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Economic burden of osteoporosis in India among treated populations (ECON-OP): a prevalence-based cost-of-illness analysis across key risk groups

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ABSTRACT

Background: Osteoporosis is a major public health concern in India, leading to fractures, disability, and increased healthcare utilization. However, evidence on its economic burden in the Indian setting remains limited. This study estimated the economic burden of osteoporosis among treated patients in India and evaluated differences between primary and secondary prevention populations.
Methods: A prevalence-based cost-of-illness model was developed for postmenopausal women (PMO), men aged ≥50 years, and patients with glucocorticoid-induced osteoporosis (GIOP). The analysis included treated patients only and applied a weighted healthcare cost mix of 70% public and 30% private sector utilization. Costs were estimated from payer and societal perspectives and reported in Indian Rupees (INR).
Results: The total annual societal economic burden among treated patients was estimated at INR 22,773.6 crores, comprising INR 16,226.5 crores for PMO, INR 6,057.3 crores for male osteoporosis, and INR 489.7 crores for GIOP. Direct medical costs were the major contributor across all populations. Per-patient costs were substantially higher among fracture patients than non-fracture patients, reaching INR 2.15 versus 0.30 lakhs in PMO, INR 2.29 versus 0.35 lakhs in men, and INR 2.16 versus 0.34 lakhs in GIOP. Fracture-related costs were approximately seven-fold higher than costs in primary prevention populations. Scenario analyses suggested a markedly greater burden associated with untreated osteoporosis.
Conclusions: Osteoporosis imposes a substantial economic burden in India, driven primarily by fracture-related costs. Early diagnosis, sustained treatment, and effective fracture prevention strategies may substantially reduce healthcare expenditure and societal burden.

Keywords: Osteoporosis, Cost-of-illness, Economic burden, Fragility fractures, India, Glucocorticoid-induced osteoporosis

INTRODUCTION

Osteoporosis is a chronic skeletal disorder characterized by reduced bone mass and deterioration of bone microarchitecture, resulting in increased bone fragility and susceptibility to fractures.[1,2] It represents a significant, but often underrecognized public health challenge, particularly in low-and middle-income countries such as India, where demographic transitions and ageing populations are rapidly increasing disease burden.[3]

Osteoporotic fractures, particularly of the hip, vertebrae, and wrist, are associated with substantial morbidity, disability, reduced quality of life, and increased mortality.[4]

Globally, osteoporosis disproportionately affects older adults, especially postmenopausal women, due to estrogen deficiency-related bone loss. However, the disease also imposes a significant burden among older men and individuals receiving long-term glucocorticoid therapy. Glucocorticoid-induced osteoporosis (GIOP) is a major secondary cause of osteoporosis and is associated with accelerated bone loss and increased fracture risk.[5]

India is expected to experience a growing osteoporosis burden owing to population ageing, increased life expectancy, nutritional deficiencies, and lifestyle-related risk factors. Previous estimates suggest that over 230 million Indians aged >50 years are at risk of osteoporosis.[3,6-9] Despite this high burden, osteoporosis remains substantially underdiagnosed and undertreated.[10,11]

Another important and often under recognized subgroup is glucocorticoid induced osteoporosis (GIOP), a secondary form of osteoporosis associated with long term corticosteroid use for chronic conditions such as asthma, autoimmune diseases, and rheumatoid arthritis. Prolonged glucocorticoid exposure accelerates bone loss and markedly increases fracture risk, with studies reporting up to a seven-fold increase in hip fractures and a seventeen-fold increase in vertebral fractures. As glucocorticoid use continues to rise in India, GIOP represents a growing clinical and public health challenge, underscoring the need for early risk assessment and timely initiation of preventive therapy.[12-14] Delayed diagnosis and inadequate treatment contribute to increased fracture incidence and associated healthcare utilization.

In addition to its clinical consequences, osteoporosis imposes considerable economic burden through hospitalization, surgery, rehabilitation, pharmacotherapy, long-term care, and productivity losses.[15,16] Although the economic impact of osteoporosis has been documented in several countries, evidence from India remains limited. Existing estimates often do not adequately capture real-world treatment patterns, fracture status, or the broader societal costs associated with osteoporosis management.[17]

A comprehensive assessment of osteoporosis-related costs is essential for healthcare planning and resource allocation. Therefore, this study aimed to estimate the economic burden of osteoporosis among treated patients in India using a prevalence-based cost-of-illness approach. The analysis assessed costs from payer and societal perspectives across postmenopausal women, older men, and patients with GIOP.

