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The Epidemiology of Dengue Fever: Comparative Analysis of Urban and Rural Transmission Dynamics

Easa Saiban Mawikli[1], Abdullah Ibrahim Murir[2], Mohammed Alhusayni[3], Mubarak Saad Zuraib Aldosari[4], Abdullah Obaed Wasel Alhejaili[5], Mohammed Ibrahim Alzamil[6], Sami Mohmed Ahmed Hijan[7], Jalal Ahmed Mohammed Sabi[8], Samiali Mohammed Shaqarah[9], Mohammed Jaber Abdullah Ali[10], Abdulkarim Abdulaziz Mahmad Alyousef[11], Ali Ahmed Ali Alamri[12], MOHAMMED ESSA ABU TAWIL[13]

Abstract

Dengue fever poses a significant public health challenge, with over 3 billion individuals at risk globally. Traditionally, urban environments have been associated with higher dengue transmission rates, primarily due to dense populations and favorable conditions for Aedes aegypti proliferation. However, recent studies indicate a notable increase in dengue prevalence in rural areas.This study conducted a comprehensive literature review, employing Medical Subject Headings (MeSH) and keyword searches across multiple databases, including PubMed, Embase, and Web of Science. The analysis focused on defining rurality, examining transmission mechanisms, and comparing dengue incidence between urban and rural settings.The findings reveal that dengue transmission risk in rural regions often equals or exceeds that in urban areas. Variability in definitions of rurality complicates the assessment of dengue dynamics. Many rural areas exhibit characteristics traditionally linked to urban settings, such as increased human mobility and altered land use patterns, which can enhance vector breeding sites and transmission rates.The study underscores the necessity for enhanced surveillance and understanding of dengue transmission in rural contexts. It emphasizes that while population size is relevant, environmental and infrastructural factors significantly influence dengue risk. Effective public health interventions must address these complexities, especially as rural areas increasingly contribute to dengue epidemiology.

Keywords: *Dengue Fever, Epidemiology, Urban Transmission, Rural Transmission, Aedes Aegypti.*

Introduction

Dengue represents a considerable public health concern, with over half of the global population residing in endemic regions and over 3 billion individuals at risk [1]. Approximately 96 million symptomatic dengue cases are reported annually, likely an underestimate owing to underreporting and misinterpretation, especially in nations with inadequate surveillance systems or limited diagnostic capabilities [2,3]. Urban areas have traditionally been perceived as having a heightened vulnerability to dengue due to escalating population density, which facilitates the transmission of the dengue virus (DENV) by vectors to extensive groups of susceptible individuals without necessitating long-distance flight; increased human mobility to and from transmission hotspots; infrastructural failures, such as the collapse of water and waste management systems;

[1] KSA, Ministry Of Health, Jazan Health Cluster
[2] KSA, Ministry Of Health, Jazan General Hospital
[3] KSA, Ministry Of Health, Al-Dawadmi General Hospital.
[4] KSA, Ministry Of Health, Al-Sulayyil General Hospital.
[5] KSA, Ministry Of Health, Health Control Center At Prince Mohammed Bin Abdulaziz Airport In Madinah
[6] KSA, Ministry Of Health, Vector Control At Dawadmi Hospital
[7] KSA, Ministry Of Health, Jazan Health Cluster Abu Arish General Hospital
[8] KSA, Ministry Of Health, Mental Health Hospital
[9] KSA, Ministry Of Health, Abu Arish North Health Center
[10] KSA, Ministry Of Health, PRINCE MOHAMMED BIN NASSER GAZAN
[11] KSA, Ministry Of Health, Al Khalidiya Health
[12] KSA, Ministry Of Health, Prince Mohammed Bin Nasser Hospital
[13] KSA, Ministry Of Health, Prince Mohammed Bin Nasser Hospital

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and human activities that create numerous urban-associated oviposition sites for *Aedes aegypti*, including discarded tires, small water-holding vessels, and larger containers used for domestic water storage [4-8]. These conditions promote vector proliferation in metropolitan settings that possess the demographic and other prerequisites for continuous arboviral transmission [9].

