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Review

Factors Contributing to Mosquito-Borne Disease: A Systematic Review in the Middle East and North Africa (MENA) Region

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Abstract: Mosquito-borne diseases (MBDs) are a group of illnesses transmitted by mosquitoes and can be caused by bacteria, viruses, or parasites. These diseases represent a significant global burden of infectious diseases, including morbidity and mortality. This systematic review delves into the multifaceted factors contributing to the spread of mosquito-borne diseases (MBDs) in the Middle East and North Africa (MENA) region. Following PRISMA guidelines, a thorough analysis of peer-reviewed articles from May 1990 to Jan 2023 was conducted, highlighting the interplay of population, environmental, disease, and mosquito factors in disease transmission and prevalence. The review incorporated 31 studies that revealed a complex relationship between various risk factors and the presence of MBDs. Significant associations were observed with age, certain occupations, environmental conditions such as rainfall and temperature, sanitation practices, specific pathogen variants, clinical symptoms, and Aedes aegypti mosquitoes. Conversely, gender, socioeconomic status, educational status, and certain sanitation-related factors showed inconsistent association with the spread of MBDs. The review underscores the need for targeted interventions, including vector control, improved sanitation, and educational campaigns to mitigate the spread of MBDs in the MENA region. This review could guide research studies to address data gaps and assist in developing effective surveillance programs in the MENA region. This work emphasizes the need for region-specific public health strategies and further research to understand and curb the burden of these diseases effectively.

Keywords: mosquito; MENA region; mosquito-borne disease; population at risk; climate; environment

1. Introduction

Mosquito-borne diseases (MBDs) are a group of illnesses transmitted by mosquitoes and can be caused by bacteria, viruses, or parasites [1]. These diseases represent a significant global burden of infectious diseases, including morbidity and mortality [2]. Mosquitoes, including malaria, dengue, West Nile virus, chikungunya, yellow fever, filariasis, tularemia, dirofilariasis, Japanese encephalitis, Saint Louis encephalitis, western equine encephalitis, eastern equine encephalitis, Venezuelan equine encephalitis, Ross River fever, Barmah Forest fever, La Crosse encephalitis, and Zika fever can transmit a variety of diseases. Some diseases have recently emerged or reemerged, emphasizing the importance of effective disease control strategies [2]. It should be noted that MBDs do not occur by chance; instead, a specific interaction of agent, host, mosquitoes, and environment is necessary for the disease to occur. Any changes in this interaction or the impact of external factors such as weather, urbanization, globalization, and socioeconomic status can lead to the introduction of MBDs in a new area, the expansion of an infected area, or the re-emergence of a previously infected area [2,3]. MBDs can be severe and even fatal, making it essential to protect individuals from mosquito bites [3].

As per the Centers for Disease Control and Prevention [4], the Middle East and North Africa (MENA) region comprises 25 countries. These include Afghanistan, Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi

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Arabia, Somalia, Sudan, Syria, Tunisia, Turkiye, United Arab Emirates, and Yemen. Historically, those countries in the MENA region have experienced outbreaks of MBDs. since the 19th century. A systematic study conducted in 2016 by Humphrey et al. [5] identified several factors influencing these outbreaks. They concluded that the epidemiology of dengue remains poorly characterized despite increasing reports of outbreaks and transmission in new areas. They found significant heterogeneity in published studies' distribution, quality, and quantity, which informs future research and surveillance priorities for the MBD in the MENA region. A more recent systematic review of MBD in North Africa was reported by Nebbak et al. [6] in 2022. They found that 26 species are involved in circulating seven MBDs in North Africa. While other reviews examine the impact of MBD on individual Arabic [7] or African [8] countries, these do not delve into the determinants of MBD spread in the whole MENA region.

Aryaprema et al. [9] conducted a recent systematic review on mosquito control worldwide in 2023. They highlighted the importance of adequate lead time to initiate control interventions and the associated surveillance characteristics, which could guide better surveillance programs to prevent the spread of MBDs. However, no systematic review has been conducted to investigate the factors influencing the spread of MBDs in the MENA region. This review could guide research studies to address data gaps and assist in developing effective surveillance programs in the MENA region.

2. Materials and Methods

2.1. Search Strategies

We adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines in our search [10]. Our search encompassed several prominent citation and abstract databases, including PubMed/MEDLINE, Scopus, Google Scholar, Embase, and the Cochrane Library. The search focused on peer-reviewed English publications published between May 1990 and Jan 2023. The following keywords were used in the search.

- (Mosquito OR Mosquito-borne disease (MBD)) AND (MBD outbreaks OR MBD risk factors) AND (Middle East and North Africa (MENA));
- Mosquito OR Mosquito-borne disease (MBD) OR MBD outbreaks OR MBD risk factors AND MENA;
- Mosquito OR Mosquito-borne disease (MBD) AND MBD outbreaks OR MBD risk factors;
- Mosquito AND MBD outbreaks OR MBD risk factors;
- Mosquito-borne disease (MBD) AND MBD outbreaks OR MBD risk factors;
- Mosquito-borne disease (MBD) AND MBD outbreaks AND MBD risk factors;
- Mosquito OR Vector-borne disease (VBD) OR VBD outbreaks OR VBD risk factors AND MENA.

Our search aimed to gather relevant studies that examined the impact of the spread of MBDs and their associated risk factors in MENA countries.

2.2. Inclusion and Exclusion Criteria

The study's selection criteria necessitated a meticulous examination of peer-reviewed papers published in English from May 1990 to Jan 2023. To maintain the rigor and integrity of the research, observational studies, including cohort, case-control, cross-sectional, longitudinal, and epidemiological studies, and experimental studies, such as quasi-experimental and randomized controlled trials, were considered in this search. The investigation focuses on the MENA region, and this systematic review has been registered in PROSPERO (CRD42022378844). However, it should be noted that the study imposes no restrictions on the setting or target population.

2.3. Study Selection

Initially, abstracts were screened by the lead author. Articles that passed the initial review underwent comprehensive full-text screening conducted independently by the initial trio of authors. In addition, this stage eliminated inaccessible or not explicitly relevant articles. **Figure 1** shows a brief list of the reasons for article deletion. To ensure the quality of the reviewed articles, they were all appraised using critical appraisal tools from the Joanna Briggs Institute (JBI) [10].

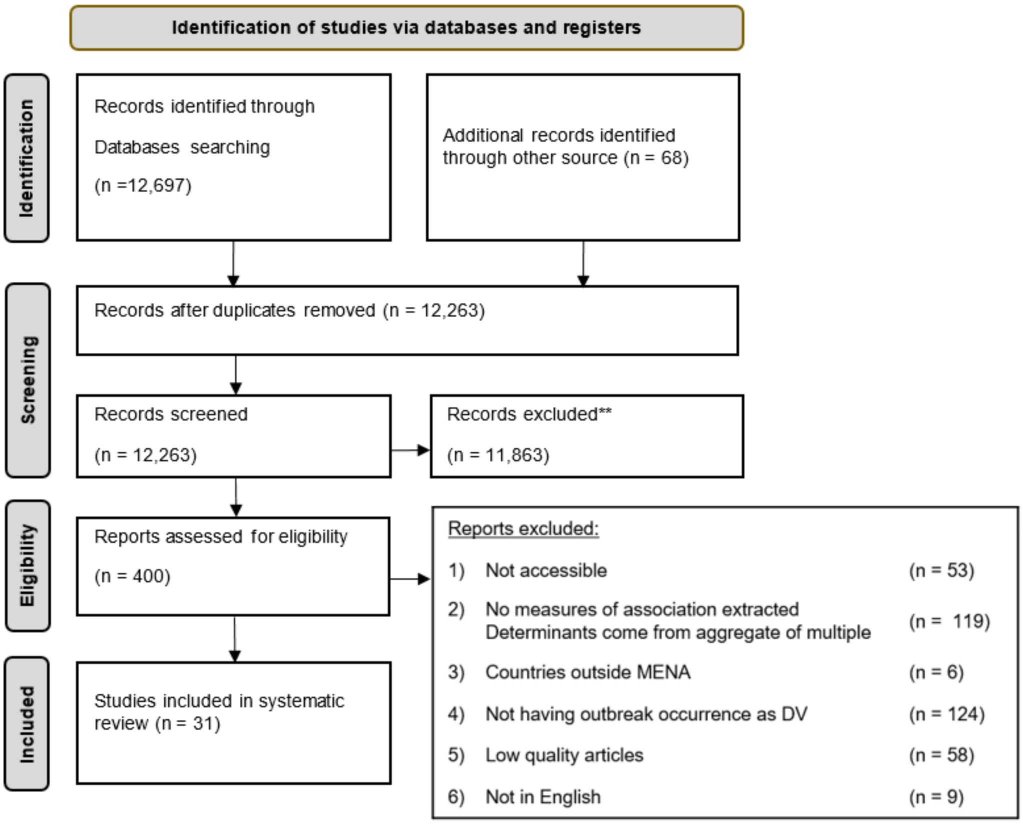

Figure 1. The flow diagram of the systematic review.

