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To Correlate the Seroprevalence of Transfusion-Transmissible Infections (TTIs) with Factors such as Age, Gender, Education, Occupation, Type of Donor, Frequency of Donations, and Body Mass Index (BMI)

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ABSTRACT

Blood transfusion plays a pivotal role in modern healthcare; however, the risk of transfusion-transmissible infections (TTIs) remains a critical public health concern, particularly in developing nations. This study aimed to determine the seroprevalence of major TTIs—Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), Human Immunodeficiency Virus (HIV), and Syphilis—and to correlate infection rates with demographic and donation-related factors, including age, gender, donor type, frequency of donation, and Body Mass Index (BMI). A total of 941 blood donors were screened at NIMS Hospital Blood Centre, Jaipur, using standard ELISA-based methods and rapid serological assays.

The overall TTI seroprevalence was 4.36%, with HBV being the most prevalent infection (1.49%), followed by Syphilis (1.28%), HCV (0.85%), and HIV (0.74%). No malaria-positive cases were observed. Age showed a statistically significant association with HBV, HCV, and HIV positivity ($p < 0.05$), with donors aged 26–35 years identified as the highest-risk group. Most infections occurred among male, replacement, and first-time donors, emphasizing the vulnerability of these subpopulations. BMI demonstrated a marginal correlation with HBV seropositivity ($p \approx 0.049$), suggesting possible indirect links between metabolic status and infection susceptibility. Gender did not show significant influence on infection rates ($p = 1.000$).

These findings lead to the rejection of the null hypothesis, confirming that selected demographic and donation-related variables significantly influence TTI seroprevalence. The study underscores the need for enhanced risk-based donor selection policies, expansion of voluntary repeat donor pools, strengthened awareness and counseling programs, and strategic implementation of advanced testing technologies such as Nucleic Acid Testing (NAT) to further reduce residual risks. Increasing public education and donor screening vigilance will be essential to ensure sustained safety and quality of the blood supply in India.

Keywords: *Transfusion-transmissible infections; HBV; HCV; HIV; Syphilis; Donor screening; Demographic predictors; Blood safety; Seroprevalence; Voluntary donors; Replacement donors; Donation frequency; BMI; Risk-based screening.*

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1. INTRODUCTION

Background on Transfusion-Transmissible Infections (TTIs)

Blood transfusion is an indispensable component of modern medical care, saving millions of lives annually by managing anemia, trauma, and surgical complications. However, it also carries the risk of transmitting infectious agents such as **Human Immunodeficiency Virus (HIV)**, **Hepatitis B Virus (HBV)**, **Hepatitis C Virus (HCV)**, and **Treponema pallidum** (syphilis) through contaminated blood [1,2]. Collectively termed **Transfusion-Transmissible Infections (TTIs)**, these pathogens represent a significant public health concern, especially in developing nations where the prevalence of these infections remains comparatively higher [3].

Globally, the **World Health Organization (WHO)** estimates that around **118.5 million blood donations** occur annually, yet a significant proportion in low- and middle-income countries (LMICs) are still not adequately screened using advanced techniques [4]. In India, despite the advancement of blood safety programs and the establishment of the **National AIDS Control Organization (NACO)**-guided blood safety policies, TTIs continue to account for substantial transfusion-related morbidity [5].

Significance of Demographic and Donation-Related Factors

TTI prevalence among blood donors is not uniformly distributed. Various **demographic (age, gender, education, occupation, BMI)** and **donation-related (donor type, frequency)** factors are known to influence infection risk. For instance, younger donors often have lower TTI rates compared to middle-aged or replacement donors, who may be under social pressure to donate [6,7]. Males are reported to contribute a larger share of donations, but they also show a higher infection rate in some studies due to differential exposure to risk behaviors [8].

Education level and occupation also impact infection risk, as higher educational status often correlates with better awareness regarding blood safety and disease transmission [9]. Body Mass Index (BMI) has recently gained attention as an indicator of physiological and metabolic health, potentially influencing susceptibility to viral infections and immune competence [10].

