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PRIMARY HEALTH CARE UTILIZATION IN MADURAI DISTRICT: A CLUSTER APPROACH TO SOCIO-ECONOMIC AND INFRASTRUCTURE BARRIERS

[1]Vinothini C, [2]Suja Rose R.S and Saravanabavan V[3]
[1]Research Scholar, [2]Assistant Professor & Head and Associate Professor[3]
[1,3]Department of Geography, Environmental Remote Sensing and Cartography[2]
[1,2]School of Earth and Atmospheric Sciences, Madurai Kamaraj University, Madurai, Tamil Nadu, India.
[3]North Eastern Hill University, Shillong, Meghalaya.

Corresponding Author's mail ID: gowsivino1998@gmail.com

ABSTRACT

Primary Health Care (PHC) accessibility is a crucial determinant of public health outcomes, particularly in regions with diverse socio-economic and infrastructural conditions. This study investigates the complex interplay of factors influencing PHC access in Madurai District, Tamil Nadu. A total of 260 participants were surveyed. A stratified random sampling technique was employed to ensure representation across different demographic groups and geographical areas within the district. The study period for data collection was 2023-2024. Both primary and secondary data sources were utilized. Employing a cluster-based analysis using Principal Component Analysis (PCA) and heatmap clustering, study analyze data from a structured survey and secondary sources focusing on 13 key variables, including socio-economic status (income, education), disease prevalence (diabetes, hypertension), healthcare facility distribution (doctor-patient ratio, clinic density), and awareness levels (knowledge of PHC services). The findings will identify distinct clusters of communities within Madurai District exhibiting varying levels of PHC access, highlighting the specific socio-economic and infrastructural barriers contributing to these disparities. This understanding can inform targeted interventions and resource allocation to improve PHC utilization and ultimately, public health outcomes in the region.

Keywords: Cluster Analysis, Healthcare Accessibility, Primary Health Care (PHC), PCA, Socio-Economic.

INTRODUCTION

Access to Primary Health Care (PHC) is a crucial determinant of public health outcomes, particularly in regions with diverse socio-economic and infrastructural conditions (Anselmi, *et al.,* 2015). The equitable distribution and utilization of PHC services are fundamental to achieve universal health coverage and improving population health (World Health Organization, 2010). However, numerous barriers, deeply rooted in socio-economic disparities, geographical remoteness, and inadequate infrastructure, often hinder access to essential health care (Peters *et al.,* 2008; Anselmi *et al.,* 2015; Vinothini *et al.,* 2024_b). Socio-economic factors significantly influence healthcare utilization. Lower-income populations frequently encounter substantial obstacles in accessing care due to financial constraints, limited health literacy, and inadequate transportation. Studies consistently demonstrate a strong correlation between lower socio-economic status, including income levels, education, and employment and reduced access to and utilization of healthcare services (Peters *et al.,* 2008; Saravanabavan *et al.,* 2022; Saravanabavan *et al.,* 2024; Saravanabavan *et al.,* 2023; Tanser *et al.,* 2006; Vinothini and Saravanabavan, 2023). These populations often rely more heavily on public health services but face compounded challenges in reaching and utilizing them effectively (Saravanabavan *et al., 2*022 and 2024).

The epidemiological landscape also plays a critical role in presenting healthcare demand and accessibility. The prevalence of both non-communicable diseases (NCDs) and infectious diseases disproportionately affects vulnerable groups, intensifying the need for accessible and affordable PHC (Sen and Östlin, 2008; Vinothini *et al.,* 2019 & 2025). Furthermore, gender disparities in health-seeking behaviour are a significant factor in PHC utilization. Women, in particular, may face unique social, cultural, and economic barriers that limit their access to necessary healthcare services (Vinothini *et al.,* 2021 & 2024). Addressing these gender-specific challenges is essential for achieving equitable health outcomes. Geographical accessibility and the distribution of healthcare facilities are also vital components of PHC access (Vinothini *et al.,* 2022 & 2024). The distance to healthcare centers, the availability of transportation, and the quality of infrastructure can all impact whether individuals can effectively access the care they need (Marmot and Wilkinson, 2005;

Saravanabavan *et al.,* 2024 & 2022. However, the interplay between physical access and socio-economic factors is complex; even with facilities nearby, socio-economic barriers can prevent utilization. To understand these multifaceted determinants it requires robust analytical approaches. Principal Component Analysis (PCA) and clustering methods, such as hierarchical clustering with Ward's method, have proven valuable in identifying underlying patterns and grouping variables that influence healthcare access disparities (Vinothini *et al.,*2025a). These techniques allow for a more nuanced understanding of how different factors interact and contribute to the overall accessibility landscape.