2.4. Evaluation of the Quality of Reports on the Studies

The first three authors independently evaluated the initial assessment of each study included in the review, including the title, abstract, methods, results, discussion, and additional sections. The JBI guidelines were used for this process, providing checklists corresponding to the article's design type under review, each presenting a distinct set of questions [10]. The inter-rater reliability among the first three authors was strong, with an intra-class correlation coefficient (ICC) of 0.91. The employed checklists encompassed various study designs, including cross-sectional, case-control, cohort, and prevalence studies [10]. A final inclusion quality criterion was established, whereby each review article has to achieve a minimum score of 75% (Table 1).

Table 1. Evaluation of the review articles using the JBI checklists.

No. of article	Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Score
#1. Adam et al., 2007 [38]	Cross-sectional	Y	Y	Y	Y	U	U	Y	Y	NA	NA	75%
#2. Al Azraqi et al., 2013 [29]	Prevalence	Y	Y	Y	Y	Y	Y	Y	Y	U	NA	88.9%
#3. Alkhaldy and Barnett, 2021 [35]	Prevalence	Y	Y	U	Y	Y	Y	U	Y	Y	NA	77.8%
#4.Al-Nefaie et al., 2022 [12]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#5. Al-Quhaiti et al., 2022 [13]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#6. Bamaga et al., 2014 [19]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#7. Elaagip et al., 2020 [16]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#8. Eldigail et al., 2018 [31]	Cross-sectional	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	100%
#9. Eldigail et al., 2020 [14]	Cross-sectional	U	Y	Y	Y	Y	Y	Y	Y	NA	NA	87.5%
#10. Elghazali et al., 2003 [24]	Case-control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
#11. Elkhalifa et al., 2021 [41]	Cross-sectional	Y	Y	Y	Y	U	U	Y	Y	NA	NA	75%
#12. Elmardi et al., 2011 [42]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#13. Elmardi et al., 2021 [30]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%

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#14. Hassanain et al., 2010 [20]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#15. Ibrahim et al., 2011 [21]	Cross-sectional	U	Y	Y	Y	U	Y	Y	Y	NA	NA	75%
#16. Kadir et al., 2003 [17]	Cross-sectional	Y	Y	Y	Y	N	N	Y	Y	NA	NA	75%
#17. Kalantari et al., 2019 [25]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#18. Kholedi et al., 2012 [26]	Case-control	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	90%
#19. Mahdi et al., 2016 [32]	Cross-sectional	U	Y	Y	Y	Y	U	Y	Y	NA	NA	75%
#20. Noureldin and Shaffer, 2019 [39]	Ecological study	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	100%
#21. Pouriayevali et al., 2019 [15]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#22. Riabi et al., 2014 [22]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#23. Saeed and Ahmed, 2003 [23]	Cross-sectional	U	Y	Y	Y	U	Y	Y	Y	NA	NA	75%
#24. Seidahmed et al., 2012 [33]	Cross-sectional	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	100%
#25. Soghaier et al., 2014 [18]	Cross-sectional	Y	Y	Y	Y	U	Y	Y	Y	NA	NA	87.5%
#26. Soghaier et al., 2015 [34]	Cross-sectional	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	100%
#27. Soghaier et al., 2018 [36]	Cross-sectional	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	100%
#28. Soleimani-Ahmadi et al., 2013 [40]	Cross-sectional	U	Y	Y	Y	Y	U	Y	Y	NA	NA	75%
#29. Tezcan-Ulger et al., 2019 [37]	Prevalence	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	100%
#30. Vasmehjani et al., 2022 [27]	Case-control	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	90%
#31. Ziyaeyan et al., 2018 [28]	Prevalence	Y	Y	U	Y	Y	Y	Y	Y	Y	NA	88.9%

JBI, Joanna Briggs Institute; Y, Yes; N, No; U, Unclear; NA, Not applicable.

For the cross-sectional study: Q1: Were the criteria for inclusion in the sample clearly defined? Q2: Were the study participants and settings described in detail? Q3: Was exposure measured in a valid and reliable way? Q4: Were objective, standard criteria used for the measurement of the condition? Q5: Were the confounding factors identified? Q6: Were the strategies to deal with the confounding factors stated? Q7: Were the outcomes measured in a valid and reliable manner? Q8: Was appropriate statistical analysis used?

For case-control study: Q1: Were the groups comparable other than the presence of diseases in cases or the absence of disease in controls? Q2: Were the cases and controls matched appropriately? Q3: Were the same criteria used for identification of cases and controls? Q4: Was exposure measured in a standard, valid, and reliable manner? Q5: Was the exposure measured in the same way for both cases and controls? Q6: Were the confounding factors identified? Q7: Were the strategies to deal with the confounding factors stated? Q8: Were outcomes assessed in a standard, valid, and reliable manner for cases and controls? Q9: Was the exposure period of interest sufficiently long to be meaningful? Q10: Was the appropriate statistical analysis used?

For the prevalence study: Q1: Was the sample frame appropriate to address the target population? Q2: Were the study participants appropriately sampled? Q3: Was the sample size adequate? Q4: Were the study participants and settings described in detail? Q5: Was data analysis conducted with sufficient coverage of the identified sample? Q6: Were the valid methods used to identify the condition? Q7: Was the condition measured in a standard, reliable manner for all participants? Q8: Was there appropriate statistical analysis? Q9: Was the response rate adequate and, if not, was the low response rate managed appropriately?

2.5. Data Extraction

Data was extracted per PRISMA guidelines [11]. After establishing inter-rater reliability among the first three authors, duplicate articles were removed, and titles and abstracts were reviewed independently. The final inclusion of studies was based on a comprehensive full-text evaluation based on the JBI checklist [10]. Disagreements between the initial reviewers were addressed by consulting with the last two authors. There was no disagreement among the three reviewers on this review procedure. The specific data extracted included the author's name, country of origin, publication year, sample size, study duration, countries, mosquito-borne disease (MBD) events, population characteristics, and detailed information about the mosquito, including type, density, feeding, and resting behaviors, habitats, and seasonality. Other risk factors, including social and environmental, are also documented. Additionally, the correlation (r) or association (χ^2) or odds ratio (OR) between outbreaks of MBD events and each risk factor were collected and are presented in Table 2.

Table 2. Compiled Full-Text Review of the Studies Included in the Systematic Review.