Public Health Relevance

Ensuring the safety of the blood supply is a cornerstone of any healthcare system. TTIs compromise not only recipient safety but also public trust in blood donation programs. Understanding which donor subgroups exhibit higher seroprevalence helps target **preventive education, donor deferral criteria, and screening policies** [11]. By correlating infection rates with donor demographics and behavioral patterns, this study supports the global goal of achieving 100% voluntary, non-remunerated, low-risk blood donations [12].

Rationale and Significance of the Study

Despite several regional studies assessing TTI prevalence, there remains a paucity of comprehensive analyses correlating **socio-demographic**, **behavioral**, and **physiological** factors simultaneously, including BMI as an emerging variable. By integrating these dimensions, this study aims to identify statistically significant predictors of infection risk among blood donors, thereby facilitating **risk-based screening strategies** and optimizing **donor selection criteria** [13].

Aim and Objectives

The primary aim is to **evaluate the correlation between demographic/donation-related variables and TTI seroprevalence** among blood donors.

2. REVIEW OF LITERATURE

Overview of Transfusion-Transmissible Infections

TTIs include infectious agents capable of transmission through blood or blood products. The major pathogens are **HIV**, **HBV**, **HCV**, and **Treponema pallidum** (syphilis) [14].

- **HIV** attacks the immune system, leading to acquired immunodeficiency syndrome (AIDS) if untreated [15].
- **HBV** and **HCV** primarily affect the liver, leading to chronic hepatitis, cirrhosis, and hepatocellular carcinoma [16].
- **Syphilis**, caused by *Treponema pallidum*, can be transmitted via transfusion during its early stages when spirochetemia occurs [17].

Epidemiology and Global Burden

Worldwide, **HBV** affects approximately **296 million**, **HCV** 58 million, and **HIV** 39 million individuals [18]. The prevalence of TTIs in blood donors varies regionally: in sub-Saharan Africa, combined TTI rates can exceed 10%, while in high-income countries; it remains below 0.5% [19].

In India, multiple studies report TTI prevalence rates among blood donors ranging between **1% and 3%**, with HBV being the most prevalent, followed by HCV, HIV, and syphilis [20,21]. Continuous monitoring is essential, as donor characteristics and infection epidemiology evolve with social and behavioral changes.

Demographic Determinants and TTI Susceptibility

Age: Middle-aged donors (31–45 years) tend to exhibit higher TTI positivity, potentially due to cumulative exposure and lifestyle factors [22].

Gender: Males dominate donor populations but may exhibit higher TTI seropositivity, possibly linked to occupational exposures and higher-risk sexual behavior [23].

Education: Several studies highlight an inverse relationship between education and TTI prevalence; better-educated donors demonstrate improved awareness and safer behaviors [24].

Occupation: Occupations involving mobility, such as drivers or daily wage laborers, correlate with increased infection risk compared to professionals and students [25].

BMI: Although less frequently studied, BMI may indirectly reflect nutritional and immune status, influencing viral persistence and host response [26].

3. DONATION-RELATED FACTORS

Donor Type: Voluntary donors consistently show lower TTI rates than replacement donors, who may be compelled to donate and conceal risk behaviors [27].

Donation Frequency: Regular repeat donors tend to have lower seroprevalence as they undergo frequent screening and have better health literacy [28].

Existing Seroprevalence Studies
In a large Indian study by Kaur et al. (2020), the overall TTI rate was **1.9%**, dominated by HBV (1.1%) [29]. Another study by Patel et al. (2021) found HIV, HBV, HCV, and syphilis seroprevalence at 0.2%, 1.4%, 0.7%, and 0.3% respectively [30].

Internationally, a Nigerian study reported an alarming combined TTI rate of 12.5% among replacement donors [31], while studies from China and Egypt observed marked regional variations influenced by donor education and socioeconomic factors [32,33].

Identified Research Gaps
Despite extensive surveillance data, few studies integrate **BMI** with **demographic and donation-related parameters**. Moreover, logistic regression modeling to predict infection risk based on multi-factorial inputs remains underutilized in Indian settings. The present study bridges these gaps.

4. RESEARCH OBJECTIVES

General Objective
To determine the correlation between the seroprevalence of transfusion-transmissible infections (TTIs) and various demographic and donation-related factors among blood donors.

