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*Original article*

# Hepatitis C Virus Seroprevalence and Associated Demographic Factors in Al-Jabal Al-Akhdar, Eastern Libya: A Cross-Sectional Laboratory Study

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**A B S T R A C T**
Hepatitis C virus (HCV) infection is a global public health challenge, causing chronic liver disease, cirrhosis, and hepatocellular carcinoma. Libya lacks comprehensive, localized epidemiological data, making identification of demographic risk factors critical for preventive strategies. To determine HCV seroprevalence and evaluate associations with age and gender among individuals attending a laboratory in Al Bayda, Libya. This cross-sectional laboratory-based study included 195 participants undergoing routine blood testing at a tertiary healthcare facility in Al Bayda, Libya, between 2023 and 2025. HCV serostatus was determined using a WHO-approved rapid immunochromatographic test. Demographic data (age and gender) were analyzed using descriptive statistics, chi-square or Fisher's exact tests, and Welch's t-test in R software ($p < 0.05$). HCV seroprevalence was 6.7% (n = 13). Among positive cases, 61.5% were male and 38.5% female. The mean age of HCV-positive individuals was 42.1 years versus 35.4 years for HCV-negative participants; the difference was not statistically significant ($t = -1.3674$, $p = 0.194$). HCV prevalence in Al Bayda is moderate. Males accounted for higher proportions of positive cases. Although age differences were not statistically significant, positive cases were older on average. These findings highlight the need for targeted screening and early intervention strategies.

## Introduction

Hepatitis C virus (HCV) infection represents a persistent global health burden, with an estimated 58 million individuals living with chronic infection worldwide. The virus is a leading cause of progressive liver disease, contributing to cirrhosis, hepatocellular carcinoma, and liver-related mortality [13,5]. Despite the availability of direct-acting antivirals (DAAs) capable of achieving sustained virologic response in over 95% of cases, HCV continues to challenge public health due to asymptomatic infections, underdiagnosis, and potential reinfection [1,20].

Globally, the epidemiology of HCV varies substantially across regions. Differences in healthcare infrastructure, blood transfusion practices, injection protocols, and population demographics influence transmission patterns and seroprevalence rates [21,8]. In Libya, available data indicate heterogeneous prevalence, with national estimates ranging from 0.9% to 3.2%, highlighting the need for localized studies to inform public health interventions [15,17]. Regional studies suggest that certain demographic factors, including age and gender, may influence susceptibility, progression, and outcomes of HCV infection [25,26]. Transmission occurs primarily through percutaneous exposure to infected blood. High-risk sources include contaminated medical injections, unsafe blood transfusions, and needle sharing. Vertical transmission and sexual transmission are less frequent but remain documented routes [2,3]. Chronic infection may also present with extrahepatic manifestations, including renal, hematologic, and dermatologic complications, complicating management and increasing morbidity [4,12].

Demographic profiling is essential to identify high-risk populations and implement targeted preventive measures. Previous studies have observed higher prevalence among males, possibly due to occupational exposure, behavioral factors, and immune response differences. Age-related prevalence trends often indicate increased HCV infection among older adults, likely due to cumulative lifetime exposure and historical healthcare practices prior to modern sterilization and blood safety standards [27,25].

Despite these insights, Al Bayda remains understudied, and reliable estimates of HCV seroprevalence and its association with age, and gender are scarce. The present study addresses this knowledge gap by assessing HCV prevalence in a laboratory-based cohort and examining demographic factors to guide local screening and intervention strategies. Additionally, this study evaluates age differences between HCV-


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positive and negative individuals using statistical analyses to provide a more nuanced understanding of infection patterns.

## Methods

### *Study Design and Setting*

This study employed a cross-sectional, laboratory-based design conducted at a tertiary healthcare facility in Al Bayda, Libya, between 2023 and 2025. The laboratory provides diagnostic and routine screening services to a diverse urban and peri-urban population. Ethical approval was obtained from the institutional review board, and written informed consent was secured from all participants or guardians for minors. The study followed the Declaration of Helsinki principles.

### *Study Population and Sampling*

The study population consisted of 195 participants undergoing routine blood testing for general health assessments, pre-employment screening, or elective health checks. Inclusion criteria were age ≥6 years and voluntary participation. Individuals with known chronic liver diseases unrelated to HCV or incomplete demographic data were excluded. Participants were recruited consecutively, and sampling was based on laboratory attendance during the study period, ensuring a representative cross-section of the population served by the facility.

