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Impact of Climatic Factors on Hepatitis A Virus Transmission in Benghazi, Libya

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تأثير العوامل المناخية على انتقال فيروس التهاب الكبد الوبائي (*A*) في مدينة بنغازي، ليبيا

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Abstract

Hepatitis A virus (HAV) remains a significant public health concern in urban settings where demographic and environmental factors may influence viral transmission. This study assessed the impact of demographic and environmental determinants on acute HAV infection in Benghazi, Libya, focusing on seasonal patterns and local climatic variables. A retrospective analysis was conducted on 158 serum samples collected from November 2024 to November 2025, with acute infection confirmed via HAV IgM seropositivity.

The overall HAV IgM positivity rate was 14.56%, with no significant difference between males (14.05%) and females (16.22%). Age-specific analysis revealed that adolescents (11–20 years, 30.8%) and young adults (21–30 years, 23.8%) were the most affected, whereas children under 10 years and individuals over 50 years showed no positive cases.

Infections occurred year-round, with minor seasonal fluctuations and a peak in April 2025 (35.3%). Statistical analyses indicated no significant correlation between HAV IgM positivity and temperature (r = -0.033) or relative humidity (r = 0.330), confirming that climatic factors alone do not drive transmission. The results indicate that age patterns were the main determinant observed in HAV infection, while climatic factors showed no significant association.These findings emphasize the need for monitoring demographic and seasonal trends to guide public health strategies and targeted vaccination programs, providing actionable insights for reducing HAV incidence in urban Libyan populations.

Keywords: Hepatitis A, HAV infection, climatic factors, demographic factors, Benghazi.

الملخص

لا يزال فيروس التهاب الكبد A (HAV) يمثل مصدر قلق كبير للصحة العامة في المناطق الحضرية التي قد تؤثر فيها العوامل الديموغرافية والبيئية على انتقال العدوى. هدفت هذه الدراسة إلى تقييم تأثير العوامل الديموغرافية والبيئية على عدوى HAV الحادة في مدينة بنغازي، ليبيا، مع التركيز على الأنماط الموسمية والمتغيرات المناخية المحلية. أُجريت دراسة استعادية على 158 عينة مصل جُمعت من نوفمبر 2024 إلى نوفمبر 2025، وتم تأكيد العدوى الحادة من خلال إيجابية HAV IgM.

بلغت نسبة الإيجابية الكلية لـ HAV IgM 14.56%، مع عدم وجود فرق ذو دلالة إحصائية بين الذكور (14.05%) والإناث (16.22%). أظهر التحليل العمري أن المراهقين (11–20 سنة؛ 30.8%) والشباب (21–30 سنة؛ 23.8%) هم الأكثر تأثرًا، بينما لم تُسجَّل أي حالات إيجابية لدى الأطفال دون سن العاشرة أو الأفراد فوق سن الخمسين.

حدثت العدوى على مدار العام مع تقلبات موسمية طفيفة وذروة ملحوظة في أبريل 2025 (35.3%). وأظهرت التحليلات الإحصائية عدم وجود ارتباط معنوي بين إيجابية HAV IgM وكل من درجة الحرارة (r = -0.033) أو الرطوبة النسبية (r = 0.330)، مما يؤكد أن العوامل المناخية وحدها لا تحدد انتقال العدوى. تشير النتائج إلى أن نمط العمر كان العامل الأبرز المرتبط بانتقال HAV في هذه العينة، بينما لم تُظهر العوامل المناخية أي ارتباط معنوي.

تؤكد هذه النتائج على ضرورة متابعة الاتجاهات الديموغرافية والموسمية لتوجيه استراتيجيات الصحة العامة وبرامج التطعيم المستهدفة، بما يوفّر رؤى عملية للحد من انتشار HAV في المجتمعات الحضرية الليبية.

الكلمات المفتاحية: التهاب الكبد الوبائي A، فيروس HAV، العوامل المناخية، العوامل الديموغرافية، بنغازي.

