

Seroprevalence of Hepatitis C Virus Infection and Demographic Correlates Among Immigrants in Al-Jabal Al-Akhdar, Eastern Libya: A Cross-Sectional Laboratory-Based Study

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ABSTRACT

Background: Migration through North Africa has increased in recent years, exposing immigrants to unstable living conditions, limited healthcare, and inconsistent infectious disease screening. These factors increase the risk of hepatitis C virus (HCV) infection. This study assessed HCV seroprevalence and demographic correlates among immigrants in eastern Libya. **Methods:** A cross-sectional study was conducted from January to October 2025. Serum samples from 402 immigrants attending laboratories affiliated with the Illegal Immigration Control Agency in Al Bayda, Shahat, and Massa were tested for anti-HCV antibodies using rapid immunochromatographic assays. Demographic data, including age, gender, nationality, and location, were collected. Descriptive statistics, chi-square tests, and Welch two-sample t-tests were performed in R. **Results:** Overall, 302 participants (75.1%) were HCV seropositive. The majority were male (92.3%), with a mean age of 35.44 ± 13.98 years. Egyptians comprised 79.9% of participants. HCV positivity was significantly associated with male gender ($\chi^2 = 35.56$, $p < 0.001$), Egyptian nationality ($\chi^2 = 96.83$, $p < 0.001$), and older age (mean 40.18 vs 33.24 years; $t = -2.702$, $p = 0.008$). **Conclusion:** HCV seroprevalence among immigrants in eastern Libya is alarmingly high. Male gender, older age, and Egyptian nationality are key risk factors. Targeted screening, confirmatory testing, and access to treatment are urgently required.

Keywords: Hepatitis C Virus, HCV Seroprevalence, Immigrants, Libya, Cross-Sectional Study, Epidemiology

INTRODUCTION

Hepatitis C virus (HCV) remains a critical global health challenge, responsible for chronic liver disease, cirrhosis, and hepatocellular carcinoma, affecting an estimated 58 million individuals worldwide and causing more than 290,000 deaths annually [1, 2]. Transmission primarily occurs through exposure to infected blood, including unsafe medical procedures, transfusions, or contaminated instruments, with secondary routes involving perinatal or sexual contact. While the advent of direct-acting antivirals (DAAs) has revolutionized HCV treatment and improved clinical outcomes, access to timely diagnosis and treatment remains limited in many low- and middle-income countries, particularly among vulnerable populations such as migrants and refugees [3, 4]. HCV is an enveloped, positive-sense single-stranded RNA virus in the Flaviviridae family, with a genome that encodes a polyprotein cleaved into structural proteins (core, E1, E2) and non-structural proteins (NS2–NS5B), all essential for viral replication and pathogenesis [5, 6].

The virus establishes persistent infection by evading host innate immune responses, particularly interferon-mediated antiviral pathways, resulting in chronic hepatic inflammation, progressive fibrosis, and, in some cases, hepatocellular carcinoma [7, 8]. Age plays a critical role in the natural history of HCV, with older adults demonstrating higher rates of fibrosis progression and complications, while younger adults are more likely to be recent transmitters in high-risk settings, such as migrant camps or detention centers.

Furthermore, age influences the epidemiology of HCV among migrants, as young adults often constitute the majority of the mobile workforce, while older individuals may carry long-standing infections acquired in their home countries. Migrants constitute one of the most epidemiologically vulnerable groups for HCV infection. Many originate from regions with high endemicity, including sub-Saharan Africa, the Middle East, and South Asia, where access to safe medical care, vaccination, and HCV screening is limited [9, 10]. During migration, individuals are frequently exposed to conditions that facilitate viral transmission, including overcrowding, inadequate sanitation, unsafe injection practices, and limited healthcare access. Demographically, migrant populations tend to be dominated by young and middle-aged adults, who often represent the economically active segment of the community, yet may also bear high infection risk due to occupational exposures, such as agricultural or construction work, and limited preventive care during transit. International studies consistently show higher HCV prevalence among immigrants than host populations, reflecting both pre-existing infections in high-endemicity regions and risk exposures during migration [11, 12].

