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Research Article

Healthcare Access as a Determinant of Dengue Recovery: A Cross-Regional Study of Clinical and Hematologic Outcomes

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Abstract

Background: Dengue fever remains a re-emerging threat to global public health, particularly in developing countries such as Pakistan, where inequalities in healthcare access influence disease outcomes.

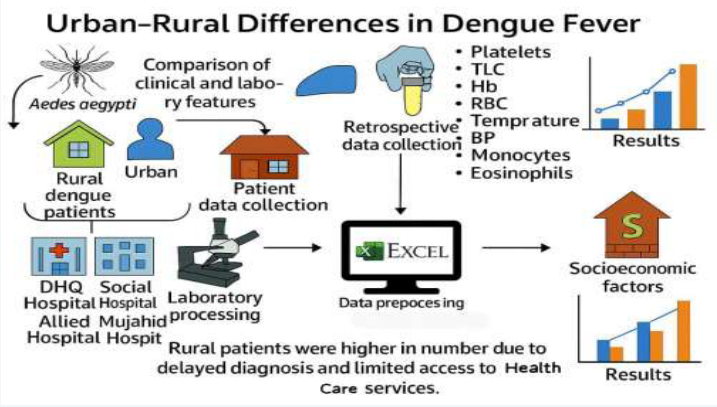
Aim: This study compared the clinical characteristics and hematology recovery patterns of dengue patients from urban and rural settings between 2020 and 2025.

Method: A hospital based comparative observational study was conducted among 106 confirmed cases of dengue fever from four hospitals in Faisalabad (DHQ, Allied, Social Security, and Mujahid Hospitals). Clinical and hematological parameters, including platelet count(×10⁹/L), hemoglobin (g/dL), total leukocyte count (×10⁹/L), and differential white blood cell percentages, were collected at admission and discharge using structured perform as and hospital records. Data were analyzed using descriptive statistics and independent sample t-tests with a significance threshold of $p < 0.05$.

Results: Urban patients showed higher mean platelet counts at admission compared rural patients (mean difference = 14,981 ×10⁹/L; 95% CI, 3,574–26,388; $p = 0.03$) while rural participants exhibited more stable leukocytes profiles. Male predominance was observed in both groups possibly reflecting occupational and environmental exposures. Although differences in packed cell volume, lymphocyte percentages and body temperature were noted, not all reached statistical significance.

Conclusion: These findings suggest measurable disparities in dengue presentation and hematologic recovery between urban and rural populations in Pakistan, underscoring the need for improved surveillance and equitable healthcare access in rural regions.

Graphical Abstract



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Keywords: Dengue Fever; Urban–Rural Comparison; Hematology; Pakistan; Healthcare Access.

Highlights

- A comparative study of dengue patients showed significant differences in clinicopathological features and wound healing between urban and rural areas.
- Urban patients were more likely to have anemia on admission compared to rural patients. ($p = 0.03$).
- The surrounding tumor showed a leukocytic phenotype for immunostaining.
- Most of the disparity has to do with access to healthcare and diagnostics, rather than biological differences.
- These findings highlight the need for improved diagnosis, surveillance, and overall healthcare in Pakistan.

INTRODUCTION

Dengue fever is turning into a serious health crisis in Pakistan, affecting people across all age groups. Recently, even newborns have shown symptoms like high fever, low platelet counts, and bleeding, highlighting the severity of the situation and the urgent need for better diagnosis, increased public awareness, and effective mosquito control [1]. What used to be occasional outbreaks have now become common seasonal occurrences, especially during and after the monsoon season when mosquitoes breed rapidly. Since the early 2000s, Pakistan has faced repeated dengue outbreaks, with the 2022 and 2023 epidemics being particularly severe. In 2023 alone, more than 24,000 cases were officially reported, especially in major cities like Karachi, Lahore, and Rawalpindi [2].

The actual number of cases is likely higher due to under-reporting in rural areas. Worldwide, dengue infects about 390 million people each year and many patients develop serious complications such as dengue hemorrhagic fever and dengue shock syndrome, which can cause death [3]. While dengue is a preventable disease, it continues to challenge healthcare systems, especially in densely populated urban areas and resource-limited rural regions [4]. The progression and recovery from dengue can depend on various factors, including immune status, timeliness of treatment, preexisting health conditions, and living environment and income level [5]. Research indicates that dengue is a complex disease and many factors can influence its progression [6]. Although many global studies have focused on the virus itself and immune responses, there remains a lack of research examining how the disease affects people in different social and geographical contexts. This is particularly relevant for countries like Pakistan, where urban and rural healthcare systems differ greatly [7].

In Pakistan, around 64% of the population resides in rural areas where access to early diagnosis, effective mosquito control, and adequate treatment for dengue is often limited [8]. Disease reporting in these regions is also weak, complicating outbreak management [9]. In contrast, urban populations often face higher dengue risks due to overcrowding and poor sanitation but generally have better access to healthcare and faster diagnoses. However, there are limited studies comparing how dengue affects patients in urban versus rural settings [10]. Research also shows that the response to dengue can vary depending on the virus type that affects a person. Given that mosquito control remains a significant issue in Pakistan, understanding how the immune system reacts to different viruses is crucial [11].

A person's living conditions like their home environment, water sources, and exposure to mosquitoes can greatly influence the severity of the illness and speed of recovery [12]. Some studies suggest the virus can harm blood vessels, worsening the illness [13]. Rural patients, who may not have regular health check-ups, might experience delayed symptoms and slower recovery, putting them at higher risk for complications [14].

This study aims to fill these gaps by comparing the clinical and laboratory characteristics of dengue patients in urban and rural areas of Pakistan from 2020 to 2025. Data was collected from four major hospitals—DHQ, Allied, Social Security, and Mujahid Hospitals—that serve diverse populations. The focus is on key blood markers such as platelet count, hemoglobin levels, white blood cell counts, packed cell volume, and recovery time. We hypothesized that urban patients would present earlier and show faster hematologic recovery than rural patients By comparing these parameters, the study seeks to understand how the disease manifests and evolves in different environments [15]. Pakistan grapples with many challenges that complicate dengue control efforts. Issues such as overcrowded living conditions, poor waste management, stagnant water, and unplanned urbanization planning create idle breeding grounds for mosquitoes [16].