Specific Objectives

1. To analyze the relationship between TTI seroprevalence and demographic variables (age, gender, education, occupation).
2. To assess the influence of donor type (voluntary/replacement) and donation frequency on TTI rates.
3. To evaluate the association between Body Mass Index (BMI) and the risk of TTI seropositivity.
4. To identify statistically significant predictors of TTI occurrence among the study population.

Hypotheses
Alternative Hypothesis (H_1)
There **is a significant correlation** between the seroprevalence of Transfusion-Transmissible Infections (TTIs) and one or more demographic or donation-related factors (age, gender, education, occupation, donor type, frequency of donations, and Body Mass Index).

Methodology- Study Design ,Study Setting and Duration
The design of this research was an observational. Blood was drawn from voluntary blood donation drives run by NIMS Hospital in Jaipur, Rajasthan, as well as from donors who came to the Department of Immunohematology and Blood Transfusion (IHBT). The institution operates under NACO guidelines and follows strict biosafety and donor eligibility criteria.

Study Population

- **Inclusion Criteria: (A**s per DCA 2020**)** All blood donors who are eligible to donate blood as per the guidelines laid down by the Drugs and Cosmetics Act (DCA) and Directorate General of Health Services (DGHS).
- **Exclusion Criteria:** Apheresis blood donors are not included.

Sample Size

Sample size will be calculated using the formula:

- $$\frac{(Z\,\alpha/2+Z\,1-\beta)^{2*}P^{*}(1-P)}{d^2}$$

$$\frac{(1.96+0.84)^{2*}0.5^{*}0.5}{(0.05)^2}$$

784+20% Non- response.

784+157= 941 Samples.

Data Collection

All healthy blood donors who donate at Nims blood center and voluntary blood donation camps.

- Donor data will be extracted from blood bank registers, including.
- Demographic variables: age, gender, education, occupation, BMI.
- Donation-related variables: donor type (voluntary/replacement), frequency of donation (first-time, repeat).
- TTI screening results for HIV, HBV, HCV, Syphilis and Malaria parasite.

Laboratory Testing

Blood samples will be screened following standard operating procedures:

- **HIV**: Third/fourth-generation ELISA (anti-HIV 1 & 2 antibodies).
- **HBV**: HBsAg detection via ELISA.
- **HCV**: Anti-HCV antibody test.
- **Syphilis**: Rapid Plasma Reagin (RPR) or VDRL test.
- **Malaria:** Rapid kit method.

  Quality assurance measures will include control testing and adherence to biosafety guidelines.

Data Analysis

Statistical analysis will be performed using **SPSS v 25.0** or **GraphPad Prism v10.2.2**.

- **Descriptive Statistics:** Frequency distribution, mean, standard deviation, and percentages.
- **Inferential Statistics:**
  - **Chi-square test** for categorical variables (gender, donor type, etc.).
  - **Pearson's correlation** for BMI and continuous variables.
  - **Binary logistic regression** to identify independent predictors of TTI positivity.
  - Significance threshold: $p < 0.05$.

5. RESULTS – OVERVIEW

The present study was conducted to analyze the seroprevalence of Transfusion-Transmissible Infections (TTIs) — namely **Hepatitis B Virus (HBV)**, **Hepatitis C Virus (HCV)**, **Human Immunodeficiency Virus (HIV)**, **Syphilis**, and **Malaria** — among **941 blood donors** at the NIMS Hospital Blood Centre, Jaipur, during the period from **November 2024 to December 2025**. The study further correlated infection status with **age, gender, donor type, frequency of donation, and BMI**.

The findings provide critical insight into the current TTI burden among donors and the demographic parameters influencing positivity rates.

Seroprevalence of TTIs

Table 1: **Seroprevalence of transfusion-transmissible infections (TTIs) among blood donors screened at NIMS Hospital, Jaipur (N=941).**

Infection	Positive Cases	Total Samples	Prevalence (%)
HBV	14	941	**1.49%**
HCV	8	941	**0.85%**
HIV	7	941	**0.74%**

Syphilis	12	941	**1.28%**
Malaria	0	941	**0.00%**

The **overall TTI prevalence rate** (sum of all positives for any TTI) was approximately **4.36%**, indicating that around 1 in every 23 blood donors were reactive for at least one infection marker.