In Libya, general population studies report HCV prevalence ranging from 3% to 7% [13, 14]. However, there is limited information regarding infection rates among migrants transiting through or temporarily residing in the country, despite Libya's critical role as a transit hub between Africa and Europe. Migrant populations in Libya

are highly diverse, comprising individuals from Egypt, Chad, Sudan, and other African and Middle Eastern countries, with age distributions skewed toward young adults. Understanding HCV prevalence within this demographic is essential, as it informs targeted screening, preventive measures, and linkage to care, particularly for those in high-risk age groups who may serve as both current and future reservoirs of infection. Age-specific data also help identify trends in transmission dynamics, distinguishing between newly acquired infections and chronic infections carried from home countries, which is crucial for public health planning. The present study aimed to estimate the seroprevalence of HCV among immigrants screened in Al Bayda, Shahat, and Massa, eastern Libya, and to examine demographic correlates including age, gender, nationality, and location. By integrating age as a key factor, this study provides insight into the distribution of HCV across different life stages and highlights vulnerable subgroups within the migrant population. These findings are intended to guide evidence-based public health interventions, inform cross-border health policies, and contribute to global efforts to reduce the burden of HCV in high-risk, mobile populations.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional laboratory-based study was conducted between January and October 2025 across three cities in eastern Libya—Al Bayda, Shahat, and Massa. The study utilized serum samples collected from immigrants processed through medical laboratories affiliated with the Illegal Immigration Control Agency, Eastern Region. These laboratories routinely perform infectious-disease screening for individuals upon arrival or prior to documentation processing. The selected cities represent the main operational coverage areas of the agency in eastern Libya and provide access to a diverse migrant population.

Study Population

The study included 402 non-Libyan individuals residing temporarily or transiting through the study region. Participants were predominantly male ($n = 371$, 92.3%) with a smaller proportion of females ($n = 31$, 7.7%). The age of participants ranged from 9 to 77 years, with a mean age of 35.4 ± 13.98 years and a median of 34 years. Analysis of age distribution showed that most participants were between 25 and 45 years old, representing the economically active segment of the migrant population. Nationality distribution reflected the heterogeneous nature of the cohort, with Egyptians comprising 79.9% of participants, followed by Sudanese (6.0%), Chadians (5.2%), Bangladeshis (3.0%), Palestinians (2.5%), and smaller numbers from Pakistan, Syria, Tunisia, Mali, and Nigeria. All personal identifiers were excluded to maintain confidentiality, and demographic variables including age, gender, nationality, and location were recorded for analysis.

Laboratory Testing

All serum samples were assessed for the presence of anti-HCV antibodies using a commercial rapid immunochromatographic assay. The rapid test employed is based on lateral flow technology, in which antigens specific to HCV are immobilized on a nitrocellulose membrane. When a serum sample is applied, any antibodies present bind to labeled antigen conjugates, producing a visible color change at the test line, indicating seropositivity. This method allows detection

of both IgG and IgM antibodies, reflecting prior or ongoing exposure to HCV. Samples were collected following standard phlebotomy procedures, using sterile vacutainer tubes and stored at $2-8^{\circ}\text{C}$ until processing, with testing completed within 24 hours to preserve sample integrity. All reagents were maintained under manufacturer-recommended storage conditions, and control samples—both positive and negative—were included in each batch to ensure assay validity. Tests were performed by trained laboratory technicians who strictly adhered to standard operating procedures, including careful timing, sample volume measurement, and interpretation of results to reduce operator-dependent variability. The rapid immunochromatographic assay was selected for its operational advantages in a high-throughput migrant screening setting. Unlike enzyme-linked immunosorbent assays (ELISA), this method does not require extensive laboratory infrastructure, specialized equipment, or prolonged incubation periods, making it highly suitable for field or decentralized laboratory conditions.

