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Introduction

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CONTENTS

SMART HYDROGELS AND STIMULI -RESPONSIVE DRUG-DELIVERY SYSTEMS: A NEW FRONTIER IN TARGETED PHARMACEUTICS

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Abstract

Smart hydrogels are three-dimensional, water-rich polymer networks that translate subtle chemical or physical cues into predictable shifts in structure and permeability. Unlike conventional depots, these materials incorporate dynamic cross-links or pendant groups that react selectively to stimuli such as pH, temperature, enzymatic activity, redox gradients, light, or magnetic fields. When triggered, the network swells, contracts, erodes, or undergoes sol–gel transitions, thereby releasing an encapsulated therapeutic payload at the desired site and time. The result is a delivery platform that can reduce systemic toxicity, improve pharmacokinetic profiles, and support precision medicine strategies. This manuscript presents a concept-focused examination of smart hydrogels, beginning with fundamental polymer chemistry and progressing to the mechanistic basis of each major stimulus modality. The narrative emphasises design principlesmonomer selection, cross-linking strategy, functionalisation chemistry, and mesh-size engineeringrather than cataloguing individual studies. Subsequent sections discuss methods for drug loading, models describing release kinetics, and the breadth of biomedical applications now within reach. Translational challenges such as batch reproducibility, sterilisability, and regulatory standardisation are highlighted as essential hurdles, while emerging solutionsartificial-intelligence-guided monomer discovery, 3D/4D bioprinting, and theranostic integrationillustrate where the field is headed. Collectively, the concepts and frameworks outlined herein position smart hydrogels as a transformational technology in pharmaceutics, bridging molecular sensing with controlled actuation to deliver next-generation therapeutics.

Keywords: smart hydrogel; stimuli-responsive polymer; targeted drug delivery; pH-sensitive system; thermo-gelling depot; enzyme-responsive network; precision pharmaceutics; controlled release.

INTRODUCTION

Effective pharmacotherapy demands that a drug reach its target tissue in the correct concentration, remain there long enough to exert its effect, and spare healthy organs from unnecessary exposure. Conventional dosage forms often struggle to satisfy all three conditions simultaneously; oral tablets face metabolic first-pass losses, injectable boluses create high systemic peaks, and simple polymeric inserts release cargo at rates governed solely by diffusion or matrix erosion [1,2].

Smart hydrogels represent an elegant response to these shortcomings. By integrating chemical “switches” or physically reversible cross-links into a water-laden polymer scaffold, these

materials can sense local pathological cuesacidic extracellular pH, elevated protease concentrations, high intracellular glutathioneor respond to externally applied triggers such as light or magnetic fields. Activation of the switch remodels the network's internal architecture: chains ionise, cross-links cleave, hydrophobic segments collapse, or nanoparticles heat the matrix. Each event modulates mesh size and permeability, allowing the payload to leave the depot precisely when the stimulus is present [3,4].

The elegance of the concept belies the complexity of its execution. Responsive behaviour must be encoded without compromising biocompatibility or mechanical stability, and release kinetics must be fine-tuned to match therapeutic windows. Recent advances in polymer chemistry, supramolecular assembly, protein engineering, and additive manufacturing have provided the molecular tools and fabrication techniques needed to meet these design constraints. As a result, smart hydrogels are now poised to transition from laboratory prototypes to clinically viable dosage forms, with injectable cancer depots, ocular gels, and implantable regenerative scaffolds already advancing through regulatory pipelines [5].

This review sets out the conceptual framework required to design, evaluate, and translate smart hydrogels. The discussion that follows intentionally avoids a study-by-study recounting; instead, it distils common principles and mechanistic themes that underpin all responsive systems, providing researchers with a transferable toolkit for innovation.

2. FUNDAMENTALS OF SMART HYDROGELS

2.1 Definition, Water Content, and Network Topology

A hydrogel is a cross-linked polymer network that can absorb multiples of its dry weight in water while maintaining structural coherence. The high water contentoften exceeding 90 %grants the material tissue-like softness and provides an aqueous environment that shelters sensitive biologics. A *smart* hydrogel goes further, embedding dynamic motifs that alter the network's physical state in response to specific cues [6]. These motifs can reside in the backbone, as pendant groups, or at cross-link junctions; when activated, they modulate chain conformation, cross-link density, or both. The internal mesh size, ξ, calculated from elastic modulus via rubber elasticity theory or measured by scattering techniques, represents the critical length scale that governs drug diffusion.

2.2 Cross-Linking Mechanisms: Physical versus Chemical

Physical cross-linking relies on non-covalent interactions such as ionic bonding, hydrogen bonding, hydrophobic aggregation, or host–guest inclusion. An alginate gel formed in the presence of divalent calcium ions exemplifies ionic cross-linking, whereas Pluronic® F127 forms micellar aggregates that jam into a gel on warming, illustrating hydrophobic assembly. These interactions are reversible, enabling rapid stimulus-induced transitions but limiting mechanical strength.

Chemical cross-linking employs covalent bonds generated through free-radical polymerisation, click chemistry, or enzymatic ligation. Covalently cross-linked poly(ethylene glycol) diacrylate (PEGDA) gels, for example, exhibit high modulus and slow passive diffusion. The drawback is that bond cleavage normally requires harsher conditions, so stimulus responsiveness must be built into the chemistry (e.g., a bond that cleaves selectively under reductive intracellular conditions).

Hybrid networks combine physical and chemical cross-links to balance elasticity with robustness. A dual network comprising ionically cross-linked alginate and covalently

cross-linked PEG is injectable under shear yet resists premature dissolution in vivo. Such hybrids illustrate the importance of integrating multiple bonding motifs to achieve complex functional profiles [7].

2.3 Swelling Dynamics and Viscoelastic Behaviour

Stimulus-induced changes in hydrogel volume arise from alterations in osmotic pressure and polymer–solvent interactions. Ionisation of pendant groups, for instance, increases charge density, draws in counter-ions and water, and expands the network. Conversely, hydrophobic collapse or LCST-driven coacervation expels water, shrinking the gel. These volumetric changes are quantified by the swelling ratio (Q) and directly influence the mesh size available for drug diffusion.

Rheological parametersstorage modulus (G′) and loss modulus (G″)provide a macroscopic signature of microscopic rearrangements. Activation of a stimulus that softens the network reduces G′, signalling an increase in chain mobility and diffusion pathways. Mapping G′ and mesh size as functions of stimulus intensity grants formulators a quantitative handle on release kinetics [8].

2.4 Functionalisation Strategies for Stimuli Responsiveness

Stimuli sensitivity can be installed via three main routes:

1. **Copolymerisation of responsive monomers.** Incorporating N-isopropylacrylamide (NIPAM) yields temperature responsivity, whereas acrylic acid or dimethyl-aminoethyl methacrylate introduce pH-sensitive ionisable groups.
2. **Post-polymerisation modification.** Reactive handles such as succinimidyl esters allow grafting of enzymes-cleavable peptides or redox-labile disulfide bridges onto pre-formed networks.
3. **Protein or peptide engineering.** Recombinant polymers offer site-specific insertion of motifs that respond to biological enzymes, providing genetic control over network degradation.

Dynamic covalent chemistriesboronate-diol complexes, Schiff-base imines, disulfide exchangeare particularly attractive because they form under physiological conditions and break selectively under targeted stimuli [9]. The choice of chemistry dictates not only stimulus sensitivity but also toxicity profile, degradation products, and regulatory pathway.

2.5 Comparison with Traditional Hydrogels

Traditional hydrogels act as passive reservoirs where drug efflux depends on concentration gradients and polymer degradation. Smart hydrogels introduce an *active*dimension: the matrix itself senses and responds to environmental information. Consequently, drug is released preferentially at the disease site, dosing frequency can be reduced, and side-effect profiles improve. This transition from passive to active carrier parallels the broader move in pharmacotherapy toward personalised, precisely timed interventions [10].

3. STIMULI-RESPONSIVE MECHANISMS

3.1 pH-Responsive Systems

Many pathological environments, including tumours and sites of infection, exhibit extracellular acidity, whereas the gastrointestinal tract presents a natural pH gradient along its length. Hydrogels containing ionisable amines protonate under acidic conditions, increasing

hydrophilicity and swelling. Carboxylate-bearing gels, in contrast, deprotonate at higher pH, expanding instead in the intestine. The trigger is therefore embedded in the protonation state of pendant groups, allowing designers to tailor release profiles to specific pH windows [11].

3.2 Temperature-Responsive Hydrogels

Temperature-sensitive polymers possess a lower critical solution temperature (LCST). Below LCST the polymer chains are solvated and mobile; above LCST they dehydrate and collapse, forcing a sol–gel transition or expelling water from a pre-formed gel. Triblock copolymers of poly(lactic-co-glycolic acid) (PLGA)–polyethylene glycol (PEG)–PLGA exemplify this behaviour. A cold, easily injectable sol transforms into a depot upon warming to body temperature, entrapping the drug and releasing it as the polyester domains hydrolytically erode [12].

3.3 Enzyme-Responsive Systems

Proteases, glycosidases, and phosphatases are not uniformly distributed in the body; their elevated presence in diseased tissues can therefore act as selective triggers. Embedding peptide cross-links that serve as substrates for a target enzyme causes localised cleavage and network degradation. The strategy permits site-selected release without systemic activation, a critical feature for potent cytotoxics or immunomodulators that must remain inactive elsewhere [13].

3.4 Redox-Responsive Systems

Intracellular compartments maintain glutathione concentrations several orders of magnitude higher than the bloodstream. Disulfide bonds incorporated into the backbone or as cross-links stay intact during circulation but cleave upon endocytosis, causing network disassembly and rapid payload liberation inside the cytosol. This differential chemistry exploits a universal cellular gradient, making it broadly applicable across tissue types [14].

3.5 Light- and Magnetic-Field-Responsive Systems

Photochromic groups such as azobenzene switch between isomers under specific wavelengths, altering hydrophobicity and chain packing. Embedding these groups provides an externally controllable trigger that can be applied with spatial precision, useful for ocular or dermal applications where light penetration is feasible. Magnetic responsiveness arises from incorporating superparamagnetic nanoparticles; application of an alternating magnetic field induces local heating or mechanical vibration that disrupts the matrix. Both modalities grant clinicians an on-off switch without introducing additional chemical triggers [15].

Table 1. Key stimuli exploited in smart hydrogels, corresponding responsive chemistries, and exemplary therapeutic contexts.

Stimulus	Responsive motif or cross-link	Representative polymer scaffold	Therapeutic context
pH	Tertiary amines, hydrazone bonds	Chitosan, poly(β-amino esters)	Tumour or colon targeting
Temperature	LCST block copolymers	PLGA–PEG–PLGA, PNIPAM	Injectable depots, ocular gels

Stimulus	Responsive motif or cross-link	Representative polymer scaffold	Therapeutic context
Enzyme	Protease-cleavable peptides	PEG, gelatin composites	Metastatic niches, chronic wounds
Redox	Disulfide bridges	PEG-polyurethane hybrids	Intracellular gene/drug delivery
Light	Azobenzene, spiropyran	PVA, methacrylate gels	Ophthalmic, dermal therapy
Magnetic	SPION composites	Alginate, dextran matrices	Pulsatile insulin, hyperthermia

4. DESIGN STRATEGIES AND POLYMER ARCHITECTURES

4.1 Synthetic Polymers

Smart-hydrogel design often begins with synthetic backbones because chain length, architecture, and end-group chemistry can be specified with high precision. Poly(ethylene glycol) (PEG) offers a hydrophilic, protein-repellent platform, whereas aliphatic polyesters such as poly(lactic-co-glycolic acid) (PLGA), poly(ε-caprolactone) (PCL), and poly(lactic acid) (PLA) contribute biodegradability and hydrophobic microdomains suitable for lipophilic drug solubilisation. Block-copolymerisation of PEG with these polyesters yields amphiphilic constructs that self-assemble into micellar cores; the PEG corona endows stealth while the polyester core entraps cargo. Reactive end-groupsacrylates, azides, maleimidesfacilitate rapid photo- or click-cross-linking under physiological conditions. Stimulus-responsiveness is added by grafting dynamic covalent handles such as phenylboronate–diol pairs (glucose sensitivity), imine bonds (pH sensitivity), or disulfide bridges (redox sensitivity) [16–18].