Author	Design	Country	Duration	Population	Samples	Disease	Factor	Sub-factor	Results	Measure of Association
Adam et al. 2007	Cross-sectional	Sudan	4 months	N/A	293 F	Malaria	Population	94 +ve, 199 –ve	Blood group A vs. non Blood group A	OR=0.77, p>0.05
									Blood group B vs. non Blood group B	OR=0.67, p>0.05
									Blood group AB vs. non Blood group AB	OR=0.68, p>0.05
									Blood group O vs. non Blood group O	OR=1.45, p>0.05
Al Azraqi et al. 2013	Prevalence	Saudi Arabia	N/A	N/A	389	Rift Valley Fever	Population	Demography	Sex: 256 M (3.1%) vs 133 F (8.6%)	χ2=3.98, P=0.048
							Environment	Livestock	history of contact with aborted animals, yes = 21	OR=13.36, P<0.005
									history of transporting aborted animals, yes = 12	OR=18.86, P<0.005
Alkhaldy & Barnett 2021	Prevalence	Saudi Arabia	4 years	3.4 Millions	N/A	Dengue	Population	Socioeconomic status	majority of dengue fever cases appeared in neighborhoods of low socioeconomic status	p=0.771
									high densities of population	r=0.59, p<.001
									large non-Saudi migrant populations	r=0.50, p<.001
Al-Nefaie et al.2022	Cross-sectional	Saudi Arabia	1 year	4.6 millions	1098	Dengue	Population	Demography	Age (yrs): < 15 (susp=98, conf=23) vs. 15–24 (susp=47, conf=57) vs. 25-44 (susp=294, conf=255) vs. 45-65 (susp=189, conf=67) vs. 65+ (susp=40, conf=6)	χ2=75.05, p<.001
									Gender: M (susp=498, conf=348) vs. F (susp=182, conf=70)	χ2=14.7, p<.001
									Occupation: not worker (susp=265, conf=114) vs. health worker (susp=23, conf=5) vs. non-health worker (susp=392, conf=299)	χ2=23.04, p<.001
									Address: North (susp=115, conf=72) vs. east (susp=84, conf=146) vs. middle (susp=174, conf=114) vs. south (susp=79, conf=41)	χ2=43.97, p<.001
								Nationality	Nationality: Saudi (susp=235, conf=160) vs. non-Sauai (susp=445, conf=285)	χ2=1.55, p=0.213
							Environment		Air condition: susp=6, conf=1	χ2=1.69, p=0.184
									Cement pool: susp=3, conf=0	χ2=1.85, p=0.237
								Sanitation:	Water container: susp=444, conf=3	χ2=20.91, p<.001
									Infiltrationsc: susp=2, conf=0	χ2=1.23, p=0.383
									Sewaged: susp=1, conf=0	χ2=0.615, p=0.615
									Street: susp=1, conf=0	χ2=0.615, p=0.619
									Water Surfaces: suspected = 0, confirmed = 3	χ2=4.89, p=0.055
									Vases: suspected = 0, confirmed = 1	χ2=1.63, p=0.388
									Water cooler: suspected = 3, confirmed = 0	χ2=1.85, p=0.237
									Open tanks: suspected = 0, confirmed = 1	χ2=1.63, p=0.318
									Water company: suspected = 1, confirmed = 0	χ2=0.615, p=0.615
									Stream water: suspected = 1, confirmed = 0	χ2=1.63, p=0.318
Al-Quhaiti et al.2022	Cross-sectional	Yemen	1 year	597	400	Malaria	Population	Demography	Age (≥ 3=250 (36) vs. <3=150 (3)	OR=8.2, p<.001

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									Gender: M=217 (24) vs. F=183 (15)	OR=1.4, p=0.33
								Socioeconomic status	Household: ≥ 6=254 (30), <6= 146(9)	OR=2.0, p=0.067
									Father's educational status: Literate=252(22) vs. Illiterate=148(17)	OR=1.4, p=0.370
									Mother's educational status: Literate=67(4) vs. Illiterate=333(35)	OR=1.9, p=0.253
									Father employment status: Employed=21(2) vs. Unemployed=377(36)	OR=1.0, p=1.000
							MBD outbreak	Morbidity	Symptoms (fever): yes = 71(11), no = 329(28)	OR=2.0, p=0.072
									Symptoms (sweating): yes = 28(5), no = 382(34)	OR=2.2, p=0.134
									Symptoms (chills): yes = 7(1), no = 393(38)	OR=1.5, p=0.505
									Symptoms (vomiting): yes = 45(2), no = 355(37)	OR=0.4, p=0.205
									Symptoms (jaundice): yes = 4(1), no = 396(38)	OR=3.1, p=0.301
							Environment	Risk factors	Sleeping under a mosquito net the previous night of the survey (No): yes=182(3) vs. no=218(36)	OR=11.8, p<.001
									Sleeping under a mosquito net the previous night of the survey (Yes): yes=64(16) vs. no=336(23)	OR=4.5. p<.001
									IRS during the last year (No): yes=240(13) vs. no=160(26)	OR=3.4, p<.001
									Residence in proximity to water collections (Yes): yes=298(32) vs. no=102(7)	OR=1.6, p=0.255
									Residence in proximity to garbage collections (Yes): yes=187(19) vs. no=213(20)	OR 1.1, p=0.795
									Screening windows (No): yes=55(1) vs. no=345(38)	OR=6.7, p=0.064
Bamaga et al. 2014	Cross-sectional	Yemen	11 months	N/A	735	Malaria	Population	Demography	District (Hajer district)	p=0.001
									Village (Kunina village)	p=0.001
									Symptoms (fever): Yes = 66, No = 75	p<0.05
									Symptoms (shivering): Yes = 38, No = 100	p<0.05
									Symptoms 9headache): Yes = 21, No = 117	p<0.05
									Symptoms (Jaundice): Yes = 14, No = 124	p<0.05
									Symptoms (Hemoglobin level): Normal = 13 vs. Low anemia = 92 vs. Moderate anemia = 33	p<0.05
									Age (years): 10-15 (25/142) vs. >15 (79/393)	OR=0.85, p>0.05
									Age (years): 5-9 (30/152) vs. >15 (79/393)	OR=0.98, p>0.05
									Age (years): <5 (4/48) vs. >15 (79/393)	OR=0.36, p>0.05
									Gender: F (52/312) (ref) vs. M (86/423)	OR=1.04, p>0.05
									Education level household's head: Secondary school and above (1/34) (Ref)	OR=1
									Primary school: 83/356	OR=10.1, p<.0.05
									Not educated: 54/345	OR=6,12, p>0.05
									Occupation of household's head: Government employees (4/76)	OR=1.0
									Not working (28/180)	OR=3.31, p<0.05
									Farmer (96/453)	OR=4.84, p<0.05

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									Fishermen (10/26)	OR=11.3, p<0.05
									Family size: >5 (ref) (49/290) vs. ≤5 (89/445)	OR=1.23, p>0.05
									House wall: mud (ref) (26/221) vs. non cement bricks (112/554)	OR=2.1, p<0.05
									Material of house floor: cement (ref) (19/120) vs. mud (119/615)	OR=1.27, p>0.05
									Availability of toilet: yes (ref) (42/285 vs. no (96/451)	OR=1.6, p<0.05
									Distance to the nearest water collection (m): >200 (ref) (44/295) vs. ≤200 (146/440)	OR=1.6, p<0.05
									Availability of electricity： yes (Ref) (66/379) vs. no (72/356)	OR=1.04, p>0.05
									Availability of fridge: yes (ref) (44/295) vs. no (94/440)	OR=1.6, p<0.05
									Availability of TV: yes (ref) (44/295) vs. no (94/440)	OR=1.6, p<0.05
									Availability of radio: yes (ref) (70/385) vs. no (68/350)	OR=1.02, p>0.05
Elaagip et al. 2020	Cross-sectional	Sudan	2 years	401.477	409	Dengue	Population	Demography	Age: 20–39 years	OR=4.2, p=0.700
									Age: 40-60 years	OR=2.09, p=0.380
									Age: >60 years	OR=6.31, p=0.040
									Gender: F vs M	OR=0.73, p=0.430
								Socioeconomic status	Socioeconomic level: Medium	OR=11.39, p=0.050
									Socioeconomic level: Low	OR=10.49, p=0.220
									No. of individuals living in the house: 6-10	OR=0.96, p=0.930
									No. of individuals living in the house: >10	OR=0.14, p=0.060
									No. of children under 5 years living in the house: 1-3 child	OR=0.87, p=0.740
							Environment	Geographical varieties:	Staying in Kassala state	OR=1.31, p=0.670
								Live in a house	Roof-constructed materials of the house: Iron sheets	OR=0.85, p=0.870
									Roof-constructed materials of the house: Iron sheets: Grass	OR=0.78, p=0.880
									Wall-constructed materials of the house: Bricks with mud	OR=0.74, p=0.650
									Wall-constructed materials of the house: Cement blocks	OR=0.53, p=0.460
									Floor-constructed materials of the house: Cement screed	OR=1.02, p=0.980
									Floor-constructed materials of the house: Mud/Sand	OR=1.0, p=0.999
								Breeding habitats: Management of water containers		OR=1.52, p=0.330
								Sanitation:	Type of toilet used in the house	OR=0.47, p=0.170
									Type of bathroom used in the house	OR=3.52, p=0.010
									Solid waste disposal method: Bin-trash	OR=0.23, p=0.250
									Solid waste disposal method: Heap	OR=1.1, p=0.950
									Type of kitchen	OR=1.7, p=0.360
									Trees at the house	OR=0.66, p=0.260
									Air-cooling system: Water-based air conditioner	OR=6.9, p=0.010
									Screen in the windows	OR=0.25, p=0.190
									Using bed net	OR=1.84, p=0.120