Differences between primary prevention (treated patients without fractures) and secondary prevention (treated patients with fractures) were also evaluated.

METHODS

Study design

This was a prevalence-based cost-of-illness (COI) modelling study conducted to estimate the annual economic burden of osteoporosis in India. This economic modelling study was not conducted within a single hospital or healthcare institution. The evidence informing the model was generated through a targeted literature review of evidence available up to February 2025 and primary market research conducted in July 2025 involving experts from different regions of India. The study included three at-risk populations: postmenopausal women (age >50 years), men (age ≥50 years), and individuals (age >15 years) receiving long-term glucocorticoid therapy (≥7.5 mg prednisone equivalent daily for ≥90 consecutive days; GIOP) (Figure 1).

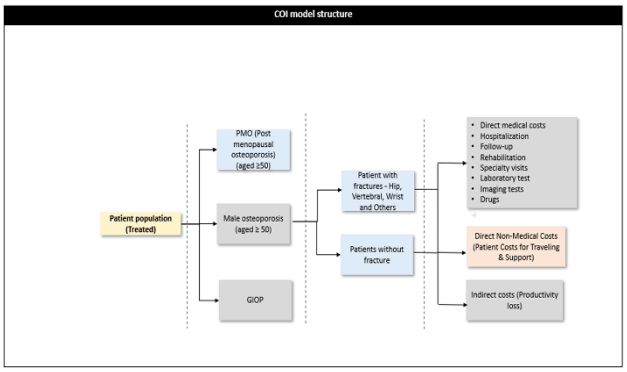


Figure 1: Structure of the prevalence-based cost-of-illness model for PMO, men with osteoporosis and GIOP.

The model adopted a one-year time horizon to capture both direct medical and non-medical costs, as well as indirect costs due to lost productivity. This short-term 1-year time horizon was selected to provide a cross-sectional snapshot of the economic impact and resource utilization associated with the condition in the Indian context. The base-case analysis adopted a societal perspective, incorporating public healthcare costs to comprehensively assess the economic impact of osteoporosis. The methodology and analytical approach were guided by previous COI studies used as references, ensuring comparability and methodological rigor.[18-20] Furthermore, the study followed recommendations from a consensus-based checklist for the critical appraisal of cost-of-illness studies, which provided a structured framework for evaluating the comprehensiveness, transparency, and reliability of the economic estimates.[21] To enhance reporting transparency, the manuscript also aligns with the CHEERS 2022 (Consolidated Health Economic Evaluation Reporting Standards) recommendations, where applicable.

The base-case analysis estimated the economic burden of osteoporosis among treated patients, reflecting real-world healthcare utilization in India. Untreated osteoporosis was

not included in the base-case analysis and was evaluated separately using a scenario-based projection to illustrate the potential economic consequences of persistent non-treatment.

Scenario-based analysis of untreated population

The untreated population analysis represents a scenario-based upper-bound estimate of the potential economic burden associated with persistent non-treatment of osteoporosis. Given the absence of robust real-world utilization data for untreated individuals in India, this analysis assumes progression to fracture in the absence of diagnosis and treatment within the one-year model horizon. These estimates are intended to illustrate the potential magnitude of economic burden under worst-case conditions and should not be interpreted as observed annual costs. Instead, they indicate the scale of unmet need and the economic implications of delayed diagnosis and lack of treatment.

Data sources and inputs

Model inputs were derived through a targeted literature review (TLR) and primary market research (PMR) (Table S1-S4). The targeted literature review included evidence available up to February 2025, while the primary market research was conducted in July 2025. The literature review identified evidence related to epidemiology, fracture distribution, treatment patterns, healthcare resource utilization, and costs associated with osteoporosis in India. Of 290 screened records, 189 publications met the inclusion criteria and were used to inform model assumptions. Literature findings were supplemented and validated through interviews with clinical experts, hospital stakeholders, and payer representatives to ensure relevance to Indian clinical practice.

The detailed evidence generation strategy, including the TLR and PMR methodology, is described.

The face validity of model assumptions and outputs was assessed through expert review; details are reported.

Population stratification

Population estimates were based on Indian demographic data and published prevalence rates for postmenopausal osteoporosis, male osteoporosis, and GIOP. Patients were further categorized according to diagnosis and treatment status. Diagnosis rates were estimated at 17.0% for PMO, 20.0% for male osteoporosis, and 22.0% for GIOP, while treatment rates were 16.8%, 10.9%, and 12.0%, respectively. The treated population constituted the base-case cohort. A summary of the population cascade used in the model is presented in Table 1. Absolute patient counts at each stage of the care pathway were estimated using prevalence, diagnosis and treatment rates derived from literature and validated through PMR.

