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Research article

Determining the bacterial and viral meningitis trend in Iraq from 2007 till 2023 using joinpoint regression

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ABSTRACT

Background: Acute meningitis is a disease with case fatality and disability rate that is dependent on the causative agent.
Objective: Determine the meningitis trend in Iraq from 2007 to 2023 using a joinpoint regression at national and sub-national levels and describe the epidemiology.
Methods: Joinpoint regression model was used on surveillance data from Jan 2007 until May 2023, to calculate annual and average annual percent changes to determine the trend. Meningitis total count was modelled by year of reporting and province using the log transformation and Poisson variance. Best-fit model was chosen based on the weighted BIC criteria as the final point.
Results: Bacterial meningitis was higher than viral meningitis from 2007 to 2018, then viral meningitis started to exceed till 2023. Meningococcal meningitis was lower than other bacterial and viral meningitis from 2007 to 2023. Most meningitis cases across the years were lower than 15 years, at almost 80 %, while 20 %–40 % were lower than one year. Across all years, 55 % of the cases were males; apart from 2019, 70 % were females.
Conclusion: In Iraq, viral meningitis has been the predominant type since 2018. Most meningitis patients were lower than 15-year-old males. The meningitis trend in Iraq was stable from 2007 till 2023.

1. Introduction

Meningitis is an acute inflammation of the protective layer of the brain and the spinal cord, which can cause a broad range of bacterial, viral, mycobacterial, parasitic, and fungal pathogens [1–3]. The most reported bacterial causes of meningitis worldwide include *Streptococcus pneumoniae*, *Neisseria meningitidis* in children and adults, *Hemophilus influenzae* type B is more frequent in children under 5, and *Streptococcus agalactiae* group B and *Listeria monocytogenes* are more abundant among neonates [4–10]. The most diagnosed viral causes of aseptic meningitis include enteroviruses, human parechoviruses, herpes simplex virus, varicella-zoster virus,

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West Nile virus, cytomegalovirus, and human immunodeficiency virus (HIV) [2,3,8,11–14].

Globally, meningitis and neonatal sepsis are the second-highest infectious cause of death in children under five years [15]. In 2019, there were 2,505,886 cases, 236,084 deaths, and 9.4 % case fatality of all causes of meningitis worldwide [15]. Africa alone had almost half of the cases (1,171,321, 46.7 %) and more than half of deaths (139,590, 59.1 %) [3,15]. The Eastern Mediterranean Region ranked third in the reported cases (300,008, 11.9 %) and deaths (28,396, 12.0 %) while coming in second in the case fatality 9.5 % [15]. Even with early diagnosis and treatment, almost 10 % of meningitis patients will die, and 20 % of survivors will have long-term disability [16]. Despite that, meningitis is rarely considered a health priority in most health systems worldwide. Some types of bacterial meningitis are vaccine-preventable, such as meningococcal, streptococcal, and Hemophilus influenzae; their vaccines are included in the immunisation program in Iraq [16].

Meningitis surveillance differs across countries according to the availability of resources, burden of different types of meningitis, and laboratory capacity [3]. Due to limited curative and preventive interventions, identifying the causative agent of meningitis is optional in most surveillance systems. Therefore, most systems usually focus on identifying *N. meningitidis*, *S. pneumoniae*, and *H. influenzae* species for which vaccines and antibiotics are available. Recently, there has been an interest worldwide in identifying meningitis causative agents through multiplex PCR tests [3,12]. In most surveillance systems, diagnosing the cause of meningitis is still vague and based on the biochemical picture of the cerebrospinal fluid.

In Iraq, meningitis has been included in the immediately notifiable diseases list since 2019. Before that, it was reported as aggregated data by age, gender, district, and province based on the clinician's classification as bacterial, viral, and unclassified meningitis [17]. A few samples are tested at the Central Public Health Laboratory (CPHL) for *Neisseria meningitidis, Streptococcus pneumoniae,* and *Haemophilus influenzae*. Using Real-time PCR in parallel to routine culture and other laboratory diagnoses, *N. meningitidis, S. pneumonia and H. influenzae* were detected in 58 %, 41 % and 0.27 %, respectively, in Baghdad, Karbala, Kirkuk a7 Maysan from 2018 to 2020. Employing real-time PCR to detect the etiological agents of meningitis improved the diagnosis of the viral cause. In Medical City Hospital, Baghdad, PCR detected herpes simplex virus 1 HSV-1 and HSV-2 in 20 % of total meningitis cases [18].

Examining the trend of meningitis in Iraq will add to not only the local literature but also the existing global literature on the meningitis trend. Until this study was written, no routine testing for bacterial or viral causes of meningitis had been performed in the public health laboratories in Iraq apart from the Central Public Health Laboratory. The current study aims to describe the epidemiology of meningitis in Iraq from 2007 to May 31, 2023, by type, age, and sex. This study aims to determine the trend of meningitis and measure the average annual per cent change (AAPC) at the national and sub-national levels.