Introduction

Hepatitis A virus (HAV) is a nonenveloped icosahedral RNA virus belonging to the genus Hepatovirus and family Picornaviridae (Kalita et al., 2020). The absence of a lipid envelope provides HAV with a significant advantage in environmental survival, as evidenced by foodborne and waterborne outbreaks (Webb et al., 2020). Anti-HAV antibodies in human sera are detectable during acute illness, coinciding with elevated serum liver enzyme levels and fecal HAV shedding. IgM antibodies rise initially and typically persist for 6–12 months. HAV infection is self-limiting and does not result in chronic disease (Kalita et al., 2020). Hepatitis A virus is primarily transmitted through the fecal–oral route, particularly via ingestion of food and water contaminated with infected stool. Person-to-person transmission can also occur in crowded settings or where sanitation is poor (Webb et al., 2020).

Globally, viral hepatitis represents a substantial public health challenge. In 2015, it accounted for 1.34 million deaths worldwide, surpassing the mortality rates associated with HIV and tuberculosis, as reported by the World Health Organization's (WHO) 2017 Global Hepatitis Report. Acute liver failure (ALF) and acute viral hepatitis (AVH) are severe conditions frequently precipitated by hepatitis A and E viruses (Palewar et al., 2022). HAV infection leads to hepatocellular damage, manifesting clinically with symptoms such as jaundice, nausea, and fatigue (Li, 2023). The virus poses a considerable threat to public health, particularly in regions characterized by inadequate sanitation, unsafe drinking water, and contaminated food sources. Recent investigations highlight the critical role of environmental and climatic factors in HAV

transmission and persistence. Extreme weather events, such as floods induced by heavy rainfall, can compromise water sources, thereby escalating the risk of infection (Gao et al., 2016). Temperature and relative humidity also exert influence over viral survival; moderate conditions generally favor HAV stability in water and soil, whereas elevated temperatures accelerate viral inactivation. Conversely, low humidity extends viral infectivity on surfaces, while high humidity tends to reduce its survival time (Cook et al., 2018; Mbithi, Springthorpe, & Sattar, 1991). Furthermore, high ambient temperatures and drought conditions can indirectly heighten transmission risk by exacerbating water scarcity and contamination (Parashar & Khalkar, 2011). A comprehensive understanding of these intricate interactions among climate, environment, and viral persistence is indispensable for deciphering HAV outbreak patterns.
Given the global burden of HAV and the profound influence of environmental factors on its transmission dynamics, it is imperative to investigate the impact of climatic variables on the virus's distribution. Elucidating the effects of temperature, humidity, and rainfall on HAV transmission is crucial for addressing the global public health challenge posed by the virus (Palewar et al., 2022; Li, 2023). Climatic and environmental factors demonstrably affect viral survival and outbreak patterns (Gao et al., 2016 ; Cook et al., 2018; Mbithi, Springthorpe, & Sattar, 1991; Parashar & Khalkar, 2011), underscoring the necessity of studying these variables to inform effective public health strategies. Insights derived from such research can facilitate the development of climate-adaptive public health interventions and predictive models for enteric viral diseases, ultimately contributing to a reduction in HAV incidence and an improvement in population health.

Research Objectives

This study endeavors to assess the influence of environmental and demographic factors on acute hepatitis A virus (HAV) infection in Benghazi, Libya, through the following specific objectives:

- To delineate the seasonal variations in HAV IgM seropositivity observed throughout the study period.
- To analyze the impact of environmental parameters, specifically temperature and humidity, on the seasonal fluctuations in HAV infection rates.
- To evaluate the contribution of sex and age groups in explaining the observed seasonal variations in HAV infection.

Materials and Methods

Study Design and Sample Collection

A cross-sectional study was conducted using 158 serum samples collected between November 2024 and November 2025 from Al-Saleem Medical Laboratory for Medical Analyses in Benghazi, Libya. The dataset included participants' age, sex, and sample collection date, enabling the classification of samples according to the four seasons: autumn, winter, spring, and summer. HAV IgM results were obtained directly from laboratory records, with no additional serological analyses performed.