### *Data Collection*

Demographic variables recorded included age in years and gender (male or female). Data were entered into a secure, password-protected database using anonymized codes. Quality checks were performed to ensure accuracy, completeness, and consistency of the dataset.

### *Laboratory Procedures*

Blood samples were collected by trained phlebotomists using strict aseptic techniques. Approximately 5 mL of venous blood was drawn from each participant using sterile Vacutainer systems. Samples were labeled with anonymized codes and transported to the laboratory at 4°C for immediate processing. Serum was separated by centrifugation at 3000 rpm for 10 minutes and stored at 2–8°C until testing, which was performed within 24 hours of collection.

HCV serostatus was determined using a WHO-approved rapid immunochromatographic test (ICT**)** for anti-HCV antibodies. This test provides qualitative detection of HCV antibodies within 15–20 minutes and is widely used for epidemiological screening in resource-limited settings. Each sample was tested once according to the manufacturer's instructions. Test strips were visually inspected for the presence of control and test lines to determine positivity. A visible line in both the control and test regions was considered positive, whereas the presence of a control line alone was recorded as negative.

Quality assurance measures included testing a subset of samples alongside known positive and negative controls to monitor test accuracy and reliability. Laboratory personnel followed standard operating procedures (SOPs) for sample handling and rapid testing, including consistent timing, correct sample volume application, and proper storage conditions. The simplicity and speed of the rapid test facilitated high-throughput screening, making it suitable for the cross-sectional study design while minimizing sample handling errors.

### *Statistical Analysis*

All statistical analyses were conducted using R statistical software (version 4.3.1) with multiple packages, including tidyverse for data manipulation, janitor for cleaning datasets, ggpubr for visualization, and RColorBrewer for color palettes in plots.

### *Descriptive Statistics*

Continuous variables such as age were summarized using mean, median, mode, standard deviation, minimum, and maximum values to describe the central tendency and dispersion. Categorical variables (HCV status, gender) were reported as frequencies and percentages, providing a clear overview of demographic distributions.

### *Bivariate Analysis*

Associations between HCV serostatus and categorical demographic factor gender were assessed using chi-square tests for independence. When expected cell counts were less than five, Fisher's exact test was applied to ensure accurate p-values. Effect sizes for significant associations were reported using Cramer's V to provide a measure of practical significance.

### *Age Analysis*


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Age differences between HCV-positive and HCV-negative participants were examined using Welch's two-sample t-test, which accounts for unequal variances between groups. This method was chosen because the HCV-positive group had a small sample size (n = 13), assuming of equal variance is less reliable. The test provided t-values, degrees of freedom, p-values, and 95% confidence intervals for mean differences.

***Multivariable Considerations***

Although this study primarily focused on univariate associations, exploratory stratified analyses were conducted to evaluate potential confounding effects of gender on age-related trends in HCV positivity. Boxplots and histograms were used to visualize distributions, check for outliers, and assess normality assumptions.

***Data Visualization***

Grouped bar plots were generated to display HCV seropositivity by gender, with counts and percentages displayed above each bar. Age distribution among HCV-positive and negative participants was visualized using boxplots, highlighting medians, interquartile ranges, and extreme values. These plots facilitated the interpretation of demographic patterns and aided in communicating findings clearly in a visual format. All statistical tests were two-tailed, and significance was set at $p < 0.05$. Results were reported with precise effect estimates and confidence intervals to allow transparent interpretation and comparison with prior studies.

## Results

A total of 195 participants were included in this study, of which the overwhelming majority were from Al-Bayda (99.5%), with only a single participant from Massa (0.5%). This geographic distribution reflects the clinic-based recruitment strategy and the primary service area of the laboratory. Gender distribution showed a predominance of males (61.5%, n = 120) compared to females (38.5%, n = 75), reflecting the gender composition of individuals presenting for routine laboratory testing in the study period.