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									Traveling to Red Sea state during last 3 months	OR=1.44, p=0.590
							Disease	Incidence and prevalence: Yellow fever vaccination		OR=1.96, p=0.180
								Incidence and prevalence: Having febrile illness during the last 3 months		OR=1.03, p=0.960
								Any household had dengue before		OR=28.73, p<.001
								Transmission of dengue (do not know)		OR=1.36, p=0.59
Eldigail et al. 2018	Cross-sectional	Sudan	10 months	1.4 millions	701	Dengue	Environment	Geographical:	Locality: Gadaref (70/21) vs. Center Gagarif (70/37) vs. Butana (70/19) vs. Elfau (70/37) vs. Al Rahad (70/41) vs. Bassunda (70/46) vs. West Galabat (70/34) vs. East Galabat (70/39) vs. Ouravshah (70/16) vs. Elfashage (71/44)	p=0.001
								Breeding	Presence of Clean water container: yes (670/322) vs. no (31/12)	p=0.308
							Population	Demography	Age: young (176/91) vs. old (525/243)	p=0.123
									Gender: M (419/207) vs. F (282/127)	p=0.145
								Socioeconomic status	Income: low (489/245) vs. medium (153/59) vs. high (59/30)	P=0.039
									Education: informal study (55/29) vs. illiterate (186/90) vs. primary (154/75) vs. secondary (199/95) vs. university (107/45)	p=0.732
									disease awareness: yes (56/26) vs. no (645/308)	p=0.849
									work: yes (356/168) vs. no (345/166)	p=0.806
								Behaviors	sleeping outdoors: yes (377/196) vs. no (324/138) (Ref)	OR=3.75, p=0.013
									mosquito nets use: yes (301/133) vs. no (400/201) (Ref)	p=0.112
									mosquito control practice: yes (388/208) vs. no (313/126) (Ref)	OR=2.73, p=0.001
									contact with an ill person: yes vs. no	p=0.01
Eldigail et al. 2020	Cross-sectional	Sudan	10 months	1,400,000	600	Dengue	Population	Demography	Age: young (209/18) vs. old (392/62) (Ref)	OR=3.24, p=0.001
								Socioeconomic status	Income: low (44) vs. medium (146) vs. high (115)	2=3.75, p=0.027
									mosquito control	OR=4.18, p=0.004
									locality	OR=2.94, p=0.044
									disease awareness: no (645) vs. yes (56)	p=0.06
									mosquito net use: no (313) vs. yes (388)	p=0.013
Elghazali et al. 2003	case-control	Sudan	1 year	1.841	175	Malaria	Population		pregnant cases (86) vs. non-pregnant controls (89) (Ref)	OR= 3.56, p=0.014
									Primagravidae vs. Multigravidae (Ref)	OR=1.56, p>0.05
								Demography	Age (years): mean: 24.5±6.2 vs. 26.7±6.2	p=0.215
								Clinical	Birth weight (kg): mean: 2.72±0.26 vs. 2.95±0.05	p<0.001
									Hemoglobin at enrolment (g/dL): mean: 9.35±0.80 vs. 9.32±1.10	p=0.80
									Hemoglobin at term (g/dL): mean: 9.10±1.30 vs. 9.50±0.60	p=0.069
Elkhalifa et al. 2021	Cross-sectional	Sudan	7 months	N/A	392	Malaria	Pathogen	Clinical (192 +ve, 200 -ve)	Hemoglobin (g/dL): Median: 11.6 vs. 14.0	p<0.001
									RBC count (x 10^{12}/L): Median: 4.5 vs. 4.7	p=0.001
									MCV (fL): Median: 86.0 vs. 87.0	p=0.452
									MCH (pg): Median: 28.5 vs. 29.0	p<.001
									MCHC (g/dL): Median: 31.5 vs. 32.5	p=0.037

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									RDW (%):Median: 15.6 vs. 13.0	p<.001
									Total WBC count (x 10^9/L): Median: 7.0 vs. 6.5	p=0.275
									Neutrophil count (%):Median: 37.0 vs. 38.0	p=0.001
									Lymphocyte count (%):Median: 24.0 vs. 26.0	p=0.004
									Monocyte count (%):Median: 5.0 vs. 5.0	p=0.021
									Platelet count (x 10^9/L): Median: 140.0 vs. 230.0	p<0.001
									Anemia	OR=3.6, p<0.001
									Low MCV (<80fL)	OR=2.6, p = 0.005
									low MCH (<27pg)	OR=4.4, p<0.001
									low MCHC (<32g/dL)	OR=2.6, p=0.008
									High RDW (>14.5%)	OR=11.2, p<0.001
									Thrombocytopenia	OR=49.8, p<0.001
									Leucopenia	OR=0.9, p=0.754
									Neutropenia	OR=2.3, p=0.001
									Lymphoneia	OR=1.7, p=0.340
Elmardi et al. 2011	Cross-sectional	Sudan	2 months	N/A	26,471	Malaria			fever in the last two weeks vs. no history of fever	aOR=6.2, p<.001
									fever on the day of the survey vs. no history of fever	aOR=3.4, p<.001
Elmardi et al. 2021	Cross-sectional	Sudan	1 month	N/A	4.478	Malaria	population		Gender: M (3.7%) vs. F (2.6%)	p=0.035
									Location: rural (1.8%) vs. urban (8.1%)	p=0.003
									IRS coverage	aOR=0.98, p=0.007
									utilization of long-lasting insecticidal nets (LLINs) at a community level	aOR=1.20, p<.001
									utilization of artemisinin-based combination therapies (ACTs)/per 10% utilization	aOR=0.97, p=0.413
									utilization of malaria diagnosis via rapid diagnostic tests/10% utilization	aOR=0.86, p=0.004
Hassanain et al. 2010	Cross-sectional	Sudan	3 months	N/A	290	Rift Valley fever	Population	Demography	Gender: M vs F	OR=2.8, p=0.040
									Job	OR=1.9, p=0.190
									Residency	OR=1.9, p=0.100
									Education	OR=2.1, p=0.100
Ibrahim et al. 2011	case-control	Sudan	3 months	100	case (50) vs. control (50)	Malaria	Population	Demography	Age (years): Mean: 18.08 vs. 15.60	p=0.62
									Weight (Kg): mean: 45.05 vs. 47.40	p=0.570
								Clinical	Hemoglobin (g/dL): mean: 11.90 vs. 13.10	p=0.020
									Urea (mg/dL): mean: 27.80 vs. 27.50	p=0.880
									Creatinine (mg/dL): mean: 0.95 vs. 0.89	p=0.400

