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ADMISSION RDW-TO-PCV RATIO AS A PREDICTOR OF SEVERE DENGUE IN CHILDREN: A RETROSPECTIVE OBSERVATIONAL STUDY

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Abstract

Background: Severe dengue in children can lead to significant morbidity and mortality. Early identification is crucial, yet current predictors are limited in practicality for resource-constrained settings. The red cell distribution width to packed cell volume (RDW/PCV) ratio integrates two pathophysiological processes—anisocytosis and haemoconcentration—and can be derived from a single admission complete blood count (CBC).

Methods: This retrospective observational study included children aged 2–12 years admitted with laboratory-confirmed dengue to a tertiary care centre between November 2022 and June 2025. Demographic, clinical, and laboratory parameters from the first 24 hours were extracted. Severity was classified according to WHO 2009 criteria. Associations were assessed using Kruskal–Wallis tests, ROC analysis, and multinomial logistic regression, with subgroup analyses by age, sex, and diagnosis type.

Results: Among 228 children, 26.8% had mild dengue, 67.5% moderate, and 5.7% severe. Median RDW/PCV increased with severity (mild: 0.327; moderate: 0.328; severe: 0.386; $p < 0.001$). The ratio predicted severe dengue with an AUC of 0.939 (95% CI 0.880–0.998); the optimal cut-off of 0.3584 achieved 92.3% sensitivity, 87.4% specificity, and 99.5% negative predictive value. Performance remained robust across subgroups (AUC ≥ 0.89). RDW/PCV was independently associated with severity after adjustment for age, sex, platelet count, and diagnosis category (adjusted OR ≈ 77.8 per 0.01 unit; $p < 0.001$). Higher ratios were also significantly linked to ICU admission ($p < 0.001$). No significant association was found with length of stay.

Conclusions: The RDW/PCV ratio at admission is a simple, inexpensive marker with high diagnostic accuracy for severe pediatric dengue and excellent utility as a rule-out tool. Its incorporation into triage protocols could enhance early risk stratification and optimize pediatric dengue management.

Key words: Dengue fever, Tropical countries, Haematocrit, Fever

INTRODUCTION

Dengue is one of the fastest-growing mosquito-borne viral illnesses worldwide, with marked surges over the last decade (Figure 1). In 2024 alone, WHO recorded >7.6 million cases by 30 April (including >16,000 severe cases and >3,000 deaths), with subsequent updates documenting record global totals through the year, underscoring the sustained expansion of transmission hotspots[1]. Since the beginning of 2025, global surveillance data compiled by the European Centre for Disease Prevention and Control (ECDC) indicate 3.6 million dengue cases and over 1,900 dengue-related deaths reported from 94 countries and territories across all WHO regions (Figure 2)[2]. There are 4 serotypes of the dengue virus (DENV – 1, 2, 3 and 4). Infection with 1 serotype doesn't reduce the risk of infection from other serotypes. Repeated infections increase the risk of severe dengue (SD), which typically manifests around defervescence with plasma leakage, haemoconcentration, and potential shock[3].

Severe dengue carries substantial risks of morbidity (shock, bleeding, organ dysfunction) and mortality, though outcomes improve with early recognition and guided fluid therapy. The 2009 WHO classification (probable dengue, dengue with warning signs, and severe dengue) was designed to support triage and reduce preventable

deaths[4] (Figure 3). Haemoconcentration with a rapid platelet fall is a key warning constellation linked to progression and severe hemorrhage.

India contributes a significant share of the global burden. National data indicate sustained annual caseloads with 289,235 cases and 485 deaths in 2023, and ~230,000 cases and ~300 deaths in 2024; the dengue case-fatality rate has remained <1% nationally (0.13% in 2024)[5]. India's National Guidelines for Clinical Management of Dengue (2023) and the Indian Academy of Pediatrics (IAP) Standard Treatment Guideline emphasize early recognition of warning signs and meticulous monitoring of haemoconcentration as core to pediatric care[6,7].

Despite guideline frameworks, there is no universally adopted, child-specific, low-cost screening tool that reliably flags severe dengue at the point of first contact using routine labs alone. The WHO warning-sign approach aids triage but has variable positive predictive value in real-world pediatric settings, motivating interest in simple hematologic markers and composites to strengthen early risk stratification[8,9].