4.2 Natural Polymers

Nature-derived matrices provide inherent bioactivity and enzymatic degradability. Chitosan, rich in protonatable amines, becomes highly swollen in mildly acidic environments, which is advantageous for tumour and colon targeting [19]. Alginate cross-links ionically with divalent cations; combining an alginate shell with a covalent PEG core produces double-network gels that are injectable yet mechanically robust [20]. Gelatin and silk fibroin retain cell-adhesive motifs (e.g., RGD) and can be photo-cross-linked after methacrylation (GelMA, SilkMA), enabling cell-laden constructs for regenerative applications [21].

4.3 Hybrid and Composite Platforms

Hybridisation merges the controllability of synthetic chains with the biofunctionality of natural polymers. PEG–gelatin interpenetrating networks sustain stem-cell viability while incorporating protease-cleavable exits for cell-driven remodelling [22]. Nanocomposite hydrogels stiffened with two-dimensional fillers such as laponite, graphene oxide, or MXene exhibit improved mechanical strength, photothermal conversion, or electrical conductivity [23]. Superparamagnetic iron-oxide nanoparticles (SPIONs) embedded in alginate gels permit magnetic-field-triggered release, whereas metallo-supramolecular networks formed by coordinating histidine-decorated PEG with Zn^{2+} or Cu^{2+} self-heal after injection and soften under acidic conditions [24, 25].

4.4 Polymer Functionalisation and Drug-Loading Techniques

Smart hydrogels accommodate therapeutics through three principal mechanisms.

- **Physical entrapment** confines small molecules within pores or micelles.
- **Electrostatic complexation** binds anionic biomacromolecules (e.g., siRNA) to cationic domains.
- **Covalent tethering** links pro-drugs to the network via cleavable bonds, establishing stimulus-coupled release.

Microfluidic double-emulsion templating affords monodisperse, drug-laden microgels at high encapsulation efficiency [26, 27]. Camptothecin attached to disulfide-bearing PEG via a thiol-cleavable linker exemplifies covalent loading that produces near-zero-order release under intracellular reducing conditions [28].

5. DRUG LOADING AND RELEASE KINETICS

5.1 Encapsulation Principles

Amphiphilic PLGA–PEG–PLGA triblock gels solubilise paclitaxel to concentrations above 50 mg mL^{-1} by accommodating the drug within hydrophobic micellar cores [29]. Protonated chitosan domains sequester siRNA electrostatically, achieving encapsulation efficiencies exceeding 80 % [30]. Aldehyde-bearing macromers form reversible Schiff-base linkages with primary-amine drugs (e.g., doxorubicin), integrating loading and stimulus sensitivity into a single step [31].

5.2 Mathematical Modelling

Drug liberation from smart hydrogels is governed by a combination of diffusion, swelling, and degradation. For purely diffusive scenarios the Higuchi square-root relation ($Q \propto t^{1/2}$) applies, whereas systems that swell or erode follow Korsmeyer–Peppas kinetics ($Q \propto t^{n}$). Values of n less than 0.5 indicate Fickian diffusion; values approaching unity approach zero-order release [32, 33]. Finite-element models that couple Fickian transport with moving-boundary swelling now predict burst-release magnitudes with single-digit-percent error [34].

5.3 Physiological Modifiers

External ionic strength compresses polyelectrolyte networks, reducing mesh size and slowing diffusion. Adsorbed serum proteins may occlude pores or, conversely, act as carriers for hydrophobic agents [35]. Cyclic mechanical loading, as encountered in joints or myocardium, superimposes convection on diffusion, necessitating viscoelastic optimisation to maintain predictable release [36].

6. APPLICATIONS IN TARGETED THERAPY

6.1 Oncology

Tumour microenvironments combine acidity, enhanced protease activity, and abnormal vasculature. Dual-responsive gelatin–hyaluronate networks that integrate protonatable side chains with matrix-metalloproteinase (MMP)-cleavable junctions remain inert in circulation and release cytotoxic drugs rapidly in tumour stroma. Photothermal fillers such as indocyanine green convert near-infra-red light into heat, inducing on-demand bursts that synergise with chemotherapy.

6.2 Wound and Tissue Repair

Protease-responsive GelMA hydrogels localise vascular-endothelial growth factor (VEGF) to chronic wounds, stimulating angiogenesis without systemic exposure. Antimicrobial-peptide (AMP) matrices eradicate methicillin-resistant *Staphylococcus aureus* biofilms and accelerate

re-epithelialisation. Thermo-setting PCL–PEG gels carrying bone-morphogenetic protein-2 (BMP-2) and mesenchymal stem cells conform to irregular defects, supporting mineralisation and biodegrading in concert with bone formation.

6.3 Ocular and Nasal Routes

Thermo-gelling formulations transition from liquid to semisolid upon contact with the ocular surface, extending timolol residence to three days. Mucoadhesive chitosan gels delivered intranasally route neuro-active compounds along the olfactory pathway, increasing central-nervous-system exposure four-fold without breaching the blood–brain barrier.

6.4 Oral and Gastroretentive Systems

Chitosan–poly(methacrylic acid) hydrogels shield peptide drugs in gastric acid and swell in neutral intestinal pH, releasing the payload for enteric absorption. Magnetically doped alginate gels remain in the stomach beneath an external belt magnet, maintaining local antibiotic concentrations against *Helicobacter pylori*.

MARKET ENTRY AND REGULATORY FRAMEWORK

Three clinical exemplars illustrate viable development pathways.

- **OncoGel™** delivers paclitaxel from a thermo-setting PLGA–PEG–PLGA matrix applied to resection cavities [47].
- **SABER-bupivacaine** extends post-operative analgesia to 72 h, reducing opioid consumption by nearly half [48].
- **Zilretta®** demonstrates that polymeric steroid depots can satisfy both safety and efficacy requirements for U.S. FDA approval [49].

The 2024 U.S. FDA draft guidance for polymer drug products now mandates stimulus-specific stability assessments, confirming formal recognition of responsive behaviour [50]. Current good-manufacturing-practice production integrates closed-loop emulsion polymerisers, microfluidic reactors for nano-gel fabrication, and real-time optical coherence tomography in 3-D printers. Process-analytical-technology (PAT) tools, including inline near-infra-red spectroscopy, track cross-link density to minimise batch-to-batch drift [51].

CHALLENGES

- **Biocompatibility.** Certain thermo-responsive monomers (e.g., N-isopropylacrylamide) generate inflammatory fragments on hydrolysis [52].
- **Reproducibility.** Minor deviations in monomer purity or curing dose alter lower-critical-solution temperature and swelling ratios; PAT-enabled feedback control mitigates this issue [53].
- **Sterilisation.** γ-Irradiation can sever labile bonds, whereas autoclaving denatures protein-rich gels. Supercritical-CO_2 and low-temperature e-beam methods preserve responsiveness but increase processing cost [54].
- **Predictive Modelling.** Conventional physiologically based pharmacokinetic (PBPK) models seldom incorporate stimulus-induced permeability shifts; hybrid mechanistic–machine-learning platforms are under development [55].

FUTURE HORIZONS

Artificial-intelligence-driven monomer generation predicts polymer propertiesincluding lower-critical-solution temperature, modulus, and degradation half-lifeaccelerating discovery workflows [56]. Four-dimensional bioprinting enables multi-material constructs that evolve post-implantation, supporting patient-specific osteochondral repair [57]. Theranostic hydrogels incorporating quantum dots or magnetic-resonance agents provide simultaneous imaging and drug delivery [58]. Redox-responsive depots carrying CRISPR–Cas ribonucleoproteins achieve single-dose gene correction without viral vectors [59]. Conductive MXene–gelatin hybrids integrate electrical stimulation with anti-inflammatory drug release, a promising strategy for regenerating neural tissues [60].

CONCLUSION

Stimuli-responsive hydrogels unite molecular sensing with controlled actuation, delivering therapeutics at the correct place and time while limiting systemic exposure. Progress in polymer chemistry, computational prediction, and biofabrication has already moved several formulations into late-stage clinical development. Continued advances in AI-assisted design, regulatory science, and scalable manufacturing are expected to establish smart hydrogels as cornerstone technologies in precision pharmaceutics.

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A STUDY ON DRUG USE EVALUATION AND ADVERSE DRUG REACTIONS OF NON-STEROIDAL ANTI-INFLAMMATORY DRUGS IN A TERTIARY CARE HOSPITAL

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ABSTRACT

Non-steroidal anti-inflammatory drugs are medicine widely used to relieve pain, reduce inflammation and bring down the high temperature. The pattern of ADRs caused by NSAIDs in different organ system is essentially similar but quantitative differences that exist in the occurrence of frequency of ADRs among the different group, especially those more frequently occurring in the GI tract, liver, kidney. ADRs are leading cause of morbidity and mortality in all health care system**.**

The aim of the study is to evaluate the drug use pattern and adverse drug reactions of non – steroidal anti- inflammatory drugs in a tertiary care hospital. A Total of 120 patients were surveyed in 3 months to assess the drug utilization pattern and the association comorbidities in patients with different diseases. The majority of the study population were male ,55.83% and remaining 44.16% were females. The highest no of patients was in the age group of 71-80. The most commonly prescribed combination therapy was diclofenac + paracetamol 34.81% followed by etoricoxib + was 32%. Diabetes was to be present as a major comorbidity. According to study out of seven ADR occurred most were caused by Ultracet semi 42.85% and followed by Zerodol, Microcid, Alnacer, paranir iv about 14.28%. Distribution patterns indicate a tendency towards the symptomatic treatment rather than specific treatment. Different type of adverse reaction occurred include dry mouth, allergic reactions, blurred vision, nausea and vomiting. Causality assessment of ADR involved evaluating the likelihood that particular medication caused reported adverse events. The

Naranjo's probability scale assessment show that ADRs were probably related to the drug. Steps must be taken to minimize adverse effects such as prescribing the appropriate dose for geriatric and female population, start with a minimum dose, necessary to control a disease condition with a single morning dose, an alternate day therapy, check the allergic status of patients, check drug interactions and minimize polypharmacy.

Key words: NSAIDs, ADRs

INTRODUCTION

Pharmacovigilance is defined as, "The science and activities relating to the detection, assessment, understanding and prevention of adverse effects or any other possible drug- related problems". In the health of the year 1968, WHO took initiative of safeguarding the health of the public at large following the Thalidomide tragedy. WHO started the Pharmacovigilance program for ADR monitoring with the aim to improve patient care and safety with the use of any kind of medication, improve public health and safety in relation to medication use, contribute to the assessment of benefits, harm, effectiveness and risks of medicines and encourage safe, rational, more effective and cost-effective use of drugs. All medicines with the ability to produce a desired therapeutic effect also have the potential to cause unwanted adverse effects. According to WHO ADR Is defined as "Any response to a drug which is noxious and unintended, and which occurs at doses normally used in man for the prophylaxis, diagnosis, or therapy of diseases or for the modification of physiological function". Non-steroidal anti-inflammatory drugs (NSAIDs) are medicines that are widely used to relieve pain, reduce inflammation, and bring down a high temperature. The incidence rate of various kinds of ADRs of NSAIDS was ranging from 28 to 33%. There was not much of a difference in the number of the ADRs in relation to gender. Gastrointestinal causes of hospitalization (egg, gastrointestinal hemorrhage and perforation) and death have increased in parallel to increased NSAID use. 'Antiulcer' agents are prescribed twice as often in NSAID users, and the economic impact (egg, diagnostic tests and hospitalization) is that about one-third of the arthritis budget has been dedicated to deal with gastrointestinal side effects of NSAIDs. The most common examples of drugs that produce ADRs include paracetamol, nimesulide and diclofenac. WHO defines Drug use evaluation (DUE) as an ongoing, systemic criteria-based program of medicine evaluation that will help ensure appropriate medicine use. If the therapy is determined to be inappropriate, interventions with providers or patients will be necessary to optimize pharmaceutical therapy.

METHODOLOGY

STUDY DESIGN

A retrospective study was conducted where the sample population was selected by inclusion and exclusion criteria. The study was conducted by collecting the data from patient's medical records by using entry form from the general medicine and orthopedic department.

STUDY LOCATION

The study was carried out in the general medicine and orthopedic department of a 450 bedded tertiary care hospital.

STUDY DURATION

Study was conducted from March 2024 to June 2024.

STUDY POPULATION

120 patients admitted in general medicine and orthopedic departments included in the study.

