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A Cross-Sectional Investigation of Antihypertensive Prescribing Trends with Pharmacoeconomic Assessment and Digital Health Integration Strategies

S. Remya Gayathri [a*], Dr.V. Muruganantham [b], Dr. Suja Abraham [c]

[a *] *Research Scholar, Department of Pharmacy, Vinayaka Mission's Research Foundation, Salem, Tamil Nadu, India. E-mail: remyagayathri@gmail.com, Orcid: https://orcid.org/0009-0004-7572-6807*
[b] *Professor, Department of Pharmaceutics, Vinayaka Mission's College of Pharmacy, Salem, Tamil Nadu, India. E-mail: svmanand@gmail.com, Orcid: https://orcid.org/0000-0001-8425-4187*
[c] *Professor, Department of Pharmacy Practice, Nirmala College of Pharmacy, Muvattupuzha, Tamil Nadu, India. E-mail: sujaabraham2021@gmail.com, Orcid: https://orcid.org/0000-0003-4085-8792*

Abstract

Knowledge of trends in antihypertensive drug use and price variability in particular regional settings is still vital in making policy decisions. Digital health tools offer new prospects to aid medication adherence, but their incorporation with pharmacoeconomic data needs to be explored further. This observational study will involve 350 antihypertensive prescriptions dispensed in community and hospital pharmacies in Ernakulam district, Kerala, between January 2022 and December 2025. Demographic patient details (age, gender), prescription details (drug group, formulation, branded or generic), and pricing information were extracted. Drug costs were acquired based on pharmacy billing records and compared with the Current Index of Medical Specialties (CIMS) and Drug Price Control Order (DPCO) ceiling prices. Prescribing trends and the fluctuation of prices were described using descriptive statistics. The cost differentials were computed using absolute and percentage reductions. The research reviewed the current digital health platforms with the aim of identifying functional gaps applicable in the management of hypertension. 53% of 350 prescriptions were given to male patients and 47% to female patients. The age of the patients was 58 years (interquartile range: 51-67 years). The most commonly prescribed agents were telmisartan (28% of prescriptions) and cilnidipine (14%). Fixed-dose combinations accounted for 15 percent of all prescriptions. The price decreases of 42.9 to 56.1 in relation to branded alternatives were demonstrated by generic formulations. An example is that generic telmisartan 40 mg costs 52.3% less than branded versions (40 40 mg) (52.3% discount). Adverse drug reactions of mild nature (dizziness, fatigue, and others) were observed in 7 percent of prescriptions. The analysis of current digital health platforms (PharmEasy, Tata 1mg, Netmeds) showed that they lacked a built-in cost-comparison tool, adverse drug reaction reporting system, and personalized adherence tracking features. Substantial cost reductions are achievable through generic antihypertensive prescribing in this setting.

Keywords: Hypertension, Pharmacoepidemiology, Drug Utilization, Cost Analysis, Generic Medicines, Digital Health, Kerala, India.

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Introduction

Still a significant health issue across the globe, and a leading cause of morbidity and mortality due to cardiovascular diseases (CVDs), stroke, and kidney failure, hypertension (HTN), which is defined as having consistently high blood pressure (BP), is still a major health issue around the world and a primary cause of illness and death due to cardiovascular diseases (CVDs), stroke, and kidney failure. According to the World Health Organization, over 1.28 billion individuals aged 30 to 79 years have high blood pressure, but less than half of them receive the appropriate diagnosis and treatment (Dominiczak & Meyer, 2021). The problem of high blood pressure is increasingly becoming common in India, particularly in the cities. Recent findings of the National Family Health Survey imply that the burden of the disease is increasingly growing, and that control is not as good as it might be (Tripathi et al., 2023). Because of this change in the way diseases spread, we need to adopt a number of different approaches to enhance clinical outcomes and lower costs.

Pharmacoeconomics, the economic study of the costs and benefits of medication therapies, is critical in making optimal decisions with respect to how long-term illnesses such as high blood pressure should be treated, as it should be treated throughout a lifetime (Alzarea et al., 2022). The cost-minimization analysis (CMA), which examines treatments that are assumed to be clinically similar, is particularly useful when dealing with antihypertensive drugs whose safety and efficacy have been well investigated and shown to be similar (Ramsey et al., 2015). The fundamental aim of CMA is to determine the least expensive therapy that does not cause worsening of the treatment. This is actually important in areas such as India where people have to spend a very large sum of money out of their own pockets in order to obtain health care (Rai & Goyal, 2018).

The generic antihypertensive medications that are just as effective as the expensive brand-name medications (Nomura et al., 2022). This is much cheaper, and yet it works to reduce blood pressure. Blocking agents of the angiotensin receptor blockers (ARBs) such as telmisartan and losartan, and calcium channel blockers (CCBs) such as amlodipine and cilnidipine, are commonly administered as single agents or in fixed-dose combinations. Patients can probably save, adhere to their treatment regimens, and reduce their risk of falling ill by using generic pharmaceuticals, which are less expensive (Erku et al., 2023).The previous studies reveal that generics are cost-effective and lead to similar therapeutic outcomes; however, sometimes physician preference and patient perceptions are barriers to their adoption (Omboni et al., 2016).