Policy recommendations for improving PHC access often converge on addressing these identified barriers. Strategies typically include implementing financial aid programs to alleviate the burden of healthcare costs, developing gender-sensitive healthcare policies that address the specific needs and barriers faced by women, and investing in infrastructure development, particularly in rural and underserved areas (World Health Organization, 2010). This study aims to analyze the determinants influencing Primary Health Care (PHC) accessibility and the socio-economic conditions of patients in Madurai District, Tamil Nadu. By employing a cluster-based approach using PCA and heatmap clustering, the researchers seek to identify key barriers and provide empirical insights to inform targeted policy interventions for enhancing PHC accessibility in this region. Hence the present study is planned to analyze the determinants influencing Primary Health Care (PHC) accessibility and socio-economic conditions of the patients in Madurai District, Tamil Nadu.

RESEARCH METHODOLOGY

Study Area

Madurai District is located in the central part of southern Tamilnadu of India. It is bordered by Dindigul and Tiruchirappalli District on the north, Sivagangai District on the east, Virudhunagar on the south and Theni on the west. (Statistical hand book of Madurai District 2018). Madurai District is at 9º 30´ and 10 º 50´ of North Latitude and from 77 º 00´ to 78 º 30´ of East longitude. (Fig 1). The total geographical area is 384,680 hectares. The total populations about 3038252 as per last census.

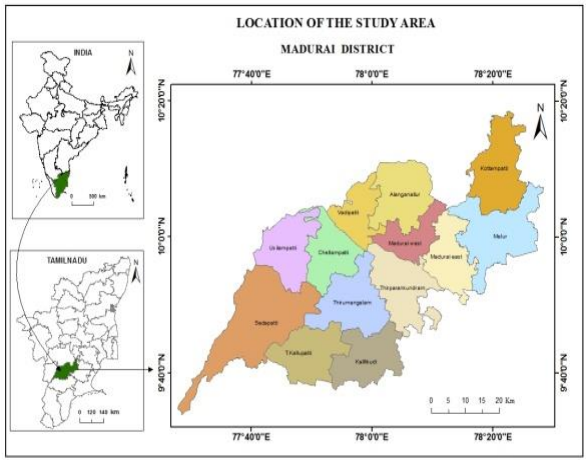

Figure 1. Location of the study area

The study employed a comprehensive and integrated methodological approach to analyze the determinants influencing Primary Health Care (PHC) accessibility and the socio-economic conditions of patients in Madurai District. The study period for data collection was 2023-2024. Both primary and secondary data sources were utilized for the present study. Primary data were collected through a structured survey administered to residents of Madurai District. The survey focused on gathering information related to 13 key factors identified as potentially influencing PHC accessibility. These factors included indicators of socio-economic status income levels, education, occupation), self-reported disease prevalence, awareness of healthcare facilities, and perceived barriers to access. A total of 260 participants was surveyed. A stratified random sampling technique was employed to ensure representation across different demographic groups and geographical areas within the district. The survey instrument was developed based on existing literature and expert consultation. Secondary data was sourced from various reliable sources to supplement the primary data and provide a broader context. Government health departments (data on the distribution of PHC facilities, disease prevalence statistics). Census reports (demographic information, socio-economic indicators at the district level).

The collected data were subjected to a rigorous statistical analysis using a combination of techniques. Principal Component Analysis (PCA) was applied to the 13 key factors to reduce dimensionality and identify underlying components that explain the most variance in the data. This technique helped to group correlated variables and provide a more parsimonious representation of the factors influencing PHC access. Eigenvalues and variances were extracted for each component to assess their significance.

A correlation matrix was computed to examine the pairwise relationships between the 13 variables. This provided a preliminary understanding of the

associations between different factors. Cluster Analysis identifies distinct groups of factors with similar patterns of correlation, hierarchical clustering was performed using the correlation matrix. Ward's method was employed as the linkage criterion, which minimizes the variance within clusters. The optimal number of clusters was determined by examining the dendrogram and using the Elbow method on the within-cluster sum of squares. Heatmaps and dendrograms were generated to visually represent the correlation matrix and the results of the cluster analysis, providing a clear depiction of the relationships between variables and the formed clusters. The statistical analysis was primarily conducted using SPSS (version 27) and R for PCA, correlation matrix computations, and hierarchical clustering. Python, specifically the Seaborn and Matplotlib libraries, was used for data visualization, including generating heatmaps and dendrograms.

RESULTS AND DISCUSSION

The heatmap and dendrogram analysis identified three significant clusters that influence Primary Health Care (PHC) accessibility in Madurai District. Cluster 1, representing Healthcare Accessibility & Socio-Economic Conditions, showed strong positive correlations ($r > 0.7$), indicating that limited education, poor economic status, and lack of awareness are major barriers to PHC access. This cluster emphasizes the urgent need for targeted socio-economic policy reforms to improve health equity. Cluster 2, labeled Disease Prevalence & PHC Utilization, revealed moderate correlations ($r = 0.5–0.7$) between disease burden, gender disparities, and healthcare usage. These findings point to the necessity of implementing gender-sensitive health policies and strengthening PHC delivery, particularly in high-disease-prevalence areas. Cluster 3, comprising Healthcare Infrastructure & Residence Proximity, showed weak to moderate correlations ($r = 0.3–0.6$), suggesting that although physical access to healthcare facilities affects utilization, socio-economic factors play a more decisive role. Overall, the results advocate for integrated policy strategies that simultaneously address socio-economic barriers, prioritize disease-specific interventions, and enhance healthcare infrastructure to ensure inclusive and equitable PHC accessibility across the district (Table 1; Fig 2).