STUDY CRITERIA

INCLUSION CRITERIA

- All patients of either sex will be included
- All Patients need at least one NSAIDS.
- All patients above 18 years are included.
- All ADR and DUE during October 2023 to February 2024

EXCLUSION CRITERIA

- Patients on additional alternative medicines
- Outpatients.
- Patients from department other than general medicine and orthopedic department

SAMPLE SIZE

A total of 120 patients were included in the study.

STUDY TOOLS

- Data entry form.
- ADR reporting form.

DATA COLLECTION

All the patients from the general medicine and orthopedic department with disease were chosen for the study. Screening was performed based on the inclusion and exclusion criteria The information on patients admitted with disorders was collected and recorded in data entry form. The study was conducted for 6 month and ADR were reported. During the study the ADR cases reported from October 2023-february 2024 were collected.

RESULTS AND DISCUSSION

DISTRIBUTION BASED ON GENDER (n= 120)

GENDER	NUMBER OF PATIENTS	PERCENTAGE (%)
Male	67	55.83
Female	53	44.16

Table :1

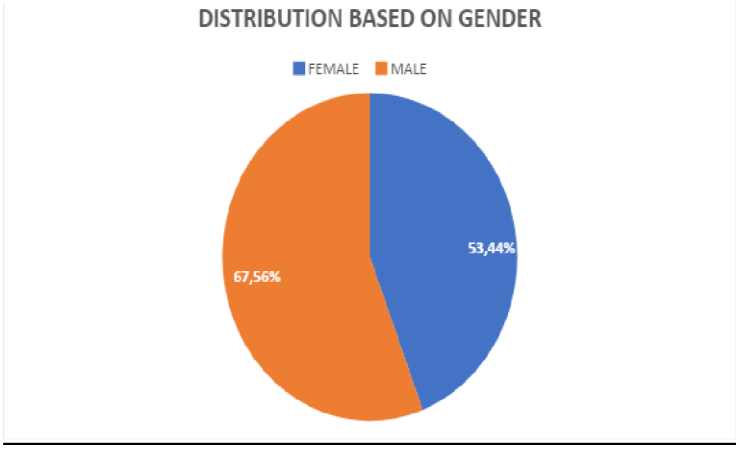


Figure :1

DISTRIBUTION BASED ON AGE (n=120)

AGE	NUMBER OF PATIENTS	PERCENTAGE (%)
20-30	16	13.33
31-40	13	10.83
41-50	21	17.50
51-60	19	15.83
61-70	20	16.66
71-80	25	20.83
81-90	6	5

Table :2

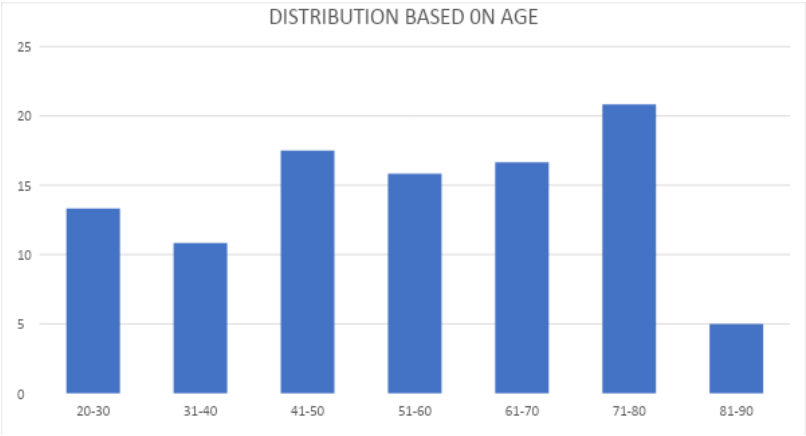


Figure: 2

DISTRIBUTION BASED ON ROUTE OF ADMINISTRATION OF DRUGS (N=686)

ROUTE OF ADMINISTRATION	NUMBER OF DRUGS	PERCENTAGE
Oral	362	52.76
Parenteral	324	47.23

Table :3

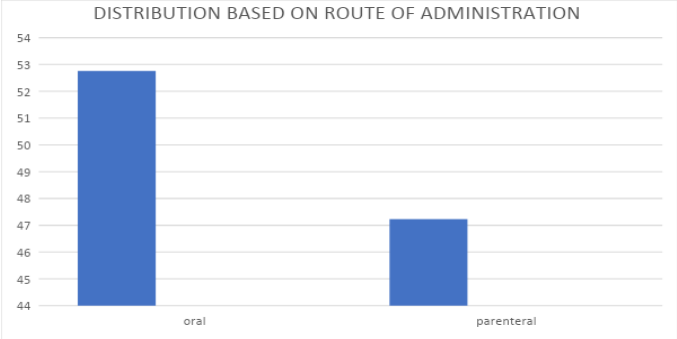


Figure:3

DISTRIBUTION BASED ON DRUG THERAPY REGIMEN(N=686)

DRUG THERAPY REGIMEN	NUMBER OF DRUGS	PERCENTAGE (%)
Monotherapy	258	37.60%
Combination therapy	428	62.39%

Table :4

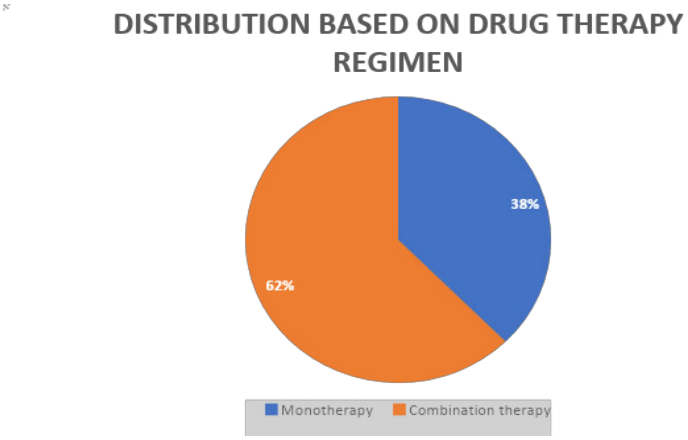


Figure :4

DISTRIBUTION BASED ON COMBINATION THERAPY (N=428)

COMBINATION DRUGS	NUMBER OF PATIENTS	PERCENTAGE (%)
Diclofenac + Paracetamol	149	34.81%
Etoricoxib+Thiocolchicoside	137	32.00%
Tramadol +paracetamol	95	22.19%
Diclofenac+Serratiopeptidase	47	10.98%

Table :5

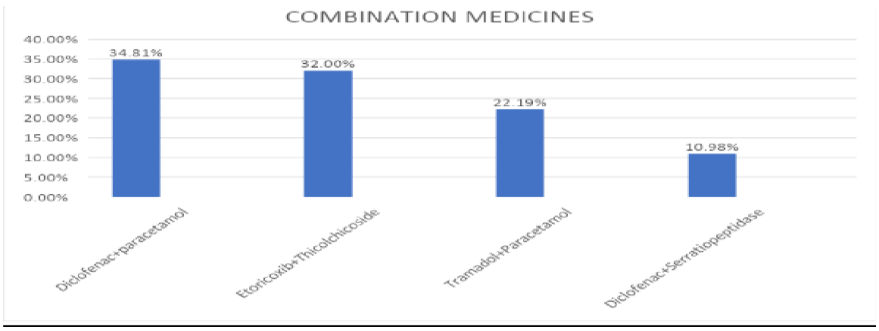


Figure :5

DISTRIBUTION BASED ON COMORBIDITIES(n=120)

COMORBIDITIES	NUMBER OF PATIENTS	PERCENTAGE (%)
Diabetes	39	32.5%
Hypertension	35	29.16%
Dyslipidemia	22	18.33%
Nil	24	20%

Table :6

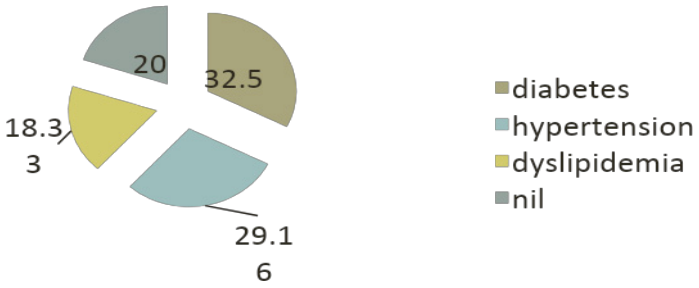


Figure no :6

DISTRIBUTION BASED ON THE NO OF DAYS OF HOSPITAL ADMISSION (n=120)

NO OF DAYS OF HOSPITAL ADMINISTRATION	NUMBER OF PATIENTS	PERCENTAGE (%)
3	9	7.5
4	5	4.16
5	22	18.33
6	12	10

7	10	8.33
8	29	24.16
9	13	10.833
10	10	8.33
11	6	5
12	4	3.33

Table :7

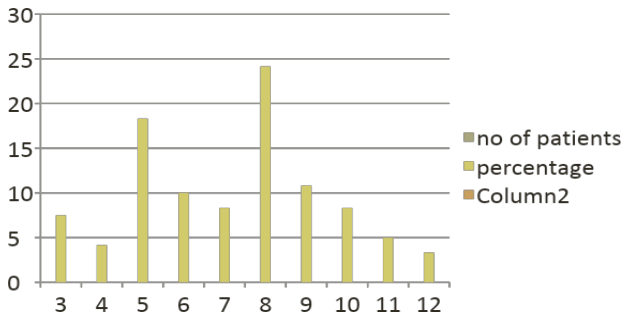


Figure no:7

DISTRIBUTION BASED ON ADR (N=7)

DRUG	NO OF ADR REPORTED	PERCENTAGE (%)
T. ALNACER	1	14.28
T. ZERODOL	1	14.28
C.MICROCID	1	14.28
T. ULTRACET SEMI	3	42.85
PARANIR IV	1	14.28

Table :8

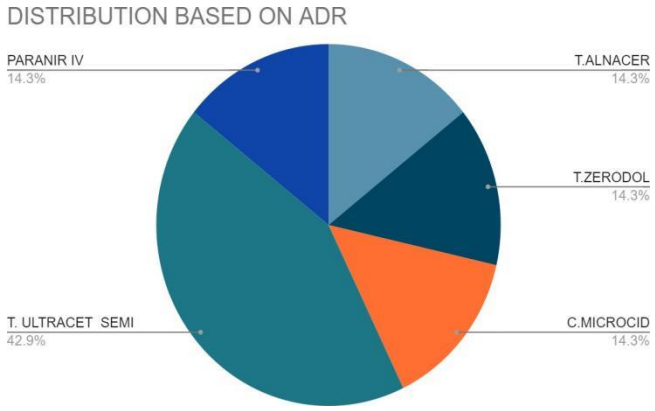


Figure :8

DISTRIBUTION PATTERN TREATMENT GIVEN TO THE REPORTED ADR(N=7)

TREATMENT GIVEN	NO OF ADR	PERCENTAGE (%)

SPECIFIC	2	28.571
SYMPTOMATIC	3	42.851
NO TREATMENT	2	28.571

Table :9

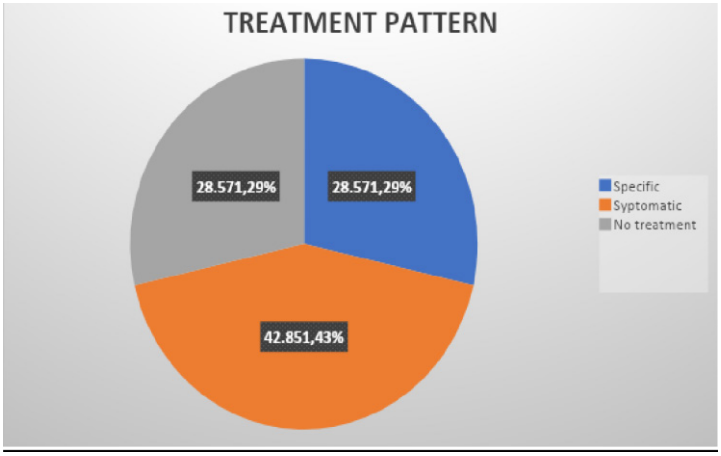


Figure :9

DISTRIBUTION PATTERN FOR MANAGEMENT OF ADR REPORTED(N=7)

ACTION TAKEN	NO OF ADRs	PERCENTAGE
Drug withdrawn	6	85.71%
Dose altered	0	0%
No treatment	1	14.28%