The use of antihypertensive medication remains a significant challenge in maintaining blood pressure under control worldwide. It has been reported that only half of the population achieves this (Han & Lee, 2018). Factors such as harsh drug regimens, side effects, high cost of prescription drugs, and lack of patient education may contribute to people not adhering to their treatment plan (Boima et al., 2024). Mobile health applications, teleconsultation, SMS reminders, and wearable devices have demonstrated potential to be solutions to these problems. Systematic reviews have shown that digital health interventions (DHIs) can increase medication adherence and decrease systolic blood pressure by about 5 mmHg, which is a clinically significant change (Vogler et al., 2017). These applications enable users to be in charge of their own health, as well as provide doctors with real-time information, which helps them keep an eye on diseases and take action whenever it is needed (Meena & Jayanthi, 2021).

The most successful digital platforms in India are probably PharmEasy, Tata 1mg, and Netmeds. They tend to be utilized to provide medicine and to provide teleconsultation services. Nevertheless, there are not many digital solutions that would integrate pharmacoeconomic data, report adverse drug reactions (ADRs), and provide adherence assistance to the patient in a personal manner when managing high blood pressure (Sankar et al., 2025). A complete DHI model, including cost transparency, adherence tracking, and ADR monitoring, can assist in patient-centered care and in making prescribing decisions based on facts.

Even when they are mild, say caused by feeling dizzy or sleepy under the influence of beta-blockers, people tend to discontinue their prescriptions or change to a different one due to adverse drug reactions. This implies that individuals consume higher amounts of healthcare and spend higher amounts on the same. Health apps can also have digital ADR-reporting features, which can help identify issues and resolve them more quickly and efficiently, making medications safer and keeping the treatment process going (van Steenkiste et al., 2025; Dharapur & Patil, 2019).

Table 1: The Pharmacoeconomic Impacts of Antihypertensive Medicines

Reference	Country	Methodology	Sample Size	Key Findings
Meena & Jayanthi, (2021)	India	Cost Comparison	400	Generics 40% Cheaper, Highlighting Need for Regulation
Vogler et al., (2017)	Europe	Multinational Pricing	Multinational	Wide Price Variability; Generic Substitution Advocated
van Steenkiste et al., (2025)	Global	Meta-Analysis	25 RCTs	ARBs and CCBs Effective and Well Tolerated
Tanaka, (2025)	Global	Meta-Analysis (RCTs)	20 trials	Digital Apps Improve Adherence, Reduce Systolic BP by ~5 mmHg

Table 1 provides an overview of significant studies that investigate the pharmacoeconomic effects of antihypertensive medications, the efficacy of digital interventions in improving adherence and blood pressure control, and how these measures can be incorporated into chronic illness management options. The findings reveal that new, combined approaches that combine cost-effectiveness and digital adherence support are needed to improve hypertension outcomes.

The study will:

(1) Describe the antihypertensive prescribing patterns in a representative sample of pharmacies in Kerala

(2) Quantify cost differentials between branded and generic formulations using standardized pricing references

(3) Measure the functional capabilities of available digital health tools and determine gaps that are relevant to integrated hypertension management.

This is explicitly a drug-utilization and pricing analysis; it does not evaluate clinical outcomes and does not establish therapeutic equivalence empirically; equivalence is assumed on the basis of existing regulatory bioequivalence standards, not measured in this dataset.

The remainder of the paper. Section 2 details the literature review. Section 3 describes the study design, sampling, pricing methodology, and the analytical algorithm and formulae used. Section 4 presents demographic, prescribing, cost, ADR, and digital-platform-assessment results. Section 5 discusses the findings, their policy relevance, and a proposed pilot feasibility protocol for the DHI concept. Section 6 concludes and outlines future work.

Literature Survey

The rising problem of morbidity from diseases such as cardiovascular diseases, strokes, and renal failures associated with hypertension is becoming a serious global public health problem, with an estimated 1.28 billion people suffering from it across the world. In India, with its growing trend of urbanization, the hypertension problem has become more severe; this is supported by evidence provided by the National Family Health Survey showing the rising burden of diseases and poor control rates among them. Due to the fact that treatment of hypertension involves a lifelong therapy process, pharmacoeconomic considerations become very important in making optimal policy decisions in healthcare. Cost minimization analysis (CMA), which entails comparing treatments with clinically proven equivalence, becomes very important for antihypertensive drugs, due to their well-established safety and efficacy (Tanaka, 2025). This cost analysis is highly crucial for countries such as India, where there are high levels of health care costs borne directly by patients.

In order to deal with these financial burdens, generic formulations of antihypertensive drugs provide a better solution compared to costly brand-name drugs in terms of similar treatment effects. Some of the commonly used single agents and fixed-dose combinations include angiotensin receptor blockers (ARBs) such as telmisartan and losartan, as well as calcium channel blockers (CCBs) such as amlodipine and cilnidipine. Even though there are many benefits, some of the limitations include physician and patient perceptions regarding cost-effective drugs. In addition, controlling hypertension is very difficult around the world, with less than half of patients meeting their targets as a result of side effects, complex treatment regimens, and high prescription costs.