Table 1: Population stratification and diagnosis–treatment cascade across osteoporosis subgroups in India.

At- Risk Population	Total	Prevalence of osteoporosis	Diagnosed (%)	Treated (%)
PMO (Women ≥50 years)	144,922,687	47,969,409	17.0%	16.8%
Male osteoporosis (Men ≥50 years)	146,386,553	25,324,874	20.0%	10.9%
GIOP (Population aged >15 years on glucocorticoids)	10,832,605	1,516,565	22.0%	12.0%

GIOP: glucocorticoid-induced osteoporosis; PMO: post-menopausal osteoporosis.

Inclusion criteria

The model included: postmenopausal women aged ≥50 years with osteoporosis. Men aged ≥50 years with osteoporosis. Individuals aged >15 years receiving long-term glucocorticoid therapy (≥7.5 mg prednisone equivalent daily for ≥90 consecutive days) who were at risk of glucocorticoid-induced osteoporosis. Diagnosed and treated osteoporosis patients included in the base-case analysis.

Exclusion criteria

The model excluded individuals below the defined age thresholds for PMO and male osteoporosis. Patients without evidence of osteoporosis. Patients with metabolic bone disorders other than osteoporosis. Untreated osteoporosis patients from the base-case analysis; these patients were evaluated separately in a scenario-based analysis. Populations for which sufficient epidemiological or economic input data were unavailable.

Fracture estimation and recurrence risk

Treated patients were categorized into primary prevention (treated patients without fractures) and secondary prevention (treated patients with osteoporotic fractures). Fractures were classified as hip, vertebral, wrist, and other osteoporotic fractures. Annual fracture rates and fracture distributions were obtained from published literature and

validated through PMR. Recurrent fracture risks were incorporated where applicable.

Detailed assumptions regarding fracture distribution and recurrent fracture estimation are described.

Costs estimation

Costs were estimated from payer and societal perspectives. The payer perspective included direct medical costs borne by healthcare providers and payers, while the societal perspective additionally included direct non-medical and indirect costs.

Direct medical costs comprised hospitalization, surgery, pharmacotherapy, diagnostic investigations, specialist consultations, and rehabilitation services. Direct non-medical costs included transportation, accommodation, caregiver support, assistive devices, and long-term care. Detailed cost categorization, healthcare resource utilization assumptions, and unit-cost inputs are provided.

Indirect costs were estimated using a human capital approach. Productivity losses associated with osteoporosis-related morbidity and premature mortality were calculated using workforce participation rates, average daily wage estimates, fracture-specific absenteeism durations, and retirement-age assumptions. Separate economic activity and wage inputs were applied for women and men to reflect differences in labor-force participation. Detailed wage estimation methods and productivity-loss assumptions are provided.

Cost standardization and analysis tools

All costs were standardized to 2025 Indian Rupees (INR). A weighted healthcare utilization distribution of 70% public and 30% private care was applied in the base-case analysis to reflect real-world treatment patterns in India. Model outputs included total economic burden, per-patient costs, and cost distribution across osteoporosis subtypes and fracture categories. Comparisons were conducted across fracture versus non-fracture populations and payer versus societal perspectives.

Weighted average costs were estimated to reflect healthcare utilization across public and private settings in India. Additional details regarding the derivation and interpretation of weighted average costs are provided.

Sensitivity analysis

Deterministic one-way sensitivity analysis (OWSA) was conducted to evaluate the robustness of model results. Key parameters were varied by ±10% around base-case estimates, and the impact on total economic burden was assessed using tornado diagrams. Parameters with the greatest influence on model outcomes were presented in the final analysis.

Additional one-way sensitivity analysis results are presented.

Detailed literature review methodology, fracture estimation assumptions, healthcare resource utilization inputs, direct and indirect cost calculations, and model validation procedures are provided.

RESULTS

Total economic burden of osteoporosis in treated patients in India

The total annual societal economic burden among treated osteoporosis patients in India was estimated at INR 22,773.6 crores. PMO accounted for the largest share of costs (INR 16,226.5 crores), followed by male osteoporosis (INR 6,057.3 crores) and GIOP (INR 489.7 crores). Direct medical costs represented the largest contributor across all populations, accounting for INR 10,796.2 crores in PMO, INR 3,813.5 crores in male osteoporosis, and INR 306.7 crores in GIOP.