Serological Data

Results for HAV IgM antibodies were retrieved from the existing laboratory records. The initial laboratory analysis was executed employing chemiluminescent immunoassay (CLIA) on the MAGLUMI 800 analyzer (Snibe Co., Ltd., China), strictly adhering to the manufacturer's stipulated instructions. No further serological testing was undertaken as part of this study.

Climatic Data

Monthly mean temperature and relative humidity data pertinent to Benghazi were acquired from TimeandDate (2026), a platform that aggregates information from the Benina Airport meteorological station. This data was instrumental in assessing potential environmental influences on the seasonal distribution patterns of HAV infection.

Data Analysis

Descriptive statistics, including the mean, standard deviation, minimum, maximum, and median, were computed for age, HAV IgM positivity, and climatic variables. The age-wise distribution of HAV IgM seropositivity was analyzed descriptively, employing frequencies and percentages exclusively, without the application of inferential statistical tests. This approach was necessitated by the presence of small or zero counts within certain age categories. Associations between sex, seasons, and HAV IgM results were evaluated using the Chi-Square test, with a predetermined significance level of $\alpha = 0.05$; seasonal fluctuations were also assessed. Furthermore, regression analysis was performed to ascertain the potential influence of climatic variables (temperature and relative humidity) on seasonal HAV IgM positivity. All statistical analyses were meticulously conducted using SPSS version 26.

Results

Distribution of HAV IgM Positivity by Sex

Among 158 serum samples obtained from laboratory records, 23 (14.56%) were positive for HAV IgM. The positivity rate was slightly higher among females (6/37; 16.22%) than males (17/121; 14.05%). Although the total number of positive cases was higher among males, the positivity rate within the female cohort was marginally greater. Females accounted for 26.1% of all positive cases, while males accounted for 73.9%. Statistical analysis using Pearson's chi-square test indicated that this difference was not statistically significant ($\chi^2 = 0.0037$, df = 1, P = 0.9516), suggesting that sex does not have a meaningful effect on infection in this dataset.

Table 1: Distribution of samples, positive and negative cases, and positivity rates by sex

Sex	Total samples	Positive cases	Negative cases	Positivity rate within sex (%)
Female	37	6	31	16.22
Male	121	17	104	14.05
Total	158	23	135	14.56