Table : 10

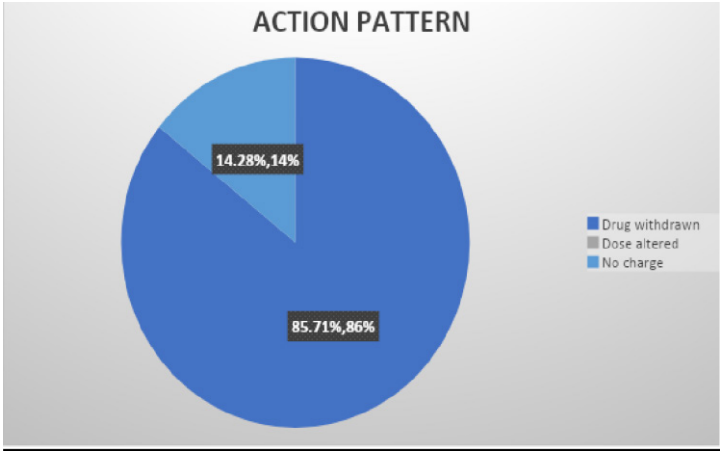


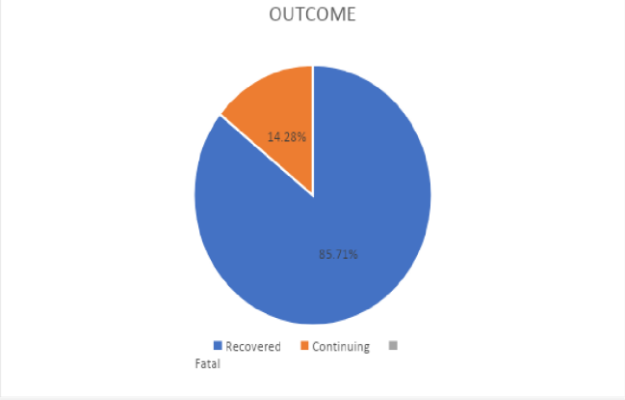
Figure :10

DISTRIBUTION PATTERN FOR THE OUTCOME OF ADR REPORTED (N=7)

OUTCOME	NUMBER	PERCENTAGE (%)
Recovered	6	85.71
Continuing	1	14.28
Fatal	0	0

Table :11

Figure :11



SUSPECTED DRUG

Name of Drugs	Description of Reaction
T.Alnacer (flupirtine+paracetamol)	Dry mouth
T. Zerodol (paracetamol, diclofenac)	Allergic reaction, blurred vision
C.Microcid (indomethacin)	Loose stools, nausea
Ultracet Semi (paracetamol tramadol)	Dry mouth, vomiting
Paranir IV(Paracetamol)	Burning sensation

Table :12

DISTRIBUTION BASED ON TYPE OF REACTION(N=7)

TYPE OF REACTION	FREQUENCY	PERCENTAGE (%)
DRY MOUTH	2	28.571
ALLERGIC REACTION	1	14.28
NAUSEA VOMITING	2	28.571
BLURRED VISION	2	28.571

Table :13

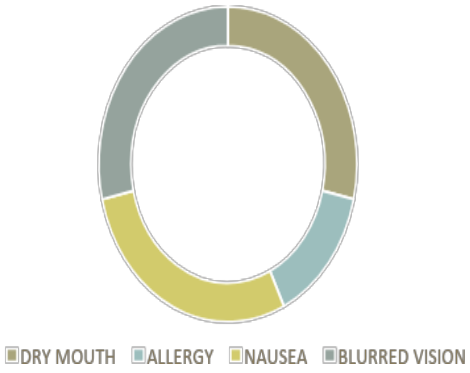


Figure : 12

CAUSALITY ASSESSMENT OF THE IDENTIFIED ADR (Naranjo scale)

DRUG	ADR	NUMBER OF CASES	CAUSALITY
T. ALNACER	Dry mouth	1	Definite
T. ZERODOL	Allergic Reactions, Blurred vision	1	Probable
C.MICROCID	Loose stools,	1	Definite
T. ULTRACET SEMI	Vomiting	3	probable
PARANIR IV	Burning sensation	1	probable

Table :14

A Total of 120 patients were surveyed in 3 months to assess the drug utilization pattern and the association comorbidities in patients with different diseases. The patients who were satisfied within the inclusion criteria were enrolled in the study. The patient's medication charts were reviewed and details were noted in the entry form.

All the 120 individuals participated in the study were grouped according to their gender for analysis as table no 1 and figure 1. Majority of the patients participating in the study were male 67 (55.83%) and the remaining were females 53 (44.16%).

The most prescribed route of administration is oral route is about (52.76%) and the parenteral route of IV and IM included in the study shows (47.23%)

The patients were grouped according to their age group into 7 categories for analyzing as table 3 and figure 3. The maximum number of patients 25(20.83%) belongs to the age group 71-80 and minimum number of patients 6(5%) belongs to the age group 81-90.

Two drug therapy regimens were compared i.e. Monotherapy and combination therapies provided to the orthopedic and general patients diagnosed with Various diseases such as rheumatoid arthritis, pain, inflammation, osteoarthritis, etc. In which 258 drugs were prescribed as monotherapy with percentage 37.60% and 428 drugs were prescribed as combination therapy with percentage 62.39%.

In this study the most prescribed combination medicine is diclofenac and paracetamol in 149 patients with 34.81%. Etoricoxib and was is the second most prescribed combination medicine

32.00%, tramadol and paracetamol are the other combination medicine given to the patients followed by diclofenac and serratio peptidase.

The study shows that comorbidities, DM shows the (35.5%) and the HTN which shows the (29.16%) and the DLP is about (18.33%) and no comorbidities for about (20%) of population.

In this study, with a sample size of 120 patients who was reviewed in between a period of 3 months most patients admitted for a period of 8 days.

The study shows that, no of ADR reported case is mostly due to the drug Ultracet semi is about 45.85%, followed by other drugs Alnacer, Zerodol, Microcid, Paranir iv about 14.28%

According to the collected reporter ADR, the distribution pattern indicates a tendency towards symptomatic (42.85%) than the specific and the no treatment (28.57%).

This study depicts that the (85.7%) shows the fatal outcome and the (14.28%) shows the recovered outcome. From data collected from the study, the distribution of management strategies reflects a balanced approach which the drug withdrawn is (85.71%) and no change in management (14.28%).

In this study 28.57% is dry mouth, nausea vomiting also the blurred vision andonly14.28% seen with allergic reaction.

CONCLUSION

Anti-inflammatory drugs (NSAIDs) are medicines that are widely used to relieve pain, reduce inflammation, and bring down ahigh temperature. NSAIDs may interact non- steroidal with other medicines and cause unwanted effects. NSAIDs should always be used cautiously, for the shortest time possible and at the lowest effective dose.

A retrospective study was conducted and it revealed that, elderly and female patients are more prone to ADRs. The prevalence and incidence rate of ADRs is consistent and comparable with the studies carried out in other parts of India, that was the signal for a need for intervention and increased prevention level in ADR related health problems.

Steps must be taken to minimize adverse effects such as prescribing the appropriate dose for geriatric and female population, start with a minimum dose, necessary to control a disease condition with a single morning dose, an alternate day therapy, check the allergic status of patients, check drug interactions and minimize polypharmacy.

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A RETROSPECTIVE STUDY ON DRUG USE PATTERN OF ANTIBIOTICS IN A TERTIARY CARE HOSPITAL

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ABSTRACT

The retrospective study on drug use pattern of antibiotics in tertiary care hospital provide a valuable insight into prescribing habits and trends within the institution. The study was carried out for a period of 6 months at tertiary care hospital. The study highlights critical aspects of antibiotic use in tertiary care hospital, which provides valuable insights into prescribing patterns, patient demographics and clinical outcomes. By analysing the data across 150 patients ,the highest use of antibiotics were in 41-50 and the gender distribution showed slight female predominance. The most frequently prescribed antibiotic class was cephalosporin + beta lactaminase inhibitors in which (cefperazone + sulbactam) and (amoxicillin + clavulanic acid) were the maximally used antibiotic combinations. Pneumonia and hypertension were the major infection and comorbidity respectively. Most of the ADR reactions were non-serious, moderate, and managed with suspected drug stoppage and symptomatic treatment and cultural sensitivity found klebsiella pneumonia as the common one.

INTRODUCTION

Antibiotics are natural, semisynthetic or synthetic substances produced by microorganisms which selectively suppress the growth or kill other microorganism at very low concentration. Antibiotics are the powerful, effective and widely used medication utilized for treatment and prevention of numerous bacterial infections. It appears that Alexander Fleming was somewhat disorganized in his work and made the unintentional discovery of penicillin. In 1928, after coming back from vacation in Suffolk, he discovered that a culture plate containing Staphylococcus bacteria that he had unintentionally left uncovered had become contaminated by the fungus Penicillium notatum. Everywhere the fungus spread across the plate, it produced areas devoid of germs. Fleming separated the mold and cultured it in pure form. He discovered that P. notatum was less toxic than the disinfectants in use at the time and shown remarkable effectiveness even at very low concentrations, inhibiting the growth of Staphylococcus even when diluted 800 times. Collaborations with British pharmaceutical companies made large manufacture of penicillin the antibiotic compound produced by P. notatum—possible after early trials in treating human wounds. Due to the enormous success of penicillin treatment, the US government started funding the drug's mass production. Penicillin was being used extensively by hospitals across Europe and in the field by D-Day in 1944 to treat infections in troops. Penicillin was dubbed "the wonder drug" and had saved many lives by the conclusion

of World War II. This study analyses the drug use pattern of antibiotics in a tertiary care hospital and antibiotic utilization in various departments.

- **STUDY DESIGN**

This is a retrospective, observational study in a 450 bedded tertiary care hospital.

- **STUDY LOCATION**

The study was carried out in general medicine, surgery and paediatrics departments of tertiary care hospital.

- **STUDY DURATION**

The Study was carried out for a period of 6 months.

- **STUDY POPULATION**

Inpatients belonging to all the age group who prescribed with antibiotics were included in the study.

- **STUDY CRITERIA**

Inclusion criteria:

Patients who got admitted in general medicine, surgery and paediatric ward.

Exclusion criteria:

Patients who are not prescribed with antibiotics.

Out–patients.

RESULT AND DISCUSSION

The study provides information about prescribing patterns of antibiotics. From the demographic data the gender distribution showed slight female predominance (51.11%) than males (48.88%). The age category in which the highest use of antibiotics was in 41-50 age group (19.44%). The most frequently prescribed antibiotic class is Cephalosporin + Beta lactamase inhibitor (and the least is sulphonamides, Oxazolidinedione and Lincosamide. Combinational therapy is maximally used of which the most frequently prescribed antibiotic combinations are (Cefoperazone + Sulbactam) and (Amoxicillin + Clavulanic acid). Pneumonia was present as the major infection in majority of the patients. Hypertension was to be present as a major comorbidity. The maximum number of ADR was reported were for Piperacillin + Tazobactam with nausea, itching and swelling of face. Also, Ciprofloxacin with redness of eye, rashes and edema. The action taken were drug withdrawal and symptomatic

treatment respectively. According to the cultural sensitivity data 7.77% only done the cultural sensitivity which found that 35.7% were with Klebsiella pneumonia.