Dengue research has mostly, but not solely, focused on viral transmission in urban environments [2,10–16]. Nonetheless, a growing body of research has shown elevated prevalence of DENV infections in rural communities [4,17–19]. Some have hypothesized that the rise in rural DENV transmission is attributable to the escalation of human travel [20]. Global advancements in transportation infrastructure have enhanced transit between urban and rural areas, as well as human mobility to distant places, hence promoting the movement of viruses into and out of rural environments [21]. Moreover, several urban characteristics often associated with heightened risk may progressively manifest in rural regions, such as increased population density and environments conducive to Ae. aegypti proliferation. Consequently, due to the often-asymptomatic nature of DENV infections [1], the infection load may be overestimated in impoverished or rural areas where monitoring systems are inadequately established. Rural DENV transmission is becoming acknowledged as vital for sustaining serotype diversity in populations and may promote disease reemergence [22–24].

Definitions of rurality exhibit considerable variability within the dengue literature. Researchers have delineated rural environments according to various criteria, including population size, population density, housing density, infrastructure or land cover type (impervious surfaces, vegetation), proximity to urban areas or distance to roads/urban centers, environmental alterations (encompassing changes in landscapes, rural production systems, climate, land use, and transportation infrastructure), and agricultural practices [4,17,25-33]. A definition pertinent to surveillance and mitigation may consist of a function, subset, or amalgamation of these characteristics and may differ by area. Our primary objective is to consolidate rurality indices used in contemporary epidemiological research on DENV transmission in the context of evolving and heterogeneous habitats. To accomplish this objective, we performed three subanalyses: to examine how authors delineated rural areas and the mechanisms of rural transmission; to synthesize papers comparing the incidence of rural dengue with urban estimates; and to evaluate dengue seroprevalence and incidence in rural regions.

Methods

Searches using Medical Subject Headings (MeSH) and text words about dengue and urbanicity were conducted in PubMed, Embase, and Web of Science. The following MeSH and keyword phrases were used in PubMed, Embase, and Web of Science: ("rural population" or "rural health" or "urbanization") AND ("dengue" or "Dengue virus").

Definitions and Methods of Dengue Transmission in Rural Areas

The study authors used many definitions of rurality, grounded on political criteria, demographic attributes, environmental and land utilization practices, proximity and trip duration to metropolitan areas, and transportation infrastructure. The criteria of rurality in this research are based on postulated or assumed processes and characteristics associated with rural DENV transmission [34, 35]. The diverse definitions and extensive array of suggested mechanisms underscore the difficulty in comprehending rural DENV transmission dynamics and the capacity to compare findings across research. This conclusion aligns with previous studies indicating that definitions of "rural" differ by location [36–38] and that several factors, outside those traditionally categorized as "rural" traits, influence risk.

Although several factors were referenced by just a limited number of writers, environmental exposures and local infrastructure were regularly cited as both criteria for defining rural regions and as later determinants of dengue prevalence. In most cases, rural drivers of DENV transmission seemed to be locally localized and did not exhibit a correlation at aggregate levels. We could not detect a significant correlation between population size and rural dengue seroprevalence. This indicates that population size may influence DENV infection in some rural areas, although it is inadequate to account for the prevailing worldwide patterns

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shown in the literature. Consequently, the population may not serve as a sufficient proxy for rurality alone. Local variations in population size may be more effective in delineating local risk patterns than in establishing global transmission levels. Regrettably, we were not equipped to evaluate the influence of population size on incidence studies. Subsequent research evaluating the influence of population size may provide a further understanding of this correlation.

Many publications we examined also detailed the evolving characteristics of rural contexts linked to heightened transmission. The factors include a heightened prevalence in politically designated rural areas exhibiting multiple "urban" characteristics [6,39,40]; enhancements in infrastructure and vector control measures in urban locales, such as consistent water supply [6,41,42], which exacerbate the disease burden in more rural regions lacking similar infrastructure advancements; and alterations in rural environments that may facilitate DENV transmission, including the increased presence of plastics, the expansion of new roadways, and modifications in land use [6,9,25,43-49]. The altering rural landscapes and the increasing human-environment interactions may influence the differential transmission of DENV across diverse rural and urban contexts.