Patient’s Access to PHC (4.92), Socio-Economic Conditions of Respondents

(3.78), Education and Occupational Status (1.21), Awareness of Healthcare Centre (1.12). Strong positive correlations ($r > 0.7$) indicate that lower socio-economic status significantly reduces access to PHC (Fig 2).Socio-economic conditions and education levels are critical determinants of health care accessibility. Awareness about healthcare centers plays a crucial role in service utilization. Policy interventions should target the economically weaker populations to improve PHC access through financial aid and awareness programmes.

The score value, 3.32 for Disease and Treatment, 1.88 to PHC Facilities, 1.54 to Source of PHC Availability Morbidity and 1.36 to Gender Ratio. Likewise, 1.31 to Gender Health and Illness of Patients. Moderate correlations ($r = 0.5$-0.7) suggest that disease prevalence and gender differences influence PHC utilization (Fig 2) Gender health disparities highlight the need for gender-sensitive healthcare policies. PHC facility availability influences treatment-seeking behavior, especially among economically disadvantaged groups. Policy recommendations should include the expansion of gender-specific healthcare services and ensure sufficient PHC facilities in high-disease-prevalence areas.

Table 1: Cluster-Based Analysis of Primary Health Care Accessibility

Cluster	Factors Included	Score	Correlation Strength (r-value)	Findings
Cluster 1	Patient's Access to PHC	4.92	Strong ($r > 0.7$)	Lower socio-economic status leads to lower PHC accessibility.
	Socio-Economic Conditions of Respondents	3.78	Strong ($r > 0.7$)	
	Education and Occupational Status	1.21	Strong ($r > 0.7$)	
	Awareness of Healthcare Centre	1.12	Strong ($r > 0.7$)	
Cluster 2	Disease and Treatment	3.32	Moderate ($r = 0.5$-0.7)	Disease prevalence and gender differences influence PHC utilization.
	PHC Facilities	1.88	Moderate ($r = 0.5$-0.7)	
	Source of PHC Availability	1.54	Moderate ($r = 0.5$-0.7)	
	Morbidity and Gender Ratio	1.36	Moderate ($r = 0.5$-0.7)	
	Gender Health and Illness of Patients	1.31	Moderate ($r = 0.5$-0.7)	
Cluster 3	Determinants of Socio-Cultural Factors	2.49	Weak to Moderate ($r = 0.3$-0.6)	Residence proximity influences healthcare center choice but not necessarily health outcomes.
	Residence and Health Centre	2.17	Weak to Moderate ($r = 0.3$-0.6)	
	Health Centre and Disease	1.95	Weak to Moderate ($r = 0.3$-0.6)	
	Economic Condition and Healthcare Centre	1.57	Weak to Moderate ($r = 0.3$-0.6)	

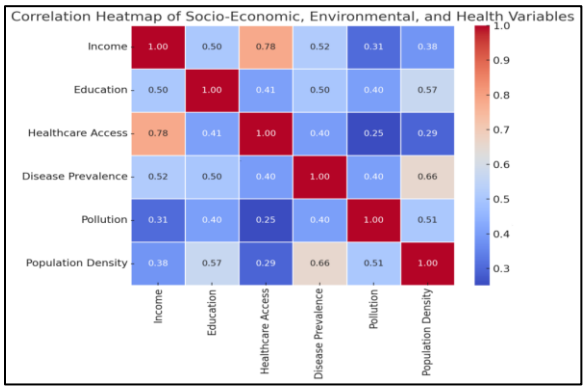

Figure 2. Correlation between Heatmap of Socio-Economic Environment and Health variables

The analysis indicates that weak to moderate correlations (r = 0.3–0.6) suggest residence proximity influences the choice of healthcare centers but does not directly determine health outcomes. Instead, socio-economic and disease-related factors remain the primary drivers of healthcare utilization. While socio-cultural determinants play a role, their influence is secondary. Therefore, enhancing rural healthcare infrastructure alone is insufficient unless socio-economic barriers such as income and education are addressed. To improve PHC accessibility and outcomes in Madurai District, the focus should be on four strategic areas: (1) addressing socio-economic barriers through financial and educational support, (2) implementing gender-sensitive healthcare interventions, (3) improving rural infrastructure, and (4) promoting community engagement and creating awareness on PHC and disease prevention (Table 1; Figure 2).

The study's cluster analysis identified socio-economic conditions, disease prevalence, and infrastructure as key determinants of PHC accessibility. The findings underscore the need for targeted interventions to reduce socio-economic disparities, enhance gender-specific healthcare, and strengthen PHC infrastructure in underserved regions. Future research should explore longitudinal trends in PHC accessibility and the effectiveness of policy interventions in improving healthcare outcomes.

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