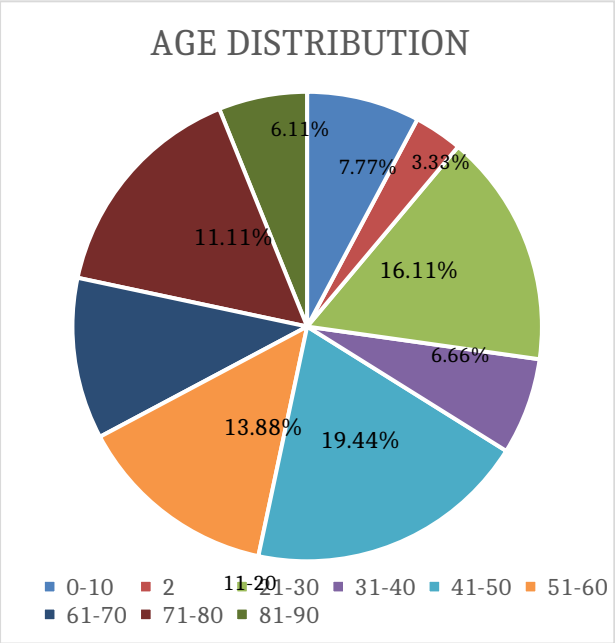

Figure 1: Percent distribution based on age

Figure 2: Percent distribution based on gender

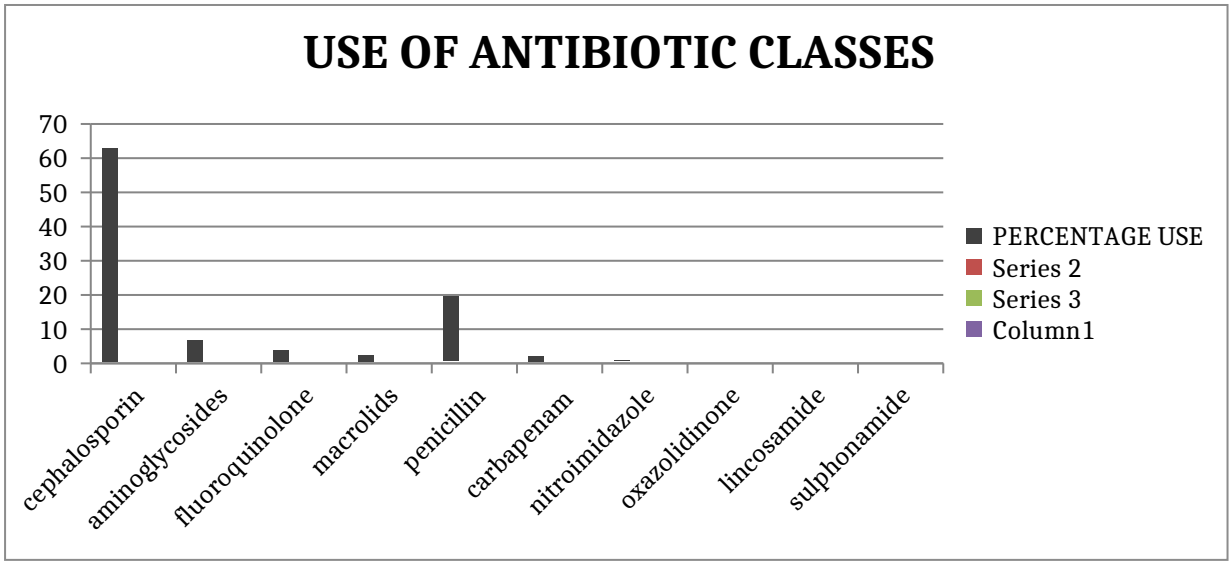

Figure 3: Distribution of patients based on uses of various classes

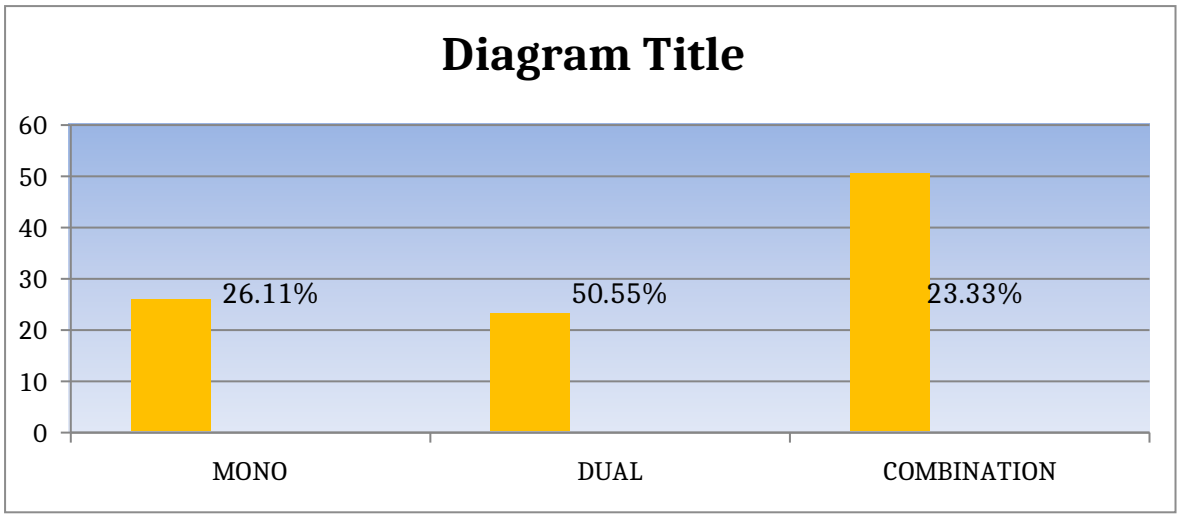

Figure 4: Distribution of patients based on type of therapy

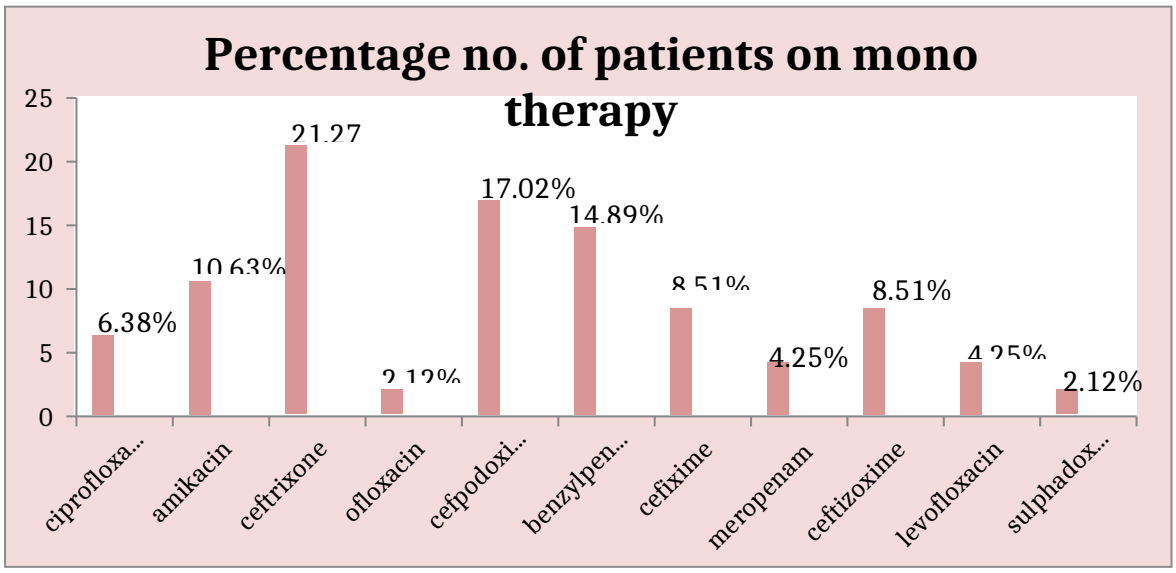

Figure 5: Distribution of patients based on mono therapy

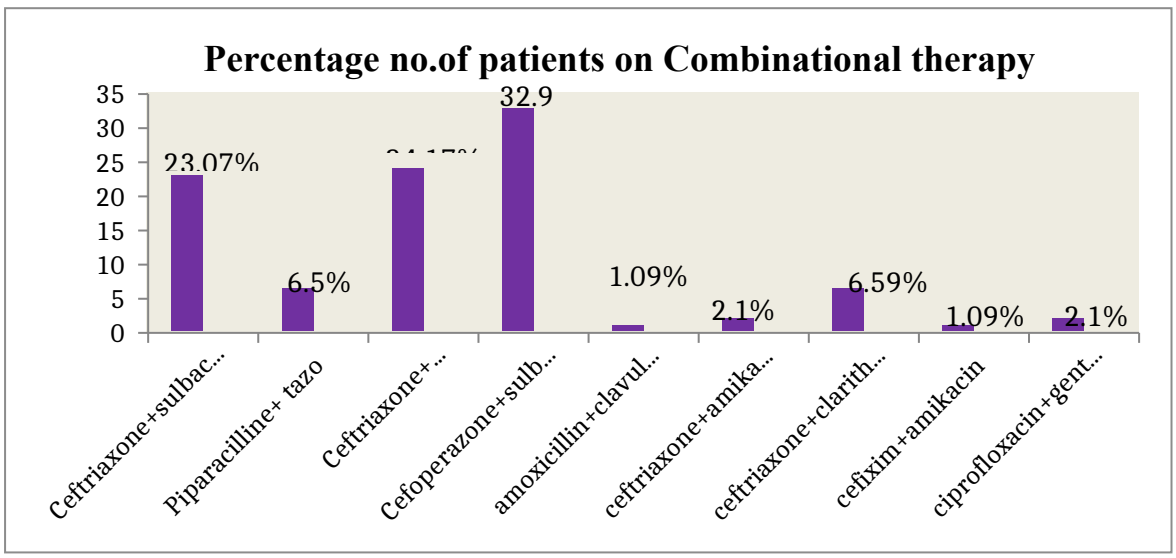

Figure 6: Distribution of patients based on combinational therapy

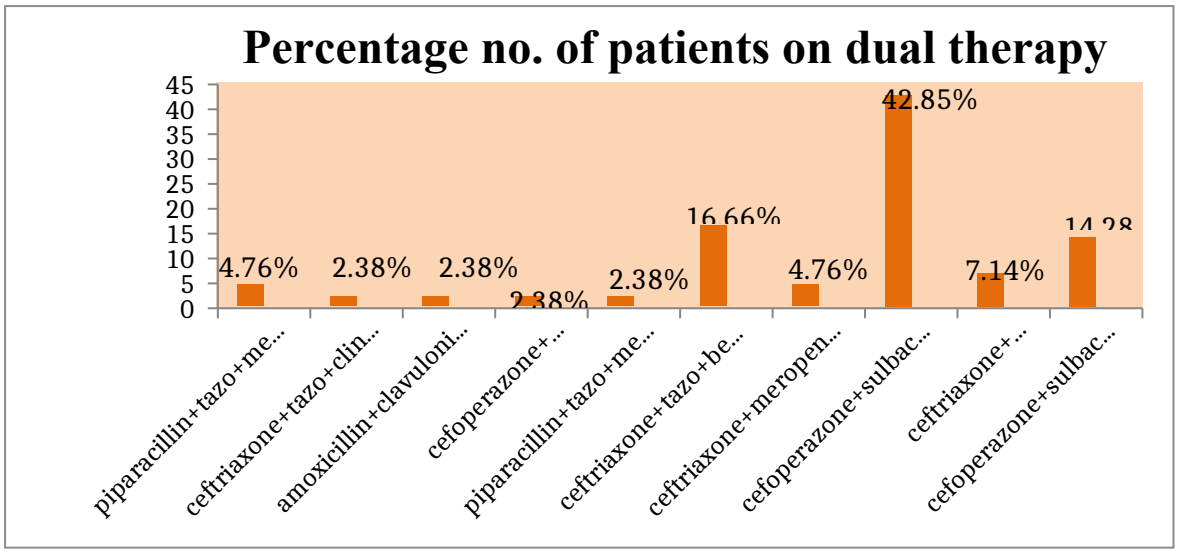

Figure 7: Distribution of patients based on dual therapy

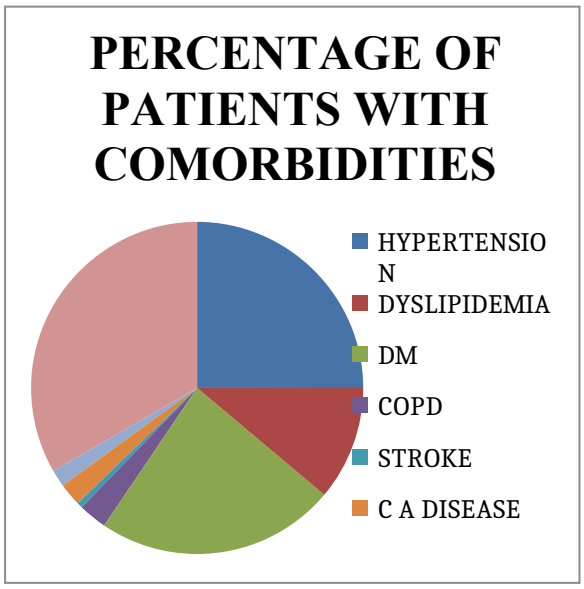

Figure 8: Distribution of patients with comorbidities

Figure 9: Distribution of patients based on number of drugs per Patients

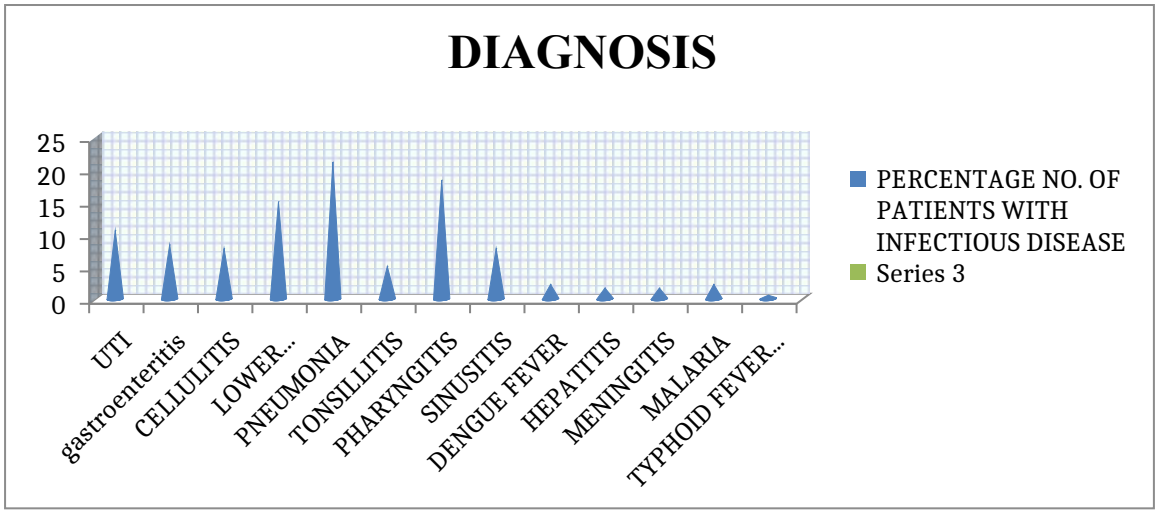

Figure 10: Distribution of patients based on infectious disease

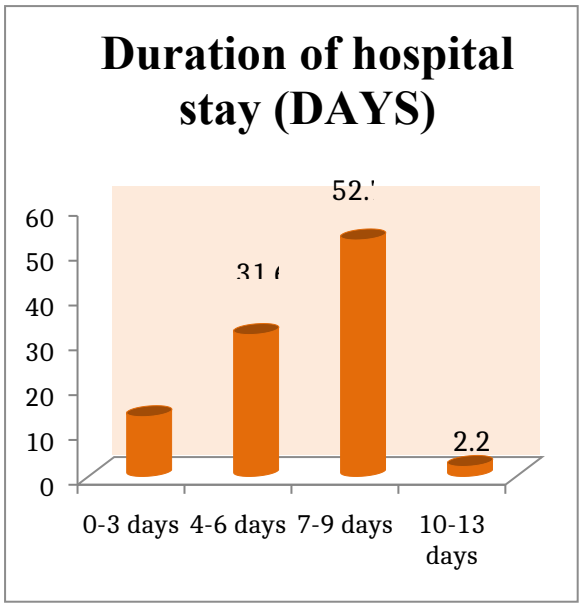

Figure 11: Distribution of patients based on duration of hospital stay

Figure :12 Distribution of patients based on route of administration

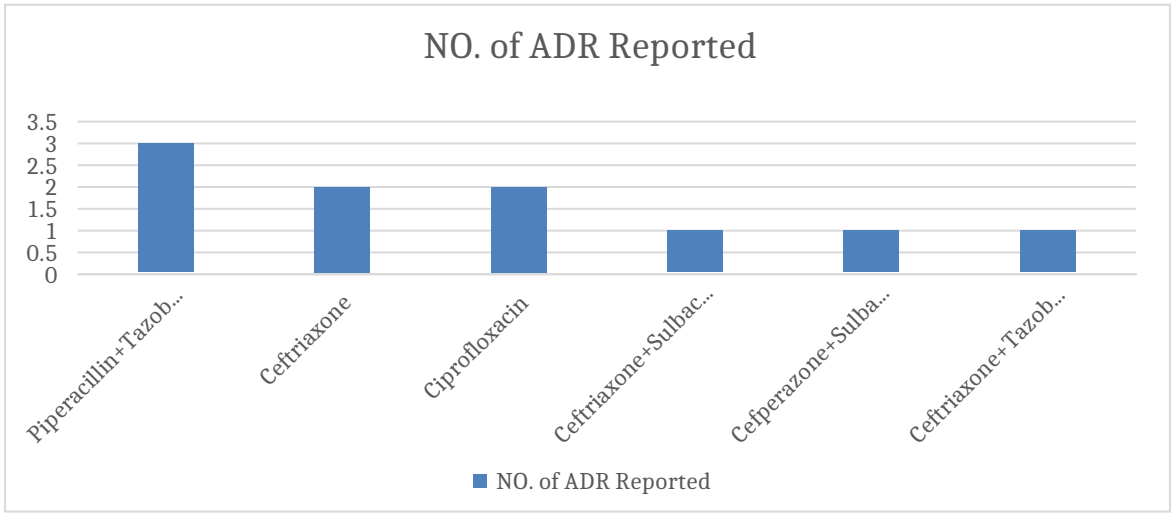

Figure 13: Distribution of patients based on ADR

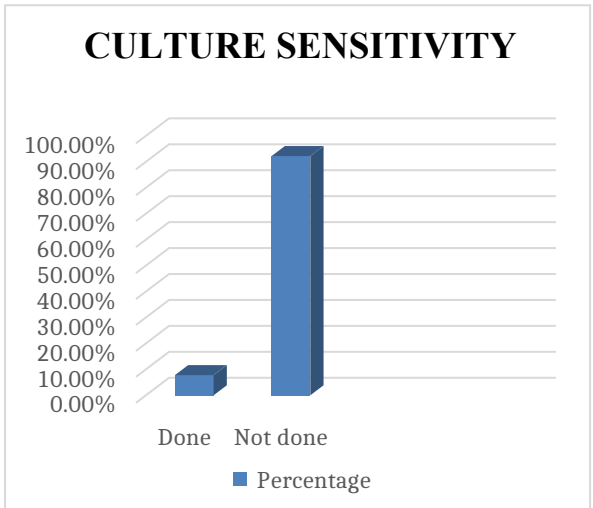

Figure 14: Distribution of patients based on cultural sensitivity

Figure 15: Distribution of patients based on organism identified

CONCLUSION

This study highlights critical aspects of antibiotic use in a tertiary care hospital, which provides valuable insights into prescribing patterns, patient demographics, and clinical outcomes. By analyzing data across various dimensions, implementing the comprehensive stewardship programs to guide appropriate antibiotic prescribing, reduce misuse, and monitor resistance patterns. Culture sensitivity testing played a vital role in guiding appropriate antibiotic therapy. Increased use of culture sensitivity results in personalized antibiotic prescriptions, reducing the risk of resistance and improving treatment outcomes, thus ensure targeted antibiotic therapy. By Providing ongoing education for healthcare providers on best practices in antibiotic prescribing, focusing on minimizing broad-spectrum antibiotic use and preventing resistance. Tailor antibiotic choices based on patient demographics, comorbidities, and clinical conditions to improve outcomes and reduce adverse effects. Strengthening of ADR monitoring and reporting systems will enhance patient safety. By implementing the above strategies, we can ensure more effective and safer use of antibiotics, ultimately enhancing the quality of care and public health

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FORMULATION OF BOUGAINVILLEA FACE SERUM

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ABSTRACT

Face serum are introduced to reverse ageing ,boost collagen of our skin to keep it firmer,making skin more radiant and help in reducing the fine lines. Bougainvillea is used in skin care for its rich levels of powerful antioxidants that aids skin.It not only moisturizes the skin but also brightens, repairs severe skin sun damage, fades darkspots, pimplespots and skin irritation. So our aim was to formulate and evaluate face serum from the extract of bougainvillea as herbal ingredients gaining much more importance because of their less side effects compared to synthetic one.The present work deals with the formulation and evaluation of face serum containing bougainvillea extract. Face serum gel was prepared and evaluated for its visual appearance, pH, spreadability, viscosity, and the result were found to be satisfactory.

KEY WORDS

Bougainvillea,Face serum,Formulation,Evaluation.

INTRODUCTION