These urban challenges, combined with a effects of climate change, heighten the risk of major outbreaks [17].While urban areas report more dengue cases due to better diagnostic and reporting systems testing and reporting, this doesn't mean that rural regions are less affected. Many rural cases go unreported because of inadequate medical care and medical diagnostic facilities [18]. Pakistan still relies heavily on data from major cities, leaving dengue patterns in rural populations largely unexamined [19].This study also investigates environmental factors such as mosquito control measures, sanitation, housing conditions, and water storage practices, evaluating their impact on disease transmission and recovery [20]. Additionally, it explores personal factors such as vaccination status, preventive practices, and awareness of dengue symptoms and transmission routes [21].

A meta-analysis by Htun et al. Reported that living conditions significantly influence dengue develops [22]. Other studies from Pakistan have also identified regional variations in dengue related knowledge and preventive behaviors. For instance, in Multan, people in rural areas were found to use fewer preventive measures compared to those in urban settings [23]. Initiatives such as HEAL-Dengue have emphasized the need for improved disease surveillance systems [24]. A study conducted in Peshawar revealed that children exhibited clinical and hematological profiles when infected with dengue [25]. Similarly, Mufti et al. Established associations between blood markers such as platelet and white cell counts and the severity of infection [26]. Our findings align with previous research including studies from Peshawar showing gender based variations in blood parameters due to varying exposure levels [27]. In 2022, genomic analysis linked changes in dengue virus strains with variations in clinical symptoms [28]. A study from Rawalpindi also associated poor environmental conditions with more severe dengue outcomes [29]. Moreover a large multi-center review indicated that rural patients often face more severe diseases due to delayed healthcare access and less effective mosquito control [30]. Dengue remains a major public health concern in Pakistan, with rising cases leading to serious issues such as low platelet counts, decreased white blood cell levels, and fluid accumulation in body tissues [31].

In Punjab, areas like Faisalabad report thousands of cases annually [32].The differences in how the illness presents and progresses across regions underscore the need for more localized research. In Abbottabad, for instance, symptom patterns and severity varied based on the studied population [33]. Some reports indicate that even doctors lack sufficient training in managing dengue in major cities of Pakistan [34].Experts have suggested that current WHO guidelines on dengue may need modifications to better fit local realities in countries like Pakistan [35].

Research points out that older patients and those who arrive late at hospitals are at a higher risk of dying from dengue [36]. These issues, along with Pakistan's slow initiation of a dengue vaccination program [37], highlight the importance of understanding the factors that lead to severe illness and delayed recovery. Delayed hospital visits and older age have been confirmed as significant risk factors for mortality in many regions [38].The slow roll out of the dengue vaccine in Pakistan raises ongoing concerns [39]. New global health recommendations stress that Pakistan requires improved disease monitoring and more trained healthcare personnel to identify and treat dengue early [40].

Recent research also furthered knowledge regarding dengue transmission and its changing patterns. A bibliometric review brought to light the international interest in dengue virus research and emerging trends [41]. A modeling study conducted at Guangzhou showed that mosquito infection intensity determines the basic reproduction number of dengue [42]. Another international systematic review underscored the utility of forecasting models to predict dengue epidemics in endemic areas [43]. Clinical trial–based evidence documented advancement in vaccine development, especially for children [44]. Hepatic dysfunction has also been reported as a frequent complication of dengue fever in

Pakistani patients further emphasizing the need for early diagnosis and close monitoring of organ involvement [45]. A study from District Dir also documented demographic and seroprevalence patterns of different dengue serotypes [46]. A review assessed global epidemiological patterns, highlighting the importance of enhanced surveillance systems [47]. Spatial modeling studies cited environmental determinants of rainfall, temperature, and urbanization as prime drivers of the risk for dengue [48]. In Lahore, environmental parameters and mosquito dynamics were correlated with outbreak intensities [49]. A Karachi hospital-based study enumerated the wide spectrum of clinical presentation of dengue among children [50]. Finally, evolutionary studies of serotypes of dengue virus in Pakistan validated noteworthy genetic heterogeneity and persistent viral evolution [51].

By understanding the nuances between urban and rural dengue cases, health authorities can develop more effective, targeted strategies to combat the disease. Leveraging local data to inform actions will help ensure that everyone, regardless of where they live or their resource availability, gets the healthcare they need. This study aims to support equitable and effective dengue control across Pakistan.

METHODOLOGY

Study Design

This study was a comparative descriptive cross-sectional study conducted to evaluate how dengue fever manifests and affects hematological parameters among patients from both urban and rural settings in Pakistan from 2020 to 2025. A cross-sectional approach was chosen because it enables comparison of sociodemographic, clinical, and environmental variables during disease presentation, which is suitable for identifying regional disparities [10].

Geographic and Institutional Setting

The study was carried out in Faisalabad, Pakistan, across four tertiary-care hospitals: District Headquarters (DHQ) Hospital, Allied Hospital, Social Security Hospital, and Mujahid Hospital. These hospitals collectively cater to both urban and rural populations. Although based in Faisalabad, many patients arrived from nearby districts, reflecting the city's regional healthcare role. Previous studies emphasize the diagnostic value of hematological indicators in dengue severity assessment [26], and variations in presentation by gender [27]. Figure 1 displays a map of patient origins during the study period [8].

Data Collection

Primary Data: were collected using structured and pre-tested forms administered at the patient admission and discharge. These forms recorded:

Demographics: Gender, age, residence, occupation, and income.

Clinical Data: Total leukocyte count, hemoglobin level, platelet count, packed cell volume, RBC count, and differential WBCs (neutrophils, lymphocytes, monocytes, eosinophils).

Environmental/Socioeconomic factors: Housing type, water storage practices, mosquito control and dengue awareness.

Secondary Data included hospital records, discharge summaries, and laboratory reports obtained from 2020 to [6- 21] results were taken directly from hospital diagnostic laboratories, which followed standard internal quality control procedures. All entries were verified by the research team, and inconsistencies were reviewed with hospital laboratory staff and clinicians before inclusion in the dataset.