2. Methods

Study design: A retrospective descriptive analysis of meningitis surveillance data from 2007 to 2023. In addition, trend analysis will determine the trend of all causes of meningitis. Before 2019, surveillance officers from 20 DsoH sent aggregated data of bacterial, viral, and meningococcal meningitis by age, gender, province, and district to the Surveillance Section at the Communicable Diseases Control Center monthly. Because data were compiled in an aggregated format, the completeness was assumed to be close to 100.0 %. Since 2019, suspected meningitis has become an immediately notifiable disease on a case-based form that should be sent to the Surveillance Section at the Communicable Disease Control Center within 72 h. The completeness of the data concerning initial and final diagnosis was 100.0 %. However, the completeness of the data for other variables was about 95 %, which did not affect the quality of the results as other variables were not included in the analysis.

Study population: The surveillance system in Iraq is implemented in 20 Departments of Health (DsoH), which collect data from the main primary healthcare centres and hospitals (surveillance sites). All surveillance sites manage patients who are residents of Iraq regardless of their age, sex, nationality, religion, or any other characteristic. Patients who suffer from meningitis are usually managed at hospitals. If their first encounter is in a primary healthcare centre, they will be referred to the nearest hospital where they will be managed.

Case definitions: Before 2019, cases were reported to surveillance after being classified into viral, bacterial, and meningococcal diseases based on the case definitions below.

Since 2019, surveillance case definitions of meningitis in Iraq started with the clinical suspicion of acute meningitis in any person with sudden onset of fever (>38.5 °C rectal or 38.0 °C axillary) and one of the following signs: neck stiffness, altered consciousness or other meningeal signs. Any patient with clinical signs and symptoms that match the surveillance case definition of acute meningitis will enter the system as suspected meningitis. Then, the final diagnosis will be either viral, bacterial, meningococcal, streptococcal, or Hemophilus influenzae based on the case definitions below.

2.1. Bacterial meningitis case

Any suspected case with a macroscopic aspect of CSF turbid, cloudy or purulent, a CSF leukocyte count >10 cells/mm^3, or bacteria identified by Gram stain in CSF.

In infants: CSF leukocyte count >100 cells/mm^3; or CSF leukocyte count 10–100 cells/mm^3 AND either an elevated protein (>100 mg/dl) or decreased glucose (<40 mg/dl) level.

2.2. Meningococcal meningitis case

Any suspected laboratory case confirmed by culturing or identifying (by polymerase chain reaction, immunochromatographic dipstick, or latex agglutination) of *N. meningitidis* the CSF or blood.

2.3. *Streptococcus pneumoniae case*

Any suspected laboratory case confirmed by culturing or identifying (by polymerase chain reaction, immunochromatographic dipstick, or latex agglutination) of *S. pneumoniae* in the CSF or blood.

2.4. *Haemophilus influenzae type b case*

Any suspected laboratory case confirmed by culturing or identifying (by polymerase chain reaction, immunochromatographic dipstick, or latex agglutination) of *H. influenzae* type b in the CSF or blood.

2.5. *Viral meningitis*

Any suspected case that has elevated cerebrospinal fluid white cell count AND one of the following three:

- Isolation of a viral pathogen from cerebrospinal fluid
- Detection of viral nucleic acid in cerebrospinal fluid
- Increased protein and normal glucose levels in the CSF

Unclassified meningitis: Any person with sudden onset of fever (>38.5 °C rectal or 38.0 °C axillary) and one of the following signs: neck stiffness, altered consciousness or other meningeal signs with no CSF examination, or inconclusive CSF findings, or diagnosed as such by the attending physician.

Data sources: Meningitis data were extracted from the database of the Surveillance Section at the Communicable Diseases Control Centre, Public Health Directorate/Ministry of Health. Meningitis data was collected in aggregate format from 2007 to 2018. Since 2019, the surveillance system has shifted to using a case-based format in collecting meningitis data. The case-based immediate notification form contains the bare minimum information: name, age, sex, residence DoH, date of onset, date of notification, initial diagnosis, and final diagnosis.

Variables: Meningitis data from 2007 to 2018 were aggregated by age, sex, district, and province. All types of meningitis (viral and bacterial, including meningococcal, streptococcal, Haemophilus influenzae, and unclassified meningitis) were grouped into a single outcome: meningitis. From 2019 to 2023, variables include age (less than 1 year, 1–4 years, 5–14 years, 15–45 years, and more than 45 years), sex (male, female), residence province, initial diagnosis (suspected meningitis), final diagnosis (bacterial, viral, streptococcal, meningococcal, Haemophilus influenzae, unclassified meningitis), date of onset, date of notification, outcome (recovered, death), and date of the outcome.

Statistical analysis: We presented the trend of meningitis types, age group distribution, and sex for the 17 years in a line graph.