Additionally, the rapid assay provides results within 15–20 minutes, allowing immediate identification of HCV-positive individuals for preliminary public health follow-up and prioritization for confirmatory testing. Although rapid tests may be less sensitive than nucleic acid amplification methods, previous studies have demonstrated their reliability and cost-effectiveness in large-scale population screening programs, particularly in resource-limited contexts where confirmatory PCR may not be routinely available [15, 16]. Quality assurance procedures included duplicate testing of 5% of randomly selected samples, regular calibration of pipettes, and adherence to laboratory biosafety protocols. Any indeterminate results were repeated with fresh reagents, and all positive cases were documented and logged for subsequent statistical analysis. The laboratory workflow was designed to minimize contamination risk, ensure reproducibility, and maintain high standards of accuracy in antibody detection across the diverse migrant population.

Statistical Analysis

All data were entered and managed using R software version 4.3.2 [17], ensuring accuracy and consistency through systematic cleaning and validation procedures. The dataset included categorical variables such as HCV serostatus, gender, nationality, and sampling location, as well as continuous variables including age. Initial data inspection involved identification of missing values, outliers, and inconsistencies, with appropriate coding applied to categorical factors for downstream analyses. Descriptive statistics were generated to summarize demographic and clinical characteristics of the study population. Frequencies and percentages were calculated for categorical variables, while continuous variables, such as age, were described using mean, median, mode, standard deviation, and range. Graphical representations—including histograms, bar charts, and pie charts—were employed to visualize the distribution of age, gender, nationality, and seroprevalence patterns. Associations between HCV serostatus and categorical demographic variables were evaluated using Pearson's chi-square test. In cases of small expected counts, Monte Carlo simulation was applied to generate robust p-values. For continuous variables, the normality of distributions was assessed using the Shapiro-Wilk test. Differences in age between HCV-positive and HCV-negative groups were analyzed using Welch's two-sample t-test, accounting for unequal variances. Confidence intervals at 95% were reported for estimated

means and differences between groups. All statistical tests were two-tailed, with a significance level set at $p < 0.05$. Data visualization was conducted using the ggplot2 and RColorBrewer packages, providing clear graphical summaries of categorical and continuous variable distributions. Tables summarizing demographic characteristics, HCV seroprevalence, and stratified analyses were generated using the janitor package to ensure standardized formatting. This methodological framework allowed systematic and reproducible analysis of seroprevalence and its demographic correlates, providing a robust foundation for subsequent interpretation of results.

Result

A total of 402 serum samples were collected from immigrants screened for HCV in Al Bayda, Shahat, and Massa between January and October 2025. The study population comprised migrants of various

nationalities, ages, and genders. This section presents the demographic characteristics, HCV seroprevalence, and associations with age, gender, and nationality.

Demographic Characteristics

The study cohort was predominantly male, with 371 males (92.3%) and 31 females (7.7%) (Figure 2). This disproportion reflects the demographic structure of migrant populations in eastern Libya, as men represent the majority of labor migrants.

Participants ranged in age from 9 to 77 years, with a mean age of 35.44 years ($SD = 13.98$) and a median age of 34 years. The distribution of age was right-skewed, with the majority falling within 25–45 years (Figure 1). These findings indicate that the screening program primarily targeted the economically active segment of the migrant population.