Within these, hospitalization and follow-up care represented the largest components of direct medical expenditure. In treated PMO patients, hospitalization costs alone accounted for INR 5,333.6 crores, while follow-up care including rehabilitation, specialist consultations, diagnostics, and pharmacotherapy contributed INR 5,462.5 crores.

Direct non-medical and indirect costs, although smaller than direct medical costs, contributed substantially to the overall societal burden. Among treated PMO patients, direct non-medical costs totaled INR 4871.7 crores, reflecting expenditures related to transportation, accommodation, caregiver support, assistive devices, and long-term care. Indirect costs capturing productivity losses due to morbidity and premature mortality contributed an additional INR 558.5 crores. Similar cost patterns were observed in male osteoporosis and GIOP patients, with non-medical and indirect costs representing a meaningful share of total societal expenditure.

Indirect costs, although smaller than direct medical costs, represented a meaningful component of total societal burden, particularly in fracture patients due to extended recovery periods, functional impairment, and associated productivity losses. Importantly, these costs are not captured in payer-based analyses, leading to a systematic underestimation of the true economic burden of osteoporosis.

Individual-level costs by fracture status

Average annual per-patient costs among treated patients were INR 1.32 lakhs for PMO, INR 1.28 lakhs for male osteoporosis, and INR 1.37 lakhs for GIOP under the weighted 70% public/30% healthcare cost mix. Costs were substantially higher among patients with fractures

(secondary prevention) than among those without fractures (primary prevention). Overall, fracture-related costs were approximately seven-fold higher than costs in patients without fractures. Table 2 summarizes per-patient costs across osteoporosis populations.

Table 2: Economic burden and per-patient costs of osteoporosis by population subgroup.

Group	PMO (₹ lakhs)	Men (₹ lakhs)	GIOP (₹ lakhs)
Primary prevention	₹0.30	₹0.35	₹0.34
Secondary prevention	₹2.15	₹2.29	₹2.16
Overall average	₹1.32	₹1.28	₹1.37

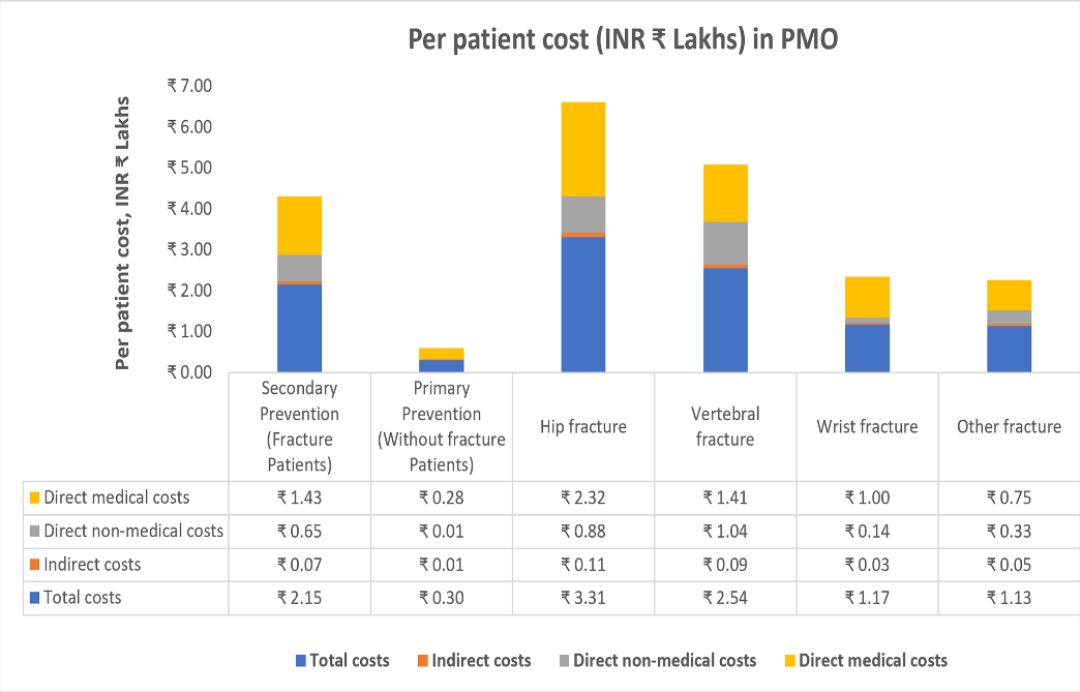
PMO: Postmenopausal osteoporosis; GIOP: Glucocorticoid-induced osteoporosis; PMR: Primary market research; KOL: Key opinion leader. Note: All costs are reported in Indian Rupees (INR) and reflect 2025 price levels.