Pathophysiologically, Packed Cell Volume (PCV) rises with plasma leakage; a defining mechanism of SD; and its magnitude tracks leakage severity, though early fluids can blunt the rise. Red Cell Distribution Width (RDW) reflects anisocytosis driven by inflammation, oxidative stress, hypoxia, and marrow stress (Red cell distribution width)—all pertinent to dengue's systemic inflammatory milieu. RDW has emerged broadly as a cheap, prognostic, inflammation-linked biomarker across diseases, while PCV remains a pragmatic indicator of haemoconcentration in dengue[10].

Combining these mechanisms in a single ratio (RDW/PCV) may enhance discrimination of early severity over either metric alone: PCV captures vascular leak/haemoconcentration, RDW captures systemic inflammatory and erythropoietic stress; the ratio normalizes inter-individual scale differences and can stabilize interpretation when either denominator or numerator varies physiologically or with hydration. This integrative signal is attractive for resource-limited pediatric settings because both inputs come from a routine CBC and are available at admission.

The primary objective of the present study was to evaluate the association between the red cell distribution width to packed cell volume (RDW/PCV) ratio and clinical severity of dengue, as classified by the World Health Organization (WHO), in children aged 2–12 years at the time of hospital admission.

The secondary objectives were threefold. First, to assess the diagnostic performance of the RDW/PCV ratio in predicting severe dengue. Second, to examine the association between the RDW/PCV ratio and the requirement for admission to an intensive care unit (ICU). Third, to explore the relationship between the RDW/PCV ratio and the length of hospital stay among pediatric dengue patients.

METHODS AND METHODOLOGY

This was a retrospective, observational study conducted in the Department of Pediatrics of Saveetha Medical College and Hospital. Medical records were reviewed for all eligible patients admitted between November 2022 and June 2025.The study analysed previously recorded clinical and laboratory data from hospital medical records of children admitted with dengue infection. No direct patient contact or additional investigations were performed.

Inclusion criteria

Medical records were included if they met all the following conditions:

1. Children between 2 and 12 years at the time of admission.
2. Confirmed dengue diagnosis: Laboratory confirmation by either:
    - Positive NS1 antigen, and/or
    - Positive IgM antibody to dengue virus,
    - documented in the hospital records.
3. Admission during the period of study: November 2022 to June 2025
4. Availability of complete clinical documentation and laboratory results from the first 24 hours of hospital admission, including RDW, PCV, and platelet count.

Exclusion criteria

Medical records were excluded if they met any of the following:

1. Pre-existing haematological disorders that could alter RDW or PCV values (e.g., thalassemia, sickle cell disease, aplastic anemia).
2. Chronic systemic illnesses affecting haematologic parameters (e.g., chronic kidney disease, chronic liver disease, malignancy, autoimmune diseases).
3. Recent blood transfusion within 3 months prior to admission, as it could modify RDW and PCV readings.
4. Incomplete records, defined as missing key demographic, clinical, or laboratory parameters necessary for analysis.

5. Mixed infections with other febrile illnesses confirmed by laboratory testing (e.g., malaria, typhoid, leptospirosis).

Data were collected retrospectively from admission notes, laboratory reports, and discharge summaries of eligible patients. For each case, information from the first 24 hours of hospital admission was reviewed and recorded. Demographic variables included age and sex. Clinical variables comprised the World Health Organization (WHO) severity classification of dengue (mild, moderate, or severe), the type of dengue diagnosis (NS1 antigen positive, IgM antibody positive, or probable/suspected), intensive care unit (ICU) admission status, and the length of hospital stay. Laboratory parameters included red cell distribution width (RDW), packed cell volume (PCV), and platelet count, along with the derived RDW/PCV ratio, calculated by dividing the RDW by the PCV.

As this was a retrospective study utilising anonymised data from existing hospital records, with no direct patient interaction or intervention, formal approval from the Institutional Ethics Committee was not required under the institution's research policy and applicable national guidelines for biomedical research. All data were de-identified prior to analysis to maintain patient confidentiality.