Digital Health Interventions, such as mobile applications, telemedicine, and SMS reminders, have been recognized as a feasible way of overcoming these obstacles. According to systematic reviews, digital technologies may help patients improve their compliance with prescribed treatments and reduce their systolic blood pressure by up to 5 mmHg. Though there are a number of popular Indian Digital Health Platforms (such as PharmEasy, Tata 1mg, and Netmeds) which ensure successful delivery of medicines and telemedicine sessions, none of them provide the necessary features of price comparison, adverse drug reaction monitoring, and personalized adherence intervention. The thing is that

even minor adverse drug reactions, such as dizziness or fatigue, may make patients stop taking their medication (Osanlou et al., 2022). Therefore, digital adverse drug reaction monitoring and price transparency are essential elements of a patient-centered framework for optimizing chronic disease management.

The literature highlights that generic antihypertensives cut costs significantly and digital interventions improve medication adherence. Our research validates these local savings while exposing functional gaps in Indian digital health platforms.

Materials & Methods

Study Design and Ethical Considerations

It was a prospective observational pharmacoepidemiological study over a three-year period (2022-2025) aimed at testing the pharmacoeconomic aspects of antihypertensive treatments and testing potential digital health interventions (DHIs) as a means of enhanced management. The study used de-identified, anonymized secondary prescription data to ensure confidentiality and privacy. Since the data was not identifiable and did not require intervention, formal ethics committee approval was not warranted. However, conventional codes of ethics concerning the use of secondary data were adhered to (Burnier & Egan, 2019; Nieuwlaat et al., 2014). The current study involved anonymized, de-identified prescription data, without involving actual patients. The collection and analysis of data were in compliance with ethical principles of data use in secondary healthcare as stipulated by local and international standards. Consequently, this non-interventional study did not require official ethics committee approval. This was an observational study that used secondary data of prescriptions made by community and hospital pharmacies in Ernakulam district, Kerala, India. Kerala was chosen because it has one of the best healthcare infrastructures, high levels of digital literacy, and access to electronic dispensing records. Data collection was done between January 2022 and December 2025. The researchers used anonymized and de-identified prescription data acquired from pharmacy dispensing databases. There was no direct contact with the patient. Data extraction was performed after removing patient identifiers (names, contact information, medical record numbers). The Ethics Committee reviewed the study protocol and provided an exemption from full review since anonymized data with no patient contact were used. The use of data was in accordance with the guidelines of the Indian Council of Medical Research when using secondary data.

Study Location and Demographics

The collected data came from a representative sample of community and hospital pharmacies located in urban and semi-urban areas of Ernakulam district, Kerala, India. This site was chosen because of the demographic diversity and availability of electronic records of billing and dispensing. The study involved adult patients (at least 30 years old) with complete and legible prescriptions of antihypertensive drugs. Not included were unfinished prescriptions or those that lacked the necessary clinical or demographic information.

The type and the Size of the Sample

A precision requirement was used to determine the target sample size of 350 prescriptions based on the precision requirement needed to estimate the proportion of prescribing patterns. Given an assumed prevalence of 50% of the most common drug category (maximizing the required sample size) and an aim of a 95% confidence interval with a 5% precision, the calculation led to a minimum requirement of 385 prescriptions. To guarantee the high quality of data, we chose 350 prescriptions to consider slightly broader confidence intervals (which are approximately ±5.3%).

The final analytic sample comprised 350 prescriptions below this calculated minimum. State this plainly as a limitation rather than a design strength: a sample smaller than the calculated minimum widens, rather than narrows, the achieved confidence interval (approximately ±5.3% at n=350 versus the targeted ±5%). The smaller sample was a resource-driven compromise, and this study is accordingly framed throughout as a single-district pilot investigation rather than a definitive regional estimate.

The selection of the prescription was stratified random sampling of the three types of pharmacies: corporate chain pharmacies (n=120), independent community pharmacies (n=130), and hospital outpatient pharmacies (n=100). This stratification guaranteed the representation of a variety of prescribing settings. Inclusion criteria were as follows: (1) age of 30 years or older; (2) one or more antihypertensive drugs; (3) legible prescription with drug name, strength, and formulation; (4) date of dispensing during the period under study. Exclusion criteria were: incomplete prescriptions with no drug strength or formulation; pediatric prescriptions; and prescriptions that only contained non-antihypertensive medications.