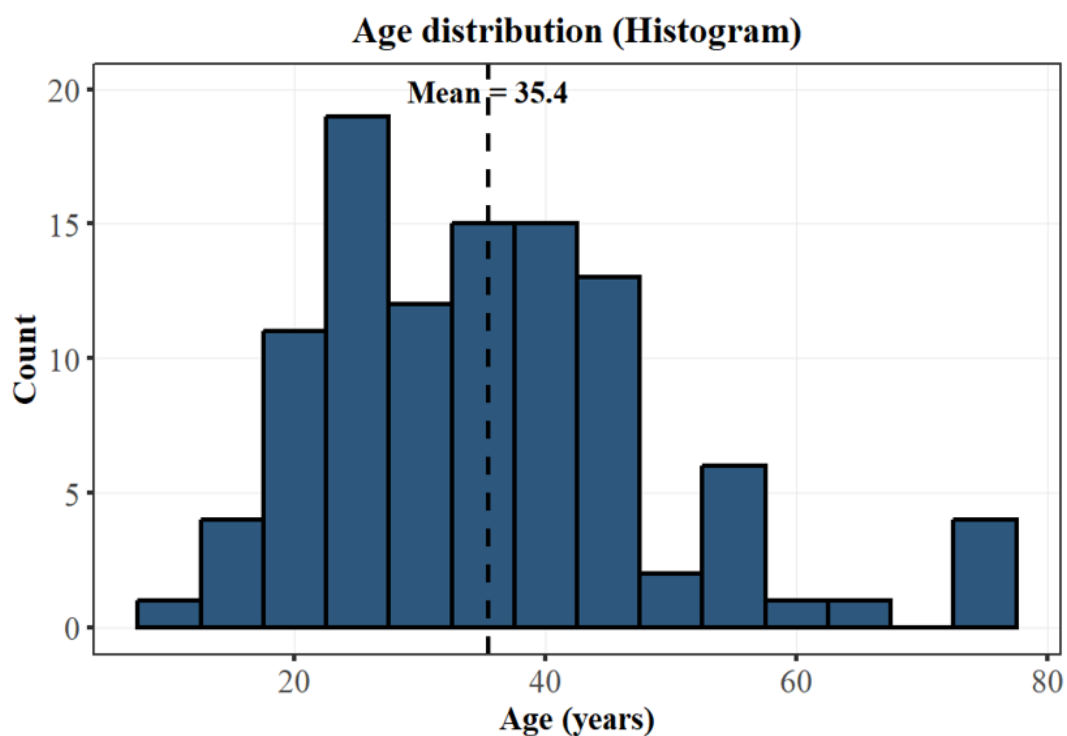


FIGURE 1: Histogram illustrates age distribution of immigrants screened for HCV ($n = 402$) in Al Bayda, Shahat, and Massa, eastern Libya (January–October 2025). Most participants were aged 25–45 years, with a mean age of 35.44 years ($SD = 13.98$). Screening primarily targeted the economically active segment of the migrant population.

Geographically, most participants were screened in Al Bayda ($n = 236$, 58.7%), followed by Shahat ($n = 147$, 36.6%) and Massa ($n = 19$, 4.7%). The smaller sample from Massa may reflect either fewer migrants residing there or logistical limitations in sample collection. The age distribution across locations showed that Al Bayda had a slightly higher proportion of older migrants (35–50 years), whereas Shahat's cohort was predominantly younger (25–40 years).

HCV Seroprevalence

Of the 402 participants, 302 tested positives for HCV antibodies, yielding an overall seroprevalence of 75.1%, while 100 participants (24.9%) were negative. The high prevalence indicates a significant burden of HCV among migrants in eastern Libya. Notably, the distribution of positive cases showed clustering in the 25–45-year age range, which aligns with the working-age demographic of migrants

(Figure 1 and Figure 4). This clustering may reflect increased exposure during adulthood, as younger participants (<20 years) exhibited very low positivity rates.

Gender and HCV Infection

HCV infection was strongly associated with gender. Among males, 293 (97.0%) were HCV-positive, whereas only 9 females (3.0%) tested positive, showing a highly significant difference ($\chi^2 = 35.56$, $p < 0.001$) (Figure 2). Male predominance in seropositivity was observed across all age groups, with the highest rates among those aged 30–45 years. Female participants were concentrated in the younger (<30 years) and older (>50 years) age brackets, and positivity among them remained minimal. This trend underscores the gendered nature of exposure risk, potentially influenced by occupation, social mobility, and migration patterns. Further stratification by location revealed that

the male-to-female ratio was highest in Al Bayda (13:1), followed by Shahat (10:1) and Massa (6:1). Despite the small number of female

participants, 100% of HCV-positive females were from Al Bayda and Shahat, with none detected in Massa.