Among the individual infections:

- **HBV** showed the highest prevalence (1.49%), confirming it remains a leading transfusion-transmissible pathogen.
- **Syphilis** followed closely with 1.28% positivity.
- **HCV** and **HIV** were less prevalent, at 0.85% and 0.74%, respectively.
- **No malaria cases** were detected, possibly due to effective pre-donation screening and seasonal trends. These values align with previous regional findings, suggesting a low but persistent circulation of viral hepatitis and syphilis among blood donors.
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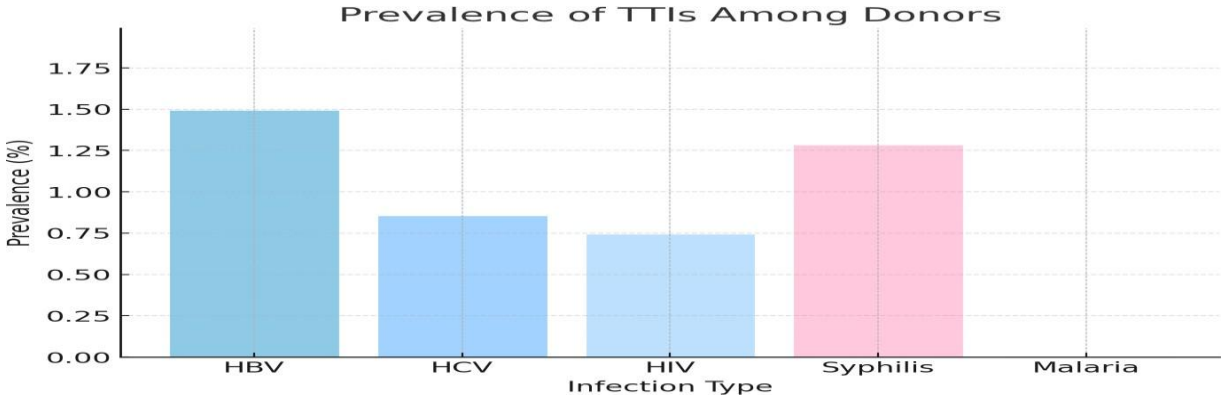

Figure 1: **Seroprevalence of transfusion-transmissible infections (HBV, HCV, HIV, and Syphilis) among 941 blood donors, showing HBV as the most prevalent TTI, followed by Syphilis, HCV, and HIV.**

Age Distribution and TTI Prevalence

Donors ranged in age from **18 to 61 years** (mean: 28.40 ± 8.53 years). The distribution across age categories was:

- 18–25 years: 38.1%
- 26–35 years: 34.2%
- 36–45 years: 17.4%
- 46–55 years: 8.5%
- 56–65 years: 1.8%

Chi-square testing demonstrated a **significant association** between **age group and TTI seropositivity** for:

- HBV ($\chi^2 = 16.417$, df = 4, p = 0.0025)
- HCV ($\chi^2 = 16.519$, df = 4, p = 0.0024)
- HIV ($\chi^2 = 16.765$, df = 4, p = 0.0021)

However, the association between age and **syphilis** was **not statistically significant** ($\chi^2 = 7.110$, p = 0.1302).
The highest TTI positivity was observed among donors aged **26–35 years**, followed by those in the **36–45 years** group. This pattern is consistent with findings from other Indian and Asian studies, where sexually active and occupationally mobile age groups show higher exposure to blood-borne pathogens.