Field Survey Design and Implementation

From October to November 2024, a trained research team from the Department of Biochemistry at Government College Women University, Faisalabad, conducted a structured field survey to investigate dengue-related risk factors. The survey design was adapted from protocols used in dengue endemic reg [37-40].We included patients from both urban and rural backgrounds. A total of 30 recovered dengue patients (n = 30) were surveyed using hospital records and outreach interviews, as illustrated in Figure 2.

Inclusion Criteria: Aged 18 or older, laboratory-confirmed dengue diagnosis (2020–2024), residing in Faisalabad or neighboring cities provided informed consent.

Exclusion criteria: Co-infection with other vector-borne diseases, Chronic hematologic or systemic disorders Incomplete clinical or survey data.

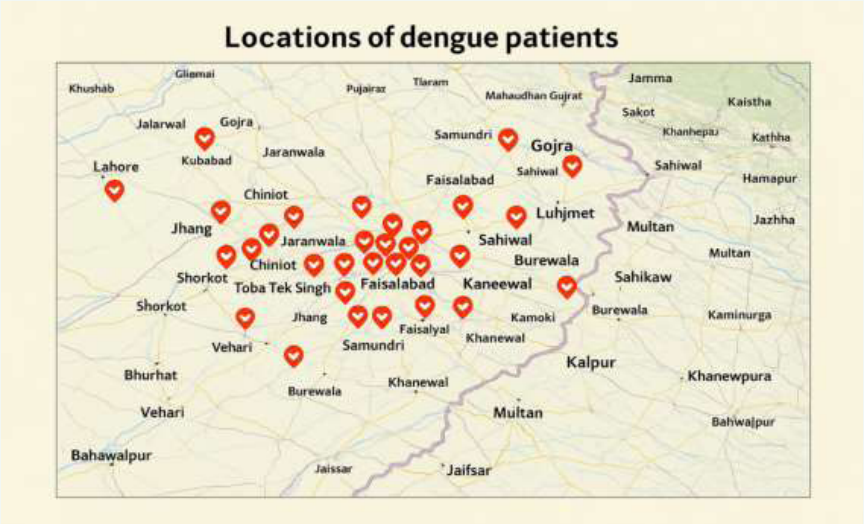

Figure 1 : Map showing Faisalabad and surrounding cities that contributed dengue fever cases

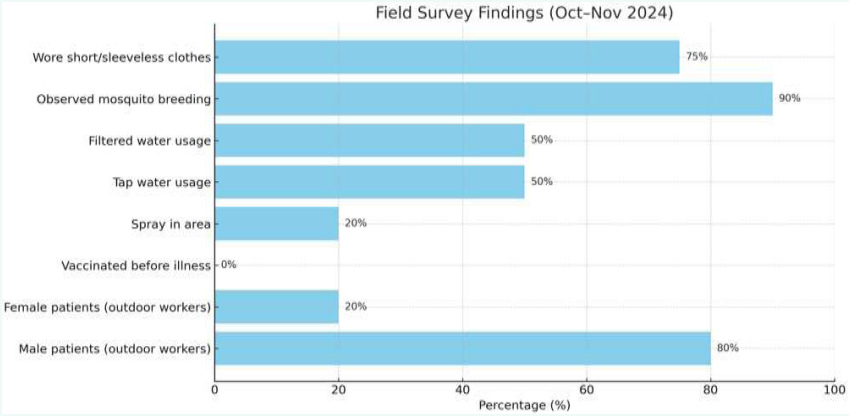

Figure 2 : Overview of patient-reported findings from the dengue field survey conducted in Faisalabad (October–November 2024).

Survey tool and parameters: A semi-structured questionnaire was used to collect data on the following domains:

Personal traits: Age, gender, residence, occupation, income

Medical history: Past dengue episodes, vaccination status, symptoms, family medical history

Environmental conditions: Living environment, water sources, mosquito presence

Awareness and preventions: Knowledge of dengue, personal prevention practices, community fogging/spraying, clothing behaviour.

Sampling Method

Due to logistical limitations and uneven patient distribution, convenience sampling was employed. Although this method limits generalizability, it is appropriate for hospital-based observational studies where random sampling is not feasible [10].

Sample Size

A total of 106 confirmed dengue cases were included (53 from urban areas and 53 from rural areas). All patients were over 18 years old, confirmed through NS1 antigen or IgM testing, and had complete laboratory records. Participants with co-infections or chronic blood disorders were excluded.

Data Analysis

Data were analyzed using SPSS version 26 (IBM Corp, Armonk, NY). Descriptive statistics (mean, standard deviation, variance) were calculated. Independent sample t-tests were applied to compare urban and rural groups, with a p-value <0.05 considered statistically significant. Data normality was checked using the Shapiro-Wilk test before applying parametric tests. Microsoft Excel was used to visualize variations in platelet count, WBCs, hemoglobin, and other relevant indicators over [14-16].

Variables

Data collection focused on the following variables:

Patient Details: Age, gender, residence, blood type

Hospital Information: Admission and discharge dates

Clinical factors: Vaccination status, health status, hematologic indices

Environmental factors: Type of residence, mosquito control measures, awareness level

Socioeconomic: Occupation, income

Other: Knowledge of dengue and personal observations

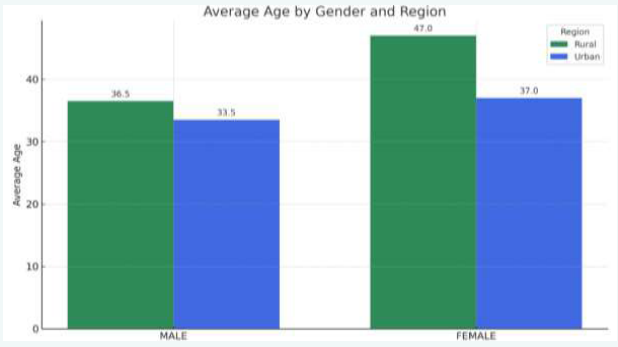

Figure 3: Gender-wise distribution of dengue patients in urban and rural areas

RESULTS AND DISCUSSION

Gender Distribution

More male patients were seen in urban and rural areas (Figure 3). In urban regions, 77.4 % of the dengue cases were in males and 22.6 % in females, while in rural regions, 84.9 % were males and 15.1 % females. The sex predominance was statistically non-significant (χ^2 = 1.64, p = 0.20) but could be due to higher outdoor occupational exposure and risk factors for behavior in men.