Statistical analysis

Data were analysed using non-parametric statistical tests to compare continuous variables across severity categories. ROC curve analysis determined the optimal RDW/PCV ratio cut-off for predicting severe dengue, with sensitivity, specificity, and AUC calculated. Multinomial logistic regression identified the independent predictive value of RDW/PCV for clinical severity, adjusting for other variables. Statistical significance was set at $p < 0.05$.

RESULTS

*Baseline characteristics of the study population:*A total of 228 children aged between 2 and 12 years with laboratory-confirmed dengue were included in the analysis. According to the WHO 2009 classification, 61 patients (26.8%) had mild dengue, 154 (67.5%) had moderate dengue, and 13 (5.7%) had severe dengue. The mean (±SD) age was 7.24 ± 3.17 years in the mild group, 6.76 ± 2.97 years in the moderate group, and 7.25 ± 3.26 years in the severe group. Sex distribution was balanced across groups, with males comprising 41.0%, 50.6%, and 38.5% of the mild, moderate, and severe categories, respectively. The median (IQR) platelet count decreased progressively with severity, from 0.84 (0.61–1.13) × 10^5/µL in mild cases to 0.79 (0.55–1.01) × 10^5/µL in moderate and 0.59 (0.43–0.77) × 10^5/µL in severe cases. The median (IQR) length of hospital stay was 3.94 (3.12–4.95) days for mild dengue, 6.26 (4.77–7.52) days for moderate dengue, and 8.09 (6.31–9.34) days for severe dengue (Table 1).

*Association between RDW/PCV ratio and clinical severity:*The median RDW/PCV ratio increased progressively from mild [0.327 (0.311–0.344)] to moderate [0.328 (0.314–0.350)] to severe cases [0.386 (0.373–0.400)], and the difference across the three severity groups was statistically significant (Kruskal–Wallis $\chi^2 = 28.37$, $p < 0.001$) (Figure 4). Pairwise comparisons showed that the severe group had significantly higher RDW/PCV ratios than both the mild and moderate groups, while the difference between mild and moderate was smaller and not statistically significant after adjustment.the RDW/PCV ratio retained high discriminatory performance across demographic categories.

*Diagnostic performance of RDW/PCV ratio for severe dengue:*Receiver operating characteristic (ROC) analysis for the RDW/PCV ratio in predicting severe dengue yielded an area under the curve (AUC) of 0.939 (95% CI: 0.880–0.998, $p < 0.001$), indicating excellent discrimination (Figure 5). The optimal cut-off value, determined by Youden's index, was ≥0.3584, which provided a sensitivity of 92.3% and specificity of 87.4%. At this threshold, the positive predictive value was 30.8% and the negative predictive value was 99.5%, with an overall diagnostic accuracy of 87.7% (Table 2).In children aged ≥6 years (n = 135), the AUC for predicting severe dengue was 0.972, compared to 0.893 in those aged <6 years (n = 93). Among males (n = 108), the AUC was 0.973, and among females (n = 120), it was 0.919 (Table 3).

*Multinomial logistic regression analysis:*Multinomial logistic regression analysis confirmed RDW/PCV as an independent predictor of dengue severity after adjusting for age, sex, platelet count, and diagnosis category. Each 0.01 increase in RDW/PCV was associated with markedly higher odds of severe dengue compared to mild disease (adjusted OR ≈ 77.8, $p < 0.001$). The final model showed excellent fit ($\chi^2 = 309.43$, df = 10, $p < 0.001$) with a Nagelkerke R^2 of 0.940.

*Association with ICU admission:*When stratified by ICU admission, patients requiring intensive care had significantly higher RDW/PCV ratios than those managed in the ward (median 0.379 vs 0.328, $p < 0.001$). Using the ≥0.3584 cut-off, the risk ratio for ICU admission was elevated, while the negative predictive value for excluding ICU need exceeded 95%.

Relationship between RDW/PCV ratio and length of hospital stay: The RDW/PCV ratio showed a weak, non-significant correlation with length of hospital stay ($R^2 = 0.008$, $p > 0.05$), suggesting its principal utility lies in early severity triage rather than predicting recovery duration (Figure 6).

DISCUSSION

In this retrospective pediatric cohort, the RDW/PCV ratio measured at admission showed a graded association with WHO-classified dengue severity and excellent discriminatory ability for severe disease (AUC ≈ 0.94). The optimal cut-off of 0.358 yielded high sensitivity (92.3%) and a very high negative predictive value, suggesting that the ratio is particularly useful for early rule-out of severe dengue in children.