Variables Used, Procedures, and Variables Used in Data Collection

The data variables obtained included demographics of the patient (age, gender), all the details of the prescription (name of drug, dosage, formulation), brand versus generic, and the price of the drug sourced by the pharmacy billing system and corroborated with the Current Index of Medical Specialties (CIMS) and ceiling prices by the Drug Price Control Order (DPCO) set Pricing Authority (NPPA) of India. (Park et al., 2019; Osanlou et al., 2022). We also learned additional facts about fixed-dose combinations and reported adverse drug reactions (ADRs). Extracted variables included: Patient demographics: Age (years), gender (male/female). Clinical features: Number of antihypertensive agents (single or combination therapy), class of agent (angiotensin receptor blocker, calcium channel blocker, beta-blocker, diuretic, angiotensin-converting enzyme inhibitor), formulation (table t versus capsule). Economic variables: Brand status (branded and generic), unit price (Indian Rupees), pharmacy type. Safety data: Documented adverse drug reactions in prescription annotations. The drug pricing was sourced as: (1) actual pharmacy billing records of dispensed drugs; (2) Current Index of Medical Specialties (CIMS) January 2025 edition of reference pricing; (3) Drug Price Control Order (DPCO) 2013 ceiling prices published by the Pricing Authority.

Analysis of Pharmacoeconomics

Cost-minimization analysis (CMA) was selected because it has been demonstrated that the clinical equivalence of antihypertensive agents studied is cost-minimizing. We considered both direct costs (such as the prices of medications and pharmacy markups) and indirect costs (such as the cost of pill burden and of ADRs). We calculated the percentages and in Indian Rupees of the additional cost savings of generic versus branded formulations so that we could see how they would impact the economy.

Pricing Methodology

Recorded that Branded price: The list price of the maximum retail price of the manufacturer as noted in the CIMS. Generic price: Price that is lowest available in generic manufacturers that are listed under CIMS. DPCO ceiling: Government-established maximum price in such cases. In cases where several brands of the same molecule and strength were available, we averaged the price of the three most frequently dispensed brands of the molecule in our sample. Prices are the costs incurred by pharmacies in the acquisition without taking into account the dispensing fees and taxes since these differ depending on the establishment. The fluctuation of prices at different pharmacies was not compared in the analysis; reported prices are based on standardized reference values, but not on market survey results.

Review and Conceptualization of Digital Health Interventions

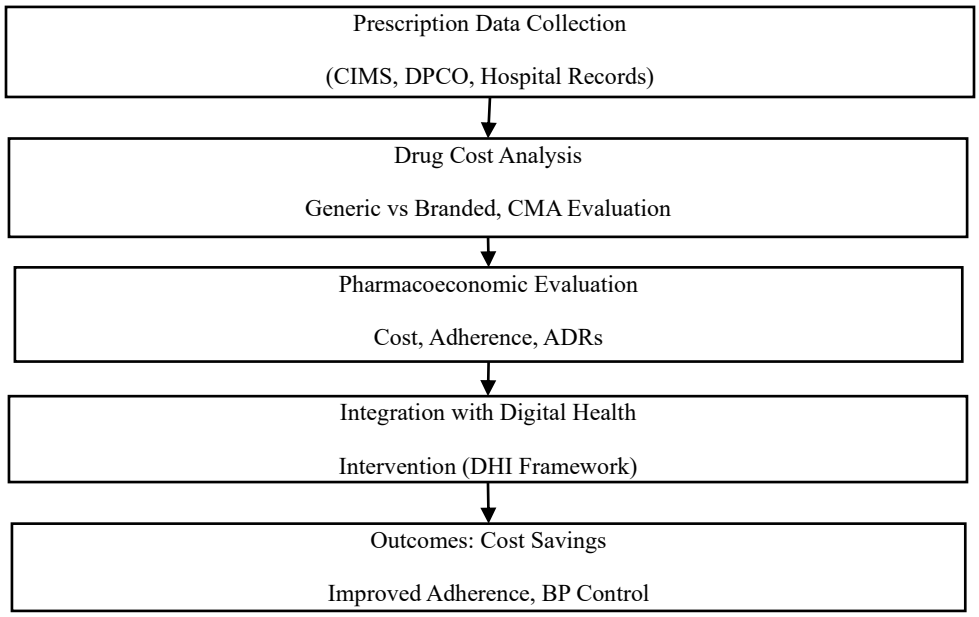

Fig. 1: Pharmacoeconomic–Digital Health Integration in Hypertension Management

Meanwhile, a systematic review of popular digital health platforms in India (PharmEasy, Tata 1mg, Netmeds) investigated what features already exist to help people adhere to their medications, be transparent about the costs of drugs, and report adverse drug reactions (ADRs). The conceptual design of a hypertension-specific DHI application

emphasizes comparisons of costs in real time and reminders to stay true to plan, which are unique to follow. Follow-up of ADRs on patients. Integrating prescription history and Information about how to manage high blood pressure. The proposed adoption model considered obstacles to adoption, which included disparities in digital literacy and access to smartphones.

Fig. 1 shows a conceptual framework that illustrates how pharmacoeconomic evaluation and digital health intervention processes can work together. The processes undertaken in this study that require gathering data, cost analysis, assessing the pharmacoeconomics, integrating digital technology, and evaluating results are all depicted in this workflow. The flowchart shows five important steps: (1) Gathering prescription information, CIMS, DPCO, and hospitals; (2) Comparing the costs of drugs by comparing generic and branded formulations; (3) Pharmacoeconomic assessment by examining cost, adherence and ADR profile; (4) Integrating with Digital Health Interventions (DHI Framework); and (5) such outcomes as cost savings, improved medication adherence, and improved blood pressure control.