Platelet Count

Urban patients recorded much higher initial mean platelet counts (85,528 ± 30,376 × 10^9/L) compared to those from rural areas (70,547 ± 29,605 × 10^9/L, p < 0.05). Nonetheless, the difference in the change of platelet count from admission to discharge was larger in urban patients (131,384 ± 226,841 × 10^9/L) compared to rural patients (108,077 ± 51,920 × 10^9/L), albeit not statistically significant Figure 4.

Total Leukocyte Count (TLC)

The initial mean TLC was slightly greater in rural patients (5.76 ± 8.92 × 10^9/L) compared to urban patients (5.30 ± 4.71 × 10^9/L), though without statistical significance (p > 0.05). Intra-admission to discharge changes in TLC were also not significant between groups Figure 5.

Hemoglobin (Hb)

The rural patients had a slightly higher mean hemoglobin concentration (14.2 ± 1.75 g/dL) than the urban patients (13.7 ± 1.91 g/dL), although this difference was not statistically significant (p > 0.05). A higher decrease in hemoglobin among rural patients was also noted but was non-significant Figure 6.

Packed Cell Volume (PCV)

The admission mean Packed Cell Volume (PCV) was marginally higher in rural patients (42.49 ± 5.19%) than in urban patients (41.17 ± 7.42%). Although the mean PCV change was more in urban patients (1.86

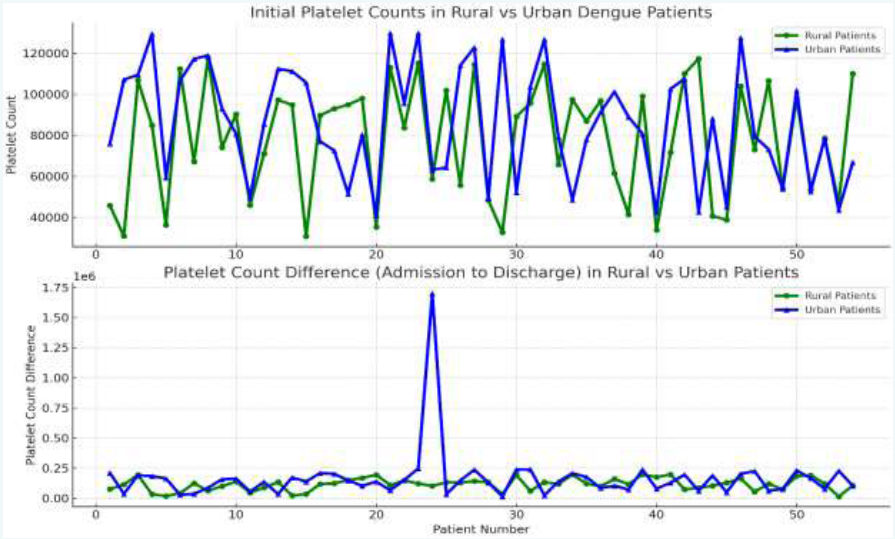

Figure 4: Comparison of initial and discharge platelet counts between urban and rural dengue patients.

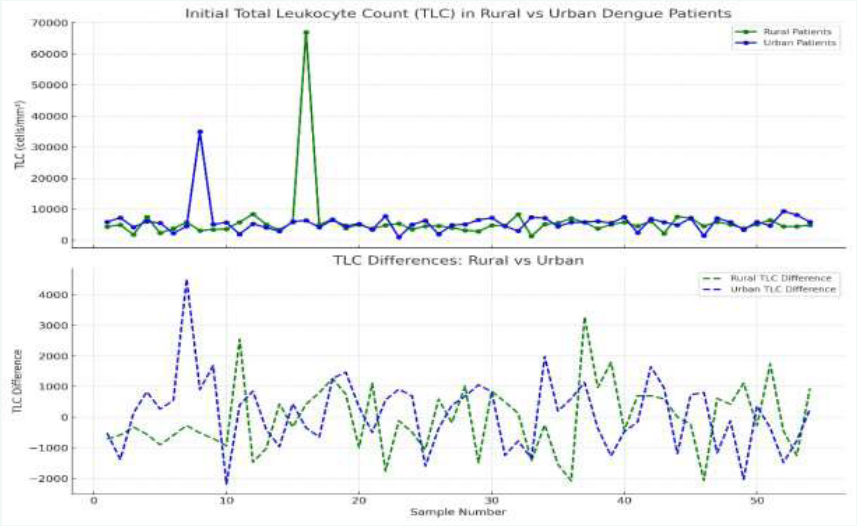

Figure 5: Comparison of Initial and Difference in TLC Levels Between Rural and Urban Dengue Patients

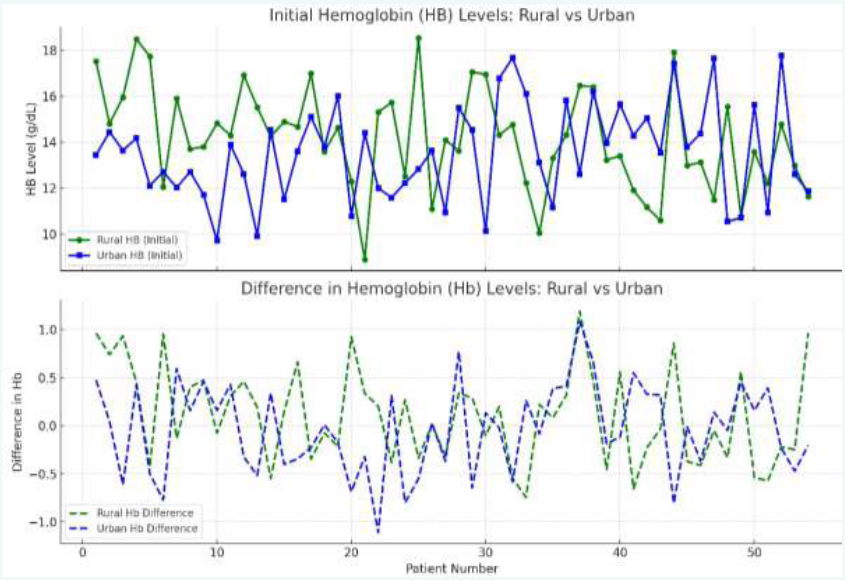

Figure 6: Comparison of Initial and Difference in HB Levels Between Rural and Urban Dengue Patients.