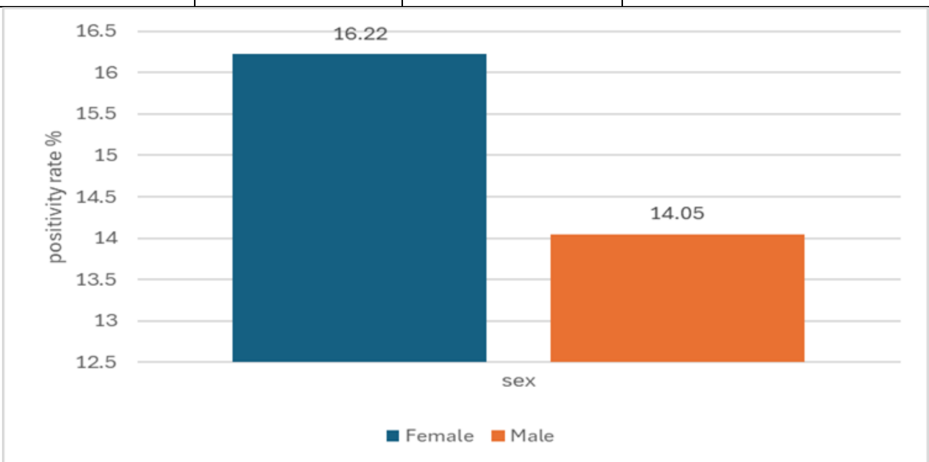

Figure 1: Distribution of samples and positivity rates by sex

Age-wise Distribution of HAV IgM Seropositivity

A total of 158 serum samples were meticulously analyzed for acute hepatitis A virus (HAV) infection based on IgM seropositivity. No positive cases were detected within the 0–10 years age group (0/13, 0.0%). In the 11–20 years cohort, 12 out of 39 samples tested positive (30.8%). The 21–30 years group registered 5 positive samples out of 21 (23.8%), while the 31–40 years group accounted for 5 positive samples out of 30 (16.7%). Only a single positive sample was recorded in the 41–50 years group (1/25, 4.0%). Notably, no positive cases were observed in the 51–60 years and >60 years age groups. The overall IgM positivity rate across all age groups was determined to be 14.6% (23/158).

Table 2 succinctly summarizes the total number of samples, alongside HAV IgM–positive and –negative cases across the various age groups.

Table 2: Distribution of HAV IgM positive and negative cases by age group

Age group (years)	Total samples	Positive cases	Negative cases	Positivity rate (%)
0–10	13	0	13	0.00
11–20	39	12	27	30.77
21–30	21	5	16	23.81
31–40	30	5	25	16.67
41–50	25	1	24	4.00
51–60	10	0	10	0.00
>60	20	0	20	0.00
Total	158	23	135	14.56

Seasonal Distribution of HAV IgM Seropositivity

A total of 158 serum samples underwent analysis to ascertain the seasonal distribution of acute hepatitis A virus (HAV) infection based on IgM seropositivity. The samples were systematically categorized into four distinct seasons: autumn, summer, winter, and spring. Table 3 provides a comprehensive summary of the total number of samples, as well as HAV IgM–positive and –negative cases across these different seasons.

Among the 158 samples examined, the highest incidence of HAV IgM–positive cases was recorded in autumn (8/48), followed by spring (7/35), winter (4/33), and summer (4/42). However, the Chi-Square test demonstrated no statistically significant association between season and HAV IgM results (P = 0.5686, which exceeds the significance threshold of 0.05).

Table 3: Distribution of HAV IgM positive and negative cases by season

Season	Total Samples	Positive Cases	Negative Cases	Positivity Rate (%)
Autumn	48	8	40	16.7
Summer	42	4	38	9.5
Winter	33	4	29	12.1
Spring	35	7	28	20.0
Total	158	23	135	14.6

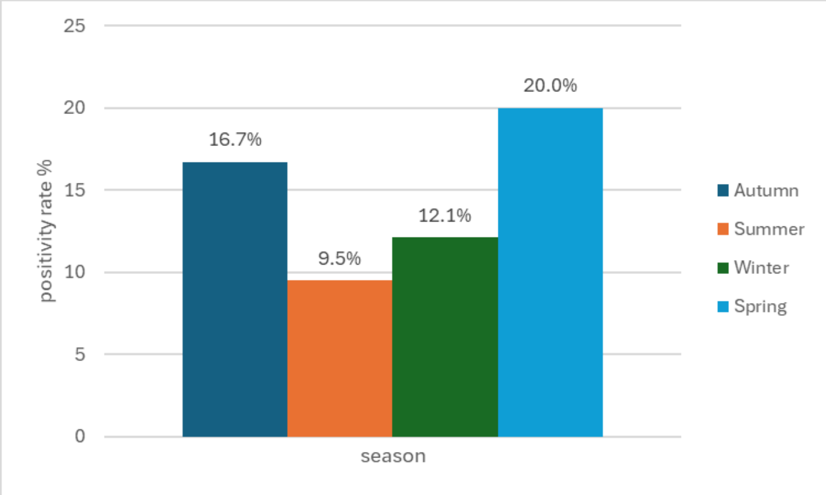

Figure 2: Seasonal distribution of HAV IgM positive cases.

Monthly Distribution of HAV IgM Seropositivity

A total of 158 serum samples were analyzed to evaluate the monthly distribution of acute hepatitis A virus (HAV) infection, based on IgM seropositivity (>1). Table 4 provides a summary of the total number of samples, positive cases, and positivity rates for each month from November 2024 to November 2025.