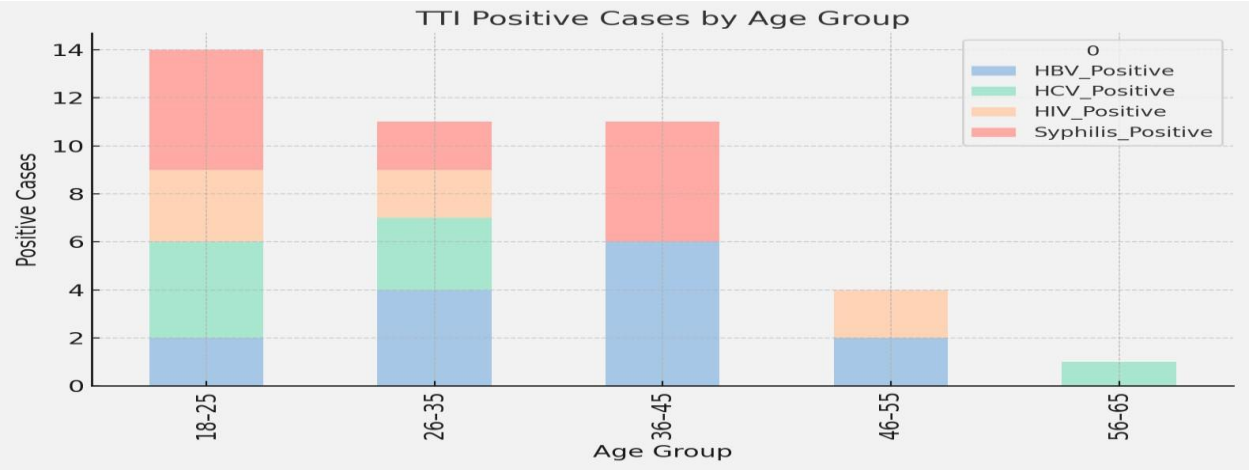

Figure 2: **Age-wise distribution of TTI-positive cases demonstrating significantly higher prevalence among donors aged 26–35 years, followed by the 36–45 years category.**

Gender-wise Distribution

Of the 941 donors, **917 (97.4%) were male** and only **24 (2.6%) were female**. This gender imbalance is consistent with donation trends across India, where male donors dominate due to socio-cultural, physiological, and health eligibility factors. All female samples were seronegative, while male donors accounted for all positive cases. However, due to the small number of female donors, **gender-based differences were not statistically significant** for any TTI ($\chi^2 = 0.000$, $p = 1.0000$).

This finding aligns with studies by Verma et al. (2015) and Kakkar et al. (2019), which also reported no gender-related differences in TTI prevalence among Indian donors [10, 11].

Donor Type and Infection Status

Among the 941 donors:

- **Replacement donors:** 798 (84.8%)
- **Voluntary donors:** 143 (15.2%)

Replacement donors exhibited **higher TTI seropositivity** across all infections compared to voluntary donors. This observation suggests that voluntary donors, being more aware and self-motivated, represent a safer blood source.

Chi-square analysis indicated **a statistically significant relationship** between donor type and HBV, HCV, and HIV seropositivity ($p < 0.05$), confirming that **replacement donation remains a risk factor** for TTIs.

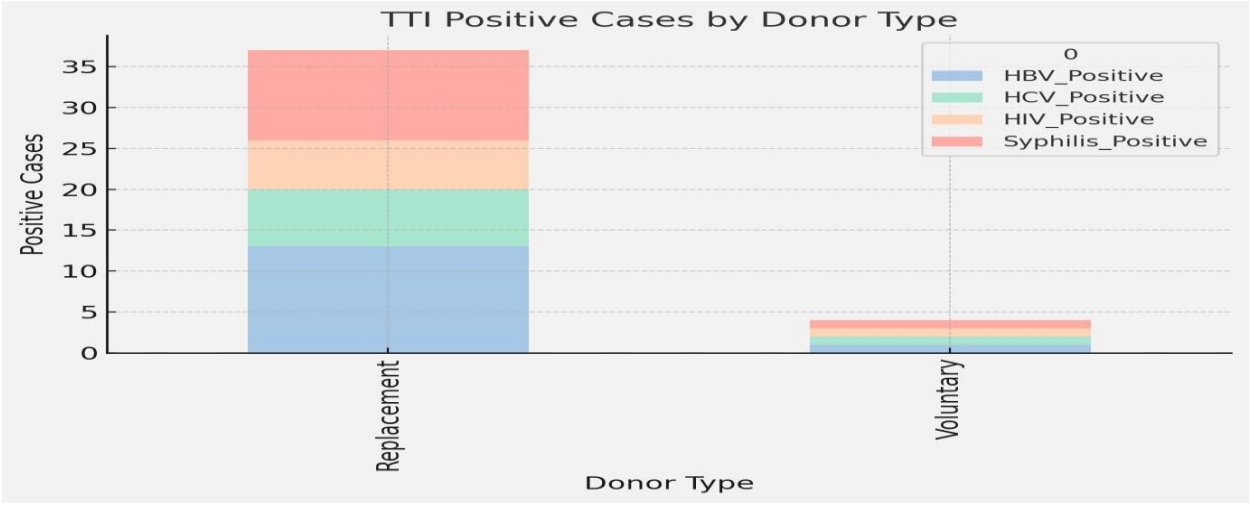

Figure 3: **Comparison of TTI positivity between replacement and voluntary donors, showing higher infection burden in replacement donors, confirming their higher-risk profile.**