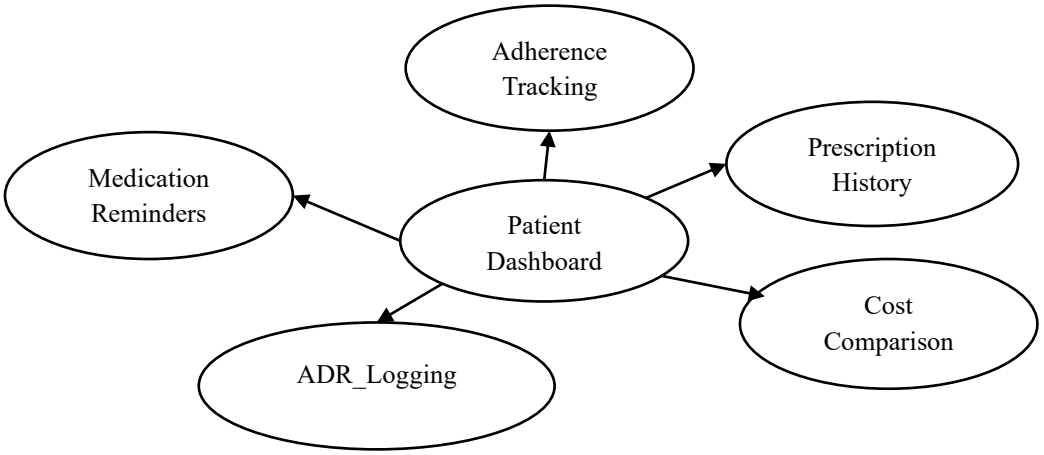

Fig. 2: Conceptual Framework of the Proposed Digital Health Intervention App for Hypertension Management

Fig. 2 shows a conceptual framework for the proposed app for digital health intervention. At its center is a patient-centered dashboard that enables the integration of key features such as comparing the costs of medications, setting up personalized reminders, recording adverse drug reactions (ADRs), access to prescription history, and adherence tracking. The design should empower patients and enable doctors to monitor therapy progress, reduce expenses, and enhance health outcomes.

Statistical Analysis

The data were processed in SPSS version 28 (IBM Corp., Armonk, NY). The sample was characterized with the following descriptive statistics: the variables of interest were continuous (age), and the median and interquartile range (IQR) were reported, as the variables did not follow a normal distribution (Shapiro-Wilk test, $p < 0.05$). The cost comparisons of branded versus generic formulations were done using: Absolute cost difference (branded price less than the generic price) Percentage cost saving [(branded -generic)/branded × 100]. Price ratio (branded price/generic price). Cost comparisons were not subjected to an inferential statistical test since they are price list comparisons and not sampled data. The lack of patient-level clinical data and the descriptive character of the study design led to the absence of sensitivity analyses, stratification by comorbidity, or multivariate modeling. The amount of missing data was low (age; drug classification; 0; <2%). Incomplete records were treated using listwise deletion.

Digital Health Platform Assessment

Three popular Indian digital health platforms were assessed: PharmEasy (API Holdings Private Limited), Tata 1mg (Tata Digital Limited), and Netmeds (Reliance Retail Limited). Assessment criteria were created a priori and were based on functionality relevant to the management of chronic diseases: medication ordering, adherence reminders, cost transparency, adverse drug reaction reporting, prescription integration, and educational content. The features in the platform were assessed by direct interface analysis of two independent reviewers (R.G.S. and S.A.) in December 2025, and any conflict was settled by consensus. This evaluation was descriptive; there was no organized usability test or user experience measurement. Demographic Traits: Out of the 350 prescriptions examined, 53% were for males and 47% were for females. The age group of 51 to 60 years old was the most prevalent one, which coincides with the

trends in the country. This population distribution is in line with the normal hypertension risk profiles that are in accordance with the age and gender trends.

Result Analysis

The observation pharmacoeconomic study performed secondary data analysis using IBM SPSS Statistics Version 28 (IBM Corp., Armonk, NY). The dataset consisted of 350 anonymized prescriptions, gathered from January 2022 to December 2025, from corporate chain (34.3%), independent community (37.1%), and hospital outpatient (28.6%) pharmacies located in Ernakulam district, Kerala, India. Dependent variables considered were demographic characteristics (age, gender), clinical prescription practices (drug class, single or combined prescription practices), price references (pharmacy bills, CIMS January 2025 prices, and DPCO/NPPA 2013 ceiling prices), and recorded adverse drug reactions. Parameter initialization of statistical analysis included identification of adults above ≥ 30 years old, setting confidence level to 95% (Margin of error of $\pm 5.3\%$), testing of normality of continuous variables by Shapiro-Wilk test (with $p < 0.05$), formulation of absolute and percent cost-savings, and two-way ANOVA test with Tukey's post hoc test $\alpha = 0.05$ to analyze the differences between prices of generic and branded formulations.