Risk of Dengue in Rural and Urban Regions

Our findings indicate that the risk of DENV transmission in rural regions is often equal to or exceeds that in metropolitan areas. This study indicates that although several studies highlight rural dengue as an expanding concern, it also demonstrates the intricacy of dengue in rural areas, revealing that dengue transmission cannot be well understood via a rural vs urban dichotomy. As rural transmission escalates, the articles in our review indicate that continued urbanization may establish a feedback loop, wherein new land and network development could facilitate closer integration of rural sectors with urban sectors, thereby enhancing the movement of individuals, goods, and services between these areas. In our review, the influence of urbanization on dengue transmission has been specifically linked to regional development, including the construction of new roads and the enhancement of transportation systems, which may facilitate the importation of infected individuals and contribute to the growth of population densities or sizes [6,7,9,25,49-59]. This has led to communities facing additional issues that may exacerbate DENV transmission, including insufficient waste management systems and altered water storage practices. Additional modifications, such as alterations to housing infrastructure or land use, may augment vector densities by further transforming breeding grounds and enhancing human exposure to the environment. These variables may generate environmental zones of elevated and diminished risk that intersect the politically delineated rural and urban areas [21].

The Prevalence of Dengue in Rural Regions

Although our findings do not definitively establish an increase in incidence in rural regions, many other pieces of evidence from our research corroborate this assertion. Four studies that categorized rural seroprevalence by age indicate a rising seroprevalence among children over time [57,60,61]. This suggests that the mean age of first infection may be declining but rural incidence may be rising over time. Certain investigations indicated a rising incidence with time; however, regional comparisons were challenging due to the cyclical nature of DENV transmission and the variability of general patterns based on the time frame used. In general, extended time scales are less prone to this tendency. Consequently, future research may provide more accurate estimations by using extended follow-up investigations.

The observed incidence of dengue may be attributable to an actual rise or influenced by other variables. Enhanced surveillance methods may result in more accurate case reporting, despite the incidence being constant. We observe that a limited number of research provides enough evidence to differentiate between these two alternatives. Comprehensive laboratory data that include seroprevalence and prospective incidence information from cohort studies might elucidate these two pathways. The techniques used in case ascertainment may significantly influence the documented connection with dengue in the literature. Numerous papers included in our study originate from passive hospital-based monitoring systems [4,6,9,49,53,61,62,63], perhaps leading to an underrepresentation of rural cases. These methods are ineffective in identifying individuals who do not pursue healthcare and those with milder symptoms [44,64],

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a situation perhaps exacerbated by transportation difficulties in more rural or economically disadvantaged regions. The total incidence of dengue in the publications reviewed was often lower in studies using passive surveillance systems than in those utilizing more aggressive case-finding approaches.

Additional variables influencing the variability of DENV rural estimates may include study size, differing definitions of rurality, and localized variations in processes. The discrepancies in estimates may be attributable to the sample sizes and aggregation methods used in several research. Numerous research included limited sample sizes, making their quantitative estimates less dependable. Additionally, most studies evaluated dengue seroprevalence in extensive rural regions or amalgamated rural estimates from various villages, yielding very large rural populations with case differences across individual locations [58,65]. Although these studies may better reflect rural people overall, aggregating communities in this manner hindered our ability to assess the influence of individual community size on dengue risk.

Although it is improbable that the isolated rural locations discussed in our research had a population enough to maintain endemic levels of dengue, some writers have posited that transportation networks among rural settlements create population dynamics akin to those of metropolitan centers [67]. Others have seen the influence of a sylvatic cycle and exposure to natural habitats on rural DENV transmission [58,59,68,69]. Regions in proximity to dense vegetation and monkeys may facilitate spillback sylvatic transmission and the intermittent reintroduction of arboviruses. Although none of the examined publications provided conclusive evidence of sylvatic DENV transmission to people [69,70], some have addressed how alterations in rural land use might heighten the risk of human exposure to current natural transmission cycles [58,59,68]. If rural dengue is independently supported by extensive networks of rural people or by reintroduction via sylvatic cycles, it is plausible that rural circulation might adequately maintain a reservoir. High immunity in metropolitan centers, along with expanding mobility networks, may enable the return of DENV into these areas once population immunity diminishes.