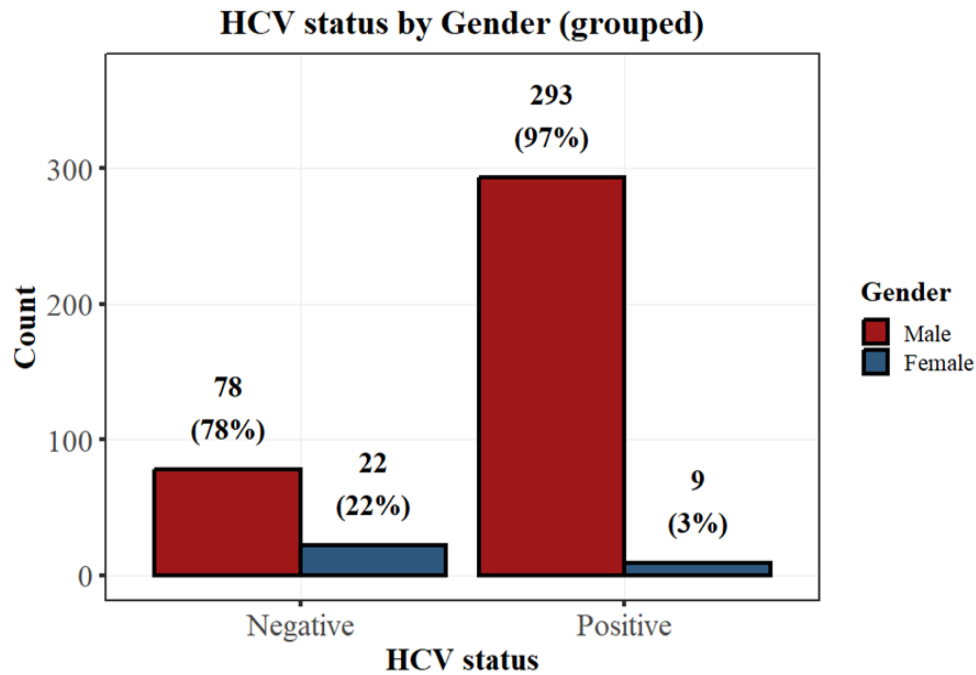


Figure 2: Grouped Bar Graph Illustrates Relationship between Gender and HCV Infection Status Among Immigrants (n = 402). HCV Seropositivity was Significantly Higher Among Males ($\chi^2 = 35.56$, $p < 0.001$), who Accounted for 97% of Positive Cases. Female Positivity Remained Minimal Across all Age Groups.

Nationality and HCV Infection

Nationality was strongly associated with HCV infection among the screened immigrants, demonstrating significant variation across different groups ($\chi^2 = 96.83$, $p < 0.001$) (Figure 3). Egyptian migrants constituted the majority of participants (n = 228, 56.7%) and also represented the highest proportion of HCV-positive cases. Among the

HCV-positive individuals, 88.4% were Egyptians, indicating a disproportionately high infection rate relative to their representation in the cohort. This finding aligns with epidemiological data from Egypt, where historical outbreaks of HCV through unsafe medical procedures have led to one of the highest prevalence rates globally [18, 19].