We used a joinpoint regression model to determine the overall trend of meningitis over 17 years (2007–2023) and identify any significant trends within the 17 years in addition to the average yearly per cent change. We modelled the total count of meningitis by

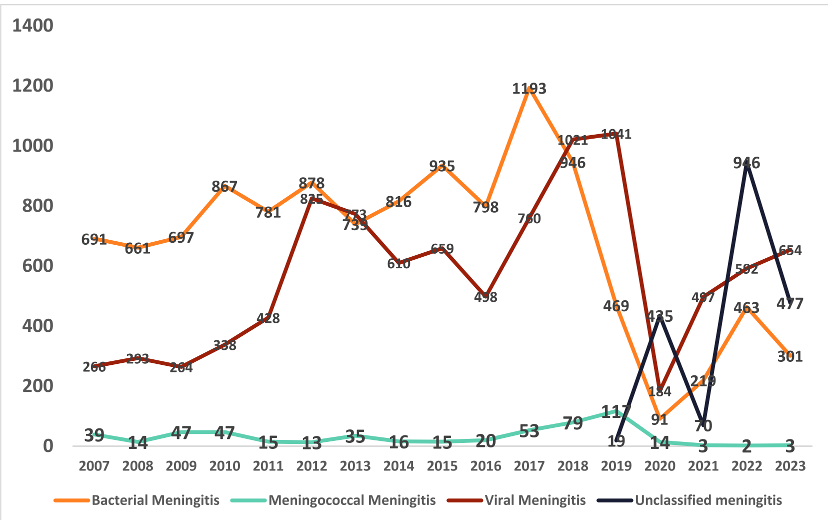


Fig. 1. Incidence dynamics of different causative agents of meningitis, bacteria, viral or unclassified meningitis (Iraq, 2007–2023). [Orange = bacterial meningitis, Green = Meningococcal meningitis, Maroon = viral meningitis and Black = unclassified meningitis.]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

year of reporting and province. We used log transformation and Poisson variance to calculate the data. We chose the empirical quantile method to calculate the estimates. We decided on the best-fit model based on the minimum Weighted Bayesian Information Criterion (WBIC) as the final model. The model calculated the annual per cent change (APC), the average APC (AAPC), and their 95 % confidence intervals. The confidence intervals were computed using a simple closed-form formula under parametric assumptions. If the AAPC is in one segment, the t-distribution is used. Otherwise, the normal (z distribution) is used. If the confidence interval contains zero, then the trend is stable. If the confidence interval is negative, then the trend is decreasing. If the confidence interval is positive, the trend is increasing. We also displayed the line graph of provinces with more than 0 joinpoints, with a non-monotonic trend. Then, we chose the AAPC as the final measure of an overall trend. The significance test results obtained through the Monte Carlo permutation statistical method were used to identify the best-fitted line segment(s) in the joinpoint regression analysis, representing significant trend changes. The AAPC was considered statistically significant when the p-value was lower than 0.05.

The analysis was done using Joinpoint regression software version 5.2.0, and the line graphs were done using Microsoft Excel 2021.

2.6. *Ethical approval*

Because the study is part of the surveillance key functions and work and used already available data, the study was not considered research, and ethical approval was unnecessary.

Results: Bacterial meningitis was higher than viral meningitis from 2007 to 2018 when viral meningitis was higher than bacterial meningitis and continued up to 2023. Meningococcal meningitis (caused by *N. meningitidis,* a bacterial infection) was lower than other bacterial causes and viral meningitis from 2007 to 2023, Fig. 1. As for the age group distribution of the patients, most meningitis patients across all years were lower than 15 years-almost 80 % and 20 %–40 % were lower than one year, Fig. 2. Across all years, about 55 % of the cases were males, apart from 2019, when around 70 % were females, Fig. 3.

Iraq has had a stable meningitis trend (AAPC = −0.13, 95%CI = −4.4- 4.7) from 2007 to 2023, as reported in Table 1. However, four provinces showed a statistically significant upward trend (Anbar (AAPC = 11.9, 95%CI = 7.1–23.5), Diyala (AAPC = 14.6, 95%CI = 9.9–22.7), Nineveh (AAPC = 13.4, 95%CI = 4.3–34.3), Salah Aldin (AAPC = 12.7, 95%CI = 3.0–44.6)). Moreover, there were another four provinces that showed a statistically significant downward trend (Basrah (AAPC = −25.9, 95%CI = −31.1 to −24.0), Erbil (AAPC = −9.1, 95%CI = −20.1 to −2.9), Kirkuk (AAPC = −14.9, 95%CI = −40.8 to −1.4), Missan (AAPC = −6.9, 95%CI = −15.2 to −1.2)).

In addition, there were eight provinces with one joinpoint characterised by an initial upward trend followed by a downward trend (Babylon, Diwaniya, Kirkuk, Muthanna, Nineveh, Salah Aldin, Thiqar, and Wasit. Nevertheless, the downward trend continued in Kirkuk only while other provinces, such as Salah Aldin and Nineveh, showed an overall stable or upward trend.

Kerbala had two joinpoints characterised by an initial steady increase followed by a rapid increase and then a decrease. Sulaymaniya had three joinpoints characterised by an increase followed by a steady count, a decline and then an increase in the count. Fig. 4 (a–j) displays the provinces with one or more joinpoints.