The overall HCV seroprevalence in the cohort was 6.7% (n = 13). Most participants tested negative (93.3%, n = 182), demonstrating a relatively low prevalence in this population. The seropositive group was composed of 8 males (61.5%) and 5 females (38.5%), reflecting a slightly higher burden in males. Despite this numerical difference, statistical analysis using Fisher's exact test indicated no significant association between gender and HCV serostatus ($p > 0.99$), suggesting that gender alone does not confer a higher risk in this study's population. These findings align with prior regional studies indicating minimal gender disparity in HCV prevalence among Libyan adults [15,8].

***Age Distribution***

The age of participants ranged from 6 to 89 years, with a mean of 35.84 years, a median of 33 years, and a standard deviation of 15.15 years. Mode values were 26 and 30 years, indicating that young adults represented the largest single age groups in this cohort. Figure 1 illustrates the age distribution across all participants. The histogram shows a clear concentration of participants in the 20–40-year age range, which corresponds to the economically active and socially mobile population. Fewer participants were younger than 15 or older than 70, reflecting typical clinic attendance patterns and the demographic composition of Al-Bayda. The age distribution has important implications for public health planning, as individuals in this range may contribute disproportionately to transmission networks due to occupational and social interactions.

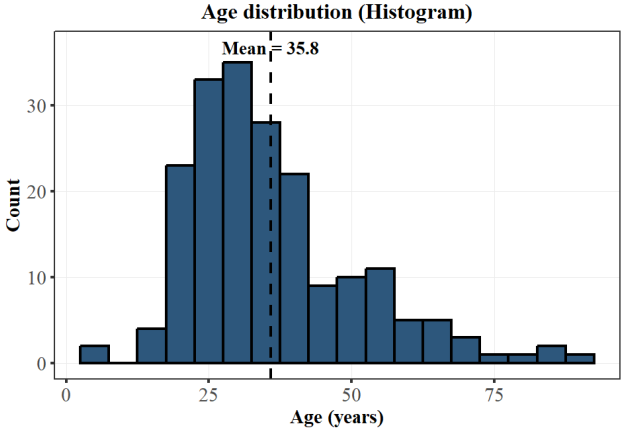



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***Figure 1. Age distribution of all participants tested for HCV. The figure illustrates a clear concentration in the 20–40-year range, while younger children and older adults are less represented***

### *HCV Serostatus by Gender*

The grouped bar graph for HCV status by gender is presented in (Figure 2). Among males, 8 of 120 (6.7%) tested positive, while 5 of 75 females (6.7%) were positive. The percentages show almost equal prevalence across genders, supporting the statistical conclusion that gender differences in HCV prevalence in this cohort are minimal. The visualization also illustrates the distribution of negative cases, with 112 males and 70 females testing negative, confirming that the majority of both genders were unaffected.

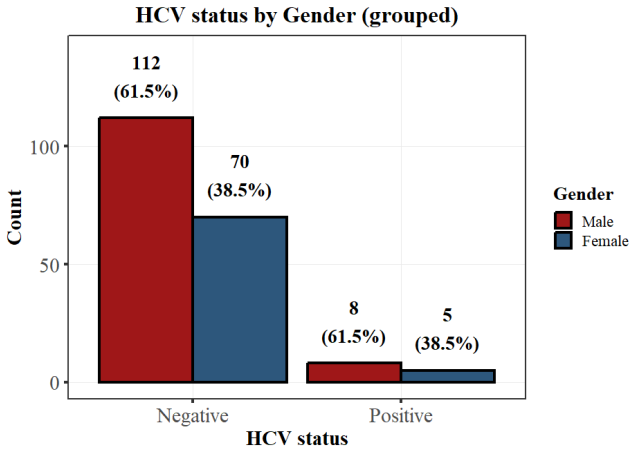


***Figure 2. Grouped bar graph of HCV serostatus by gender. Both males and females showed comparable prevalence, indicating minimal influence of gender on infection rates.***

This finding aligns with prior studies in Libya and other regions, where gender has not consistently emerged as a strong independent predictor of HCV seropositivity [20,15].

### *HCV Serostatus and Age*

Analysis of the relationship between age and HCV serostatus was performed using a Welch two-sample t-test due to unequal sample sizes and variances between groups. HCV-positive participants had a higher mean age (42.08 years) compared to HCV-negative participants (35.39 years), though this difference did not reach statistical significance (t = -1.367, df = 13.33, p = 0.194). Figure 3 presents a box plot of age by HCV serostatus, highlighting that the HCV-positive group not only had a higher median age but also a narrower interquartile range compared to HCV-negative participants. This observation suggests that older age groups may be at slightly higher risk of HCV infection, consistent with the natural history of HCV acquisition and the delayed diagnosis often seen in asymptomatic infections [6,13].