Cosmetics are considered as essential components in life..The herbal products or drugs are derived from vegetable sources from various parts of the plants like root, leaf, flower, fruit extrude or plant as a whole. Herbal Cosmetics are referred as Products,which are formulated using various permissible cosmetic ingredients to form the base in which one or more herbal ingredients are used to provide defined cosmetic benefits only or shall be called as "Herbal Cosmetics"[(1)].Face serums are topical skincare products that have a high percentage of active ingredients with this viscosity. They penetrate deeper into the skin to provide benefits to the skin in lesser time & effectively.' Face serums are basically a target treatment for the skin as it targets on various skin related problems & solves skin concerns like hyperpigmentation, fine lines, wrinkles, crow's feet, acne, dehydrated skin dark circles, under eye puffiness etc[(2)] . These are packed with various active ingredients and penetrators that take the actives deeper in to the desired layers of the skin. Face serums contain active ingredients in concentrated amounts. The time to show desired results depends on the type of serum. Ideally, it takes 4-6 weeks to see visible results.[(3)]

1.**Collection and seperation of Bougainvillea bracts**

The fresh bougainvillea plants (2kg) were collected, washed and authenticated by Pharmacognosist.The bracts were separated from Bougainvillae plant

2.**Drying of Bougainvillea bracts**

The Bougainvillae bracts are then dried in shade for a week

3.**Extraction of Bougainvillea**

Dried bougainvillea bracts are grinded to powder.Weighed out 40g of powder and packed into the column.Extraction done by soxhlet apparatus using 100ml ethanol as solvent for 6 hours[4]

4.**Concentration of Bougainvillae extract**

After soxhlet extraction, the Bougainvillae extract was concentrated by simple distillation method at temperature maintained at 600C. The concentrated extract is now stored in glass container

5.**Formation of aqueous phase and oil phase for the preparation of face serum**

Mix bougainvillea extract , amla extract with water .Mix sandalwood oil, olive oil, coconut oil and tween 20 with homogenizer seperately Then mix oil phase to aqueous phase again with homogenizer.[5]

Sl.no	Ingredients	Quantity
Aqueous phase		
1	Water	Qs to 30ml
2	Glycerin	5ml
3	**Bougainvillea extract**	**5ml**
4	Amla extract	5ml
Oil phase		
5	Sandalwood oil	0.02ml
6	Coconut oil	0.4ml
7	Olive oil	1.8ml
8	Tween 20	0.2ml

EVALUATION

Face serum was evaluated for following:
Phytochemical screening was performed to analyse the bioactive components present in the plant

1 Organoleptic Evaluation

The colour and appearance of the formulation was observed visually.The formulation produced a uniform distribution of extracts.This test was confirmed by observing visual appearance and by touch.[6]

2. Homogenity

Press a small quantity of formulated gel between thump and index finger and find for its consistency and presence of any coarse particle.

3. Determination of pH

The pH measurement was carried out using a digital pH meter by completely immersing the glass electrode on gel system to cover the electrode 0.5g of formulation was dissolved in 50ml of distilled water and the pH was determined.[7]

4. Viscosity

Viscosity of the herbal under eye derma gel was determined using Brookfield viscometer (S-62, model LVDV-E) with a spindle speed of the viscometer rotated at 60 rpm.[8]

5. Spreadablity

Two sets of standard size slides were taken. The herbal gel formulation was placed on one of the slides. Another slide was placed on top of the gel so that the gel was sandwiched between the two slides. 50 g of weight was placed on the upper slide so that the gel between the two slides was pressed evenly to form a thin layer. The weight is removed and the excess gel adhering to the slide is scraped off. Diameter of the spread of the gel was measured[9]

RESULTS AND DISCUSSIONS

SL. NO	TESTS	CONSTITUENTS	RESULT
1	Molisch'sTest Fehling'sTest	Carbohydrates Reducingsugar	Present
2	Ferricchloridetest	Phenols and tannins	Present
5	Mayer's test, Hager's test Wagner'stest Dragendroffs test	Alkaloids	Absent
6	Alkaline reagent test	Flavonoids	Absent
7	Foamtest	Saponins	Present

The formulation exhibited pale brown colour and characteristic odour and it showed an accepable pH,Homogenity,Spreadability and viscosity within limits and was stable over the tested duration.