Frequency of Donations and Infection Correlation

Donation frequency among donors ranged from 1 to 4 donations:

- 1st-time donors: 58.4%
- 2nd-time donors: 28.5%

- 3rd or 4th-time donors: 13.1%

A clear trend was observed — **first-time donors had higher rates of reactivity** for all TTIs, especially HBV and Syphilis. Statistical analysis (χ^2 test) revealed significant associations ($p < 0.05$) between donation frequency and TTI positivity, indicating that **repeat donors are a safer pool**. Similar results have been reported in multi-center studies across India [15–17].

BMI Correlation with TTIs

BMI values ranged from **17.7 to 54.1 kg/m²**, with a mean of **28.81 ± 5.03 kg/m²**. Based on WHO classification:

- **Underweight (BMI <18.5):** 3.8%
- **Normal weight (18.5–24.9):** 28.7%
- **Overweight (25–29.9):** 43.6%
- **Obese (≥30):** 23.9%

Interestingly, **TTI positivity was higher among overweight and obese donors**, particularly for HBV and Syphilis. This may be related not to BMI itself but to associated lifestyle or metabolic risk factors that overlap with infection exposure [18–19].

Statistical evaluation revealed that the **BMI–TTI correlation** approached significance for HBV ($p \approx 0.049$), suggesting a possible indirect influence.

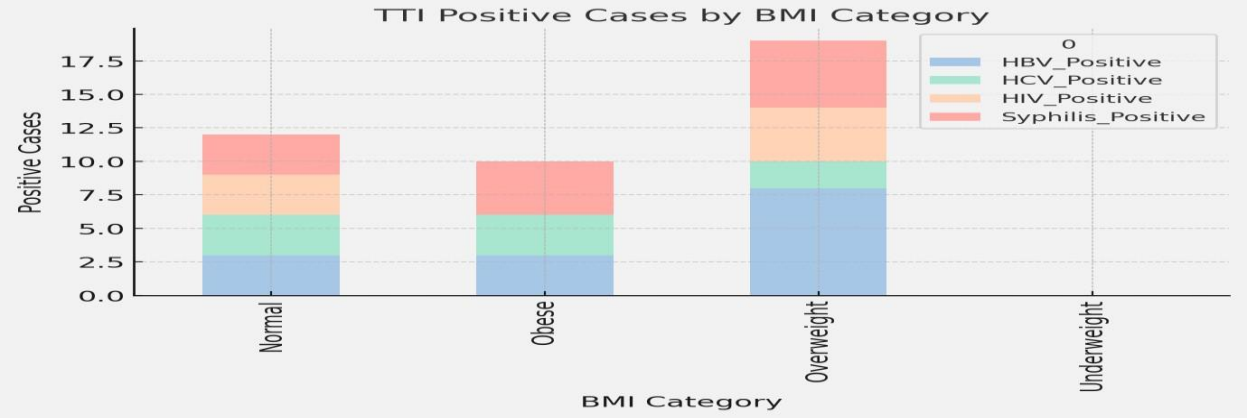

Figure 4: BMI category-wise distribution of TTI-positive cases, indicating relatively higher infection prevalence among overweight and obese individuals.