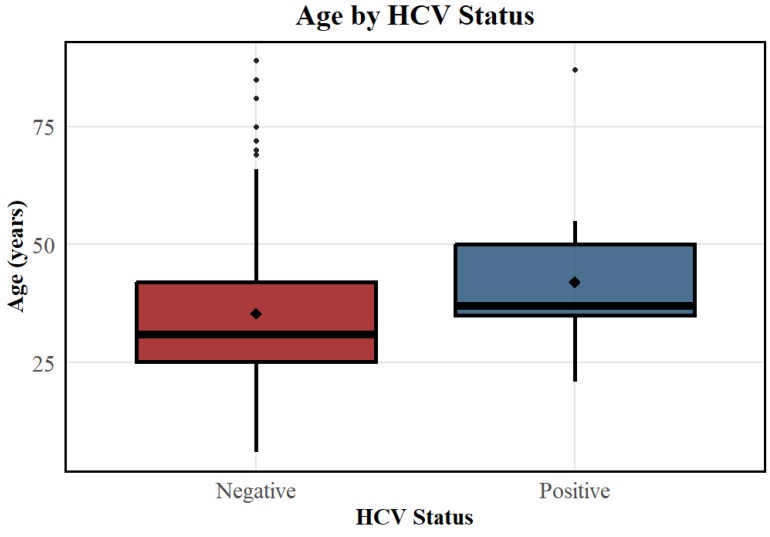



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***Figure 3: Box plot of age by HCV serostatus, showing median, interquartile range, and outliers. HCV-positive participants were slightly older and more clustered, while negatives displayed greater age variability, highlighting trends in age-related risk.***

***Descriptive Patterns in HCV-Positive Individuals***

Among the 13 HCV-positive participants, the age range was 19 to 65 years, with a mean of 42.08 years. Males accounted for 61.5%, indicating a slight male predominance in positivity rates. This aligns with trends observed in multiple epidemiological studies, where males often show higher HCV prevalence due to occupational exposures, injection drug use, or other high-risk behaviors [16,14]. The lack of significant gender association in statistical testing highlights the need for more granular behavioral and exposure data in future studies.

The age analysis suggests a possible age-related trend, with participants in their 30s and 40s representing the largest share of HCV-positive cases. Although the t-test did not yield statistical significance, the visual pattern in the box plot (Figure 3) and the histogram (Figure 1) indicates that middle-aged adults may constitute a key target population for screening initiatives. Early detection in this age group could prevent progression to chronic liver disease and reduce the potential for onward transmission. Overall, the results indicate that age and geographic location may be relevant factors in HCV seroprevalence in Al-Bayda, Libya, while gender does not appear to significantly affect serostatus. These findings provide a foundation for targeted interventions and public health strategies aimed at reducing HCV burden in the region

## Discussion

This study aimed to investigate the seroprevalence of Hepatitis C Virus (HCV) and its associations with demographic factors, including age, and gender, among a cohort of participants attending a clinical laboratory in Al-Bayda, Libya. The overall HCV seroprevalence observed in our cohort was 6.7%, which is consistent with previous reports from Libya and comparable North African regions. For example, Daw et al. reported prevalence rates of 5–7% in localized Libyan populations, highlighting a persistent, low-to-moderate burden of HCV in the region [8]. Similarly, Ismail et al. emphasized the ongoing need for improved HCV screening and linkage to care in eastern Libya, noting that many cases remain undiagnosed [15].

In our study, males accounted for 61.5% of HCV-positive cases, while females represented 38.5%, yielding an almost equal prevalence rate when considering overall gender proportions. Statistical analysis demonstrated no significant association between gender and HCV serostatus ($p > 0.99$). This finding aligns with global observations in adult populations where gender, while sometimes associated with risk behaviors such as occupational exposure or injection drug use, does not consistently predict infection status [20,27]. Our results suggest that in Al-Bayda, both males and females are equally at risk of HCV infection, reinforcing the importance of inclusive public health interventions targeting all genders.