Our findings are biologically plausible. Plasma leakage in the critical phase leads to haemoconcentration, captured clinically by an increase in haematocrit (PCV), while systemic inflammation and bone marrow stress contribute to anisocytosis and elevated RDW. This dual pathophysiological basis supports combining the two parameters. As *Nandwani S et.al.* showed, haematocrit rises (>20% from baseline) can precede thrombocytopenia in severe dengue[11], making it an important early marker of plasma leakage. Similarly, *Nandhini RV et.al.* found significantly higher RDW in non-survivors and those with organ dysfunction, linking anisocytosis to poor outcomes[12]. By normalizing RDW to PCV, the RDW/PCV ratio integrates these complementary processes into a single, scale-free metric derived from a standard CBC.

The pattern we observed—a progressive rise in RDW/PCV from mild to severe dengue—mirrors the findings of *Day et al.* in their serial CBC study of pediatric dengue, which documented higher RDW values and early haematocrit increases in severe cases[13]. *Day et al.* also emphasized the importance of temporal trends, but in resource-limited settings, a single admission measurement often determines triage decisions[13]. Our study demonstrates that this single-time-point ratio retains strong prognostic power.

Comparatively, *Sahassananda et al.* evaluated the relationship between haematocrit and haemoglobin in adult dengue and found that high RDW (>18%) weakened this correlation, suggesting that anisocytosis could confound the use of haematocrit alone[14]. This supports our finding that the RDW/PCV ratio may be more robust than either parameter individually.

More complex predictive models, such as the alternating decision tree approach of *Kumar et al.*, can achieve high accuracy but rely on multivariable inputs, including biochemical markers not always available at admission[15]. The RDW/PCV ratio offers a simpler, low-cost, and rapid alternative suitable for routine pediatric use.

The high negative predictive value in our study suggests that children below the cut-off are at low short-term risk of deterioration, enabling safe ward management and focusing monitoring resources on higher-risk patients. The ratio performed consistently across subgroups (age, sex, diagnostic method), reinforcing its potential for broad applicability.

We did not find a significant association between RDW/PCV and length of hospital stay, which is consistent with *Day et al.*'s observation that duration of hospital stay is influenced more by admission timing and local discharge practices than by admission-day haematological parameters[13]. This underlines that the primary value of RDW/PCV is in early severity triage rather than prognosis for recovery duration.

Strengths of our work include the use of a single, universally available test, subgroup performance analysis, and integration of biological plausibility with clinical utility. Limitations include the retrospective, single-centre design, potential confounding by comorbid conditions (iron deficiency, hemoglobinopathies), small numbers of severe cases affecting precision, and lack of serial measurements. Additionally, hydration status at sampling could influence PCV values, potentially attenuating the association with severity.

CONCLUSION

This study demonstrates that the red cell distribution width to packed cell volume (RDW/PCV) ratio, calculated from a single admission complete blood count, is a simple, cost-effective, and biologically grounded marker for predicting severity in pediatric dengue. A higher RDW/PCV ratio was strongly associated with WHO-defined severe dengue and the need for intensive care, with excellent diagnostic performance and a very high negative predictive value, making it particularly valuable as a rule-out tool in resource-limited settings.

By integrating markers of systemic inflammation and anisocytosis (RDW) with haemoconcentration from plasma leakage (PCV), the RDW/PCV ratio captures two key pathophysiological processes that underlie disease progression. The consistency of its performance across age groups, sexes, and diagnostic categories further supports its potential for universal applicability in pediatric dengue triage.

While these findings need validation in larger, multicentre prospective cohorts and exploration of illness-day-specific thresholds, the RDW/PCV ratio holds promise as an adjunct to established WHO warning signs and platelet trends. Its incorporation into admission assessment protocols could facilitate earlier identification of children at risk of deterioration, optimize allocation of monitoring and treatment resources, and ultimately contribute to reducing dengue-related morbidity and mortality.