Secondary prevention patients contributed disproportionately to the overall burden despite representing a smaller proportion of treated patients. Hip and vertebral fractures were the most resource-intensive fracture types across all osteoporosis subgroups, reflecting higher hospitalization, rehabilitation, and follow-up care requirements. To further understand the drivers of this burden, fracture-specific cost patterns were evaluated separately across PMO, male osteoporosis, and GIOP populations.

Postmenopausal osteoporosis (PMO)

Among women with PMO, hip fractures generated the highest per-patient costs (INR 3.30 lakhs), followed by vertebral fractures (INR 2.54 lakhs), wrist fractures (INR 1.17 lakhs), and other fractures (INR 1.13 lakhs).

Direct medical costs accounted for the largest proportion of expenditure, particularly for hip and vertebral fractures. Figure 2 illustrates the distribution of costs according to fracture status and fracture type in the PMO population.

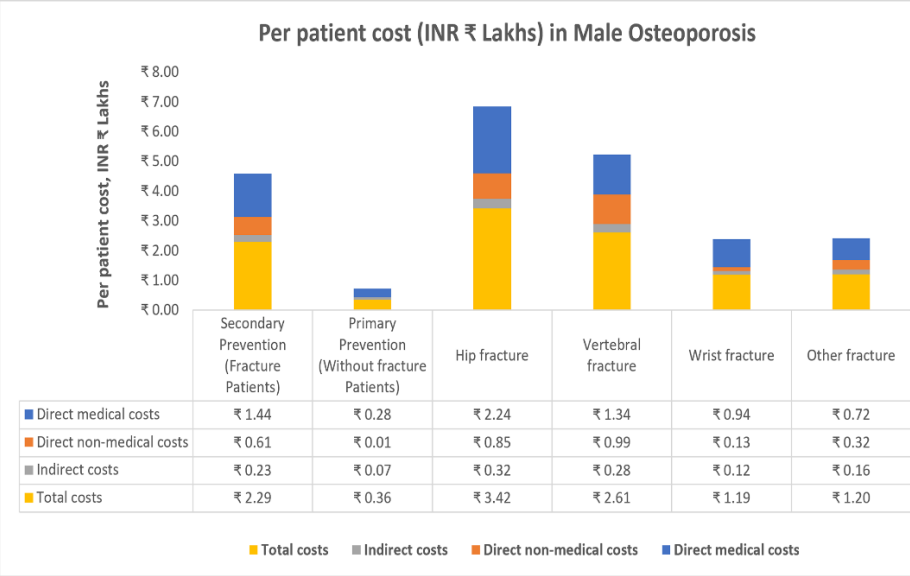


	Secondary Prevention (Fracture Patients)	Primary Prevention (Without fracture Patients)	Hip fracture	Vertebral fracture	Wrist fracture	Other fracture
Direct medical costs	₹ 1.43	₹ 0.28	₹ 2.32	₹ 1.41	₹ 1.00	₹ 0.75
Direct non-medical costs	₹ 0.65	₹ 0.01	₹ 0.88	₹ 1.04	₹ 0.14	₹ 0.33
Indirect costs	₹ 0.07	₹ 0.01	₹ 0.11	₹ 0.09	₹ 0.03	₹ 0.05
Total costs	₹ 2.15	₹ 0.30	₹ 3.31	₹ 2.54	₹ 1.17	₹ 1.13

Figure 2: Distribution of costs by fracture status in PMO (age ≥ 50)

Men with osteoporosis

A similar pattern was observed among men with osteoporosis. Hip fractures were associated with the highest per-patient costs (INR 3.42 lakhs), followed by vertebral (INR 2.61 lakhs), other (INR 1.20 lakhs), and wrist fractures (INR 1.19 lakhs). Direct medical costs remained the predominant cost component, while productivity-related losses contributed substantially in patients with severe fractures. The distribution of costs in male osteoporosis is presented in Figure 3.

