for random-effects meta-analysis of the prevalence of \( Y. \) enterocolitica by (a) culture method and (b) PCR method according to income of countries.

Figure 5: Forest plots for random-effects meta-analysis of the prevalence of \( Y. \) enterocolitica by (a) age and gender of participants and season of sampling and (b) biotypes and serotypes.
from children, whereas *Y. enterocolitica* serotype O9 was frequently isolated from adults (≥40 years of age). Exposure of children to *Y. enterocolitica* O3 may conceivably provide some immunity against acute infections due to the same serotype during their life, but not necessarily from other serotypes [65]. According to HDI, the prevalence of

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**Figure 6:** Metaregression results between the prevalence of *Y. enterocolitica* and (a) publication year of the culture studies; (b) publication year of the molecular studies; (c) human development index of the culture studies; (d) human development index of the molecular studies; (e) longitude of the countries of the culture studies; (f) longitude of the countries of molecular studies; (g) latitudes of the countries of the culture studies; (h) latitudes of the countries of molecular studies.
4.1. Strengths and Limitations. This was the first systematic review and meta-analysis to gain a global prevalence of Y. enterocolitica in gastroenteritis patients. We considered both the culture and PCR isolation of the organism. There was high heterogeneity among the studies especially due to income but mostly reduced by the application of subgroup analysis and metagression. Additionally, this study has some limitations that must be acknowledged: first, in some analyses, the number of included studies was low, especially in the older ages (e.g., >60 years); second, there were not sufficient related studies for assessing risk factors; third, the age of participants was not reported clearly in some included studies. Forth, the transmission method of the organism was not reported in the studies. However, estimating the global prevalence of Y. enterocolitica is challenging as most of the studies were performed in hospitalized patients with gastrointestinal symptoms. We encourage further studies, especially in the western Pacific and southeast WHO regions to produce and share local data about yersiniosis. An update of our study should be done due to the availability of additional data.

5. Conclusion

In conclusion, the findings of this systematic review show that Y. enterocolitica is prevalent in gastroenteritis in all age groups. Y. enterocolitica was not prevalent in high-income countries and countries with higher HDI values. Serotypes O3 and O9 of Y. enterocolitica had the highest prevalence and O5:27 had the least prevalence in diarrheal patients. The prevalence of Y. enterocolitica was similar in both gender and different seasons. It should be noted that to determine the role of the organism, more studies are needed especially in food-borne diseases.

Abbreviations

Y. enterocolitica: Yersinia enterocolitica
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TZ: Tayebeh Zeinali
SMR: Seyed Mohamad Riahi
EA: Ehsan Ahmadi
HDI: Human development index
WHO: World Health Organization
SD: Standard deviation
PCR: Polymerase chain reaction
Fig: Figure
USA: United States of America.

Data Availability

The data are available from the corresponding author on reasonable request.

Ethical Approval

The study was approved by the ethical committee of Birjand University of Medical Sciences (Ir.bums.rec.1399.176).

Conflicts of Interest

The authors declare that there are no conflicts of interest about the results of the present study.

Authors’ Contributions

SMR, EA, and TZ designed the research. SMR, EA, and TZ conducted the meta-analysis and drafted the manuscript. SMR and TZ analyzed the data. SMR, EA, and TZ revised the manuscript. All the authors read and approved the final manuscript.

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Supplementary Materials

The search strategy is presented in the supplementary material. (Supplementary Materials)

References

[1] A. E. J. Okwori, P. O. Martinez, M. Fredriksson-Ahomaa, S. E. Agina, and H. Korkeala, “Pathogenic Yersinia enterocolitica 2/O:9 and Yersinia pseudotuberculosis 1/O:1 strains isolated from human and non-human sources in the Plateau State of Nigeria,” Food Microbiology, vol. 26, no. 8, pp. 872–875, 2009.
[2] E. J. Bottone, “Yersinia enterocolitica: revisitation of an enduring human pathogen,” Clinical Microbiology Newsletter, vol. 23, no. 9, pp. 1–8, 2015.
[3] R. Duan, J. Liang, J. Zhang et al., “Prevalence of Yersinia enterocolitica Bioseerotype 3/O:3 among children with Diarrhea, China, 2010–2015,” Emerging Infectious Diseases, vol. 23, no. 9, pp. 1502–1509, 2017.
[4] M. Bucher, C. Meyer, B. Grötzbach, S. Wacheck, A. Stolle, and M. Fredriksson-Ahomaa, “Epidemiological data on pathogenic Yersinia enterocolitica in southern Germany during 2000–2006,” Foodborne Pathogens and Disease, vol. 5, no. 3, pp. 273–280, 2008.
[5] M. Fredriksson-Ahomaa, A. Stolle, and H. Korkeala, “Molecular epidemiology of Yersinia enterocolitica infections,” FEMS Immunology and Medical Microbiology, vol. 47, no. 3, pp. 315–329, 2006.