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									Total Cortisol (mg/dL): mean: 602.2 vs. 449.2	p=0.120
Kadir et al. 2003	Cross-sectional	Iraq	10 years	N/A	261,763	Malaria	Population	Demography	Gender (M=165,721 vs. F=96,042)	OR=1.07, p=0.137
									Age group (21-30 vs. <1-10)	OR=8.34, p<.001
									Age group (21-30 vs. 11-20)	OR=1.3, p<.001
									Age group (21-30 vs. 31-40)	OR=1.28, p<.001
									Age group (21-30 vs. 41+)	OR=4.9, p<.001
Kalantari et al. 2019	Cross-sectional	Iran	1 year	N/A	408	West Nile Virus	Population	Demography	Gender: M (261) vs. F (147)	p=0.600
									Age (years): <19 vs. 20-29 vs. 30-39 vs. 40-49 vs. 50+	p=0.001
									occupation	p=0.749
									educational level	p=0.001
									geographical distribution	p=0.446
Kholedi et al. 2012	case-control	Saudi Arabia	1 year	3 millions	650	Dengue	Population	Demography	Gender: M (case=84 control=161) vs. F (case=45, control=79)	χ2=0.146, p=0.703
									Age (years): (case/control) <10 (18/59) vs. 10-19 (23/47) vs. 20-29 (26/56) vs. 30-39 (28/35) vs. 40-49 (21/20) vs. 50+ (13/23)	χ2=12.342, p=0.03
									Nationality: (case/control) Saudi (67/153) vs. non-Saudi (62/87)	χ2=4.863, p=0.027
									working (case/control): inside (70/144) vs. outside (24/31) vs. not working (35/65)	χ2=0.146, p=0.705
							Mosquito	Type: case vs. control	Presence of indoor Aedes aegypti: adult (32 vs. 37)	χ2=4.863, p=0.027
									Presence of indoor Aedes aegypti: larvae (43 vs. 39)	χ2=14.167, p=0.001
							Environment	Breeding (case vs control)	Possible indoor breeding sites: Stagnant water in the bathroom basin (4 vs. 10)	p=0.422
									Possible indoor breeding sites: Uncovered water containers in the bathroom (13 vs. 18)	χ2=0.781, p=0.244
									Possible indoor breeding sites: Uncovered water containers in the kitchen (4 vs. 9)	P=0.509
									Possible indoor breeding sites: Stagnant water in a water cooler (10 vs. 19)	χ2=0.004, p=0.951
									Possible indoor breeding sites: Stagnant water at the base of the refrigerator (3 vs. 6)	p=0.610
									Possible indoor breeding sites: Stagnant water in the indoor drainage holes (14 vs. 7)	χ2=9.830, p=0.002
									Possible outdoor breeding sites: Uncovered water containers on the balcony (7 vs. 4)	p=0.040
									Possible outdoor breeding sites: Private garden (21 vs. 47)	χ2=0.423, p=0.516
									Possible outdoor breeding sites: Neglected private pool (4 vs. 13)	χ2=0.911, p=0.340
								land use (case vs. control)	Nearby buildings under construction: 88 vs. 123	χ2=8.222, p=0.004

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									Nearby brick manufacturers: 17 vs. 18	χ2=3.428, p=0.064
									Presence of underground water seepage: 7 vs. 9	χ2=0.656, p=0.418
									Nearby public garden: 25 vs. 40	χ2=0.623, p=0.430
									Nearby public water tap: 22 vs. 30	χ2=1.664, p=0.147
									Nearby public water cooler: 11 vs. 16	χ2=0.496, p=0.481
									Nearby solid garbage: 9 vs. 18	χ2=0.011, p=0.917
									Old used tyres: 7 vs. 12	χ2=0.060, p=0.807
									Empty cans: 14 vs. 19	χ2=1.076, p=0.300
Mahdi et al. 2016	Cross-sectional	Sudan	1 month	N/A	140	Malaria	Pathogen	Species	Plasmodiu11alciparumum: MSP1 gene (severe malaria vs. uncomplicated malaria)	OR=0.48, p=0.096
									Plasmodiu11alciparumum: MSP2 gene (severe malaria vs. uncomplicated malaria)	OR=0.119, p=0.008
							Population	Demography	Gender (M vs. F, severe malaria vs. uncomplicated malaria)	OR=0.5, p=0.052
Noureldin & Shaffer 2019	Ecological	Sudan	6 years	N/A	N/A	Dengue	Climate	Rainfull	2011-2013 – 6 months prior to the dengue fever reporting month	p<0.05
									2008-2011 - 6 months prior to the dengue fever reporting month	p=0.0433
									2008-2011 - 5 months prior to the dengue fever reporting month	p=0.0298
								Humidity	2008-2010, association with dengue fever/dengue hemorrhagic fever at the 3-month lag time	p=0.0025
									2011-2013, association with dengue fever/dengue hemorrhagic fever at the 3-month lag time	p=0.0003
									2008-2010, association with dengue fever/dengue hemorrhagic fever at the 3-month lag time	p=0.0037
									2011-2013, association with dengue fever/dengue hemorrhagic fever at the 3-month lag time	p=0.0038
									< 56% vs. ≥ 56% at 3, 4 and 5 months	2=222.32, p<.001
								Temperature	Min. temperature was significantly correlated with dengue at the 1-month lag times, 2008–2010	p=0.0.0427
									Min. temperature was significantly correlated with dengue at the 2-month lag times, 2008–2011	p=0.0012
									Min. temperature was significantly correlated with dengue at the 3-month lag times, 2008–2012	p=0.0024
									Min. temperature was significantly correlated with dengue at the 4-month lag times, 2008–2013	p=0.0215
Pouriayevali et al. 2019	Cross-sectional	Iran	14 months	N/A	159	Chikungunya	Population	Demography	Gender: F (57) vs. M (62)	p=0.584
									Age (years)	p=0.001
									History: Aboard traveling history (21)	p<.001
									History: Travel duration	p=0.218
									Country with travel history: Afghanistan (2)	p=0.230
									Country with travel history: Malaysia (1)	p=0.426

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									Country with travel history: Pakistan (18)	p=0.001
									City of residence: Sarbaz (50)	p=0.010
									Season of Symptom onset: Spring (34) vs. Summer (48) vs. Fall (17) vs. winter (7)	p=0.042
									Mosquito bite: yes (30)	p=0.096
									Clinical signs: chill (1)	p<0.001
									Clinical signs: headache (34)	p=0.020
									Laboratory findings: Leukopenia (9)	p=0.191
Riabi et al. 2014	Cross-sectional	Tunisia	3 months	N/A	113	West Nile Virus	Population	Demography	Gender: M (27) vs. F (15)	p=0.010
									age (years): <55 (20) vs. ≥55 (20)	p=0.100
							Disease	Morbidity	Meningitis	p=0.001
							Population	demography\SEVERITY	Age (years): Patients with meningoencephalitis are older than those with meningitis	p=0.001
								demography\SEVERITY	mortality\age (years): The age of 55 years or older was the factor most strongly associated with death	p<0.005
Saeed & Ahmed 2003	Cross-sectional	Sudan	14 months	N/A	856	Malaria	Population	Demography	Gender (Male vs. Female)	aOR=2.02, p<0.05
									Age (years) group (21-40 vs. 41+)	aOR=1.71, p>0.05
									Age (years) group (<21 vs. 41+)	aOR=1.37, p>0.05
									Language (local dialectic -Dinka only- vs. Arabic)	aOR=1.78, p>0.05
									Language (local dialectic + Arabic vs. Arabic)	aOR=3.38, p>0.05
									Education (basic vs. illiterate)	aOR = 2.01, p<0.05
									Education (secondary or higher vs. illiterate)	aOR = 3.24, p<0.05
								Socioeconomic status	Housing conditions (acceptable vs. poor)	aOR=0.77, p>0.05
									Food expenditure: no income vs.≤ 50% of income	aOR=2.04, p>0.05
									Food expenditure: All income vs. ≤50% of income	aOR=0.84, p>0.05
								nationality	Tribe (Nuba vs. Western tribe)	aOR=1.33, p>0.05
									Tribe (Southern vs. Western tribe)	aOR=1.30, p>0.05
									Tribe (Dinka vs. Western tribe)	aOR=0.90, p>0.05
									Knowledge (poor vs. good)	aOR=1.85, p<0.05
									Attitude and practices (poor vs. good)	aOR=0.76, p>0.05
									treatment-seeking behavior (poor vs. good)	aOR=1.44, p>0.05
									Keeping water (no vs. yes)	aOR=1.19, p>0.05
							Environment	potential breeding habitat:	Water source (well vs. cart)	aOR=2.25, p>0.05
Seidahmed et al. 2012	Cross-sectional	Sudan	1 year	450	2825	Dengue	Population	Demography	Age group	χ2=5.05 , p=0.030
									gender	χ2=0.168, p=0.400