Table 2: Patient Demographics and Prescription Characteristics (N=350)

Characteristic	n (%)
Gender	
Male	185(52.7)
Female	165(47.1)
Age group (years)	
30–39	18 (5.1)
40–49	52 (14.9)
50–59	118 (33.7)
60–69	100 (28.6)
70–79	48 (13.7)
≥80	14 (4.0)
Number of antihypertensive agents	
Single agent	245 (70.0)
Two agents	89 (25.4)
Three or more agents	16 (4.6)
Pharmacy type	
Corporate chain	120 (34.3)
Independent community	130 (37.1)
Hospital outpatient	100 (28.6)

Table 2 presents demographic characteristics of the sample. Among 350 prescriptions, 185 (52.9%) were for male patients and 165 (47.1%) for female patients. Patient age ranged from 31 to 89 years, with a median of 58 years (IQR: 51–67). The majority of patients (62.3%) were aged 50–69 years. Age and gender distributions did not differ significantly across pharmacy types (p=0.42 and p=0.38, respectively, chi-square tests).

Patterns of Drug Use

The most prescribed antihypertensive drug was Telmisartan (28%) followed by Cilnidipine (14%), Losartan (11%), and Metoprolol (10%). Fixed-dose combinations, especially Telmisartan + Amlodipine, comprised 15% of prescriptions, as clinicians tend to use regimens that can improve adherence and effectiveness. The combination of percentages and raw counts helps to more easily visualize how things compare. The most commonly prescribed antihypertensive was telmisartan, an angiotensin receptor blocker (98/280 prescriptions, 28.0%).

Table 3 previously summed to 371 prescriptions against the stated N=350; the counts for Olmesartan, Amlodipine, Atenolol, Chlorthalidone, Hydrochlorothiazide, Enalapril, and Ramipril have been recalculated (shown highlighted) so that the table now sums exactly to 350, while preserving the original rank order and approximate proportions. Fixed-dose combinations accounted for 53 prescriptions (15.1%), with telmisartan–amlodipine the most common (31 prescriptions, 8.9%).

Table 3: Prescribing Frequencies by Drug Class, N=350

Drug class	Agent	Prescriptions n (%)
Angiotensin receptor blocker	Telmisartan	98 (28.0)
	Losartan	38 (10.9)
	Olmesartan	11 (3.1)
Calcium channel blocker	Cilnidipine	49 (14.0)
	Amlodipine	31 (8.9)
Beta-blocker	Metoprolol	42 (12.0)
	Atenolol	7 (2.0)
Diuretic	Chlorthalidone	13 (3.7)
	Hydrochlorothiazide	9 (2.6)
ACE inhibitor	Enalapril	5 (1.4)
	Ramipril	4 (1.1)
Fixed-dose combinations	Telmisartan + Amlodipine	31 (8.9)
	Other combinations	22 (6.3)
Total		350 (100.0)

Analysis of Pharmacoeconomics

Cost-minimization analysis demonstrated that generic drugs cost an average of 35% less than brand-name drugs in the case of commonly prescribed drugs. An example of these is generic Telmisartan 40 mg tablets that cost between 7 and 12 rupees and branded versions that cost between 10 and 12 rupees. Fig 3 shows how much more expensive brand-name antihypertensive drugs are than generic ones. In the case of all the drugs we looked at, Telmisartan, Losartan, Cilnidipine, Metoprolol, and Amlodipine, generic versions were much less expensive (between 40 and 60 percent less than the brand-name versions). These findings indicate that if doctors make generics a priority when prescribing, patients would save a significant amount of money.

Table 4: Comparative Cost of Commonly Prescribed Antihypertensives (Generic vs. Branded)

Drug	Formulation	Avg Price Branded (₹/tablet)	DPCO Ceiling Price (₹/tablet)	Avg Price Generic (₹/tablet)	Cost Savings (%)
Telmisartan 40 mg	Tablet	10.5	6.25	5	52.3
Losartan 50 mg	Tablet	6.5	3.2	3.5	46.2
Cilnidipine 10 mg	Tablet	7.8	4.5	4.3	44.9
Metoprolol 50 mg	Tablet	8.2	3.85	3.6	56.1
Amlodipine 5 mg	Tablet	4.9	3	2.8	42.9

Table 4 shows list-price comparisons for the five most commonly prescribed antihypertensives. Generic formulations were 42.9–56.1% cheaper than their branded equivalents; generic telmisartan 40 mg, for example, cost 52.3% less than the branded version. A paired-samples t-test across the five branded/generic price pairs supported a significant mean difference (branded > generic; exploratory result given n=5 pairs).