± 5.29% vs. –0.15 ± 5.57%), this was not statistically significant ($p > 0.05$) as shown Figure 7.

Neutrophil and Lymphocyte Counts

The admission mean neutrophil level was marginally higher among rural patients (61.23 ± 11.56%) than urban patients (59.48 ± 11.79%). Rural patients also demonstrated a higher reduction in neutrophil value during recovery, but the difference was not significant statistically ($p > 0.05$) (Figure 8). In the same vein, the mean lymphocyte percentage was also greater among urban patients (39.28 ± 11.33%) compared to rural patients (36.32 ± 10.51%). The two groups showed similar mean increases of about 4.2% while recovering from infection, with no corresponding difference between them ($p > 0.05$) (Figure 9).

Monocytes, RBCs, and Eosinophils.

The average monocyte level was 1.6 ± 0.55 $\times 10^9$/L among rural patients, while all urban patient results were 0, which is probably an anomaly of data entry or measurement ($p > 0.05$) (Figure 10).The average red blood cell (RBC) level was greater among rural patients (6.54 ± 8.34 $\times 10^{12}$/L) than in urban patients (5.36 ± 4.67 $\times 10^{12}$/L), although this difference was not statistically significant ($p > 0.05$) (Figure 11). Eosinophil counts were consistent at 1.0 among rural patients and 0.0 among urban patients, revealing no measurable fluctuation (Figure 12).

Blood Pressure and Temperature

Average systolic and diastolic blood pressures were equal in groups. Rural patients had systolic BP 108.11 ± 11.61 mmHg and diastolic BP 75.47 ± 11.36 mmHg, whereas urban patients recorded 108.49 ± 11.16 mmHg and 74.72 ± 12.34 mmHg, respectively ($p > 0.05$). Body temperature was more in rural patients (99.66 ± 2.56 °F) compared to urban patients (98.88 ± 2.23 °F), though not statistically significant ($p > 0.05$) (Figures 13,14).

Field Survey Findings

30 dengue-recovered persons from Faisalabad and surrounding areas were included in the field survey. Important observations were:

Gender Distribution: 80% male and 20% female, indicating more outdoor exposure in men.

Vaccination Status: None of the participants had previously been vaccinated with a dengue vaccine at the time of infection.

Vector Control: 20% reported mosquito spraying in their area, but 80% didn't have the same.

Water Usage: 50% of the participants used unfiltered tap water, while 50% utilized filtered water.

Mosquito Breeding Sites: The majority of respondents noticed stagnant water or exposed drains within their vicinity, mainly in rural areas.

Clothing Habits: Short or sleeveless clothing were common among some people because of hot conditions, promoting increased exposure risk.

These results indicate low levels of awareness and preventive behaviors, especially among rural communities.

Vector control practices should be heightened, water practices improved, and health education campaigns implemented to mitigate dengue transmission (Figure 15).

Urban patients had greater initial platelet levels and more labile leukocyte profiles, while rural patients had more consistent but late hematologic recovery. Hemoglobin, PCV, and TLC differences were not significant, but trends indicate baseline health and timing of diagnosis variations. Field survey findings also highlight the necessity of community-based targeted interventions and awareness programs, especially

DISCUSSION

This research highlights how dengue fever presents and progresses differently among patients from urban and rural areas in Pakistan. Urban patients exhibited relatively higher initial platelet counts than rural patients, although both groups remained below the clinical reference range and which is a typical finding in dengue infection. These differences likely reflect earlier hospital presentation and better access to diagnostic facilities in urban settings rather than true biological variation. Prior studies have [5-19]. Thus, the observed difference most likely represents

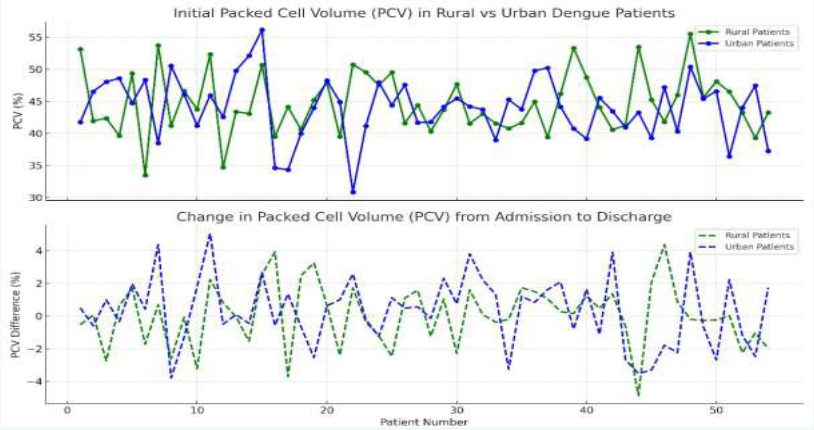

Figure 7: Comparison of Initial and Difference in PCV Levels Between Rural and Urban Dengue Patients

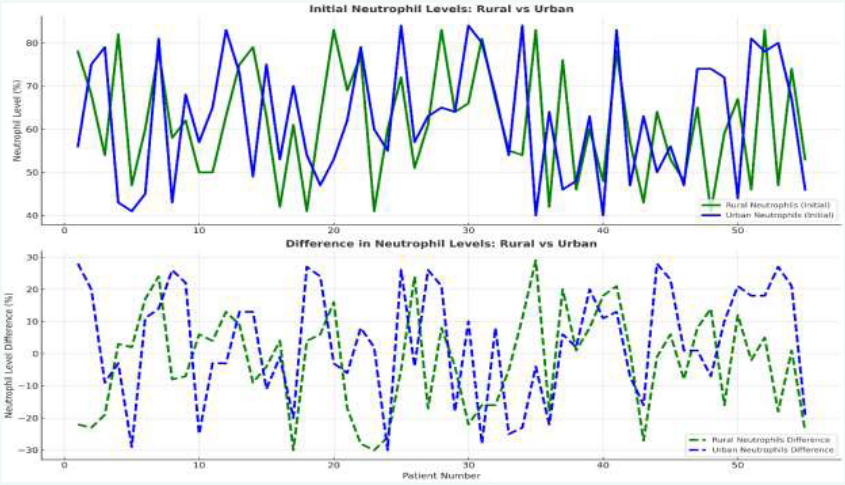

Figure 8: Comparison of Initial and Difference in Neutrophils Levels Between Rural and Urban Dengue Patients.