[6] K. Nikolaou, A. Hensel, C. Bartling et al., “Prevalence of anti-Yersinia enterocolitica outer protein antibodies in goats in lower saxony,” Journal of Veterinary Medicine Series B, vol. 52, no. 1, pp. 17–24, 2005.

[7] S. Boqvist, H. Pettersson, ˚A. Svensson, and Y. Andersson, “Sources of sporadic Yersinia enterocolitica infection in children in Sweden, 2004: a case-control study,” Epidemiology and Infection, vol. 137, no. 6, pp. 897–905, 2008.

[8] L. A. Lee, J. Taylor, G. P. Carter, B. Quinn, J. J. Farmer, and R. V. Tauxe, “Yersinia enterocolitica O:3—an emerging cause of pediatric gastroenteritis in the United States,” Journal of Infectious Diseases, vol. 163, no. 3, pp. 660–663, 1991.

[9] H. Zheng, Y. Sun, S. Lin, Z. Mao, and B. Jiang, “Yersinia enterocolitica infection in diarrheal patients,” European Journal of Clinical Microbiology & Infectious Diseases, vol. 27, no. 8, pp. 741–752, 2008.

[10] S. M. Riahi and Y. Mokhayeri, “Methodological issues in a meta-analysis,” Current Medical Research and Opinion, vol. 33, no. 10, p. 1813, 2017.

[11] J. Higgins, Assessing Risk of Bias in Included Studies, D. G. Altman and J. P. T. Higgins, Eds., UK: The Cochrane Collaboration, Wiley-Blackwell, Chichester, UK, 2008.

[12] F. E. A. Assis, S. Wolf, M. Surek et al., “Impact of Aeromonas and diarrheagenic Escherichia coli screening in patients with diarrhea in Paraná, southern Brazil,” The Journal of Infection in Developing Countries, vol. 8, no. 12, pp. 1609–1614, 2014.

[13] I. Hilmarsdottir, G. E. Baldvinsdottir, H. Harðardóttir, H. Briem, and S. I. Sigurðsson, “Enteropathogens in acute diarrhea: a general practice-based study in a Nordic country,” European Journal of Clinical Microbiology & Infectious Diseases, vol. 31, no. 7, pp. 1501–1509, 2012.

[14] Y. A. El Quouqa, M. A. E. Jarou, A. S. A. Samaha, A. S. A. Afifi, and A. M. K. Al Jarousha, “Yersinia enterocolitica infection among children aged less than 12 years: a case-control study,” International Journal of Infectious Diseases, vol. 15, no. 1, pp. e48–e53, 2011.

[15] X. Wang, Z. Cai, H. Wang et al., “Pathogenic strains of Yersinia enterocolitica isolated from domestic dogs (Canis familiaris) belonging to farmers are of the same subtype as pathogenic Y. enterocolitica strains isolated from humans and may Be a source of human infection in Jiangsu province, China,” Journal of Clinical Microbiology, vol. 48, no. 5, pp. 1604–1610, 2010.

[16] K. R. Tauxe, A. Zafiroupolou, M. Mavrikou et al., “Acute diarrhoea in children treated in an outpatient setting in Athens, Greece,” International Journal of Infection, vol. 43, no. 2, pp. 122–127, 2001.

[17] S. Huhulescu, R. Kiss, M. Brettlecker et al., “Etiology of acute gastroenteritis in three sentinel general practices,” Infection, vol. 37, no. 2, pp. 103–108, 2007.

[18] D. C. Bublitz, P. C. Wright, J. R. Bodager, F. T. Rasambainarivo, J. B. Bliska, and T. R. Gillespie, “Epidemiology of pathogenic enterobacteria in humans, livestock, and peridomestic rodents in rural Madagascar,” PLoS One, vol. 9, no. 7, Article ID e101456, 2014.

[19] A. E. Agra, K. Egawa, F. Kuroki, O. I. a. M. Okawa, and M. Okawa, “Age-dependent expression of abdominal symptoms in patients with Yersinia enterocolitica infection,” Pediatries International, vol. 42, no. 4, pp. 364–366, 2000.