ORGANOLEPTIC EVALUATION

Colour	Palegreen
Odour	Pleasant
Appearance	Good

PHYSICAL EVALUATION

Feel	Non sticky
Washability	Washable
Irritancy	Non-irritant
Homogeneity	Homogenous
pH	5.1
Spreadability	5-6cm
Viscosity	4082.65cp

CONCLUSION

In this study, bougainvillea extract was prepare during maceration process. All the ingredients in Aqueous phase and oil phase mixed as per the procedure and bougainvillea face serum was formulated successfully. It is a water- based serum..The odour of the product was accecptable and the colour was palegreen with a smooth homogeneous texture and glossy appearance.The extract was tested for the presence of various chemical constituents like catechin, Carbohydrates,Phenol & Tannins.The face serum was also subjected to the following evaluation test including pH, Spreadability,Homogenity and Viscosity.The pH of the formulation is in an acidic range. Hence it is suitable for application on skin. The formulation produced uniform distribution of extract.After use, it feel like emollient, slipperiness and no residue were formed and easy to wash out.The study concluded that we can formulate a Face serum containing bougainvillea extract as the principle ingredient along with other ingredients with glycerine , L- ascorbic acid, benzylalcohol, xanthangum, olive oil and coconut oil . It can be conveniently applied to the skin to get exposed benefits on skin.

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Emerging Insights into Hypertension in India: Epidemiology, Management, and Research Perspectives

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Abstract

Hypertension is a major public health challenge in India, contributing substantially to cardiovascular morbidity and mortality. The increasing prevalence of hypertension is driven by urbanization, dietary changes, obesity, sedentary lifestyle, and genetic predisposition. This review consolidates contemporary trends in Indian hypertension research, highlighting epidemiology, risk factors, diagnostic innovations, therapeutic strategies, and emerging technologies. Special focus is given to population-specific characteristics such as early-onset hypertension, salt sensitivity, central obesity, and metabolic comorbidities. Indian studies have contributed to understanding hypertension epidemiology, mechanisms of blood pressure regulation, pharmacogenetic variations, and the effectiveness of lifestyle and pharmacological interventions. Technological innovations, including ambulatory blood pressure monitoring, home monitoring devices, telemedicine, wearable sensors, and digital health interventions, are expanding the scope of hypertension management. Despite significant advances, challenges such as limited awareness, low treatment adherence, regional disparities, and inadequate longitudinal data remain. Future research directions include precision medicine approaches, genomics-guided therapy, culturally tailored lifestyle interventions, large-scale cohort studies, and integration of digital health platforms to improve prevention, detection, and management of hypertension in India.

Keywords: Hypertension, India, epidemiology, risk factors, lifestyle intervention, pharmacotherapy, technology, digital health, precision medicine.

1. Introduction

Hypertension is a silent but potent risk factor for cardiovascular diseases (CVDs), including stroke, coronary artery disease, heart failure, and chronic kidney disease (CKD) [1]. Globally, hypertension affects over 1.3 billion individuals, and India represents a significant portion of this burden due to its large population, rapid urbanization, and lifestyle transitions [2]. Recent data

suggest that **approximately 25–30% of Indian adults are hypertensive**, with higher prevalence in urban populations [3]. Early-onset hypertension, central obesity, salt sensitivity, and coexisting metabolic disorders are prominent features in Indian cohorts, differentiating the population from Western counterparts [4].

Over the last two decades, India has witnessed an expansion of hypertension research encompassing epidemiological surveys, interventional trials, observational studies, and health systems research. Research has focused on defining population-specific risk factors, evaluating lifestyle and pharmacological interventions, exploring mechanistic pathways, and integrating innovative diagnostic and monitoring technologies. This review synthesizes current trends in Indian hypertension research, emphasizing human studies and their translational implications.

---

2. Epidemiology of Hypertension in India

2.1 National and Regional Prevalence

Hypertension prevalence in India varies based on geography, urbanization, age, and socioeconomic status:

- **NFHS-5 (2019–21):** Adult prevalence ~24% [5]
- **CARRS Study (Chennai, Delhi, Karachi):** Urban prevalence ~30% [6]
- Rural prevalence ranges from 15–20% but is rising due to lifestyle transitions [7]

2.2 Age and Gender Distribution

- Indians develop hypertension earlier than Western populations, often in the **30–40-year age range**.
- Younger men exhibit higher prevalence; postmenopausal women show increased rates [8].

2.3 Socioeconomic and Regional Variations

- Northern and Southern India have higher prevalence than Eastern and Western regions, reflecting dietary, genetic, and lifestyle differences [9].
- Urban populations show faster progression, partly due to high salt intake, sedentary behavior, and processed food consumption.

2.4 Awareness, Treatment, and Control

Despite growing prevalence, awareness and control remain suboptimal:

- Awareness: ~50–60%
- Treatment: ~30–40%

- Control: ~10–20% [10]

This highlights a significant public health gap requiring targeted interventions.

---

3. Risk Factors for Hypertension in India

3.1 Modifiable Risk Factors

1. **Obesity and Central Adiposity:** Central obesity strongly predicts hypertension, even at relatively low BMI in Indians [11].
2. **Dietary Patterns:** Excess salt intake (>10 g/day), low potassium intake, high refined carbohydrates, and saturated fats are major contributors [12].
3. **Sedentary Lifestyle:** Reduced physical activity increases sympathetic activity and insulin resistance [13].
4. **Tobacco and Alcohol Consumption:** Smoking and chronic alcohol intake exacerbate vascular stiffness and hypertension [14].
5. **Stress and Mental Health:** Chronic psychosocial stress is increasingly recognized as a contributing factor [15].

3.2 Non-Modifiable Risk Factors

- **Age:** Hypertension prevalence rises with advancing age.
- **Family History and Genetics:** Polymorphisms in ACE, AGT, and CYP11B2 genes have been associated with elevated risk [16].
- **Ethnicity:** South Asian populations demonstrate salt sensitivity, early-onset hypertension, and higher risk of metabolic syndrome [17].

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4. Pathophysiology Insights from Indian Research

Indian human studies have elucidated multiple mechanisms contributing to hypertension:

4.1 Renin-Angiotensin-Aldosterone System (RAAS) Dysregulation

- Altered RAAS activity is common in Indian cohorts.
- Polymorphisms in ACE gene correlate with response to ACE inhibitors [18].

4.2 Sympathetic Nervous System Overactivity

- Heart rate variability studies show elevated sympathetic tone in urban Indian populations [19].

4.3 Endothelial Dysfunction and Oxidative Stress

- Increased oxidative stress, reduced nitric oxide availability, and arterial stiffness are common in hypertensive patients [20].

4.4 Salt Sensitivity and Renal Sodium Handling

- Salt sensitivity is higher among Indians, contributing to elevated BP at lower salt loads [21].
- Studies using salt loading and excretion assays confirm renal sodium retention as a major contributor.

4.5 Metabolic Comorbidities

- Insulin resistance, central obesity, and dyslipidemia often co-occur with hypertension, enhancing cardiovascular risk [22].

---

5. Diagnostic Approaches and Innovations

5.1 Office Blood Pressure Measurement

- Standard sphygmomanometer and oscillometric devices remain primary.
- White-coat hypertension prevalence ~20% necessitates confirmatory methods [23].

5.2 Ambulatory Blood Pressure Monitoring (ABPM)

- ABPM detects masked hypertension, nocturnal hypertension, and diurnal patterns.
- Non-dipping patterns are associated with target-organ damage in Indian cohorts [24].

5.3 Home Blood Pressure Monitoring (HBPM)

- Home monitoring improves adherence, BP control, and long-term outcomes [25].

5.4 Biomarkers and Imaging

- **Biomarkers:** Natriuretic peptides, high-sensitivity CRP, urinary albumin excretion.
- **Imaging:** Echocardiography and carotid intima-media thickness are used to assess end-organ damage [26].

Table 1: Diagnostic Innovations in Indian Hypertension Research

Diagnostic Tool	Key Findings in India	Clinical Implication
ABPM	High prevalence of masked hypertension and non-dipping pattern	Improved risk stratification
HBPM	Better adherence and BP control	Early detection and management
Echocardiography	Left ventricular hypertrophy common	Assess target-organ damage
Biomarkers	hs-CRP, NT-proBNP elevated in high-risk patients	Risk prediction

6. Therapeutic Strategies

6.1 Lifestyle Interventions

Lifestyle modification is the cornerstone of hypertension management in India:

1. **Dietary Interventions:**
   - Salt reduction (<5 g/day)
   - DASH diet adaptation using Indian foods (lentils, vegetables, low-fat dairy) [27]
2. **Weight Management:**
   - Even modest weight loss (5–10%) reduces BP significantly [28]
3. **Physical Activity:**
   - Minimum 150 minutes/week of moderate-intensity activity recommended [29]
4. **Stress Management:**
   - Yoga and meditation interventions are effective in lowering BP in Indian studies [30]

Table 2: Lifestyle Intervention Outcomes in Indian Cohorts

Intervention	Study Type	Systolic BP Reduction	Diastolic BP Reduction
Salt restriction	RCT, Delhi	5–7 mmHg	3–5 mmHg
Yoga & pranayama	RCT, Kerala	6 mmHg	4 mmHg
DASH diet adaptation	Observational, Chennai	8 mmHg	5 mmHg
Weight loss 5–10%	Cohort, Mumbai	4–6 mmHg	3–4 mmHg

6.2 Pharmacological Management

6.2.1 First-Line Agents

- **ACE inhibitors:** Enalapril, Ramipril
- **ARBs:** Telmisartan, Losartan
- **Thiazide diuretics:** Hydrochlorothiazide
- **Calcium channel blockers:** Amlodipine, Nifedipine [31]

6.2.2 Fixed-Dose Combinations

- ACEI/CCB, ARB/CCB, and ARB/diuretic combinations enhance adherence and BP control.

6.2.3 Resistant Hypertension

- Defined as uncontrolled BP despite ≥3 agents including a diuretic.
- Prevalence ~10–12% among treated Indians [32]
- Mineralocorticoid receptor antagonists (spironolactone, eplerenone) and lifestyle optimization are effective.

6.2.4 Pharmacogenetic Considerations

- ACE I/D polymorphism affects ACE inhibitor efficacy.
- CYP3A5 and CYP2C9 polymorphisms influence response to calcium channel blockers and ARBs [33].

Table 3: Major Antihypertensive Classes and Usage in India

Drug Class	Common Drugs	Trends/Comments
ACE inhibitors	Enalapril, Ramipril	Widely used first-line therapy
ARBs	Telmisartan, Losartan	Increasing preference, fewer side effects
Calcium channel blockers	Amlodipine, Nifedipine	Commonly prescribed, effective in salt-sensitive patients
Thiazide diuretics	Hydrochlorothiazide	Frequently used in combination therapy
Beta-blockers	Metoprolol, Atenolol	Useful in patients with comorbid IHD
Mineralocorticoid antagonists	Spironolactone, Eplerenone	Effective for resistant hypertension

7. Comorbidities and Population-Specific Considerations

- **Diabetes Mellitus:** Coexistence increases cardiovascular risk; combination therapy often needed [34]
- **Chronic Kidney Disease (CKD):** Both a cause and consequence of hypertension [35]
- **Obesity and Metabolic Syndrome:** Central obesity is highly prevalent and accelerates disease progression [36]
- **Dyslipidemia:** Frequently coexists, requiring integrated therapy.

---

8. Technological Innovations and Emerging Trends

8.1 Digital Health and Telemedicine

- Mobile health apps and SMS-based reminders improve adherence.
- Teleconsultation programs enhance follow-up, especially in rural populations [37].

8.2 Ambulatory and Wearable Devices

- Continuous monitoring and cuffless devices are being validated in Indian cohorts.
- Detect trends such as nocturnal hypertension, morning surge, and masked hypertension.

8.3 Precision Medicine and Pharmacogenomics

- Integration of genetic data and pharmacogenetics to guide individualized therapy.
- Example: ACE polymorphism–guided therapy improves BP control in Indian patients [38].

8.4 Large-Scale Cohort Studies

- **CARRS**, **PURE India**, and **ICMR-INDIAB** provide longitudinal insights into risk factors, treatment patterns, and outcomes [39].