3. Discussion

Findings from our study show that Iraq has had a stable meningitis trend since 2007, with viral meningitis being the predominant type since 2018 [19–21]. The increase in viral meningitis and the highest incidence of meningitis was at ages less than 15 years old. In

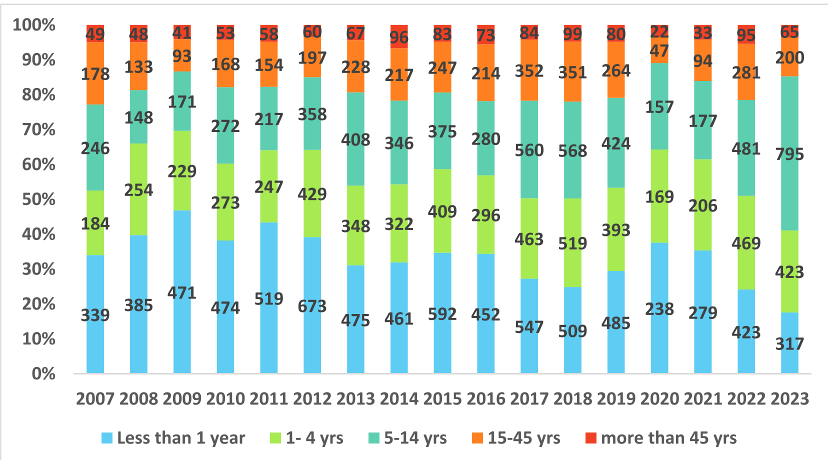


Fig. 2. Age group distribution of all types of meningitis in Iraq, 2007–2023. The figure shows age-dependent meningitis burden in 5 age groups. [Blue= <1, light green = 1-4, dark green = 5-14, orange = 15–45 and red= >45.] Data was extracted from the Surveillance Section database at the Communicable Diseases Control Centre, Public Health Directorate/Ministry of Health, Iraq. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

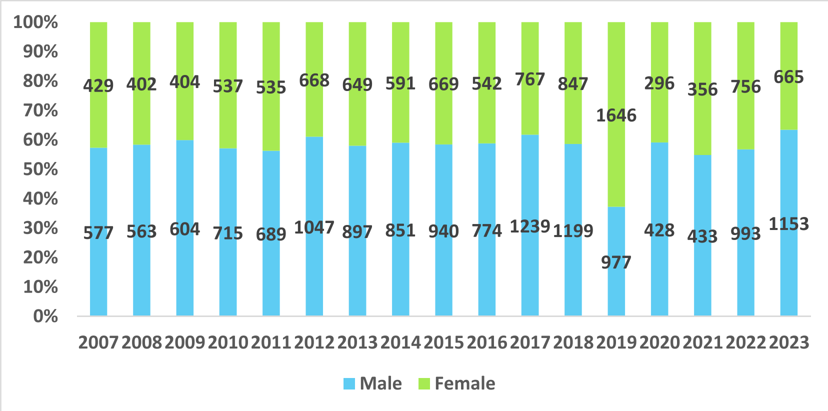


Fig. 3. Sex distribution of meningitis in Iraq, 2007–2023. [Blue = male and green = female.] Data was extracted from the Surveillance Section database at the Communicable Diseases Control Centre, Public Health Directorate/Ministry of Health, Iraq. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

addition to the vaccination program that was applied to prevent bacterial meningococcal infection, other reasons may contribute to such a trend. Non-polio enteroviruses, the leading causes of meningitis, can be transmitted through the oral-faecal or respiratory tract and have shown a global increase in recent years [22]. The shortage of water supply and poor sanitation in schools could be significant sources of enterovirus meningitis in children under 15. In 2019, high viral meningitis was detected in children under 14 years old in Diyala, with Coxsackie as the most common virus. Furthermore, recent climate change and increased temperatures all over the year compared with prior years may have contributed to the continued circulation of the viruses. Bacterial and viral causes were detected to belong to *S. pneumonia* or enteroviruses, with more prevalence in males than females [23].

The study showed an increase in bacterial meningitis other than *N. meningitidis*, which suggests other species, such as *S. Pneumonia,* one of the most common causes of meningitis worldwide [24]. Consistently, *S. pneumonia* was detected in 50 % of meningitis cases in Duhok [25], suggesting a high prevalence of this species in Iraq. However, a study identified the causative agents of meningitis using PCR in 4 provinces in Iraq from 2018 to 2020. *S. pneumoniae* was diagnosed in 41 % as a second bacterial pathogen after *N. meningitidis* [26]. WHO identified *S. pneumonia* as 1 of 12 types of antibiotic-resistant species, and it causes a burden on public health with a high mortality rate. Hence, strengthening and reviewing the pneumococcal vaccination policy in Iraq will be more effective than treating antibiotic-resistant circulating strains.