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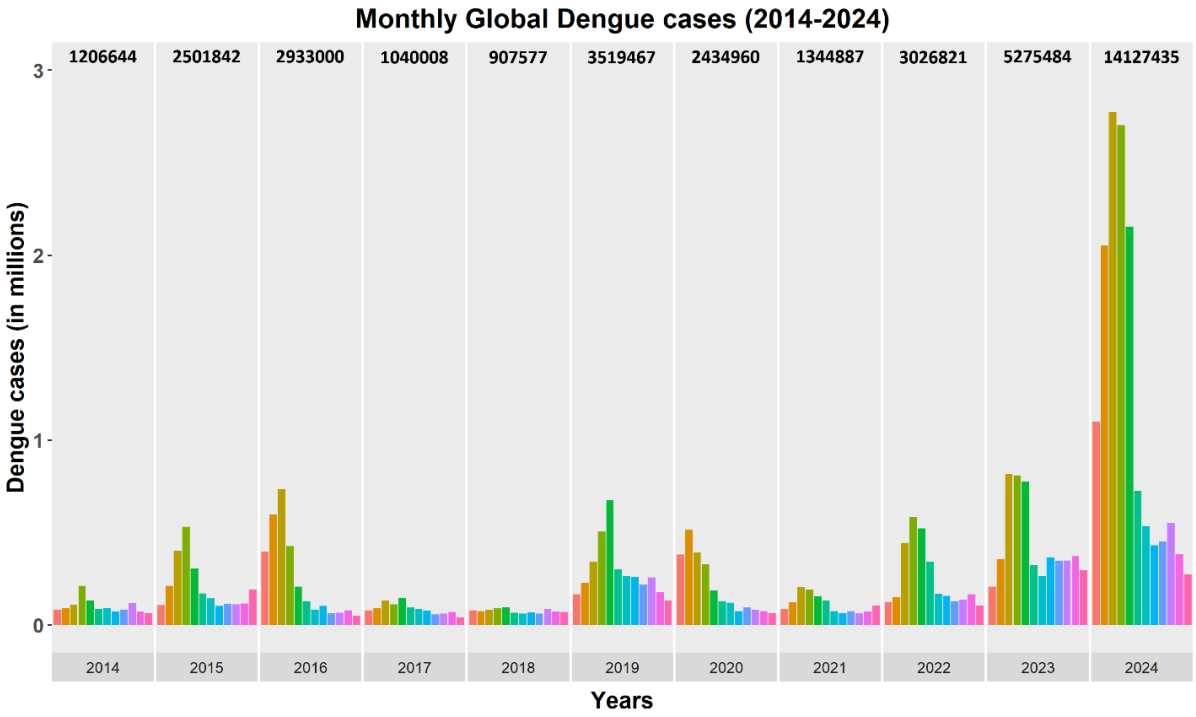

Figure 1: Monthly Global Dengue Cases, 2014–2024[16]