The mean age of HCV-positive participants (42.08 years) was higher than that of HCV-negative participants (35.39 years). Although this difference did not reach statistical significance ($p = 0.194$), the box plot analysis revealed a pattern suggesting higher vulnerability among middle-aged adults. This observation is consistent with findings from other regions, where HCV infection tends to accumulate with age due to cumulative exposure to risk factors and delayed clinical diagnosis [6,13]. Yeh et al. further emphasized that chronic HCV infection can exacerbate age-related health risks, highlighting the importance of age-stratified screening programs [25]. The age distribution in our study shows that young adults (20–40 years) constituted the majority of participants tested, yet the HCV-positive cases were relatively older, suggesting that older adults may serve as a reservoir of undiagnosed infections. This emphasizes the need for age-targeted interventions, including education, screening, and timely antiviral therapy, especially as direct-acting antivirals (DAAs) now allow for high rates of cure and reduced disease progression [1,5].

Our findings underscore the critical role of laboratory-based screening for HCV in identifying undiagnosed cases, especially among middle-aged adults who may be asymptomatic. The use of rapid serological testing, although limited by the absence of confirmatory RNA testing in our study, allowed for efficient case identification and could be integrated into broader public health initiatives [11,2]. While RNA confirmation is recommended to define active infection and guide treatment, our approach provides preliminary epidemiological data necessary for planning interventions in resource-limited settings. The observed prevalence also aligns with regional and international data, indicating that Libya's HCV burden, while moderate, warrants sustained prevention efforts. Globally, HCV prevalence varies widely, from less than 1% in low-prevalence countries to over 10% in high-endemic regions [21,16]. Comparison with Asian populations further emphasizes the heterogeneity of HCV prevalence and the influence of local transmission dynamics [22,23,24].

The slightly higher mean age among HCV-positive individuals highlights the need for age-focused screening and education programs. Treatment strategies leveraging DAAs have transformed HCV management


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globally, offering >95% cure rates and reducing liver-related complications [1,5]. Implementing such therapies in Libya could significantly reduce the HCV burden if linked to effective screening and diagnosis. Our study also identifies potential gaps in data collection, including behavioral risk factors, past medical exposures, and comorbidities, which were not captured in the current dataset. Future studies should aim to integrate these variables, allowing for more robust risk factor modeling and improved targeting of interventions [7,4].

Recent research highlights additional considerations for HCV epidemiology. For instance, Oltmanns et al. demonstrated that successful HCV cure may reverse aspects of biological aging, suggesting that early detection and treatment carry benefits beyond viral eradication [26]. Chen et al. and Po-Hung et al. highlighted age- and pregnancy-related considerations in HCV, emphasizing that demographic factors intersect with clinical outcomes [28]. Similarly, Angela Chiunhsien Wang et al. showed minimal sex differences in HCV risk when controlling for confounders, which mirrors our findings of no significant gender association in Al-Bayda [27]. Taken together, these studies underscore the multifactorial nature of HCV epidemiology, combining demographic, behavioral, and clinical factors. Our findings contribute to the growing body of evidence that targeted, locally informed strategies are essential for effective HCV control in Libya

## Conclusion

This cross-sectional laboratory study in Al-Bayda, Libya, demonstrates a 6.7% seroprevalence of HCV among participants. Although no statistically significant associations were observed between HCV status and gender or age, the data suggest that middle-aged adults may have higher exposure and undiagnosed infections, highlighting the importance of age-targeted screening programs. demonstrates a 6.7% seroprevalence of HCV among participants. Although no statistically significant associations were observed between HCV status and gender or age, the data suggest that middle-aged adults may have higher exposure and undiagnosed infections, highlighting the importance of age-targeted screening programs. The exclusive use of rapid serological testing allowed efficient preliminary detection, but future studies should include confirmatory RNA testing to establish active infection and guide treatment. The findings align with regional epidemiology and underscore the ongoing need for integrated public health strategies, including comprehensive screening, education, and access to direct-acting antivirals (DAAs), which have been shown to offer high cure rates and long-term clinical benefits. Overall, the study provides essential baseline data on HCV distribution in Al-Bayda, supporting the implementation of targeted interventions to reduce transmission, improve diagnosis, and enhance treatment uptake. These results can inform policymakers and healthcare providers aiming to achieve HCV elimination goals in Libya and similar low-to-moderate prevalence settings.

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