---

9. Challenges in Hypertension Research in India

1. **Awareness Gaps:** Nearly 40–50% of hypertensives remain undiagnosed [5]
2. **Treatment Adherence:** Complex regimens, side effects, and cost constraints contribute.
3. **Healthcare Access:** Rural populations often lack specialist care and diagnostic facilities.
4. **Limited Longitudinal Data:** Few large-scale follow-up studies; high attrition rates.
5. **Heterogeneity:** Ethnic and regional differences complicate generalization of findings.

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10. Future Directions

10.1 Genomics and Precision Medicine

- Identify genetic determinants and personalize antihypertensive therapy.

10.2 Digital Health Integration

- Expand telemonitoring, mobile apps, and AI-assisted risk prediction.

10.3 Early Detection and Prevention

- Target young adults and high-risk populations with lifestyle and pharmacological interventions.

10.4 Integrated Multimodal Care

- Combine pharmacotherapy, lifestyle counseling, and behavioral support.

10.5 Population-Based Longitudinal Research

- Expand registries and multicenter cohort studies for real-world evidence.

---

11. Conclusion

Hypertension research in India has advanced considerably, focusing on epidemiology, mechanisms, risk factors, therapeutics, and emerging technologies. Indian studies have elucidated population-specific characteristics such as early-onset hypertension, salt sensitivity, and metabolic comorbidities. Lifestyle modification, pharmacotherapy, and technological innovations are central to management strategies. Despite these advances, challenges remain in awareness, adherence, longitudinal follow-up, and regional disparities. Future research integrating precision medicine, genomics, digital health, and culturally tailored interventions holds promise for improving hypertension prevention and control in India, ultimately reducing cardiovascular morbidity and mortality.

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Contemporary Approaches to Obesity Research in India: From Epidemiology to Intervention

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Abstract

Obesity is a major public health challenge in India, contributing to metabolic disorders, cardiovascular diseases, type 2 diabetes, and certain cancers. Its prevalence is rising rapidly due to urbanization, dietary transitions, sedentary lifestyles, and genetic predisposition. Recent Indian research has focused on epidemiology, risk factors, pathophysiology, therapeutic interventions, and emerging technologies for management and prevention. This review summarizes current trends in obesity research in India, highlighting population-specific factors such as central obesity, early-onset obesity, and ethnic susceptibility. Lifestyle interventions, pharmacotherapy, bariatric procedures, and digital health innovations are discussed, alongside challenges including limited awareness, cultural barriers, and healthcare disparities. Future directions include precision nutrition, genomics-guided interventions, integration of wearable technology, and large-scale cohort studies to improve prevention and management strategies. Indian studies provide critical insights into obesity trends and offer opportunities to tailor interventions for the country's diverse population.

Keywords: Obesity, India, epidemiology, metabolic syndrome, lifestyle intervention, pharmacotherapy, bariatric surgery, digital health, precision nutrition.

1. Introduction

Obesity is defined as abnormal or excessive fat accumulation that presents a risk to health. Globally, obesity prevalence has nearly tripled since 1975, and India is experiencing a rapid rise in obesity rates, particularly in urban regions [1]. Unlike Western populations, Indians tend to develop **central obesity** and metabolic complications at lower BMI thresholds, a phenomenon termed the "South Asian phenotype" [2]. Obesity is a key driver of metabolic syndrome, type 2 diabetes, cardiovascular disease, non-alcoholic fatty liver disease (NAFLD), and certain cancers [3].

Research on obesity in India has expanded significantly over the last decade, encompassing epidemiological surveys, clinical studies, interventional trials, and public health initiatives. Studies have focused on understanding the prevalence, risk factors, metabolic and genetic mechanisms, therapeutic approaches, and emerging technologies to monitor and manage obesity. This review provides a comprehensive overview of current trends in obesity research in India, emphasizing human studies and translational applications.

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2. Epidemiology of Obesity in India

2.1 Prevalence Trends

Obesity prevalence is increasing across age groups and regions in India:

- **NFHS-5 (2019–21):** Overweight/obesity prevalence in adults ~19–22% [4]
- Urban adults: ~25–30%
- Rural adults: ~10–15%, rising in recent years [5]

2.2 Age and Gender Distribution

- Obesity is increasingly observed in children and adolescents.
- Women tend to have higher prevalence of obesity than men, partly due to hormonal, cultural, and lifestyle factors [6].

2.3 Regional Variations

- Southern and Western India report higher obesity prevalence than Northern and Eastern regions, reflecting dietary patterns, physical activity levels, and socioeconomic differences [7].

2.4 Trends in Children and Adolescents

- Childhood obesity prevalence: ~5–8% in urban populations; 2–4% in rural areas [8]
- Rising trend associated with increased consumption of processed foods, sugary beverages, and reduced physical activity.

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3. Risk Factors for Obesity in India

3.1 Modifiable Risk Factors

1. **Dietary Patterns:** High intake of refined carbohydrates, sugar-sweetened beverages, fried foods, and low fruit/vegetable consumption [9].
2. **Sedentary Lifestyle:** Reduced physical activity due to urbanization, mechanization, and screen time.
3. **Sleep Deprivation:** Associated with appetite dysregulation and metabolic changes [10].
4. **Stress and Psychological Factors:** Emotional eating and stress-induced weight gain are common [11].

3.2 Non-Modifiable Risk Factors

- **Genetics:** Polymorphisms in FTO, MC4R, and LEP genes increase susceptibility [12].
- **Age:** Risk increases with age due to reduced basal metabolic rate and hormonal changes.
- **Gender:** Hormonal differences and cultural factors contribute to higher obesity in women.
- **Ethnicity:** South Asians are prone to central obesity and metabolic complications at lower BMI.

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4. Pathophysiology and Mechanisms

4.1 Adipose Tissue Dysregulation

- Adipocyte hypertrophy and hyperplasia lead to increased secretion of inflammatory cytokines (TNF-α, IL-6), contributing to insulin resistance [13].

4.2 Insulin Resistance and Metabolic Syndrome

- Obesity is a key driver of insulin resistance, dyslipidemia, and hypertension in Indians.
- Central obesity is strongly associated with type 2 diabetes and cardiovascular risk [14].

4.3 Gut Microbiota

- Emerging research indicates altered gut microbiome composition contributes to energy metabolism dysregulation [15].

4.4 Genetic and Epigenetic Factors

- Gene-environment interactions play a major role; early-life undernutrition followed by caloric surplus predisposes to obesity (“thrifty phenotype hypothesis”) [16].

4.5 Endocrine and Hormonal Factors

- Leptin resistance, ghrelin dysregulation, and cortisol excess contribute to appetite and weight gain [17].

5. Diagnostic Approaches

5.1 Anthropometric Measurements

- **BMI:** Standard WHO cutoff; for Indians, BMI ≥23 kg/m² considered overweight, ≥25 kg/m² obese.
- **Waist Circumference:** Central obesity more predictive of metabolic risk.
- **Waist-to-Hip Ratio:** Used for cardiovascular risk assessment [18].

5.2 Body Composition Analysis

- Bioelectrical impedance analysis (BIA) and DEXA used in research settings to assess fat distribution.

5.3 Biomarkers and Imaging

- Fasting insulin, HOMA-IR, lipid profile, liver function tests, and inflammatory markers (CRP, IL-6).
- Ultrasound and MRI for visceral adiposity and NAFLD assessment [19].

Table 1: Diagnostic Methods in Indian Obesity Research

Diagnostic Tool	Purpose	Key Findings in Indian Studies
BMI & WC	Screening	High prevalence of central obesity even at normal BMI
BIA/DEXA	Fat distribution	Visceral fat predicts metabolic complications
Ultrasound/MRI	NAFLD & visceral adiposity	Strong correlation with insulin resistance
Biomarkers	Insulin, leptin, adiponectin	Elevated inflammatory markers in obese Indians

6. Therapeutic Strategies

6.1 Lifestyle Interventions

Lifestyle modification remains the cornerstone of obesity management in India:

1. **Dietary Approaches:**
    - Reduced calorie intake, portion control, balanced macronutrients.

- Traditional Indian diet adaptations emphasizing pulses, vegetables, and low refined sugar [20].

2. **Physical Activity:**
   - Minimum 150 minutes/week of moderate-intensity exercise recommended.
   - Yoga and aerobic exercises widely studied in Indian trials [21].
3. **Behavioral Interventions:**
   - Cognitive behavioral therapy, goal setting, self-monitoring, and counseling improve adherence [22].

Table 2: Lifestyle Intervention Outcomes in Indian Cohorts

Intervention	Study Type	BMI Reduction	Metabolic Improvements
Diet + Exercise	RCT, Delhi	2–4 kg/m²	↓Fasting glucose, ↓BP
Yoga-based program	RCT, Kerala	1–3 kg/m²	Improved lipid profile
School-based lifestyle	Observational, Pune	1–2 kg/m²	Reduced waist circumference

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6.2 Pharmacotherapy

Pharmacological options are limited but used in selected patients:

- **Orlistat:** Pancreatic lipase inhibitor; modest weight reduction (~5%) [23].
- **Metformin:** Used in overweight patients with insulin resistance or prediabetes.
- **Emerging agents:** GLP-1 receptor agonists (liraglutide) evaluated in small Indian studies [24].

6.3 Bariatric Surgery

- Indicated for BMI ≥32.5–35 kg/m² with comorbidities.
- Procedures include Roux-en-Y gastric bypass, sleeve gastrectomy.
- Indian studies report significant weight loss and metabolic improvement [25].

Table 3: Pharmacological and Surgical Interventions in Indian Obesity Studies

Intervention	Type	Key Outcomes	Indian Studies
Orlistat	Pharmacotherapy	3–5% weight reduction	Agarwal et al., 2017
Metformin	Pharmacotherapy	Improved insulin sensitivity	Kumar et al., 2020
GLP-1 agonists	Pharmacotherapy	5–8% weight loss	Kumar et al., 2020
Bariatric surgery	Sleeve/Roux-en-Y	25–35% weight loss; metabolic improvement	Chandrasekaran et al., 2019

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7. Comorbidities and Population-Specific Considerations

- **Type 2 Diabetes:** Strong association with central obesity; Indian patients develop diabetes at lower BMI [26].
- **Cardiovascular Disease:** Hypertension, dyslipidemia, and atherosclerosis common.
- **Non-Alcoholic Fatty Liver Disease:** Highly prevalent in urban obese adults [27].
- **Polycystic Ovary Syndrome (PCOS):** Obesity exacerbates reproductive and metabolic dysfunctions in women [28].

8. Technological Innovations in Obesity Management

8.1 Digital Health Interventions

- Mobile apps, SMS reminders, and online counseling improve adherence and weight loss outcomes [29].

8.2 Wearables and Activity Trackers

- Monitor physical activity, energy expenditure, and sleep patterns; validated in urban Indian cohorts [30].

8.3 Precision Nutrition and Genomics

- Genetic profiling for obesity risk and dietary response; limited Indian studies but emerging [31].

9. Challenges in Obesity Research in India

1. **Limited Awareness:** Many individuals underestimate obesity-related risks.
2. **Cultural and Dietary Barriers:** Traditional food habits, festivals, and social norms impact interventions.

3. **Urban-Rural Disparities:** Access to healthcare, lifestyle programs, and monitoring devices limited in rural areas.
4. **Lack of Longitudinal Data:** Few prospective cohort studies on obesity outcomes.
5. **Healthcare Infrastructure:** Limited obesity clinics and trained personnel.

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10. Future Directions

- **Early-Life Interventions:** Target childhood and adolescent obesity.
- **Precision Medicine:** Genetics-guided dietary and pharmacological interventions.
- **Digital Health Expansion:** Tele-nutrition, mobile apps, AI-driven monitoring.
- **Integration with NCD Programs:** Obesity management linked with diabetes, CVD, and hypertension programs.
- **Population-Based Cohort Studies:** Longitudinal studies for risk prediction, metabolic outcomes, and intervention efficacy.

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11. Conclusion

Obesity research in India has progressed significantly, with insights into epidemiology, mechanisms, interventions, and technological innovations. Indian populations exhibit unique susceptibility due to central adiposity, metabolic risk at lower BMI, and early-onset obesity. Lifestyle modification, pharmacotherapy, and bariatric procedures remain core management strategies. Emerging digital health platforms and precision nutrition offer new avenues for intervention. Despite advances, challenges such as awareness, cultural barriers, and healthcare disparities persist. Future research integrating genomics, technology, and culturally tailored interventions will be critical to reduce the burden of obesity and associated metabolic diseases in India.

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