The highest positivity rate was observed in April 2025 (35.29%), with 6 positive cases out of 17 samples. Conversely, the lowest positivity rates (0.00%) were recorded in March 2025 and November 2025. The largest number of samples was collected in July 2025 (23 samples). A subtle seasonal trend was discernible, characterized by higher positivity during the transitional period from winter to spring (April), and lower positivity in late summer and early spring.

Table 4: Monthly distribution of HAV IgM positive and negative cases (November 2024 – November 2025)

Month	Year	Total samples	Positive cases	Positivity rate (%)
November	2024	17	4	23.53
December	2025	10	2	20.00
January	2025	14	1	7.14
February	2025	9	1	11.11
March	2025	8	0	0.00
April	2025	17	6	35.29
May	2025	10	1	10.00
June	2025	8	1	12.50
July	2025	23	1	4.35
August	2025	11	2	18.18
September	2025	16	3	18.75
October	2025	11	1	9.09
November	2025	4	0	0.00

Monthly Distribution of HAV IgM Positivity and Climatic Factors

Analysis of the relationship between monthly mean temperature, relative humidity, and HAV IgM positivity (November 2024–November 2025) revealed no statistically significant associations. Pearson correlation indicated a very weak negative correlation with temperature (r = -0.033) and a weak positive correlation with humidity (r = 0.330), neither of which reached statistical significance.

Multiple linear regression further confirmed that temperature and humidity exerted no significant effect on HAV IgM positivity (Adjusted $R^2 = -0.047$, F = 0.731, P = 0.506). Despite the absence of significant linear relationships, a clear monthly trend was observed, with the highest positivity rate in April 2025 (35.29%), suggesting the potential influence of seasonal or non-climatic factors.

As shown in Table 5, the highest positivity rate in April 2025 (35.29%) is consistent with the monthly trend described above.

Table 5: Monthly Temperature, Humidity, and Hepatitis A Positivity Rates (Nov 2024–Nov 2025)

Month	Year	Temperature (°C)	Relative Humidity (%)	Total samples	Positive cases	Positivity rate (%)
November	2024	21	61	17	4	23.53
December	2024	16	66	10	2	20.00
January	2025	16	67	14	1	7.14
February	2025	16	46	9	1	11.11
March	2025	20	45	8	0	0.00
April	2025	20	67	17	6	35.29
May	2025	24	63	10	1	10.00
June	2025	25	75	8	1	12.50
July	2025	28	73	23	1	4.35
August	2025	29	70	11	2	18.18
September	2025	27	69	16	3	18.75
October	2025	25	36	11	1	9.09
November	2025	21	59	4	0	0.00

Discussion

In this study, the overall HAV IgM positivity rate was 14.56%. Although the rate was slightly higher among females (16.22%) than males (14.05%), statistical analysis using Pearson's chi-square test showed no significant gender difference ($\chi^2 = 0.0037$, df = 1, P = 0.9516). Females represented 26.1% of all positive cases, while males accounted for 73.9%. These results align with previous studies from other regions. For instance, in South Korea, minor variations in HAV infection across genders were observed, but differences were not statistically significant **(Son et al., 2024**). Similarly, **Jain et al. (2024**) in India reported comparable HAV infection rates between males and females, indicating that gender alone is not a major determinant of HAV epidemiology. Collectively, these findings suggest that environmental and behavioral factors may have a stronger influence than gender in shaping HAV transmission patterns.