Most of the meningitis patients in our study were males and under 15 years across all years. Anbar, Diyala, Nineveh, and Salah Aldin have an upward trend. In contrast, Basrah, Erbil, Kirkuk, and Missan have a downward trend. The increasing trend in each of Anbar, Diyala, Nineveh, and Salah Aldin is both assuring that the surveillance system is back on track after the insecurities the provinces have gone through from 2013 to 2018 and alert to the possibility of enhancing conditions in these provinces that facilitates the transmission of and causing meningitis. Moreover, even after stabilising the security situation in these provinces, displaced populations from Syria usually tend to settle in Anbar, Nineveh, and Salah Aldin, which could have contributed to this increase. Therefore, this upward trend should be accompanied by public health actions that facilitate the identification of the causative organism, transmission routes, and risk factors, ultimately leading to effective preventive measures [3]. In Anbar, several risk factors were associated with increased meningitis, including living in urban areas, bottle feeding, recent respiratory tract infection, passive smoking, and low economic state [27]. However, other cities could share all or some of these factors since they are not specific to Anbar.

On the other hand, the significant downward trend in Basrah, Kirkuk, Erbil, and Missan requires further investigation into the causes of the decline. The surveillance of other infectious diseases in Erbil is low, and meningitis is no exception [28]. Therefore, the downward trend in Erbil is most likely to be an artefact due to poor reporting to surveillance and a lack of human and financial resources. In contrast, the quality of surveillance of other infectious diseases in each of Basrah, Kirkuk, and Missan is good; therefore, the downward trend needs to be investigated to identify the possible causes, such as an actual decrease, change of surveillance officers in surveillance sites, or lack of knowledge. Contradictory contributors could explain the decrease in Basra and southern provinces, and there needs to be better documentation about meningitis due to the hesitation to take CSF samples for social reasons. On the other hand, awareness of vaccination programmes among health workers, medical and related specialities students and people frequently going to Hajj and Omra.

The significant decline in disease reporting in 2020 coincides with the COVID-19 pandemic, which had led to a chain of events that contributed to the decline, such as lockdowns that limited people's mix-up and spread of communicable diseases other than COVID-19. The downward trend of meningococcal meningitis after 2020 could be attributed to the advance in using PCR as a diagnostic tool. Pneumococcal meningitis was reported to be very high among meningitis causes, reaching more than 40 %. On the other hand, implementation of PCV conjugate pneumococcal vaccination after 2017 is very limited compared to the increased uptake of quadrivalent ACYW135 against meningococcal meningitis during Hajj and Umrah [26,29].

This is the first study in Iraq that statistically examines the trend of bacterial and viral meningitis over 17 years. Using 17 years of

Table 1
Showing reported DOH total count of meningitis and AAPC (%) in Iraq Provinces from 2007 till 2023.

Reported DoH	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Trend	AAPC%, 95%CI
ANBAR	8	5	1	5	6	28	9	0	0	0	1	1	14	5	40	57	23		11.9 (7.1- 23.5)*
BABYLON[1jp2017]	156	89	62	145	122	189	146	254	211	225	279	132	179	68	135	88	57		-3.2 (-10.7- 2.3)
BAGHDAD-KARKH	87	131	208	241	249	258	197	90	233	329	318	219	320	156	184	289	160		1.9 (-3.6- 8.3)
BAGHDAD-RESAFA	309	367	350	248	229	324	201	136	92	105	230	358	287	101	64	133	75		-5.2 (-11.9- 0.4)
BASRAH	124	70	60	73	30	27	25	12	15	2	7	2	1	0	0	1	0		-25.9 (-31.1- -24.0)*
DAHUK	50	27	25	49	27	19	10	14	53	45	59	50	53	14	9	53	2		1.5 (-8.1- 13.1)
DIWANIYA[1jp2017]	9	3	24	14	11	19	82	52	82	79	110	61	68	28	5	9	7		-2.8 (-11.7- 5.7)
DIYALA	4	47	42	116	73	64	73	79	81	67	139	83	255	106	211	471	214		14.6 (9.9- 22.7)*
ERBIL	13	1	39	28	11	9	4	15	39	4	0	9	5	0	0	2	0		-9.1 (-20.1- -2.9)*
KERBALA[2jp2015,2018]	1	18	25	41	31	25	37	43	47	54	285	375	226	30	25	28	7		- 5.9 (-16.3- 2.2)
KIRKUK[1jp2018]	35	27	15	15	38	47	39	31	20	33	51	66	13	0	1	7	2		-14.9 (-40.8- -1.4)*
MISSAN	13	14	11	27	4	9	3	2	2	0	1	0	13	1	2	4	8		-6.9 (-15.2- -1.2)*
MUTHANNA[1jp2017]	18	16	11	29	20	2	19	47	38	51	87	46	20	12	26	40	19		2.8 (-9.2- 19.3)
NAJAF	86	52	20	50	16	112	132	159	173	110	63	9	5	2	1	162	46		2.9 (-6.4- 13.1)
NINEVEH[1jp2012]	25	29	42	76	163	357	345	247	233	29	0	40	121	54	33	269	89		13.4 (4.3- 34.3)*
SALAH AL-DIN[1jp2018]	2	2	3	8	10	9	2	0	0	0	52	75	34	8	14	26	19		12.7 (3.0- 44.6)*
SULAYMANIYA[3jp2013,2018,2021]	44	62	36	45	103	155	178	165	232	119	176	195	30	2	2	2	47		1.5 (-5.6- 8.16)
THI-QAR[1jp2011]	3	5	18	25	47	47	15	29	22	23	9	18	25	9	19	0	2		5.2 (-5.8- 24.6)
WASSIT[1jp2018]	9	3	16	16	34	16	25	67	31	41	139	307	139	37	18	81	37		12.8 (-1.4- .3)
Total	996	968	1008	1251	1224	1716	1542	1442	1604	1316	2006	2046	1808	633	789	1722	814		-0.13 (-4.4- 4.7)