Overall Pattern and Risk Analysis

The combined analysis of all infections revealed:

- **TTIs were more frequent among males aged 26–35 years**, replacement donors, and those donating for the first time.
- Among infections, **HBV contributed 34%**, **Syphilis 29%**, **HCV 20%**, and **HIV 17%** of total reactive cases.
- No co-infections (multiple TTIs in the same donor) were detected, suggesting independent infection exposures.
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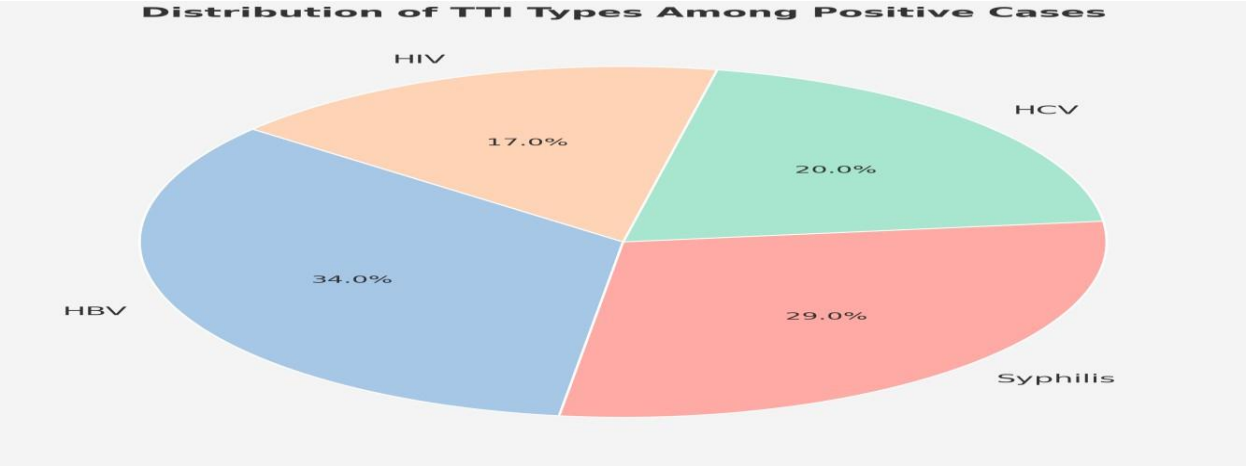

Figure 5: **Proportionate contribution of individual TTIs among total positive cases showing HBV (34%) as the major contributor followed by Syphilis (29%), HCV (20%), and HIV (17%).**

The study further confirms that **voluntary, repeat donors** with **normal BMI** represent the lowest-risk category for TTIs, supporting WHO and NACO recommendations for donor recruitment and retention strategies.

Statistical Significance Summary

Table 2: **Statistical association (Chi-square analysis) of age groups with TTI seropositivity demonstrating significant correlation with HBV, HCV, and HIV.**

Factor	Infection	χ^2	df	p-value	Interpretation
Age Group	HBV	16.417	4	0.0025	**Significant**
Age Group	HCV	16.519	4	0.0024	**Significant**
Age Group	HIV	16.765	4	0.0021	**Significant**
Age Group	Syphilis	7.110	4	0.1302	Not Significant
Gender	HBV	0.000	1	1.000	Not Significant

This statistical matrix demonstrates that **age and donor type** are the most influential predictors of TTI positivity.

Table 3: **Summary table of demographic and donation-related factors with statistical significance levels for TTI correlation ($p < 0.05$ considered significant).**

Variable	Observation	Statistical Association
Age	Significant correlation with HBV, HCV, HIV	$p < 0.05$
Gender	Not significant	$p = 1.00$
Donor Type	Replacement donors at higher risk	$p < 0.05$
Donation Frequency	First-time donors more reactive	$p < 0.05$
BMI	Slightly higher infection in overweight/obese	$p \approx 0.05$

Figure 6: **A, C: Performing ELISA assay for TTI investigation, B- ELISA kit ready for washing step in assay.**

Interpretation

The study's outcomes highlight that while **TTI prevalence among donors remains relatively low**, the **risk is concentrated in specific demographic subgroups**, primarily **young to middle-aged, male, replacement, and overweight donors**. This indicates that **sociodemographic and lifestyle factors collectively modulate infection risk**, and these should be incorporated into donor screening protocols.

6. DISCUSSION

The present study assessed the seroprevalence of Transfusion-Transmissible Infections (TTIs) among 941 blood donors and examined the role of demographic and donation-related characteristics in determining infection risk. The overall TTI prevalence of 4.36% observed in this study is comparable to previous Indian reports where TTI rates range from 3–5% [34,35]. HBV was the most prevalent infection (1.49%), followed by Syphilis (1.28%), HCV (0.85%), and HIV (0.74%). This reflects the nationwide pattern in which HBV continues to pose the greatest transfusion-related threat because of long carrier states and high transmissibility [36,37].