Age-specific analysis revealed distinct trends. The HAV IgM positivity rate was 0% in children aged 0–10 years (0/13), increased markedly to 30.8% in adolescents aged 11–20 years (12/39), and then progressively declined in older age groups: 21–30 years (23.8%; 5/21), 31–40 years (16.7%; 5/30), and 41–50 years (4.0%; 1/25). No positive cases were detected among individuals aged 51–60 years (0/20) and above 60 years (0/10). The overall positivity rate across all ages was 14.6% (23/158). These findings are consistent with reports from Sakarya, Turkey, which observed very low HAV positivity in children under 10, a peak of approximately

28% in adolescents, followed by a gradual decline with increasing age (**Köroğlu, Demiray**, Terzi, & Altındiş, 2014). Global data also support this pattern, showing that acute HAV infection predominantly affects individuals under 20 years (20–35%), decreasing to less than 5% in those older than 40 years (**Jacob**sen & Wiersma, 2010). The introduction of the hepatitis A vaccine into Libya's national immunization program in 2023, administered at 15 months of age (A**busrewil** et al., 2025), likely reduced early childhood exposure, explaining the higher positivity among adolescents and young adults compared to younger children.

Analysis of seasonal patterns indicated that HAV IgM positivity occurred throughout all seasons, with no statistically significant association between season and infection rates (χ^2 = 2.00, df = 3, P = 0.5686). Slightly higher positivity was observed in autumn and spring, but these differences were not statistically significant. Monthly analysis revealed the highest positivity in April 2025 (35.29%), corresponding to the transitional period from winter to spring, while no cases were detected in March and November 2025. These findings suggest minor fluctuations during transitional periods, but confirm that HAV infections can occur year-round. Similar results were reported by **Sood et al. (**2024) in India, who observed seasonal peaks without consistent patterns, and **by Sağlam** et al. (2020) in Turkey, who found HAV infections distributed evenly across the year. A review **by Gloriani et al.** (2024) in the WHO Western Pacific Region also concluded that seasonal variations are minor, with transmission driven more strongly by environmental and public health conditions than by season or calendar month.

The present study also evaluated the potential influence of climatic factors, analyzing the relationship between monthly mean temperature, relative humidity, and HAV IgM positivity from November 2024 to November 2025. Results indicated no statistically significant correlations. Temperature showed a very weak negative correlation (r = -0.033), while relative humidity had a weak positive correlation (r = 0.330), neither of which was significant. Multiple linear regression confirmed that temperature and humidity had no significant effect on HAV IgM positivity (Adjusted R^2 = -0.047, F = 0.731, P = 0.506). Despite the absence of significant linear associations, the observed peak in April 2025 suggests that other seasonal or non-climatic factors may influence HAV transmission.

These results are consistent with findings from **Islam et al**. (2025) in Dhaka, Bangladesh, who reported no significant associations between climatic variables and HAV incidence, emphasizing the role of environmental and sanitary conditions, such as water contamination and hygiene practices. Similarly, B**ae**k et al. (2022) in Seoul, Korea, concluded that climatic factors alone do not explain HAV transmission, highlighting the importance of non-climatic determinants. Overall, the present findings support the view that environmental and behavioral factors, including sanitation, hygiene, and vaccination coverage, likely play a more prominent role than climatic variables in shaping HAV epidemiology.

In conclusion, this study demonstrates that while HAV infection affects both genders, adolescents and young adults are disproportionately affected. Transmission occurs year-round, with minor seasonal fluctuations, and is influenced more by environmental and behavioral factors than by climate. These insights provide valuable information for public health strategies in Libya, emphasizing the importance of vaccination, improved

Conclusion

This study provides important insights into the epidemiology of acute hepatitis A virus (HAV) infection in Benghazi, Libya, highlighting the predominant role of age in shaping infection patterns within the urban environmental context. Adolescents and young adults were disproportionately affected, while children under 10 and adults over 50 showed minimal or no positivity. Infections occurred year-round with minor seasonal fluctuations, peaking in April 2025, and no significant associations were found between HAV IgM positivity and local climatic variables such as temperature or relative humidity.

The results indicate that age patterns were the main determinant observed in HAV infection, while climatic factors showed no significant association. The study also emphasizes that monitoring age-specific trends in the urban context is essential to guide public health interventions, including vaccination programs and preventive strategies, providing actionable insights for reducing HAV incidence in urban Libyan populations.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.