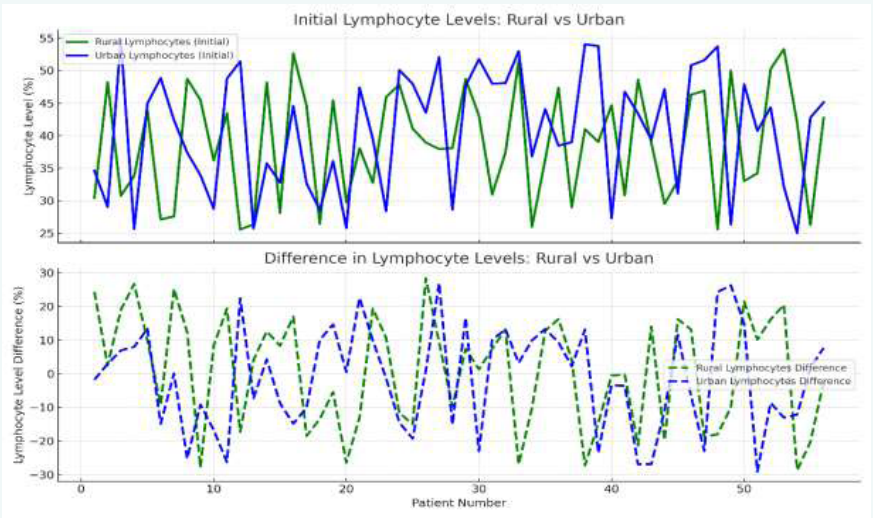

Figure 9: Comparison of Initial and Difference in Lymphocyte Levels Between Rural and Urban Dengue Patients.