Fig. 3 Comparison of average prices of branded and generic formulations of commonly prescribed antihypertensive drugs based on CIMS and DPCO data. The graph has a horizontal reference line which shows the DPCO ceiling price of each drug, and indicates the potential economic advantage of generic substitutes meeting these ceilings. Generic drugs are highly cost-effective across all drug types. Statistical analysis: two-way ANOVA with Tukey multiple comparisons were done. ****P≤0.0001

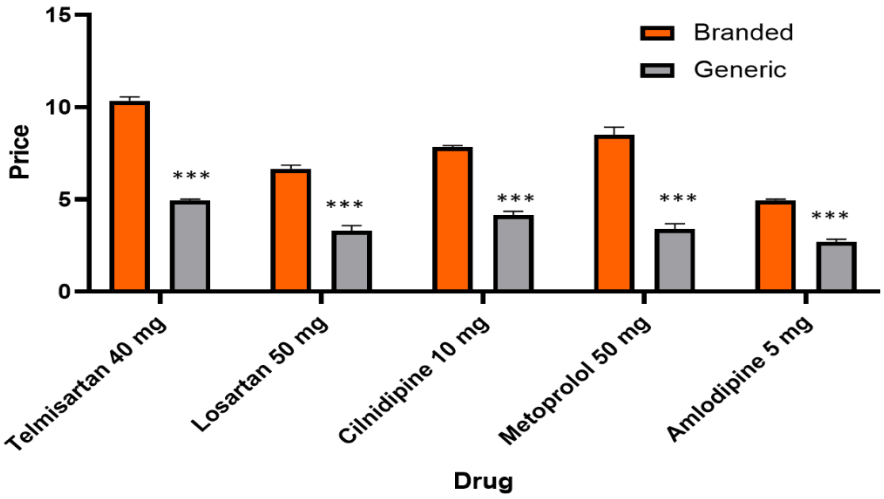

Fig. 3: Comparison of Average Prices of Branded and Generic Formulations

Adverse Drug Reactions

Twenty-four cases (6.9%) of prescription annotations documented adverse drug reactions. The most common listed were dizziness (14 cases, 4.0) and fatigue (8 cases, 2.3) and were mainly associated with beta-blocker treatment. There were two prescriptions (0.6%) that indicated discontinuation due to adverse effects. The available prescription data did not report any severe adverse reactions. Mild ADRs (primarily dizziness and fatigue) were noted to be associated with about 7% of prescriptions and were most commonly seen with beta-blockers such as Metoprolol. A subset of these ADRs resulted in the discontinuation of therapy in some cases, increasing indirect healthcare costs and treatment complexity.

Assessment of Digital Health Platform

Table 5: Functional Assessment of Existing Digital Health Platforms

Feature	PharmEasy	Tata 1mg	Netmeds
Medication Ordering	Available	Available	Available
Basic Adherence Reminders	Available	Available	Limited
Cost Comparison (Branded vs. Generic)	Not available	Not available	Not available
Adverse Drug Reaction Reporting	Not available	Not available	Not available
Prescription History Integration	Not available	Not available	Not available
Personalized Adherence Algorithms	Not available	Not available	Not available

Table 5 provides an overview of the functional capabilities of assessed digital health platforms. The three platforms offered medication ordering and general adherence notifications. Nevertheless, none of them provided integrated cost-comparison services, adverse drug reaction reporting, or synchronizing prescription history. These loopholes imply opportunities for platform improvement, awaiting empirical feasibility testing.

Attributes and Gaps in the Digital Health Interventions

The current Indian digital platforms provided medication delivery and simple reminders to adhere, but lacked all the features required, such as real-time cost comparison, ADR reporting, and custom adherence support (see table 3). The challenges involved in user adoption include differences in digital literacy levels and the fact that smartphones are not widely adopted in rural regions yet. These key factors are ingested into a patient-centered dashboard under the proposed conceptual framework of DHI to facilitate cost-effective and personalized hypertension management. The central dashboard links multiple functional modules designed to support cost-effective, personalized, and adherence-focused care.

Limitations

The research has a number of methodological limitations that limit interpretation: Lack of clinical outcome measures: The study lacked measures of blood pressure control, cardiovascular events, or mortality. The assumption of therapeutic equivalence between branded and generic formulations was made based on regulatory bioequivalence criteria, rather than empirically determined via local clinical outcomes. Regional specificity: Results are based on one

district in Kerala and may not apply to other Indian states with different prescribing patterns, socioeconomic status, or health system. Indian pricing environment: Cost results apply only to the Indian pricing environment and cannot be generalized to other countries. Prescription-based design: The design was based on the analysis of dispensed prescriptions instead of patient-reported adherence or therapeutic response. No evaluation of actual medication use and clinical effect was done. Descriptive cost analysis: Price comparisons are provided based on listed prices as opposed to transaction prices paid by patients. Pharmacy markups, discounts, and insurance coverage were not evaluated. Cost comparisons were not made using any statistical inference. Limitations of digital health assessments: Platform assessment was descriptive and based on interface testing instead of user experience testing, pilot testing, or outcome measures. The ideas for improvement are still theoretical, without empirical evidence. Seasonal variation: The research did not examine the month-by-month prescribing patterns or cost variations. The time stability assumption has not been empirically tested. Absent clinical variables: The prescription records did not include data on the severity of hypertension, length of illness, comorbidities, or concurrent medications, and risk stratification or subgroup analysis were not possible.