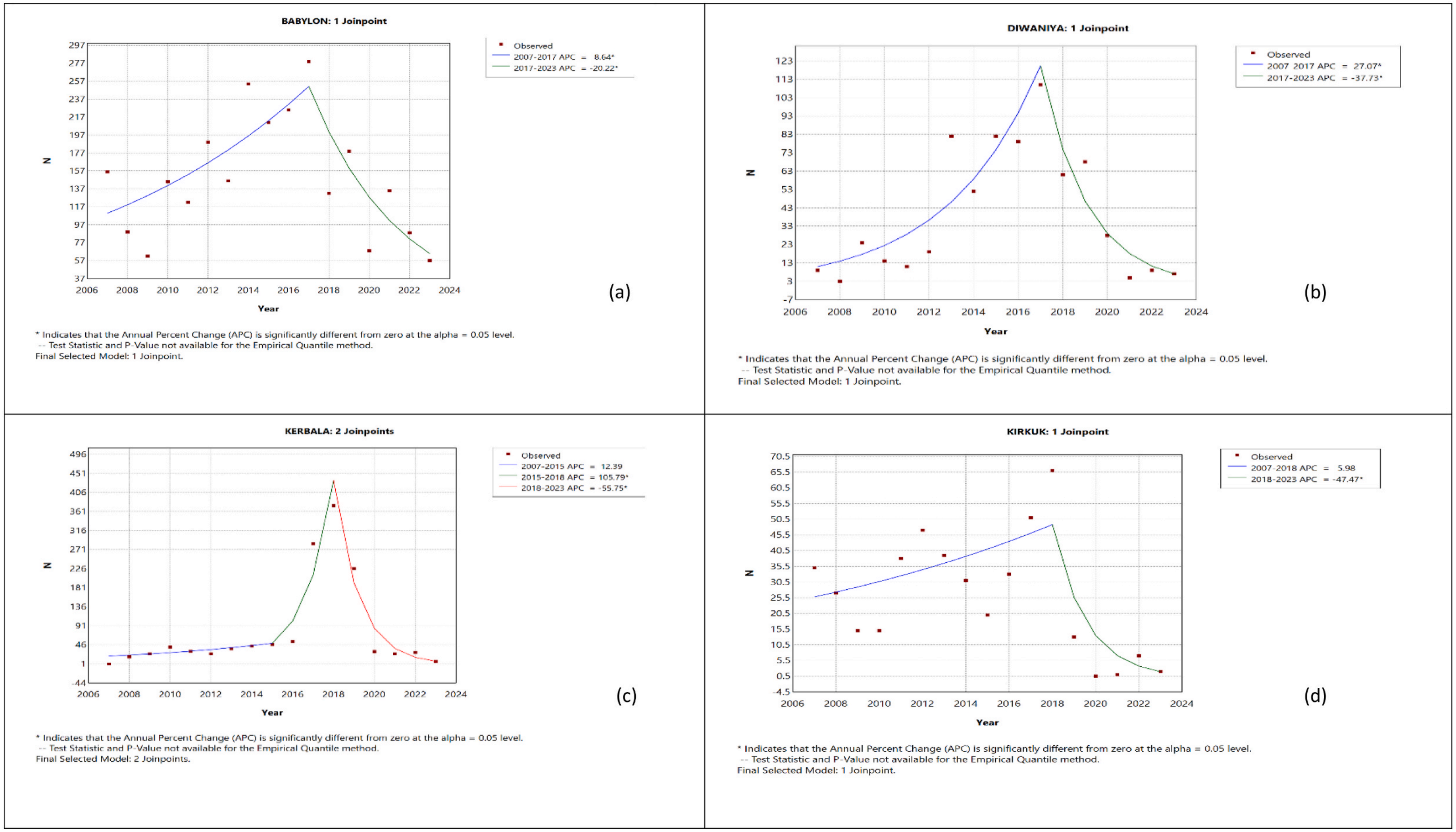