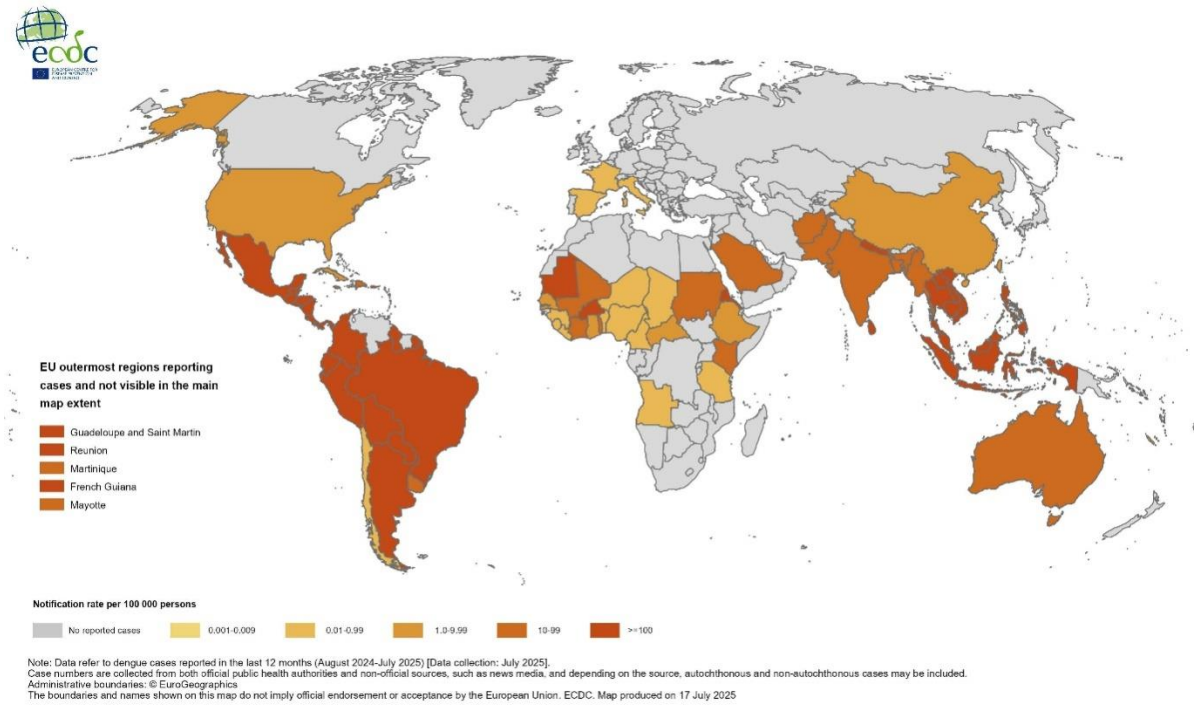

Figure 2: Global Distribution of Reported Dengue Cases (ECDC, July 2025)[2]

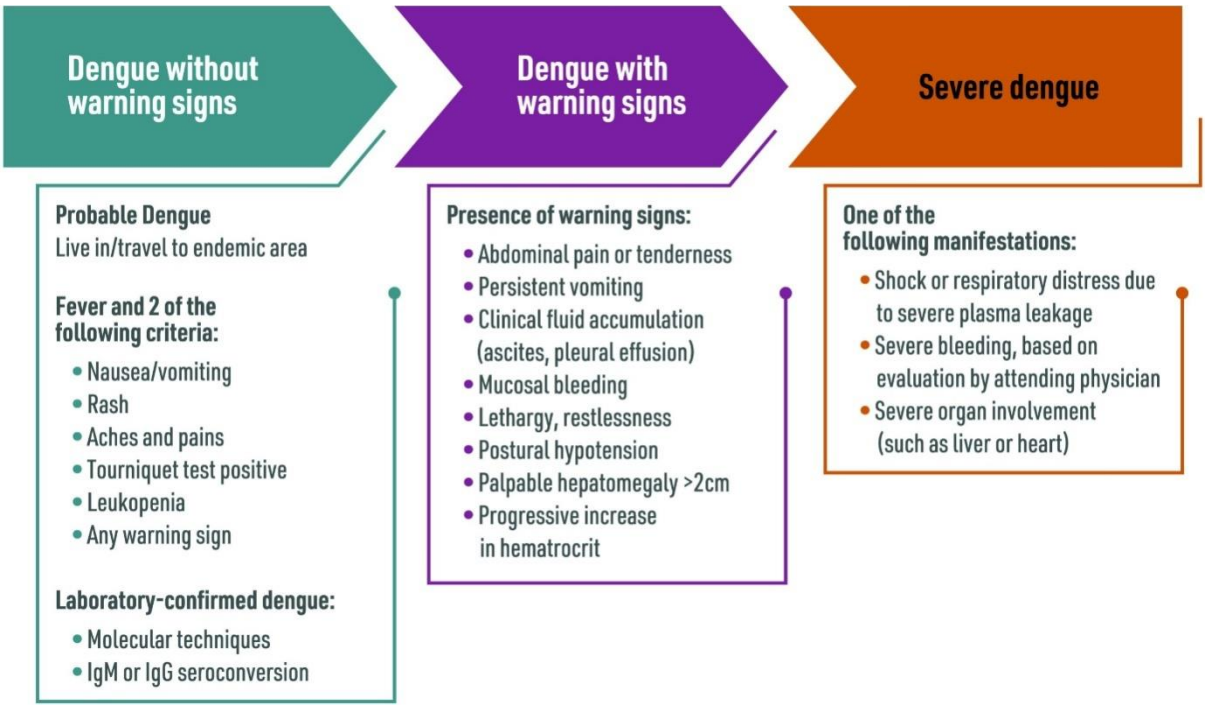

Figure 3: WHO 2009 Classification of Dengue Severity and Warning Signs[3]