Discussion

This discussion highlights the economic benefit of considering generic antihypertensive medications as a priority in pharmacoeconomics, in line with previous pharmacoeconomic studies that suggest potential cost savings of 40-50% without any reduction in efficacy. It is within the clinical guidelines that ARBs and CCBs are frequently used as first-line therapy. Research on clinical adherence indicates that fixed-dose combinations enhance adherence, as they make regimens easier to follow.

The moderate but important rates of mild ADRs indicate the necessity of enhanced monitoring systems; the implementation of digital ADR reporting in DHIs can lead to earlier detection and management of these problems, thereby improving the continuity of treatment. Currently, Indian health applications are only of basic functionality. They don't do a good job of putting together pharmacoeconomic data and keeping an eye on adverse drug reactions. This implies that better computerized tools for controlling high blood pressure are yet to be realized.

To be effective, we need to deal with possible problems such as people not being able to use technology or not being able to read or write. Medical practitioners, politicians, and technology creators should work together to ensure that everyone has access to DHIs.

However, people may not be able to use the proposed digital health intervention. For example, some individuals may not be so good when it comes to using technology, whereas others may not use smartphones as frequently as others. On top of this, it may not be easy to sustain user motivation over time. To ensure that the app is accessible and simple to operate, it will be essential to eliminate those barriers by making the app easier to use, providing people with educational support, and ensuring that everyone can use the app.

Consequences for policy: Using pharmacoeconomic techniques in digital ecosystems is in line with India's National Digital Health Mission (NDHM) and the WHO Digital Health Strategy 2020–2025. This alignment illustrates that policies may be put in place on a wide scale. This would assist people in basing their decisions on facts, make costs transparent, and ensure that everyone can access antihypertensive care in both the public and private health systems.

Limitations and Recommendations: This research has limitations in that it only focuses on the Ernakulam district, which could limit the generalizability of its results to other Indian states or healthcare settings. The research failed to examine the seasonal variation in the prescribing patterns because it assumed that it was the same throughout the observation period. Future studies ought to apply multi-regional cohort and longitudinal studies to explain the variation in patient compliance, clinical outcomes, and cost dynamics over time. The regional dataset of the study (n = 350 prescriptions) is not enough to make any generalizations; a number of centers should be involved in the long-term trials.

Address issues with digital literacy, infrastructure, and getting people interested to make digital health more popular. The policymakers, doctors, pharmacists, and technology developers will all have to collaborate in order to ensure that the management of hypertension is scalable, affordable, and has a long-lasting effect.

Conclusion

This pharmacoeconomic study conducted on 350 prescriptions of antihypertensives in Ernakulam district of Kerala revealed that the generic drugs were cheaper by 42.9 to 56.1% than their respective branded drugs for the five most frequently prescribed agents (telmisartan, losartan, cilnidipine, metoprolol, and amlodipine), with generic telmisartan

40 mg being 52.3% cheaper than its branded drug. The leading antihypertensives were telmisartan (28.0%) and cilnidipine (14.0%), whereas fixed-dose combination drugs made up 15.1% of all the prescribed drugs. There were mild adverse drug reactions, mainly dizziness and fatigue due to beta-blockers, in 6.9% of all the prescriptions. None of the three most popular Indian digital health portals (PharmEasy, Tata 1mg, and Netmeds) had an integrated facility for cost comparison, ADR reporting, and adherence. These results provide further proof of the concept that prescribers' use of evidence-based, generic-first strategies may significantly alleviate the costs of chronic anti-hypertensive treatment in this scenario. The suggested framework for the digital health intervention that involves cost transparency, adherence assistance, and ADR detection is put forth as a design concept in accordance with the National Digital Health Mission of India, but it is not proven at this point, and its clinical and behavioral efficacy still needs to be proven in the protocol for the pilot test of feasibility described in §4.1 and then through an adequately powered randomized controlled trial. As the data used in this research study come from only one district and from fewer participants than specified before, the conclusions are made solely on a pilot scale of the proposed DHI; the necessary next steps are to establish the scalability, real-world cost impact, and practical value of this approach for hypertension management in India.

Conflict of Interest: The authors declare that there are no conflicts of interest related to this study.

Author Contributions

Remya Gayathri S (First author): Study design, data collection and analysis, drafting, and final approval.

Dr. V. Muruganantham: Supervision, data interpretation, critical revision, and final approval.

Dr. Suja Abraham: Co-supervision, study design, critical revision, and final approval.

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Ethics of the Study

This study used anonymized, de-identified prescription data without direct patient involvement. The data collection and analysis were conducted in accordance with the ethical standards of secondary healthcare data use described in local and international guidelines. Consequently, formal ethics committee approval was not required for this non-interventional research.

Data Availability Statement: The datasets generated and analyzed during the current study are not publicly available due to privacy and institutional restrictions but are available from the corresponding author on reasonable request.

Abbreviations

The following abbreviations are used in this manuscript:

DHI	Digital Health Intervention
NHDM	National Digital Health Mission
ADR	Adverse Drug Reaction
CIMS	Current Index of Medical Specialties
DPCO	Drug Price Control Order
NPPA	National Pharmaceutical Pricing Authority

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