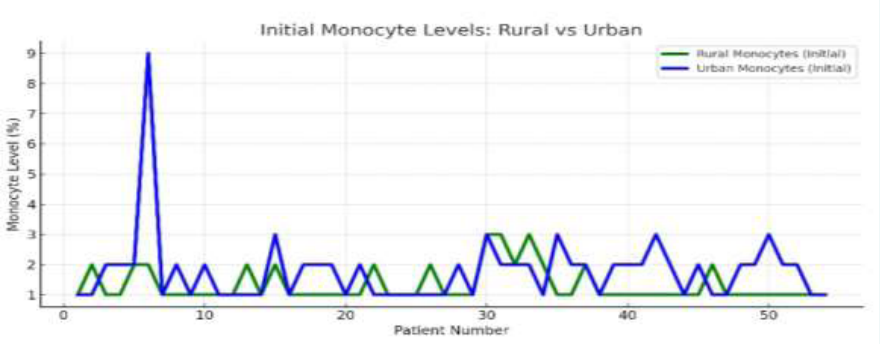

Figure 10: Monocytes in urban vs rural patients

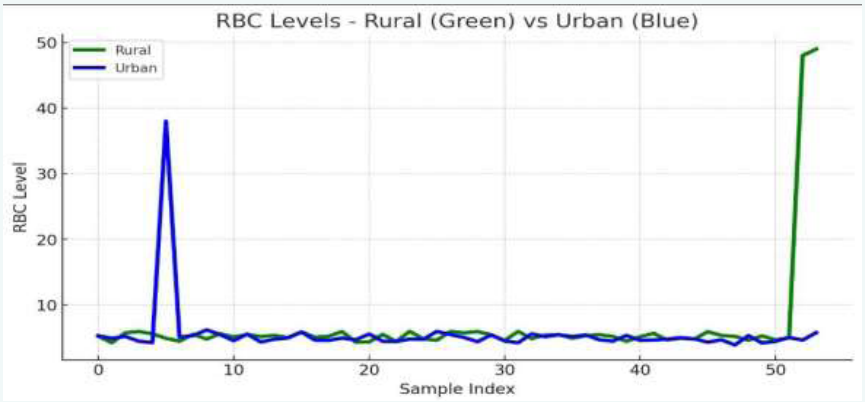

Figure 11: RBC in urban vs. rural patients

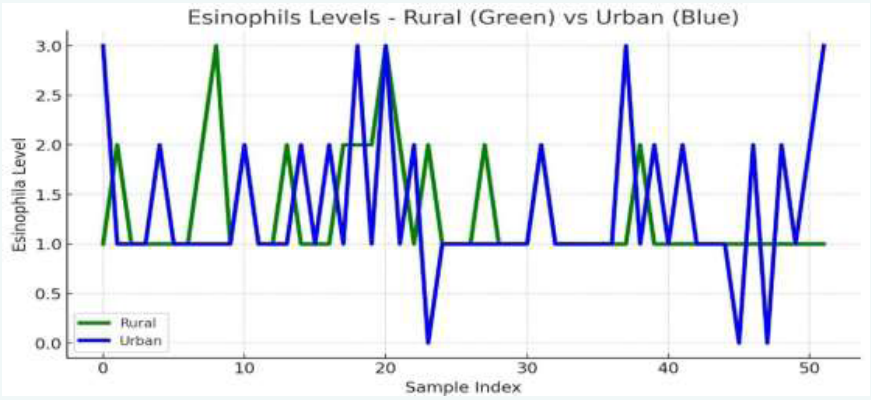

Figure 12: Esinophils in urban vs. rural patients

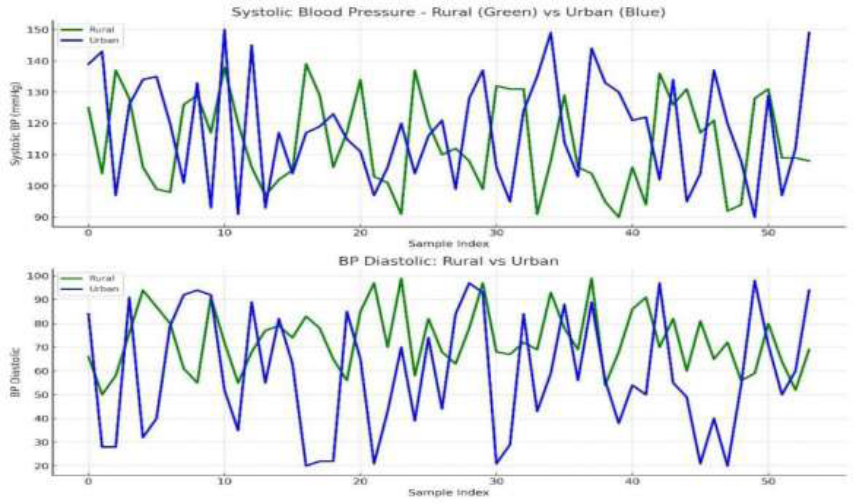

Figure 13: Comparison of BP systolic and BP diastolic in Between Rural and Urban Dengue Patients.

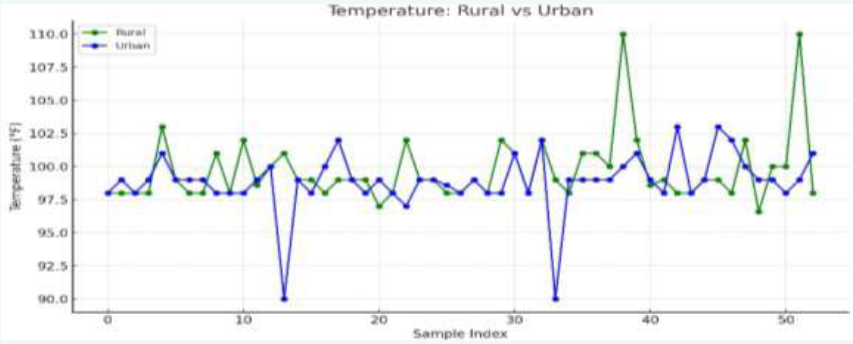

Figure 14: Temperature in urban vs. rural patients

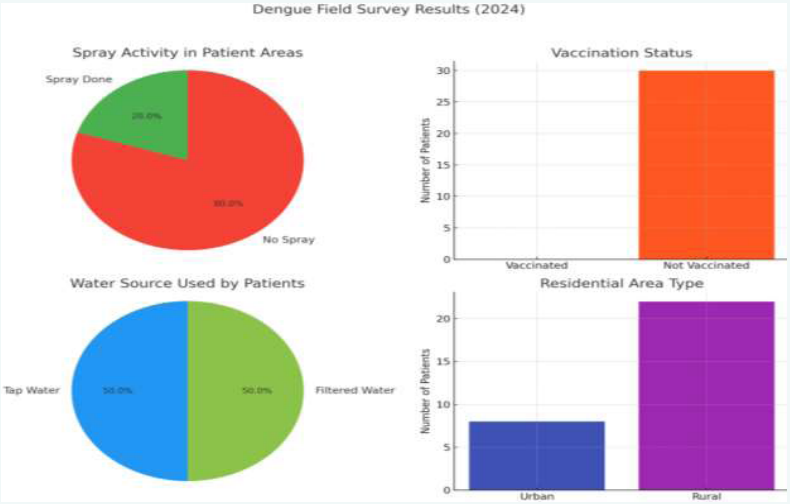

Figure 15: Summary of field survey data on dengue awareness, spray coverage, water usage, and residential area types among 30 respondents in Faisalabad region.

Table 1: Comparison of Clinical and Hematological Parameters between Urban and Rural Dengue Patients (n = 106)

Parameter	Unit	Area	n	Mean	SD	Variance	P value	Significance
Platelets (Initial)	10^9/L	Rural	53	70,547.17	29,604.81	876,444,847.61	**0.032**	**Significant**
		Urban	53	85,528.30	30,376.23	922,715,529.75		
Platelets (Difference)	10^9/L	Rural	53	108,076.92	51,920.18	2,652,170,537.00	0.214	Not significant
		Urban	53	131,384.61		51,456,821,480.00		
TLC (Initial)	10^9/L	Rural	53	5,759.61	8,924.16	79,640,602.30	0.487	Not significant
		Urban	53	5,298.07	4,712.80	22,210,522.50		
TLC (Difference)	10^9/L	Rural	53	454.72	2,218.76	4,922,910.01	0.276	Not significant
		Urban	53	1,120.75	3,407.25	11,609,368.65		
Hemoglobin (Initial)	g/dL	Rural	53	14.2	1.75	3.07	0.193	Not significant
		Urban	53	13.7	1.91	3.66		
Hemoglobin (Difference)	g/dL	Rural	53	-0.53	2.26	5.09	0.355	Not significant
		Urban	53	-0.04	1.12	1.26		
PCV (Initial)	%	Rural	53	42.49	5.19	26.89	0.284	Not significant
		Urban	53	41.17	7.42	55.09		
PCV (Difference)	%	Rural	53	-0.15	5.57	31.03	0.388	Not significant
		Urban	53	1.86	5.29	28.01		

Neutrophils (Initial)	%	Rural	53	61.23	11.56	133.64	0.445	Not significant
		Urban	53	59.48	11.79	139.08		
Neutrophils (Difference)	%	Rural	53	-4.53	13.91	193.50	0.371	Not significant
		Urban	53	-2.90	13.41	179.86		
Lymphocytes (Initial)	%	Rural	53	36.32	10.51	110.52	0.296	Not significant
		Urban	53	39.28	11.33	128.48		
Lymphocytes (Difference)	%	Rural	53	4.19	13.03	169.83	0.478	Not significant
		Urban	53	4.20	13.04	169.94		

Table 2: Comparison of Addtional Laboratory and Vital Parameters between Urban and Rural Dengue Patients.