[20] A. Ternhag, A. Törner, A. Svensson, K. Ekdahl, and J. Giesecke, “Short- and long-term effects of bacterial gastrointestineal infections,” Emerging Infectious Diseases, vol. 14, no. 1, pp. 143–148, 2008.

[21] C. Gijsbers, M. Benninga, and H. Büller, “Clinical and laboratory findings in 220 children with recurrent abdominal pain,” Acta Paediatrica, vol. 100, no. 7, pp. 1028–1032, 2011.

[22] J. R. Rees, M. A. Pannier, A. McNees, S. Shallow, F. J. Angulo, and D. J. Vugia, “Persistent diarrhea, arthritis, and other complications of enteric infections: a pilot survey based on California FoodNet surveillance, 1998–1999,” Complications of Enteric Infections, vol. 38, no. 3, pp. S31–S37, 2004.

[23] L. Vernacchio, R. M. Vezina, A. A. Mitchell, S. M. Lesko, A. G. Plaut, and D. W. K. Acheson, “Diarrhea in American infants and young children in the community setting,” The Pediatric Infectious Disease Journal, vol. 25, no. 1, pp. 2–7, 2006.

[24] D. A. Talan, G. J. Moran, M. Newdow et al., “Pathogenicity of bloody diarrhea among patients presenting to United States emergency departments: prevalence of Escherichia coli 0157: H7 and other enteropathogens,” Clinical Infectious Diseases, vol. 32, no. 4, pp. 573–580, 2001.

[25] M. A. S. de Wit, M. P. G. Koopmans, L. M. Kortbeek, N. J. van Leeuwen, J. Vinje, and Y. T. H. P. van Duynhoven, “Etiology of gastroenteritis in sentinel general practices in the
Netherlands," Clinical Infectious Diseases, vol. 33, pp. 280–288, 2001.

[34] C. Karsten, S. Baumgarte, A. W. Friedrich et al., "Incidence and risk factors for community-acquired acute gastroenteritis in north-west Germany in 2004," European Journal of Clinical Microbiology & Infectious Diseases, vol. 28, no. 8, pp. 935–943, 2009.

[35] B. Svenungsson, A. Lagergren, E. Ekwall et al., "Enteropathogens in adult patients with diarrhea and healthy control subjects: a 1-year prospective study in a Swedish clinic for infectious diseases," Clinical Infectious Diseases, vol. 30, no. 5, pp. 770–778, 2000.

[36] B. Olesen, J. Neumann, B. Böttiger et al., "Etiology of diarrhea in young children in Denmark: a case-control study," Journal of Clinical Microbiology, vol. 43, no. 8, pp. 3636–3641, 2005.

[37] M. I. Sinclair, M. E. Hellard, R. Wolfe, T. Z. Mitakakis, B. Olesen, J. Neumann, B. Böttiger, "Role of Yersinia enterocolitica among diarrhoeal patients attending university of Benin teaching hospital, Benin city, Nigeria," Sahel Medical Journal, vol. 5, no. 4, pp. 182–185, 2002.

[38] N. M. Abdel-Haq, R. Papadopol, B. Asmar, and W. Brown, "Antibiotic susceptibilities of Yersinia enterocolitica recovered from children over a 12-year period," International Journal of Antimicrobial Agents, vol. 27, no. 5, pp. 449–452, 2006.

[39] C. Perdikogianni, E. Galanakis, M. Michalakis et al., "Yersinia enterocolitica infection mimicking surgical conditions," Pediatric Surgery International, vol. 22, no. 7, pp. 589–592, 2006.

[40] H. Zheng, J. Wang, Y. Sun, and B. Jiang, "Clinical isolation and characterization of Yersinia enterocolitica in China using real-time PCR and culture method," Digestion, vol. 75, no. 4, pp. 199–204, 2007.

[41] N. J. Gasco, M. Vargas, D. Schellenberg, H.URassa, C. Casals, and E. Kahigwa, "Diarrhea in children under 5 years of age from Ifakara, Tanzania: a case-control study," Journal of Clinical Microbiology, vol. 38, no. 12, pp. 4459–4462, 2000.

[42] R. Stephon, S. Joutsen, E. Hofer et al., "Characteristics of Yersinia enterocolitica biotype 1A strains isolated from patients and asymptomatic carriers," European Journal of Clinical Microbiology & Infectious Diseases, vol. 32, no. 7, pp. 869–875, 2013.

[43] E. Garveriani, M. M. Aslani, S. Habibzadeh, and A. Fathi, "Role of Yersinia enterocolitica in acute diarrhea of children under 5 years old in cold seasons in Ardabil," Journal of Ardabil University of Medical Sciences, vol. 7, no. 4, pp. 387–391, 2008.