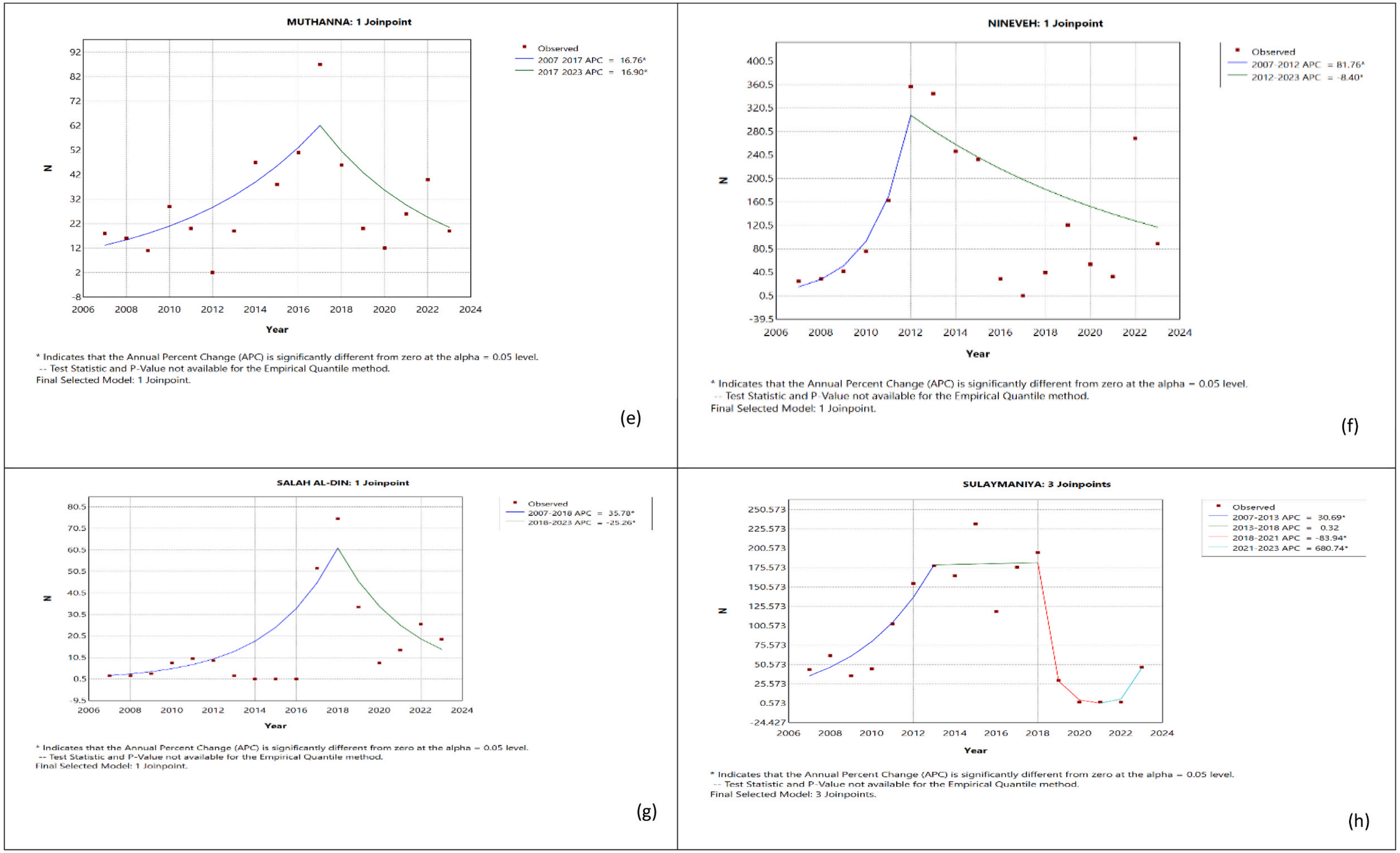