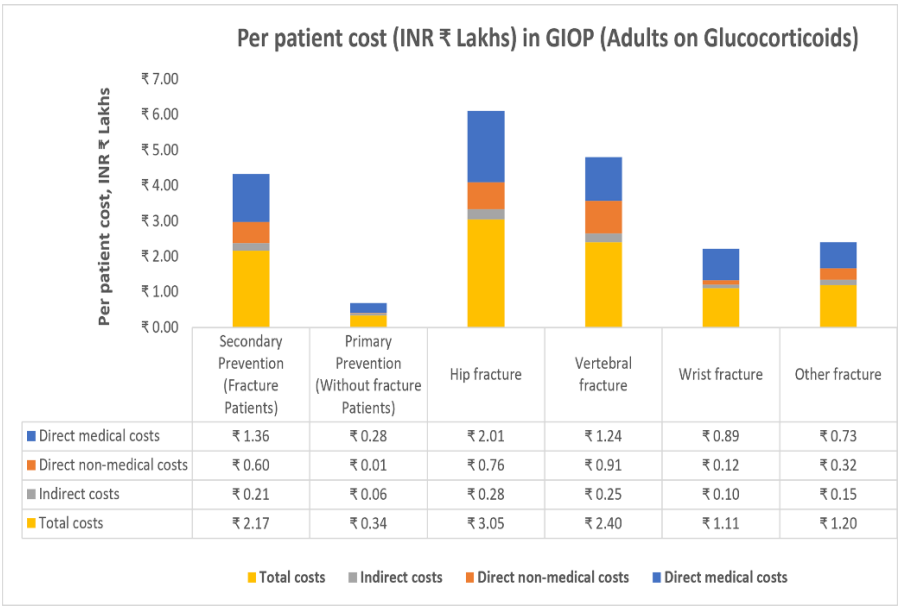


	Secondary Prevention (Fracture Patients)	Primary Prevention (Without fracture Patients)	Hip fracture	Vertebral fracture	Wrist fracture	Other fracture
Direct medical costs	₹ 1.44	₹ 0.28	₹ 2.24	₹ 1.34	₹ 0.94	₹ 0.72
Direct non-medical costs	₹ 0.61	₹ 0.01	₹ 0.85	₹ 0.99	₹ 0.13	₹ 0.32
Indirect costs	₹ 0.23	₹ 0.07	₹ 0.32	₹ 0.28	₹ 0.12	₹ 0.16
Total costs	₹ 2.29	₹ 0.36	₹ 3.42	₹ 2.61	₹ 1.19	₹ 1.20

Figure 3: Distribution of costs by fracture status in male osteoporosis (age ≥ 50).

Glucocorticoid-induced osteoporosis (GIOP)

Among patients with GIOP, hip fractures imposed the greatest economic burden (INR 3.05 lakhs per patient), followed by vertebral (INR 2.40 lakhs), other (INR 1.20 lakhs), and wrist fractures (INR 1.10 lakhs). Across fracture categories, direct medical costs were the dominant contributor, although non-medical and indirect costs also contributed meaningfully. Figure 4 presents the fracture-specific distribution of costs within the GIOP population.



	Secondary Prevention (Fracture Patients)	Primary Prevention (Without fracture Patients)	Hip fracture	Vertebral fracture	Wrist fracture	Other fracture
Direct medical costs	₹ 1.36	₹ 0.28	₹ 2.01	₹ 1.24	₹ 0.89	₹ 0.73
Direct non-medical costs	₹ 0.60	₹ 0.01	₹ 0.76	₹ 0.91	₹ 0.12	₹ 0.32
Indirect costs	₹ 0.21	₹ 0.06	₹ 0.28	₹ 0.25	₹ 0.10	₹ 0.15
Total costs	₹ 2.17	₹ 0.34	₹ 3.05	₹ 2.40	₹ 1.11	₹ 1.20

Figure 4: Distribution of costs by fracture status in GIOP (individuals on glucocorticoids ≥ 3 months).

Across all osteoporosis populations, hip and vertebral fractures consistently generated the highest economic burden. Direct medical costs, particularly hospitalization and follow-up care, accounted for the majority of expenditure, while indirect and non-medical costs contributed substantially to the overall societal burden.

These findings indicate that fracture occurrence is the primary driver of osteoporosis-related economic burden in India. Detailed prevalence, diagnosis, and treatment inputs for PMO, male osteoporosis, and GIOP populations are provided.

Untreated osteoporosis scenario analysis

Osteoporosis remains substantially underdiagnosed and undertreated in India. Approximately 83% of postmenopausal women, 80% of men, and 78% of GIOP patients remain undiagnosed.

Scenario-based analyses suggested that untreated osteoporosis could result in a substantially greater economic burden than that observed in treated populations,

driven primarily by fracture-related complications, long-term disability, and productivity losses.