[44] F. GhasemiKebria, B. Khodabakshi, H. Kouhsari, M. SadeghiSheshpoli, N. Behnampoor, and S. Livani, "Yersinia enterocolitica in cases of diarrhea in Gorgan, northern Iran," Medical Laboratory Journal, vol. 4, no. 1, 2010.

[45] A. M. K. Al Jarousha, M. A. El Jarou, and I. A. El Quouqa, "Bacterial enteropathogens and risk factors associated with childhood diarrhea," Indian Journal of Pediatrics, vol. 78, no. 2, pp. 165–170, 2011.

[46] E. Huovinen, L. M. Sihvonen, K. Haukka, A. Siitonen, M. Kuusi, and M. Kuusi, "Symptoms and sources of Yersinia enterocolitica-infection: a case-control study," BMC Infectious Diseases, vol. 10, no. 1, p. 122, 2010.

[47] L. M. Sihvonen, K. Haukka, K. Haukka, M. Kuusi, M. J. Virtanen, and A. Siitonen, "Yersinia enterocolitica and Y. enterocolitica-like species in clinical stool specimens of humans: identification and prevalence of bio/serotypes in Finland," European Journal of Clinical Microbiology & Infectious Diseases, vol. 28, no. 7, pp. 757–765, 2009.

[48] P. P. Orlandi, T. Silva, G. F. Magalhães et al., "Enteropathogens associated with diarrheal disease in infants of poor urban areas of Porto Velho, Rondônia: a preliminary study," Memórias do Instituto Oswaldo Cruz, vol. 96, no. 5, pp. 621–625, 2001.

[49] M. M. Abdel-Haq, B. I. Asmar, W. M. Abuhammour, and W. J. Brown, "Yersinia enterocolitica infection in children," The Pediatric Infectious Disease Journal, vol. 19, no. 10, pp. 954–958, 2000.

[50] L. F. Nimri and M. Meqdad, "Enteropathogens associated with cases of gastroenteritis in a rural population in Jordan," Clinical Microbiology and Infections, vol. 10, no. 7, pp. 634–639, 2004.

[51] S. Maraki, A. Georgiladakis, Y. Tselentis, and G. Samonis, "A 5-year study of the bacterial pathogens associated with acute diarrhoea on the island of Crete, Greece, and their resistance to antibiotics," European Journal of Epidemiology, vol. 18, pp. 85–90, 2003.

[52] M. E. Torres, M. C. Pérez, F. Schelotto et al., "Etiology of children's diarrhea in montevideo, Uruguay: associated pathogens and unusual isolates," Journal of Clinical Microbiology, vol. 39, no. 6, pp. 2134–2139, 2001.

[53] M. M. Dallal, M. R. Khorramizadeh, and K. MoezAradal, "Occurrence of enteropathogenic bacteria in children under 5 years with diarrhoea in south Tehran," Eastern Mediterranean Health Journal, vol. 12, no. 6, pp. 792–797, 2006.

[54] M. M. Soltan-Dallal and K. MoezAradal, "Frequency of Yersinia species infection in paediatric acute diarrhoea in Tehran," Eastern Mediterranean Health Journal, vol. 10, no. 1, pp. 152–158, 2004.

[55] A. A. Soleymani-Rahbar, F. Fayaz, A. Zargarzadeh, and R. Nikazma, "Surveying the prevalence and pattern of antimicrobial resistance of Yersinia enterocolitica among diarrheal children attending health care centers in Qom," Iranian Journal of Clinical Infectious Diseases, vol. 2, no. 3, pp. 143–147, 2007.

[56] N. Drummond, B. P. Murphy, T. Ringwood, M. B. Prentice, J. F. Buckley, and S. Fanning, "Yersinia enterocolitica: a brief review of the issues relating to the zoonotic pathogen, public health challenges, and the pork production chain," Foodborne pathogens and disease, vol. 9, no. 3, pp. 179–189, 2012.

[57] A. Chakraborty, K. Komatsu, M. Roberts et al., "Yersinia enterocolitica among cases of diarrhea in Gorgan, northern Iran," Medical Laboratory Journal, vol. 4, no. 1, 2010.

[58] J. F. Buckley, and S. Fanning, "Yersinia enterocolitica infection: a case-control study," BMC Infectious Diseases, vol. 8, no. 1, p. 122, 2010.

[59] Memórias do Instituto Oswaldo Cruz, vol. 19, no. 10, pp. 859–902, 2006.