Constraints

The principal constraint of this study was the variable quality of surveillance systems in the literature and the absence of longitudinal data, which hindered the assessment of changes in dengue burden over time. Secondly, although our inclusion criteria emphasized studies conducted in rural locations, permitting urban areas only if directly compared with rural sites by the same research group, this approach excluded a significant amount of incidence data from urban sites, potentially constraining our capacity to compare incidence between urban and rural areas more broadly. Furthermore, in light of the absence of an international agreement on the definitions of "rural" and "urban," we used regional definitions as advised by the UN [38]. Consequently, research in one area indicated rural dengue may have been categorized as urban in a different setting. We are optimistic that the comprehensive data obtained in this study may facilitate the advancement of uniform definitions in the next investigations.

Conclusions and Implications for Public Health

There is an urgent need to enhance comprehension of the evolving and perhaps escalating burden of DENV transmission in rural regions. Although population size may correlate with dengue risk, our findings indicate that comprehending the environmental and infrastructural factors that influence risk may be as, if not more, significant than the sheer population number. As rural populations expand, our research indicates that infrastructure enhancements are necessary to reduce population vulnerability. Reliable water systems and proper waste disposal may alleviate worries about the increasing frequency of dengue by reducing breeding habitats. The expansion of transportation networks may link smaller rural areas, hence augmenting the effective population size. Effective surveillance methods for monitoring dengue incidence in rural regions might facilitate the identification of emerging population risk surges associated with infrastructural changes, such as transportation developments. Without such actions, sometimes underfunded rural areas may significantly contribute to the spread of dengue illness, acting as both producers of new infections and reservoirs for introductions from other regions, often unnoticed. The increasing urbanization of these infrastructural elements may establish a feedback loop that perpetuates the rise of incidence in rural regions.

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Enhanced identification of critical dengue risk factors in rural areas would facilitate monitoring and aid in formulating contextually suitable intervention methods.

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وبائيات حمى الضنك: تحليل مقارن لديناميكيات الانتقال في المناطق الحضرية والريفية

الملخص

الخلفية :تشكل حمى الضنك تحديًا كبيرًا للصحة العامة، حيث يتعرض أكثر من 3 مليارات شخص حول العالم لخطر الإصابة. تقليديًا، ارتبطت البيئات الحضرية بمعدلات انتقال أعلى لحمى الضنك، ويرجع ذلك بشكل أساسي إلى الكثافة السكانية العالية والظروف الملائمة لتكاثر بعوض *Aedes aegypti*. ومع ذلك، تشير دراسات حديثة إلى زيادة ملحوظة في انتشار حمى الضنك في المناطق الريفية.

الطرق :أُجريت مراجعة شاملة للأدبيات باستخدام رؤوس موضوعات طبية (MeSH) وكلمات مفتاحية عبر قواعد بيانات متعددة، بما في ذلك PubMed و Embase و Web of Science. ركز التحليل على تعريف المناطق الريفية، دراسة آليات الانتقال، ومقارنة معدلات الإصابة بحمى الضنك بين المناطق الحضرية والريفية.

النتائج :أظهرت النتائج أن خطر انتقال حمى الضنك في المناطق الريفية غالبًا ما يساوي أو يفوق ذلك في المناطق الحضرية. ومع ذلك، فإن تباين تعريفات المناطق الريفية يعقد تقييم ديناميكيات حمى الضنك. تُظهر العديد من المناطق الريفية خصائص تقليدية ترتبط بالمناطق الحضرية، مثل زيادة التنقل البشري وتغير أنماط استخدام الأراضي، مما يؤدي إلى تعزيز مواقع تكاثر النواقل ومعدلات الانتقال.

الخلاصة :تؤكد الدراسة على ضرورة تعزيز المراقبة والفهم لديناميكيات انتقال حمى الضنك في السياقات الريفية. وتُبرز أنه في حين أن حجم السكان ذو أهمية، فإن العوامل البيئية والبنية التحتية تلعب دورًا كبيرًا في تحديد خطر الإصابة بحمى الضنك. يجب أن تأخذ التدخلات الصحية العامة هذه التعقيدات في الاعتبار، خاصة مع تزايد مساهمة المناطق الريفية في وبائيات حمى الضنك.

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الكلمات المفتاحية :حمى الضنك، الوبائيات، انتقال حضري، انتقال ريفي، بعوض *Aedes aegypti*.