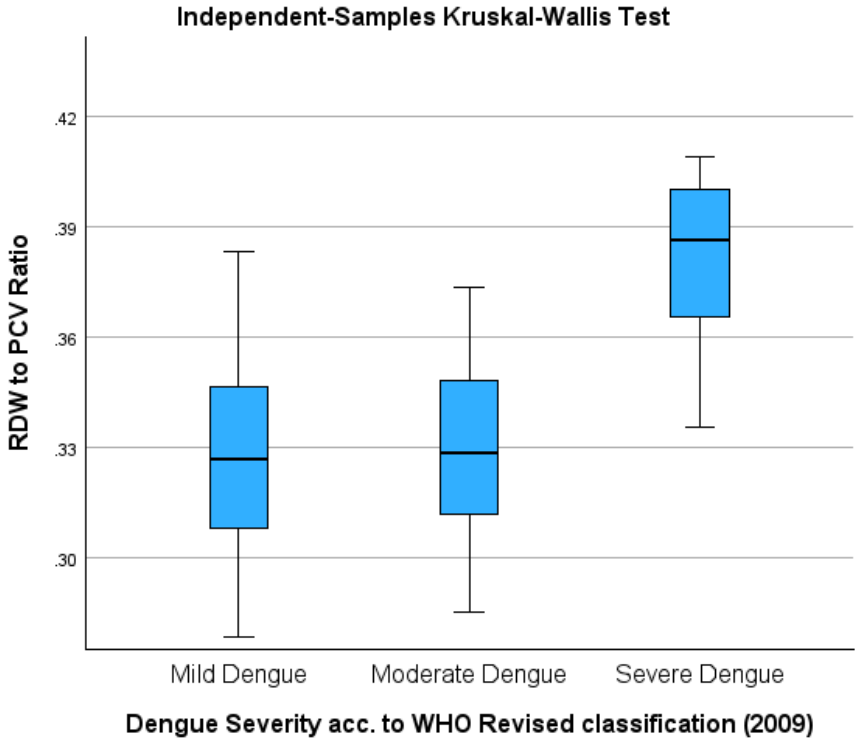

Figure 4: Distribution of RDW to PCV ratio across dengue severity categories according to WHO 2009 classification

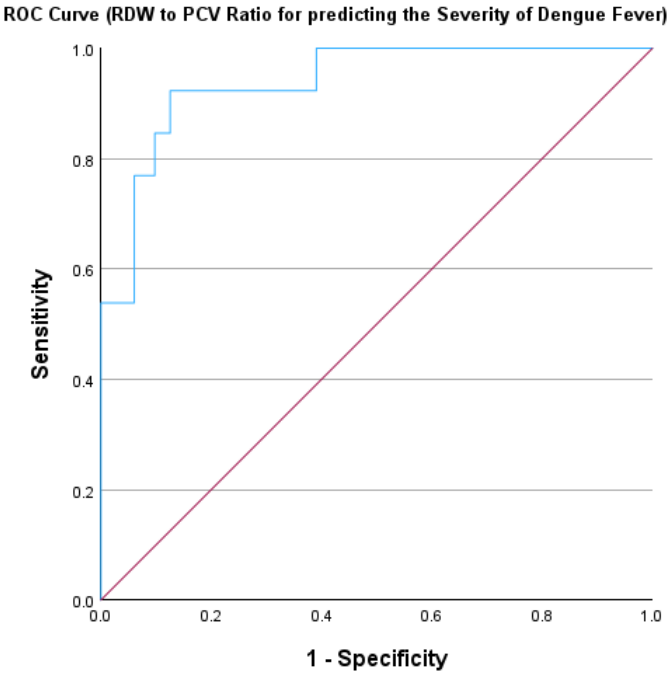

Figure 5: Receiver operating characteristic (ROC) curve for RDW to PCV ratio in predicting severe dengue