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								Socioeconomic status	upper class (15/265)	p=0.0031
									Middle class (12/263)	p=0.0036
									Lower class (14/263)	p=0.0036
							Mosquito	Density	pupae/person index: +ve correlation between P/P index and IgM seroprevalence	r=0.71, p=0.015
							Climate	Temperature	minimum temp: +ve correlation between the minimum temperature and seropositivity rates	r=0.67, p=0.03
									maximum temp: -ve correlation between the minimum temperature and P/P index was significant	r=−0.83, p=0.027
Soghaier et al. 2014	Cross-sectional	Sudan	1 year	1.4 millions	600	Dengue	Population	Demography	Age (years): <35 (141) (ref) vs. 35-39 (139) vs. 40-44 (167) vs. ≥45 (153)	PR=1.4, p=0.020
									Gender: M (294) (ref) vs. F (306) (Male)	PR=0.7, p=0.030
									Residence: Lagawa (250) (ref) vs. Alsunut (161) vs. Jangaru (120) vs. Shingil (69)	PR=1.4, p=0.040
									Travel history: Travel to Red Sea State (vs no): Red Sea State (79)	PR=1.4, p=0.040
							Environment	Breeding	Indoor water storage (544)	PR=2.9, p<.001
									Indoor mosquito breeding (vs. no): yes (54)	PR=0.2, p=0.003
							Population	Socioeconomic status	No use of mosquito nets (vs yes): Use of mosquito nets (545)	PR=0.2, p=0.003
									Interrupted use of mosquito nets (vs. every day)	PR=0.5, p=0.002
									Use of mosquito nets at night (vs day and night)	PR=2.5, p=0.030
									Indoor insecticidal spraying (vs. no): Regular use of indoor insecticidal spraying (55)	PR=1.8, p<.001
Soghaier et al. 2015	Cross-sectional	Sudan	1 year	N/A	530	Dengue	Population	Demography	Age (years): ≤35 (28/281) vs. >35 (18/206)	OR=1,17, p=0.690
									Gender: M (29/288) vs. F (17/199)	OR=1.55, p=0.240
									Permanent residence in Kassala: outside (1/12) vs. inside (45/472)	OR=1.31, p=0.810
								Socioeconomic status	Never heard about dengue: no (27/197) vs. yes (19/289)	OR=2.84, p=0.014
									Education level: No formal education (16/144) vs. Formal education (30/344)	OR=0.84, p=0.670
									Household density: >3 (24/178) vs. ≤3 (22/311)	OR=2.08, p=0.034
							Population	Socioeconomic status	Use bed net: No (23/241) vs. yes (23/242)	OR=1.08, p=0.820
Soghaier et al. 2018	Cross-sectional	Sudan	1 year	N/A	1775	Zika	Environment	Geographical	locality zone 2	OR=1.2, p=0.310
									locality zone 3	OR=1.3, p=0.360
									locality zone 4	OR=1.4, p=0.190
								Urban/rural residence	Urban: zone1 525(85), zone2 601(92), zone3 108(60), zone4 235(83) vs. rural: zone1 102(15), zone2 55(8), zone3 73(40), zone4 49(17)	OR=1.4, p=0.090
							Population	Demography	Age (years): 15-39 (907/51) vs. <15 (172/10)	OR=2.1, p=0.010
									Age (years): 40-65 (656/53) vs. <15 (172/10)	OR=2.1, p=0.010
									Age (years): >65 (65/14) vs. <15 (172/10)	OR=2.2, p=0.070
									Gender: M (826/47) vs. F (949/53)	OR=1.3, p=0.060

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Soleimani-Ahmadi et al. 2015	Cross-sectional	Iran	9 months	112.423	2,973	Malaria	Environment	Breeding habitat	water temperature	r=0.17, p<0.010
									Sulphate ions in water	r=0.23, P<0.040
									Chloride ions in water	r=0.19, P<0.020
									alkalinity of water	r=0.16, P<0.010
									conductivity of water	r=0.29, P<0.030
									Permanence (permanent vs. temporary): mean density: 31.12±2.07 vs. 19.78±1.93	p<0.001
									Water current (still flowing vs. still): mean density: 20.05±2.67 vs. 30.22±1.92	p=0.001
									Intensity of light (full sunlight, partial sunlight, shaded): mean density: 31.13±1.92, 18.21±1.96, 12.85±2.70	p=0.041
									Turbidity (turbid vs. clear): mean density: 19.28±1.20 vs. 30.48±1.93	p=0.002
									Substrate type (Mud, Sand, & Gravel): mean density: 21.39±2.05 vs. 33.12±2.40, 18.85±2.13	p=0.504
									Origin of habitat (River edge: natural vs. man-made): mean density: 20.52±2.32 vs. 30.10±1.95	p=0.045
Tezcan-Ulger et al. 2019	Cross-sectional	Turkey	7 months	N/A	977	Rift Valley Fever	Environment	Geographical	Urban vs Rural	p=0.933
									positivity between rural in different regions	p=0.141
									positivity between urban in different regions	p=0.029
							Population	Demography	gender from the urban area	p=0.581
									gender from the rural area	p=0.321
Vasmehjani et al. 2022	case-control	Iran	10 months	N/A	1,257	West Nile virus	population	Demography	Age (years): 25-34 vs. 1-24	OR=1.35, p=0.220
									Age (years): 35-44 vs. 1-24	OR=1.45, p=0.152
									Age (years): 45-54 vs. 1-24	OR=1.82, p=0.040
									Age (years): >=55 vs. 1-24	OR=3.52, p<.001
									Gender: M vs. F	OR=0.732, p=0.530
						Dengue virus	population	Demography	Age (years): 25-34 vs. 1-24	OR=0.63, p=0.300
									Age (years): 35-44 vs. 1-24	OR=1.15, p=0.730
									Age (years): 45-54 vs. 1-24	OR=0.65, p=0.400
									Age (years): >=55 vs. 1-24	OR= 2.19, p=0.070
									Gender (Male vs. Female)	OR=1.17, p=0.310
						Chikungunya virus	population	Demography	Age (years): 25-34 vs. 1-24	OR=1.35, p=0.320
									Age (years): 35-44 vs. 1-24	OR=1.35, p=0.330
									Age (years): 45-54 vs. 1-24	OR=1.35, p=0.340
									Age (years) >=55 vs. 1-24	OR=1.35, p=0.350

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									Gender: M vs. F	OR=1.35, p=0.360
Ziyaeyan et al. 2018	Prevalence	Iran	10 months	1.7 millions	494	West Nile Fever / Zika	Population	Demography	Age (years): 26-45 (39) vs. 0-25 (22)	OR=1.3, p=0.416
									Age (years): >45 (41) vs. 0-25 (22)	OR=4.1, p<.001
									Gender: M (35) vs. F (67)	OR=2.0, p=0.005
							Environment	Geographical	Jask (23) vs. Bandar Khamir (17)	OR=1.5, p=0.252
									Bandar Abbas (30) vs. Bandar Khamir (17)	OR=2.0, p=0.040
									Bashagard (32) vs. Bandar Khamir (17)	OR=2.2, p=0.020
							Population	Demography	Skin Type: III/IV (77) vs. I/II (10)	OR=2.9, p=0.003
									Skin Type: V/VI (15) vs. I/II (10)	OR=3.8, p=0.003
								Occupation	Mostly indoor (Child/student/Housewife): 67	OR=1.0
									Usually indoor (Office employee/ Freelancer): 20	OR=1.7, p=0.085
									Mostly outdoor (Fisherman/Sailor/ Worker/Retiree): 15	OR=3.7, p<.001
							Environment	Geographical	Urban (43) (ref) vs. rural (59)	OR=1.5, p=0.056

M, male; F, Female; N/A, Not available; OR, Odds Ratio; aOR, adjusted OR; r, correlation coefficient; Susp=suspected; Conf, confirmed; Yrs, Years; Ref: Reference; PR, Prevalence ratio

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3. Results

3.1. Description of Studies

3.1.1. Search Flow Result

A total of 12,697 and 68 records were evaluated from the journal database and other sources, respectively. After removing the duplicate records, 12,263 unique records were obtained. Eleven thousand eight hundred and sixty-three records were excluded during abstract and full-text screening, resulting in a final set of 400 records. Following the eligibility screening of these records, 31 records were included in this systematic review.