[60] I. A. El Qouqa, "Enteropathogens associated with cases of gastroenteritis in a rural population in Jordan," Clinical Microbiology and Infections, vol. 10, no. 7, pp. 634–639, 2004.

[61] S. Maraki, A. Georgiladakis, Y. Tselentis, and G. Samonis, "A 5-year study of the bacterial pathogens associated with acute diarrhoea on the island of Crete, Greece, and their resistance to antibiotics," European Journal of Epidemiology, vol. 18, pp. 85–90, 2003.

[62] M. M. Dallal, M. R. Khorramizadeh, and K. MoezAradal, "Frequency of Yersinia species infection in paediatric acute diarrhoea in Tehran," Eastern Mediterranean Health Journal, vol. 10, no. 1, pp. 152–158, 2004.

[63] A. A. Soleymani-Rahbar, F. Fayaz, A. Zargarzadeh, and R. Nikazma, "Surveying the prevalence and pattern of antimicrobial resistance of Yersinia enterocolitica among diarrheal children attending health care centers in Qom," Iranian Journal of Clinical Infectious Diseases, vol. 2, no. 3, pp. 143–147, 2007.

[64] N. Drummond, B. P. Murphy, T. Ringwood, M. B. Prentice, J. F. Buckley, and S. Fanning, "Yersinia enterocolitica: a brief review of the issues relating to the zoonotic pathogen, public health challenges, and the pork production chain," Foodborne pathogens and disease, vol. 9, no. 3, pp. 179–189, 2012.

[65] A. Chakraborty, K. Komatsu, M. Roberts et al., "The descriptive epidemiology of yersiniosis: a multistate study, 2005–2011," Public Health Reports, vol. 130, no. 3, pp. 269–277, 2015.

[66] Foodborne Diseases Active Surveillance Network (FoodNet), "Incidence and trends of infection with pathogens transmitted commonly through food —foodborne diseases active surveillance Network, 10 U.S. Sites, 1996–2012," Morbidity and Mortality Weekly Report, vol. 62, no. 15, pp. 283–287, 2013.
[62] (ECDC) European Centre for Disease Prevention and Control. Yersiniosis, ECDC Annual Epidemiological Report for 2016, ECDC, Stockholm, Sweden, 2018.

[63] M. Fredriksson-Ahomaa, N. Lindstrom, and H. Korkeala, Pathogens and Toxins in Food: Challenges and Interventions, ASM Press, Washington, DC, USA, 2010.

[64] A. Rahman, T. S. Bonny, S. Stomsaoavapak, and C. Ananchaipattana, “Yersinia enterocolitica: epidemiological studies and outbreaks,” *Journal of Pathogens*, vol. 2011, Article ID 239391, 11 pages, 2011.

[65] B. M. Rosner, K. Stark, and D. Werber, “Epidemiology of reported *Yersinia enterocolitica* infections in Germany, 2001–2008,” *BMC Public Health*, vol. 10, no. 1, p. 337, 2010.

[66] S. M. Ray, S. D. Ahuja, P. A. Blake, M. M. Farley, M. Samuel, and T. Rabatsky-Ehr, “Population-based surveillance for *yersinia enterocolitica* infections in FoodNet sites, 1996–1999: higher risk of disease in infants and minority populations,” *Clinical Infectious Diseases*, vol. 38, no. 3, pp. 181–189, 2004.

[67] (ECDC) European Centre for Disease Prevention and Control. Surveillance Report: Annual Epidemiological Report on Communicable Diseases in Europe 2010, (ECDC) European Centre for Disease Prevention and Control, Stockholm, Sweden, 2010.

[68] M. M. Soltan-Dallal, “Diarrhea caused by enteropathogenic bacteria in children,” *Archives of Iranian Medicine*, vol. 4, no. 4, pp. 201–203, 2001.

[69] N. Bhagat and J. S. Virdi, “The Enigma of *Yersinia enterocolitica* biovar 1A,” *Critical Reviews in Microbiology*, vol. 37, no. 1, pp. 25–39, 2011.

[70] M. Arrausi-Subiza, X. Gerrikagoitia, V. Alvarez, J. C. Ibabe, and M. Barra, “Prevalence of *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* in wild boars in the Basque Country, northern Spain,” *Acta Veterinaria Scandinavica*, vol. 58, no. 4, 2016.

[71] J. Liang, X. Wang, Y. Xiao et al., “Prevalence of *Yersinia enterocolitica* in pigs slaughtered in Chinese abattoirs,” *Applied and Environmental Microbiology*, vol. 78, no. 8, pp. 2949–2956, 2012.