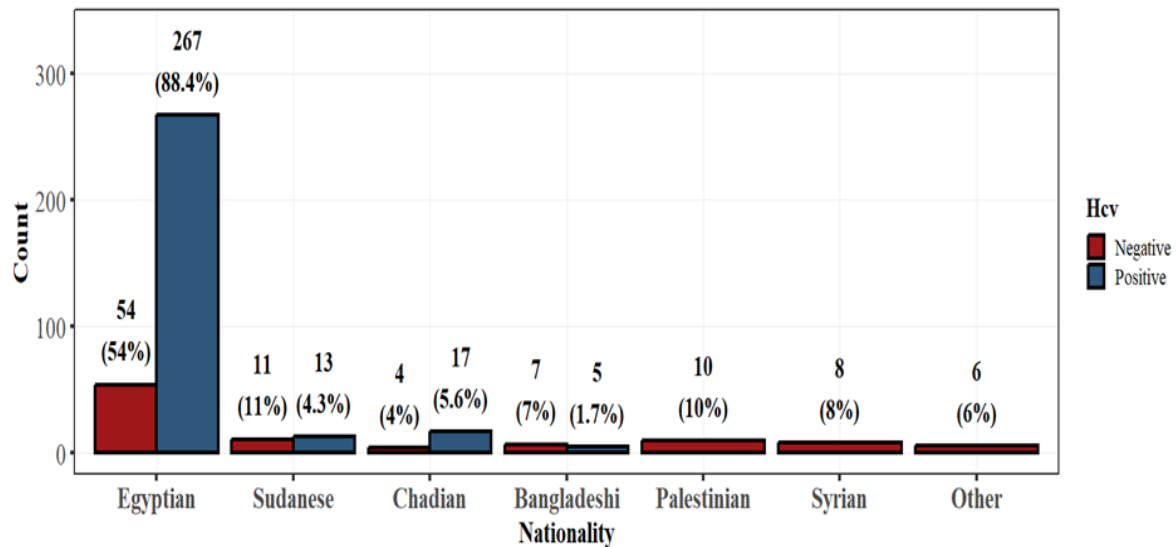


Figure 3: HCV Infection Status by Nationality Among Screened Immigrants (N = 402). Egyptian Migrants Showed the Highest Positivity (88.4%), Followed by Chadian (5.6%) and Sudanese (4.3%) Participants ($\chi^2 = 96.83$, $P < 0.001$). Variations Suggest Differing Exposure Risks Linked to Country of Origin

Other nationalities included Chadian (n = 90, 22.4%), Sudanese (n = 62, 15.4%), and smaller groups from other African countries (n = 22, 5.5%). The prevalence among Chadian and Sudanese migrants was 5.6% and 4.3% of total HCV-positive cases, respectively. Although these proportions are smaller than among Egyptians, they highlight

that HCV infection is not restricted to a single nationality, suggesting that both country-of-origin prevalence and local risk factors during migration may influence infection risk. The grouped bar chart (Figure 3) illustrates that Egyptian migrants consistently had the highest infection rates across all age and gender subgroups, while Chadian

and Sudanese participants showed moderate variability. This variation may reflect differences in exposure to risk factors, such as healthcare practices, occupational hazards, and community-level transmission patterns in the countries of origin. For example, limited access to safe medical injections, traditional scarification practices, or blood transfusions in some regions could explain the observed disparities. Interestingly, the distribution of HCV-positive cases by nationality also interacted with gender. Most HCV-positive Egyptians were male (96%), reflecting the overall male predominance in the cohort (Figure 2). This suggests that occupational or behavioral factors associated with male-dominated migration routes, such as construction work, farming, or crowded living conditions, could further increase the risk of HCV transmission among Egyptian migrants. Among Sudanese and Chadian nationals, the number of female participants was slightly higher relative to other groups; however, the infection rates among females remained low, reinforcing the strong gender-specific pattern observed across all nationalities. The significant association between nationality and HCV infection underscores the importance of tailoring screening and intervention programs to specific migrant groups. For

instance, prioritizing Egyptian migrants for early HCV screening and educational outreach could maximize the efficiency of public health interventions in eastern Libya. Furthermore, the results suggest that national policies and health programs in migrants' countries of origin should also be considered, as pre-migration exposure plays a crucial role in shaping infection risk. Overall, nationality emerged as a key determinant of HCV risk, with Egyptian migrants being the most affected group, followed by Chadian and Sudanese participants. The interaction between nationality, gender, and age highlights the complex epidemiology of HCV among migrants and emphasizes the need for multifaceted prevention strategies that consider both demographic and socio-cultural factors.

Age and HCV Infection

Age was significantly associated with HCV seropositivity. HCV-positive individuals had a mean age of 40.18 years, while negative participants had a mean age of 33.24 years. The Welch Two Sample t-test confirmed a significant difference between groups ($t = -2.7021$, $df = 83.388$, $p = 0.0083$) (Figure 4).