These findings highlight the potential economic consequences of delayed diagnosis and non-treatment and underscore the need for improved screening and treatment strategies. Table 3 presents a detailed breakdown of total economic burden and per-patient costs among fracture patients across osteoporosis populations.

Table 3: Total economic burden and per-patient costs of osteoporosis in secondary prevention (with fracture).

Osteoporosis economic burden in treated population (Total fracture cost)						
Category	Total economic burden (in INR Crores)			Per patient cost (In INR Lakhs)		
Cost by population	PMO (Women ≥ 50)	Male Osteoporosis (Men ≥ 50)	GIOP (Individuals on Glucocorticoids ≥3 months)	PMO (Women ≥ 50)	Male Osteoporosis (Men ≥ 50)	GIOP (Individuals on Glucocorticoids ≥3months)
Direct medical costs	₹ 10,796.24	₹ 3,813.55	₹ 306.70	₹ 1.43	₹ 1.44	₹ 1.35
Hospitalization cost	₹ 5,333.66	₹ 2,000.02	₹ 158.92	₹ 0.70	₹ 0.75	₹ 0.70
Follow-up cost	₹ 5,462.58	₹ 1,813.52	₹ 147.77	₹ 0.72	₹ 0.68	₹ 0.65
Rehabilitation	₹ 689.71	₹ 228.19	₹ 18.90	₹ 0.09	₹ 0.08	₹ 0.08
Specialty visits	₹ 430.89	₹ 145.92	₹ 11.61	₹ 0.05	₹ 0.05	₹ 0.05
Laboratory test	₹ 539.30	₹ 181.73	₹ 14.54	₹ 0.07	₹ 0.06	₹ 0.06
Imaging tests	₹ 467.41	₹ 157.48	₹ 12.59	₹ 0.06	₹ 0.06	₹ 0.05
Drugs	₹ 3,335.28	₹ 1,100.19	₹ 90.12	₹ 0.44	₹ 0.41	₹ 0.39
Direct non-medical cost	₹ 4,871.73	₹ 1,623.54	₹ 135.41	₹ 0.64	₹ 0.61	₹ 0.59
Indirect costs	₹ 558.55	₹ 620.28	₹ 47.58	₹.07	₹ 0.23	₹ 0.21
Total costs	₹ 16,226.53	₹ 6,057.36	₹ 489.68	₹ 2.15	₹ 2.29	₹ 2.16

PMO: Postmenopausal osteoporosis; GIOP: Glucocorticoid-induced osteoporosis; PMR: Primary market research; KOL: Key opinion leader. Note: All costs are reported in Indian Rupees (INR) and reflect 2025 price levels.

The base-case analysis assumes a treated patient population and incorporates a weighted healthcare cost mix of 70% public and 30% private sector utilization to reflect real-world care patterns in India.

Clinical and epidemiological inputs, including diagnosis and treatment rates, were informed by published literature and refined through primary market research (PMR) with key opinion leaders to reflect real-world clinical practice in India.

Direct medical cost represents the sum of hospitalization and follow-up costs. Follow-up cost includes expenses related to rehabilitation, specialty visits, laboratory tests, imaging tests, and prescribed medications. Direct non-medical costs include non-treatment-related expenses due to osteoporosis, such as transportation to clinics, and caregiver support for daily activities. Indirect costs were estimated using the human capital approach, incorporating productivity losses due to absenteeism, long-term disability, and reduced workforce participation. Calculations were based on average income levels, employment rates, and fracture-specific workdays lost, validated through primary market research and literature.

Hospital perspective and variability in per-patient costs within a mixed healthcare system

Given India's mixed healthcare delivery system, per-patient costs for osteoporosis treatment vary depending on the setting and intensity of care. The base-case analysis applied a weight 70% public and 30% private cost mix to reflect real-world treatment patterns.

Across all populations, higher per-patient costs were observed in settings with greater reliance on private-sector care, primarily driven by differences in hospitalization, procedures, diagnostics, and pharmacotherapy. In contrast, non-medical and indirect costs showed comparatively limited variation across care settings.

Overall, these findings highlight that while costs differ by healthcare setting, the weighted approach provides a representative estimate of real-world economic burden in India. The variability observed underscores the importance

of improving access to affordable osteoporosis care, particularly in the public sector.