3.1.2. Study Characteristic

A comprehensive review was conducted between 2003 and 2022 and included 31 studies (Table 1, #1 to #31). The studies were primarily conducted in Sudan (n=18; #1, 7-15, 19, 20, 23-27), followed by Iran (n=5; #17, 21, 28, 30, and 31), Saudi Arabia (n=4; #2-4, and 18), Yemen (n=2; #5 and 6), Iraq (n=1; #16), Tunisia (n=1; #22), and Turkey (n=1; #29). Most studies employed a cross-sectional design (n=23; #1, 4-9, 11-17, 19, 21-28). Other study designs included prevalence (n=4; #2, 3, 29, and 31), case-control (n=3; #10, 18, and 30), and ecological studies (n=1; #20). The studies covered a range of mosquito-borne diseases, with 11 studies focused on dengue, 11 on malaria, 3 on Rift Valley fever, 4 on West Nile fever, 3 on chikungunya, and 2 on Zika.

3.2. Population Factors

3.2.1. Age

Seventeen studies examined the relationship between age and MBDs. Al-Nefaie et al. [12] reported a significant association between age and MBDs (χ^2=75.05, p<0.001), as did Al-Quhaiti et al. [13] (OR=8.2, p<0.001), Eldigail et al. [14] (OR=3.24, p=0.001), and Pouriayevali et al. [15] (p=0.001). Elaagip et al. [16] found a significant association between individuals aged > 60 years and dengue (OR=6.31, p=0.04), while Kadir et al. [17] identified a significant difference between individuals aged 21-30 years and other age groups (p<0.001). Soghaier et al. [18] observed significant associations in age groups, with those under 15 years compared to those aged 15-39 years (OR=2.1, p=0.01) and those aged 40-65 years (OR=2.1, p=0.01) in Zika disease. However, no significant association was found in the age group > 65 years (OR=2.2, p=0.07). Conversely, the remaining 11 out of 17 articles [14,19-24] found no significant association between age and MBDs (p>0.05). In the context of malaria in pregnant women, Elghazali et al. [24] also reported no significant correlation with age (p=0.215). However, Kalantari et al. [25] (p=0.001) and Kholedi et al. [26] (χ^2=12.34, p=0.03) reported a significant association between age and the presence of dengue. Vasmehjani et al. [27] reported significant associations in different age groups, specifically between those aged 1-24 years compared to those aged 45-54 years (OR=1.82, p=0.04) and those aged 55 years and older (OR=3.52, p<0.001) in West Nile disease. However, no significant differences were found in other age groups for West Nile disease, dengue, or chikungunya. Ziyaeyan et al. [28] reported significant differences between the age group 0-25 years and those over 45 years (OR=4.1, p=0.00), but no significant differences were observed between the age group 0-25 years and those aged 26-45 years (OR=1.3, p=0.416) in West Nile and Zika diseases.

3.2.2. Gender

Seventeen studies analyzed the association between gender and MBDs. Al Azraqi et al. [29] (χ^2=3.98, p=0.048) and Al-Nefaie et al. [12] (χ^2=14.7, p<0.001) both found a statistically significant association between sex and Rift Valley fever and dengue, respectively. Riabi et al. [22] (p=0.01), Saeed and Ahmed [23] (adjusted OR=2.02, p<0.05), Elmardi et al. [30] (p=0.035), and Soghaier et al.

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[18] ($p=0.03$) showed similar significant associations. Ziyaeyan et al. [28] supported these findings with a significant association (OR=2.0, $p=0.005$). Conversely, Al-Quhaiti et al. [13] (OR=1.4, $p=0.33$), Bamaga et al. [19] (OR=1.04, 95% CI 0.98-1.12), Elaagip et al. [16] (OR=0.73, $p = 0.43$), Eldigail et al. [31] ($p=0.123$), Kadir et al. [17] (OR=1.07, $p=0.137$), Kholedi et al. [26] ($\chi^2=0.146$, $p=0.703$), Mahdi et al. [32] (OR=0.5, $p=0.052$), Pouriayevali et al. [15] ($p=0.584$), Seidahmed et al. [33] ($\chi^2=0.168$, $p=0.400$), Soghaier et al. [34] (OR=1.55, $p=0.240$), and Vasmehjani et al. [27] (West Nile virus: $p=0.53$; dengue: $p=0.310$; chikungunya: $p=0.36$) reported no statistically significant association between sex and MBDs.

3.2.3. Occupation

Seven studies examined the relationship between occupation and MBDs. Notably, Al-Nefaie et al. [12] ($\chi^2=23.04$, $p<0.001$) and Bamaga et al. [19] found significant associations with different occupational categories (government employees vs. not working: OR=4.84, $p<0.05$; government employees vs. farmers: OR=1.33, $p<0.05$). Al-Nefaie et al. [12] identified a significant correlation between occupation types (not working, health worker, and non-health worker) and MBDs. Eldigail et al. [14,31] reported a significant association between low-income levels and MBDs (OR=1.61, $p = 0.039$) in 2018 and (OR=3.75, $p=0.027$) in 2020. Ziyaeyan et al. [28] highlighted significant differences between individuals who primarily work outdoors and those who work mostly indoors in the context of Zika and West Nile diseases (OR=3.7, $p<0.001$). However, no significant difference was observed between those who usually work indoors (OR=1.70, $p=0.085$). Conversely, Al-Quhaiti et al. [13] (OR=1.0, $p=0.999$) and Hassanain et al. [20] (OR=1.9, $p=0.19$) reported no significant association between occupation and MBDs, specifically malaria and Rift Valley fever, respectively.

3.2.4. Socioeconomic Status

Al-Quhaiti et al. [13] found no significant association between parents' educational status and MBDs for fathers ($p=0.370$) and 0.253 for mothers ($p=0.253$). Eldigail et al. [31] ($p=0.732$) and Hassanain et al. [20] ($p=0.1$) also reported no significant association between educational status and MBD. Similarly, a study by Saeed and Ahmed [23] revealed no significant association between educational status and the presence of malaria ($p>0.05$). Al-Quhaiti et al. [13] reported a significant association in individuals who had slept under a mosquito net the previous night of the survey, with a significant association with malaria (OR=4.5, $p<0.001$), compared to those who had not (OR=11.8, $p<0.001$). The study also found that malaria incidence was significantly higher in households without indoor residual spraying the previous year (OR=3.4, $p<0.001$). However, no significant association was observed between malaria and residence proximity to garbage collection and screened windows ($p>0.05$).

3.2.5. Demography

Alkhaldy and Barnett [35] reported that high-density populations and large non-Saudi migrant populations were significantly associated with MBD ($p<0.001$). Elmardi et al. [30] reported that people in urban areas have significantly higher MBDs than in rural ($p=0.003$). Soghaier et al. [36] reported no significant difference in Zika virus infection between urban and rural areas (OR=1.4, $p=0.09$). Tezcan-Ulger et al. [37] reported no significant difference in Rift Valley fever between rural and urban areas ($p=0.933$). Ziyaeyan et al. [28] reported no significant difference between urban and rural areas with Zika and West Nile disease (OR=1.5, $p=0.056$).

3.2.6. Blood Group

Only one study considered the effect of blood group on MBDs, which was by Adam et al. [38]. No significant correlation was reported between the blood group and MBDs ($p>0.05$).

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3.2.7. Skin Type

Regarding the possible effect that skin type may have on MBDs, Ziyaeyan et al. [28] reported there is a significant difference in Zika and West Nile disease between skin type I/II vs III/IV (OR=2.9, p=0.003) and type V/VI (OR=3.8, p=0.003).

3.2.8. Number of households

Elaagip et al. [16] reported that there is no significant correlation between the number of individuals living in the house or the number of children under five years living in the house with MBDs (p>0.05)

3.3. Environmental Factors

3.3.1. Climate

Noureldin and Shaffer [39] identified a significant correlation between rainfall and the outbreak of dengue (p<0.05) and the minimum temperature on the spread of dengue (p<0.05). Pouriayevali et al. [15] reported a significant correlation between the season of symptom onset and chikungunya (p=0.042). Seidahmed et al. [33] found significant correlations between dengue and minimum temperature (*r*=0.67, p=0.03) and maximum temperature (*r*=-0.83, p=0.027). Soleimani-Ahmadi et al. [40] demonstrated a significant correlation between malaria and various environmental conditions, including water temperature (*r*=0.17, p<0.01), sulfate ions in water (*r*=0.23, p<0.04), chloride ions in water (*r*=0.19, p<0.02), alkalinity of water (*r*=0.16, p<0.01), conductivity of water (*r*=0.29, p<0.03), permanence of water (p<0.001), water current (p=0.001), light intensity (p=0.041), and turbidity (p=0.002) except the substrate type (p=0.581).