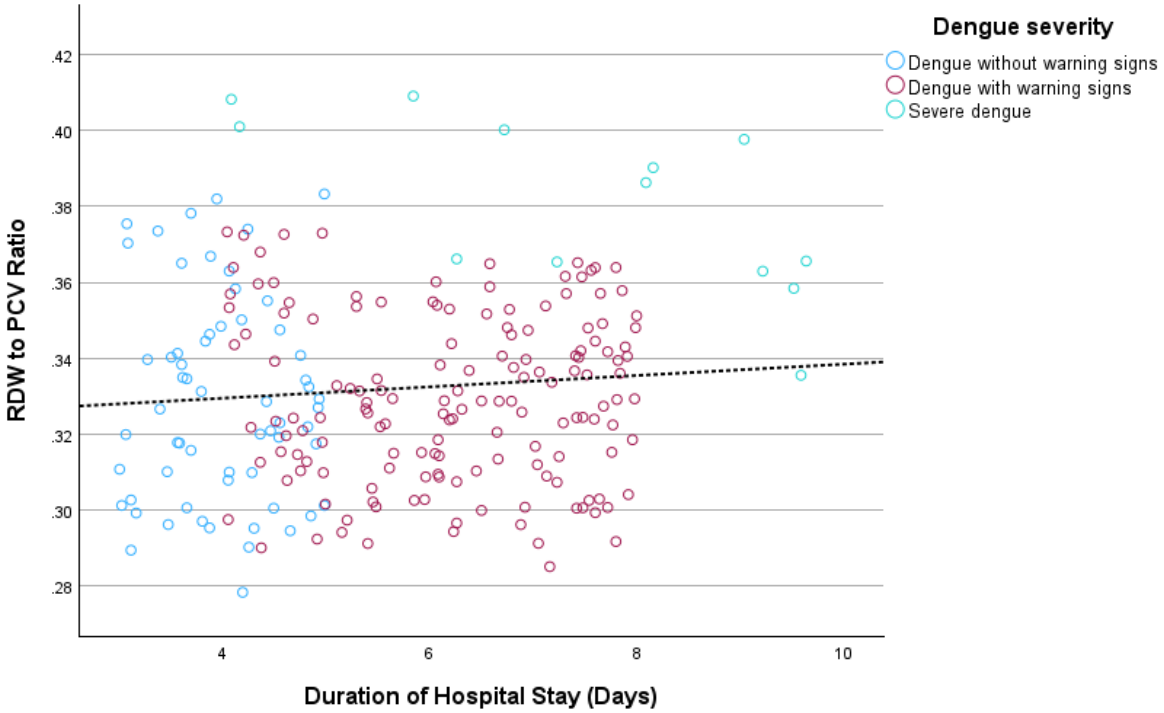

Figure 6: Scatter plot showing the relationship between RDW to PCV ratio and duration of hospital stay, stratified by dengue severity

Characteristic	Mild (n = 61)	Moderate (n = 154)	Severe (n = 13)
Age, years (mean ± SD)	7.24 ± 3.17	6.76 ± 2.97	7.25 ± 3.26
Male sex, n (%)	25 (41.0)	78 (50.6)	5 (38.5)
Female sex, n (%)	36 (59.0)	76 (49.4)	8 (61.5)
RDW (%) (median)	13.6	14.43	16.88
PCV (%) (median)	41	43.92	42.77
RDW/PCV ratio (median)	0.327	0.328	0.386
Platelet count ($\times 10^5$/µL) (median)	0.84	0.79	0.59
Length of stay, days (median)	3.94	6.26	8.09

Table 1: Baseline characteristics of study participants according to dengue severity

Metric	Value
AUC (95% CI)	0.939 (0.880–0.998)
Optimal cut-off	0.3584
Sensitivity	92.30%
Specificity	87.40%
Positive predictive value (PPV)	30.80%
Negative predictive value (NPV)	99.50%
Accuracy	87.70%

Table 2: Diagnostic performance of RDW/PCV ratio in predicting severe dengue

Subgroup	Cut-off	AUC	p-value	95% CI	Sensitivity	Specificity
Age ≥6 years	0.3584	0.97	<0.001	0.940 – 1.000	92.3	88.1
Age <6 years	0.3584	0.89	<0.001	0.819 – 0.967	92.3	84.7
Male	0.3584	0.97	<0.001	0.948 – 0.999	92.3	88.9
Female	0.3584	0.92	<0.001	0.856 – 0.982	92.3	86.7

Table 3: Subgroup analysis: diagnostic performance of RDW/PCV ratio for predicting severe dengue