Fig. 4. (a–j): Provinces with one or more joinpoints of meningitis in Iraq from 2007 to 2023.


MUTHANNA: 1 Joinpoint
Observed
2007-2017 APC = 16.76*
2017-2023 APC = -16.90*
N
Year
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic and P-Value not available for the Empirical Quantile method.
Final Selected Model: 1 Joinpoint.
(e)
NINEVEH: 1 Joinpoint
Observed
2007-2012 APC = 81.76*
2012-2023 APC = -8.40*
N
Year
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic and P-Value not available for the Empirical Quantile method.
Final Selected Model: 1 Joinpoint.
(f)
SALAH AL-DIN: 1 Joinpoint
Observed
2007-2018 APC = 35.78*
2018-2023 APC = -25.26*
N
Year
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic and P-Value not available for the Empirical Quantile method.
Final Selected Model: 1 Joinpoint.
(g)
SULAYMANIYA: 3 Joinpoints
Observed
2007-2013 APC = 30.69*
2013-2018 APC = 0.32
2018-2021 APC = -83.94*
2021-2023 APC = 680.74*
N
Year
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic and P-Value not available for the Empirical Quantile method.
Final Selected Model: 3 Joinpoints.
(h)

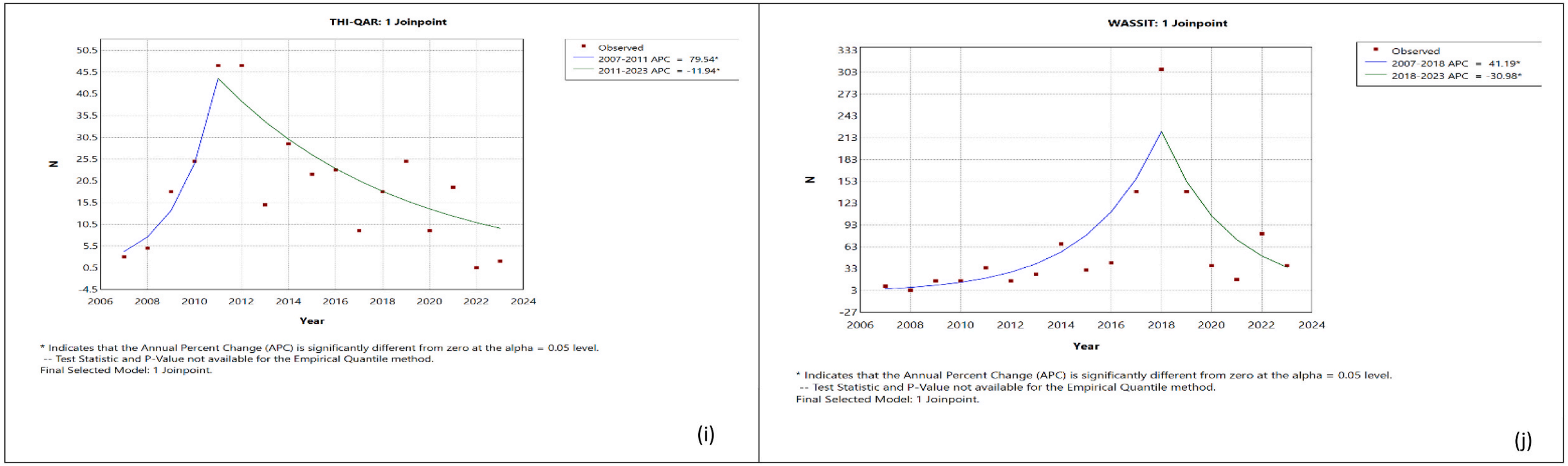


Fig. 4. (*continued*).

data in a joinpoint regression model has given a more accurate description of the national and sub-national trends. All CSF samples in Iraq should be tested at the CPHL to confirm the causative agents of meningitis; therefore, the testing quality could not have contributed to the discrepancy in the numbers between the provinces. Limitations of the study include the need for further epidemiologic information regarding risk factors of meningitis, which, had it been present, would have also given an insight into the trend of these factors. Although there was a minor increase in the population over the years, the effect on the AAPC is trivial, if any. Including 2023 data may have affected the results in favour of a downward trend as the data was up to May 31, 2023, and not the whole year. Nevertheless, this effect is not statistically significant. In addition, the study used data from the national surveillance system, which relies on the performance of surveillance officers in each province, which could have contributed to the discrepancy in numbers across different provinces. Weak or lack of integrated healthcare system guarantees effective data flow in Iraq, weak application of standard operating procedures in collecting infection data, improper diagnostic facilities in clinical laboratories, inconsistency in data entry, and weak trained laboratory personnel, especially in rural areas, all are limitation factors for this study.

4. Conclusion

In Iraq, viral meningitis has been the predominant type since 2018, and this could be due to the effectiveness of bacterial meningitis implemented vaccination and due to the infection with non-polio enteroviruses, which is higher at school age due to poor sanitation. Most meningitis patients across all years were lower than 15 years and males. The meningitis trend in Iraq was stable from 2007 to 2023. However, four provinces showed a statistically significant upward trend (Anbar, Diyala, Nineveh, Salah aldin). Moreover, another four provinces showed a statistically significant downward trend (Basrah, Erbil, Kirkuk, Missan).

We recommend studying viral and bacterial meningitis in Iraq by starting a sentinel surveillance program to select major hospitals from four provinces or more to test the samples of the patients with laboratory testing kits that can identify the causative agents for both types. In addition, we recommend enhancing surveillance in provinces with a statistically significant downward trend. Detailed case investigations in provinces with statistically significant upward trends are necessary to identify risk factors and guide control strategies. Monitoring the clustering of cases is essential to help control outbreaks.

Ethical approval

Because the study is part of the surveillance key functions and work and the study used already available data, the study was not consideredprimary data research and ethical approval was not necessary.

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Data availability statement

The raw data has not been deposited into a publicly available repository and is kept confidential.

CRediT authorship contribution statement

Hanan Abdulghafoor Khaleel: Writing – original draft, Methodology, Conceptualization. **Riyadh Abdulameer Alhilfi:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Salman Rawaf:** Writing – review & editing, Visualization, Supervision. **Zeenah Atwan:** Writing – review & editing, Formal analysis. **Ameen Abdulhasan Al-Alwany:** Writing – review & editing. **Mays Raheem:** Writing – review & editing. **Celine Tabche:** Writing – review & editing, Validation, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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