3.3.2. Sanitation

Al-Nefaie et al. [12] reported a significant correlation between the presence of water containers and MBDs (χ^2=20.91, p<0.001). In contrast, other factors, including air conditioning, cement pools, infiltration, sewage systems, water surfaces, vases, water coolers, open tanks, water company supply, and stream water sources, were not significantly correlated (p>0.05). Elaagip et al. [16] identified a significant association between the type of bathroom used in households (OR=3.52, p=0.01) and the use of water-based air conditioners (OR=6.9, p=0.01) with MBDs. However, no significant association was observed between MBDs and the other household condition factors (p>0.05).

3.3.3. Breeding Habitats

Eldigail et al. [31] reported no significant association between clean water and MBDs (p = 0.308). Conversely, Kholedi et al. [26] found a significant association between MBDs and the presence of uncovered water containers (χ^2=4.09, p=0.04) and nearby buildings under construction (χ^2=8.22, p=0.004). In contrast, Saeed and Ahmed [23] reported no significant association between potential breeding habitats and malaria (adjusted OR=2.25, p>0.05).

3.4. Disease Factors

3.4.1. Pathogen

Mahdi et al. [32] reported a significant association between the Plasmodium falciparum variant MSP2 gene and malaria severity (OR=0.119, p=0.008).

3.4.2. Clinical Symptoms

Bamaga et al. [19] identified a significant correlation between various symptoms, including fever, shivering, headache, jaundice, and anemia, and MBDs (p<0.05). Elghazali et al. [24] reported a significant correlation between birth weight and MBDs (p<0.001). However, there was no significant

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correlation between hemoglobin levels and MBDs ($p>0.05$) in this study. Elkhalifa et al. [41] observed significant correlations between MBDs and various hematological parameters, including hemoglobin levels ($p<0.001$), red blood cell (RBC) count ($p<0.001$), mean corpuscular hemoglobin (MCH) levels ($p<0.001$), mean corpuscular hemoglobin concentration (MCHC) ($p=0.037$), red cell distribution width (RDW) ($p<0.001$), neutrophil count ($p<0.001$), lymphocyte count ($p=0.004$), monocyte count ($p=0.021$), and platelet count ($p<0.001$). Ibrahim et al. [21] reported a significant correlation between hemoglobin levels and MBDs ($p=0.02$), but no significant correlations were found for weight ($p=0.57$), urea ($p=0.88$), creatinine ($p=0.4$), and total cortisol ($p=0.12$). Pouriayevali et al. [15] reported a significant correlation between chills ($p<0.001$) and headache ($p=0.02$) with chikungunya. In contrast, no significant correlations were observed between myalgia, rash, conjunctivitis, retroorbital pain, stomachache, nausea, vomiting, diarrhea, white blood cell (WBC) count, and platelet count with chikungunya. Riabi et al. [22] identified a significant correlation between meningitis and West Nile disease ($p=0.001$). In contrast, Al-Quhaiti et al. [13] reported no significant correlation between MBDs and symptoms such as fever, sweating, chills, vomiting, and jaundice ($p>0.05$).

3.4.3. Mosquito

Kholedi et al. [26] discovered a noteworthy association between indoor Aedes aegypti mosquitoes and the incidence of dengue fever cases from Jeddah in Saudi Arabia. Their findings revealed a statistically significant correlation ($p=0.027$) for adult mosquitoes and an even stronger correlation ($p=0.001$) for mosquito larvae. Meanwhile, in a study by Seidahmed et al. [33], a significant correlation was observed between the pupae/person index and the IgM seroprevalence of dengue fever in Port Sudan. This correlation suggests a notable relationship between the density of mosquito pupae and the prevalence of dengue fever in the area.

4. Discussion

The results of this study highlight several key findings regarding population, environmental, disease, and mosquito factors in the context of MBDs. Concerning population-related factors, the study findings suggest that the relationship between age and MBDs is complex. While some studies reported significant correlations between age and diseases such as dengue, Zika, and West Nile fever, with individuals over 60 at a higher risk for dengue, others observed no significant age-related differences. This variation could be attributed to differences in disease dynamics, mosquito vector behavior, and population demographics across different regions.

4.1. Impacts of Population Factors on MBD

When considering the population's occupation, this study's findings suggest that occupational factors play a significant role in some studies, with certain occupations, such as farming, showing a higher risk of MBDs [12,28]. This could be attributed to increased outdoor exposure and proximity to mosquito breeding sites for individuals with specific occupations [7]. However, not all studies have identified a significant correlation, indicating that occupational risk varies across contexts.

Regarding gender, the study's findings suggest that the association between gender and MBDs yielded mixed results. While some studies have found significant correlations, others have not. This suggests that gender may not consistently predict disease risk, with factors such as exposure patterns, immune responses, and behavioral differences between genders contributing to these variations [19,27].

Finally, regarding the population's socioeconomic status, the study's findings suggest that the influence of socioeconomic status on MBDs did not show significant correlations in most studies [6]. This suggests that other factors, such as environmental conditions and healthcare access, could be more influential in determining the disease risk [13].

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4.2. Impact of Environmental Factors on MBD

Another aspect of MBDs is highlighted by findings related to environmental factors. First, several studies have emphasized the significance of climate, such as rainfall, temperature, and water quality, in transmitting MBDs [39]. Climate changes can impact mosquito breeding and survival rates, leading to fluctuations in disease prevalence [9]. The correlation between seasonality and disease incidence underscores the need for targeted interventions at specific times of the year [15].

Second, this study noted the influence of sanitation practices on MBDs. Water containers were a significant risk factor for MBDs, and proper sanitation practices, such as eliminating potential mosquito breeding sites, are essential for disease prevention [12]. However, other sanitation-related factors did not consistently demonstrate significant correlations, indicating that specific practices and their impacts could vary widely [16].

The impact of breeding habitats also plays an important role in the spread of MBD. In some studies, uncovered water containers and construction sites near residences were associated with a higher risk of MBDs (Humphrey et al., 2016). This highlights the importance of mosquito breeding site management and construction site sanitation in disease prevention [26]. However, not all studies found significant correlations, suggesting that local environmental factors may influence the significance of these risk factors [31].

4.3. Impact of Disease Factors on MBD

The last aspect of note illustrated by the findings of this study was the impact of different disease factors on MBDS. First, the pathogen itself was found to be necessary, as specific pathogen variants have been linked to disease severity in some studies [32,42]. Understanding the genetic diversity of mosquito-borne pathogens can aid in predicting disease outcomes and developing targeted interventions [9].

The role of clinical conditions in affecting MBDs was noted. Various clinical symptoms, such as fever, anemia, and hematological parameters, have been associated with MBDs in different studies [6,15,41,42]. These findings underscore the multifaceted nature of disease manifestations and their potential implications in diagnosis and patient care.

The results also highlighted the significance of the type and species of mosquito affecting the incidence of MBDs in MENA countries [5]. The indoor presence of Aedes aegypti mosquitoes was significantly associated with dengue fever cases from Jeddah, in Saudi Arabia, as reported by Kholedi et al. [26]. This underscores the importance of implementing vector control measures, such as indoor mosquito control, to prevent dengue transmission. Moreover, the correlation between mosquito pupae density and dengue seroprevalence in Port Sudan, as reported by Seidahmed et al. [33], highlights the crucial role of mosquito breeding site management for disease prevention.

4.4. Limitations

Considering the finite time and resources at our disposal, it is essential to recognize the inherent limitations of this systematic review. These limitations include confining the literature search solely to the MENA countries, restricting the search timeframe to 1990-2023, and limiting the inclusion of literature to the English language only. These limitations, while imperative for the feasibility of the study, may have resulted in the inadvertent exclusion of noteworthy publications beyond the findings from this study.

5. Conclusions

The findings of these studies emphasize the need for region-specific strategies and interventions to effectively control and prevent these diseases. Targeted public health measures, such as vector control, sanitation improvement, and education campaigns, can play a crucial role in reducing the burden of these diseases in affected regions. Further research and surveillance are essential to understanding these diseases better and developing evidence-based interventions.

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