	Unit	**Area**	**N**	**Mean**	**SD**	**Variance**	**P value**	**Significance**
Monocytes	10^9/L	Rural	53	1.6	0.55	0.30	<0.001	Significant(Data anomaly suspected)
		Urban	53	0	0	0		
RBC Count	10^6/µL	Rural	53	6.54	8.34	69.48	0.142	Not significant
		Urban	53	5.36	4.67	21.80		
Eosinophils	10^9/L	Rural	53	1	0	0	-	Fixed values(no variance)
		Urban	53	0	0	0		

BP Systolic	mmHg	Rural	53	108.11	11.61	134.83	0.856	Not significant
		Urban	53	108.49	11.16	124.60		
BP Diastolic	mmHg	Rural	53	75.47	11.36	129.10	0.644	Not significant
		Urban	53	74.72	12.34	152.32		
Temperature	°F	Rural	53	99.66°F	2.56	6.56	0.227	Not significant
		Urban	53	98.88°F	2.23	4.99		

disparities in healthcare access and response time rather than variation in disease severity.

Rural patients, in contrast, exhibited higher baseline Hemoglobin (Hb) levels and more stable blood counts [6]. These findings may reflect delayed healthcare-seeking behavior and limited medical resources in rural areas. Healthcare practitioners in rural regions often face resource constraints and inadequate diagnostic capacity, which delay the recognition of abnormal hematological changes. Previous studies have shown that delayed diagnosis due to weak monitoring frameworks correlate with poorer outcomes [11]. Recent genomic data from Pakistan supported the presence of multiple co-circulating dengue serotypes, which could potentially account for hematological presentation variability [51]. These findings reinforce the need for strengthened national dengue monitoring and response systems in Pakistan [40].

A clear gender disparity was also observed, with males predominating in both settings. This aligns with earlier studies attributing higher dengue incidence in men to outdoor occupational exposure and longer time spent in mosquito-prone environments [7-21]. Occupational and behavioral patterns likely contribute more than biological susceptibility. In rural regions, men are at greater risk due to outdoor labor, limited awareness, and inadequate protective measures. Delayed care seeking remains a key factor behind poorer outcomes in rural settings [30]. Moreover, the coexistence of multiple dengue virus serotypes may influence disease progression. One study reported that concurrent circulation of several virus serotypes during an epidemic can alter disease severity [28-46]. This may partially explain the clinical differences observed between regions.

Environment and social conditions also play a central role in dengue transmission. While urban centers have better hospitals, they also suffer from dense population, poor waste management, stagnant water, and unplanned settlements that favor mosquito [2-17], rural areas face limited healthcare infrastructure and vector control programs, leading to delayed diagnosis and reduced prevention efforts [13]. Spatial modeling and ecological studies have pointed to rainfall, temperature, and urbanization as important predictors of dengue outbreak occurrence [42-49]. Without regular testing, effective mosquito control, and public awareness campaigns, rural populations remain vulnerable to severe outcomes.

Some hematological variables, specifically monocytes, eosinophils, and red cell counts, exhibited aberrant distributions or zero variance in some groups. These profiles are likely to be an indication of data entry errors or unit variations among hospital labs rather than genuine biological variation. Since all entries had been checked and traced against hospital laboratory records, the data were kept to maintain authenticity but these anomalies were openly mentioned and interpreted cautiously in the findings.

Education and awareness are critical determinants of early detection and prevention. Urban residents are generally more informed about dengue symptoms and seek care earlier. In contrast, low literacy and poor awareness in rural areas delay diagnosis and treatment, increasing the risk of complications. Strengthening community education, vector control initiatives, and health outreach programs can help reduce transmission and improve outcomes. This study addresses an important gap in dengue research in Pakistan by comparing hematological and clinical parameters such as platelet recovery, Packed Cell Volume (PCV), and leukocyte trends between rural and urban patients [15-22]. These regional comparisons illustrate how environment and healthcare disparities shape disease patterns. International reviews and bibliometric analyses have also highlighted the imperative for country-level, contextualized data to enhance dengue management and control [41-47].

Nevertheless, the study has limitations. The use of convenience sampling may introduce bias and limit generalizability [10]. Moreover, as hospital-based data were used, milder community cases might have been underrepresented. Despite these limitations, the findings underscore the importance of region-specific prevention strategies and equitable healthcare access. Improving diagnostic networks, healthcare infrastructure, and public awareness in underserved areas remains essential for reducing the dengue burden in Pakistan [44].

CONCLUSION

This research illustrates measurable differences in the hematological and clinical dengue patient profiles in urban and rural Pakistani populations. While the relatively more rapid recovery patterns among urban patients were observed, the results must be interpreted with some caution since they reflect largely previous hospital presentation and superior access to therapy rather than inherent biological differences.

The findings emphasize the importance of enhanced dengue

surveillance, awareness at the community level, and early consultation to healthcare facilities. Enhancing diagnostic strength and reliable hematologic monitoring in rural hospitals would assist in earlier detection of disease progression and better patient outcomes.

With hospital-based and convenience-sample design of the current study, larger population-based studies are suggested to verify the findings. Ongoing commitment to healthcare infrastructure, vector control, and education initiatives is important in order to decrease the burden of dengue in Pakistan.

ETHICS, DATA AVAILABILITY, AND GOVERNANCE

This study was reviewed and approved by the Departmental Research Committee, Department of Biochemistry, Government College Women University, Faisalabad, Pakistan (Approval Reference No. GCWUF/BCH/2024/12). The corresponding institutional contact for ethics oversight is Dr. Naila Raffique, Department of Biochemistry, Government College Women University, Faisalabad (Email:naila.raffique@gcwuf.edu.pk). Formal Institutional Review Board (IRB) clearance was not required because the research utilized anonymized hospital records and secondary data obtained for routine clinical purposes.

For the field survey component, verbal informed consent was obtained from each participant after explaining the study objectives and ensuring confidentiality and voluntary participation. The use of verbal consent was approved and justified by the departmental ethics committee due to the low-risk, non-invasive nature of the study. Consent was documented in a signed survey logbook containing the date, interviewer's signature, and participant's study code.

All personal identifiers were removed before data entry. The de-identified datasets were stored in password-protected files accessible only to authorized members of the research team. Data were not shared across hospitals, except in aggregated form for statistical analysis. All electronic files were securely stored on university servers with restricted access controls. De-identified data supporting the findings of this study can be made available upon reasonable request to the author Maryam Javed (maryamrajpoot687@gmail.com) or the authorized hospital record custodian, Mr. Asif (asif.hmasif232@gmail.com).

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