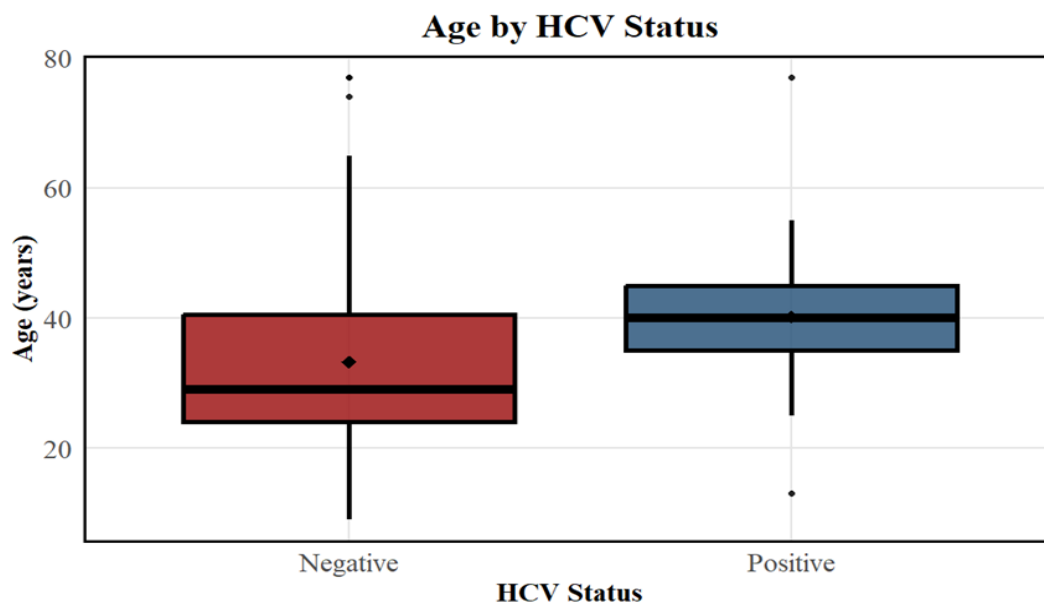


Figure 4: Boxplot of HCV Infection Status by Age ($n = 402$). HCV-Positive Individuals had a Higher Mean Age (40.18 years) than Negatives (33.24 years) ($t = -2.7021$, $df = 83.388$, $p = 0.0083$). Infection Peaked Among 30–45-Year-Old Migrants, Indicating Age-Related Cumulative Exposure.

The age distribution of HCV-positive participants showed a peak in the 30–45-year range, with lower prevalence in younger (<20 years) and older (>60 years) individuals. This pattern reflects increased cumulative exposure with age, consistent with global epidemiological trends in migrant populations. Boxplot analysis (Figure 4) demonstrates that older male migrants had higher antibody titers and a broader interquartile range, suggesting more variable exposure histories. Further stratification by nationality and age revealed that Egyptian males aged 35–45 years had the highest HCV positivity, while Sudanese and Chadian participants showed slightly lower age-specific prevalence. The data highlight the need to consider both age and nationality when designing HCV screening programs for migrant populations.

Summary of Key Patterns

In this study of 402 immigrants screened for HCV in Al Bayda, Shahat, and Massa between January and October 2025, a high overall seroprevalence of 75.1% was observed, highlighting a substantial

burden of HCV among migrants in eastern Libya. The cohort was predominantly male (92.3%), reflecting the demographic structure of labor migration, and participants were primarily within the working-age range of 25–45 years (mean 35.44 years, $SD = 13.98$) (Figure 1). HCV seropositivity was strongly associated with gender, with 97% of positive cases occurring in males ($\chi^2 = 35.56$, $p < 0.001$) (Figure 2), indicating that male migrants are disproportionately affected, likely due to occupational and social exposure factors. Nationality emerged as a major determinant of infection risk. Egyptian migrants, who constituted 56.7% of the cohort, accounted for 88.4% of HCV-positive cases, reflecting a disproportionately high prevalence consistent with epidemiological trends in their country of origin (Figure 3). Chadian and Sudanese migrants represented smaller proportions of positive cases (5.6% and 4.3%, respectively), yet still demonstrated measurable infection rates, suggesting that both pre-migration exposure and migration-related factors contribute to HCV transmission. Gender-specific patterns were maintained across nationalities, with male predominance evident in all groups. Age was also significantly