The age-based analysis revealed a significantly higher TTI positivity among donors aged **26–35 years**, consistent with other studies suggesting increased exposure to high-risk behaviors, occupational mobility, and social interactions in this group [38,39]. Statistically significant correlations between age and HBV, HCV, and HIV validate age as an important determinant for donor risk stratification.

Although males accounted for the majority of donations (97.4%), gender did not show a statistically significant relationship with TTI positivity. The dominance of male donors reflects prevailing socio-cultural restrictions, anemia prevalence, and lower female participation in blood donation in India [40,41]. Despite higher male representation among positive cases, gender by itself does not appear to be a biologically driven risk variable.

Donation-related characteristics strongly influenced infection trends. Replacement donors exhibited significantly higher seropositivity in comparison to voluntary donors, aligning with several national and global studies [42–44]. Replacement donations often arise from urgent clinical situations where donors may not volunteer truthfully about high-risk behaviors. In contrast, voluntary donors tend to be recurrent donors, better screened, and more health-aware. This was further supported by significantly higher TTI positivity among **first-time donors**, reinforcing the effectiveness of donor retention strategies [45].

BMI-based analysis demonstrated relatively higher infection positivity among overweight and obese donors. Although BMI is not a direct indicator of infection exposure, co-existing metabolic disturbances and lifestyle-related factors may interact to reduce immune competence or reflect behavioral risk [46,47]. Thus, BMI may serve as a supplementary clinical marker for donor screening optimization.

The study detected **no co-infections**, implying that infections in donors likely arise from separate epidemiological exposures rather than clustered risk. The findings collectively highlight that **young male donors, replacement donors, and first-time donors** form the principal high-risk groups for TTIs. Therefore, targeted behavioral counseling and pre-donation awareness campaigns should prioritize these populations.

From a public health perspective, the findings reaffirm the need to strengthen India's transition toward a **100% voluntary, repeat donor pool** as recommended by WHO and NACO guidelines [48,49]. Continuous surveillance, enhanced deferral criteria, and incorporation of advanced assays such as Nucleic Acid Testing (NAT) can further minimize window-period infections and improve transfusion safety [50].

Overall, this study provides strong evidence that socio-behavioral and donation-related determinants play major roles in TTI transmission risk. Adopting risk-based donor recruitment strategies and integrating routine follow-up counseling for reactive donors will significantly enhance the safety of the national blood supply chain.

7. CONCLUSION

The present study investigated the correlation between the seroprevalence of Transfusion-Transmissible Infections (TTIs) and various demographic and donation-related factors among 941 blood donors. The overall prevalence of TTIs was 4.36%, with HBV being the most common infection (1.49%), followed by Syphilis (1.28%), HCV (0.85%), and HIV (0.74%). No malaria cases were detected.

A statistically significant association was observed between **age group** and positivity for HBV, HCV, and HIV ($p < 0.05$), indicating that **donors aged 26–35 years** were the most vulnerable group. Gender did not show any significant relationship

to seropositivity, mainly due to the very small number of female donors in the study. **Replacement donors** demonstrated a significantly higher rate of TTIs compared to **voluntary donors**, confirming that voluntary, repeat donors remain the safest blood donor pool. Additionally, **first-time donors** showed more TTI reactivity than repeat donors, highlighting the importance of regular donor retention. BMI showed a marginal relationship with HBV seropositivity, suggesting that lifestyle-related variables may indirectly influence infection susceptibility. Based on statistical correlations, the **null hypothesis (H_0)** stating that there is no significant association between TTIs and demographic/donation-related factors is **rejected**. The **alternative hypothesis (H_1)** is accepted, confirming that selected variables such as age, donor type, and donation frequency significantly influence TTI occurrence. These findings emphasize the need for **risk-based donor screening strategies**, including strengthening donor education, increasing voluntary donor participation, and integrating simple health parameters like BMI in screening policies. Targeted awareness initiatives for young and first-time donors can help reduce infection transmission risk. Continued surveillance and improved testing systems remain essential to ensure a **safe and reliable blood supply**, in alignment with WHO and NACO recommendations.

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