associated with infection status. HCV-positive individuals had a higher mean age (40.18 years) compared with HCV-negative participants (33.24 years), and infection peaked among those aged 30–45 years ($t = -2.7021$, $df = 83.388$, $p = 0.0083$) (Figure 4). Stratified analyses indicated that Egyptian males aged 35–45 years had the highest HCV prevalence, whereas Chadian and Sudanese migrants showed slightly lower age-specific rates. These findings collectively underscore that HCV risk among migrants is influenced by the interplay of gender, nationality, and age. Overall, the results highlight the need for targeted screening and intervention strategies that prioritize high-risk groups, particularly male Egyptian migrants in the working-age bracket. Tailoring preventive measures to demographic and socio-cultural factors can enhance the effectiveness of public health programs and reduce the burden of HCV in migrant populations in eastern Libya.

Discussion

This study reveals an alarmingly high seroprevalence (75.1%) of hepatitis C virus (HCV) infection among a cohort of 402 immigrants screened in Al Bayda, Shahat, and Massa during 2025. These findings are substantially higher than the background prevalence reported in the general Libyan population, highlighting the disproportionate burden of HCV among migrant populations. The demographic pattern observed—predominantly male migrants of working age—reflects known migration trends in North Africa. The predominance of males among HCV-positive cases (97%) may be associated with occupational and social risk factors, including labor-intensive jobs, crowded living conditions, and increased exposure to unsafe medical practices. This aligns with the understanding that male-dominated migration cohorts are often at higher infectious-disease risk due to both environmental and behavioral exposures. Nationality emerged as a major determinant of HCV infection. Egyptian migrants, who constituted the largest subgroup (56.7%), accounted for 88.4% of HCV-positive cases, reflecting the high endemicity of HCV in Egypt, historically linked to unsafe medical procedures and parenteral therapy campaigns [18, 19]. Other nationalities, including Chadian and Sudanese participants, also showed measurable HCV positivity (5.6% and 4.3%, respectively), indicating that infection is not limited to a single origin

country and may be influenced by both pre-migration exposure and conditions encountered during migration. Age was significantly associated with seropositivity: HCV-positive participants had a mean age of 40.18 years compared to 33.24 years for negatives. The peak prevalence among 30–45-year-olds suggests cumulative exposure over time, consistent with global trends observed in migrant populations [18, 19]. Stratification by nationality and age revealed that Egyptian males aged 35–45 years had the highest positivity, emphasizing the need for age- and nationality-targeted screening strategies. The strong association of HCV infection with male gender, working age, and Egyptian nationality underlines the importance of implementing focused interventions. Prioritizing Egyptian migrants for rapid screening, education, and linkage to care could enhance public health efficiency. Moreover, understanding pre-migration exposure and integrating knowledge of high-prevalence origin countries into screening strategies can strengthen preventive efforts. Despite the study's contributions, limitations should be noted.

Rapid antibody testing cannot distinguish between active and resolved infection, and the cross-sectional design precludes causal inference. Behavioral risk factors were not collected, limiting the ability to analyze precise transmission routes. Nevertheless, the findings provide critical insight into a vulnerable and understudied population, highlighting the urgent need for tailored interventions in eastern Libya.

Conclusion

This study demonstrates a high burden of HCV infection among migrants in eastern Libya, with strong associations with male gender, older age, and Egyptian nationality [18, 19].

These findings underscore the necessity of targeted public health interventions, including prioritized screening, education, and linkage to care for high-risk groups. Consideration of both pre-migration epidemiology and local migration-related risk factors is essential. Addressing HCV among migrants is crucial not only for individual health but also for regional disease control and achieving broader hepatitis elimination goals.

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