Population level economic burden: payer vs societal perspective

At the population level, a substantial gap was observed between payer and societal perspectives across all

osteoporosis populations. For treated PMO patients, the estimated burden from a payer perspective was estimated at INR 12,496.0 crores, while the societal perspective, which includes direct non-medical and indirect costs raised the total burden to ₹INR 16,226.5 crores. The difference highlights the significant economic impact of osteoporosis that is not captured in payer-only evaluations, particularly in patients experiencing fractures. The additional burden is primarily driven by productivity losses, caregiver dependence, and other non-medical costs associated with fracture management (Figure 5 and 6). The payer perspective, which captures direct medical costs only, systematically underestimated the true economic burden borne by patients, families, and society.

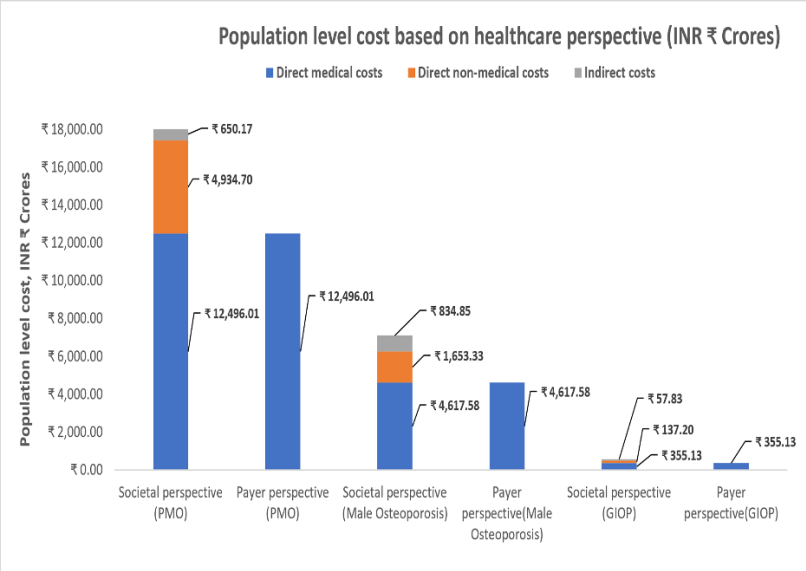


Figure 5: Population level comparison of costs between payer and societal perspectives across population category.

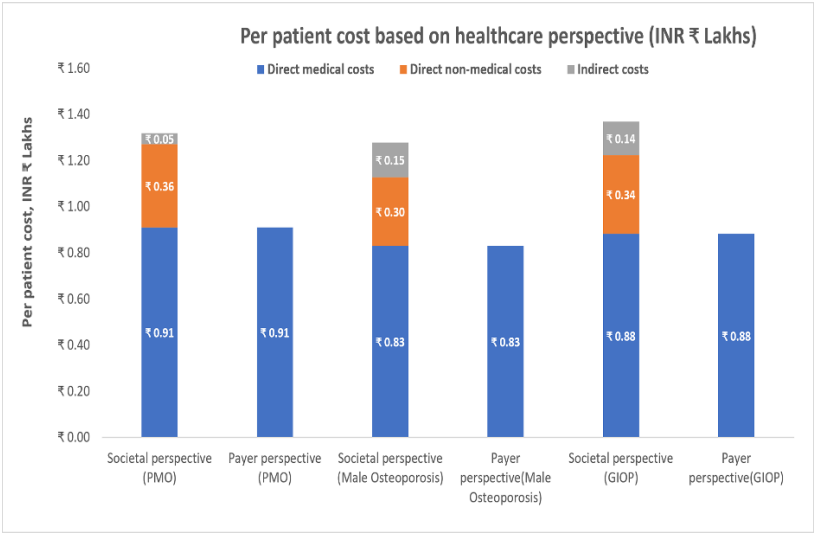


Figure 6: Per patient level comparison of costs between payer and societal perspectives across population category.

Similar patterns were observed in men with osteoporosis and in patients with GIOP, where the societal perspective consistently demonstrated a higher total economic burden compared with the payer perspective.

Although per-patient costs differed between perspectives, the population-level impact was more pronounced, with fracture-related cases contributing disproportionately to the overall gap between payer and societal estimates. In particular, secondary prevention patients, who require

surgical and prolonged conservative management, account for a substantial share of indirect and non-medical costs due to extended recovery, functional limitations, and reliance on informal caregiving. Overall, these findings highlight that payer-based analyses substantially underestimate the true economic burden of osteoporosis, especially in secondary prevention. Incorporating a societal perspective is therefore essential for fully understanding the value of fracture prevention

strategies and for informing resource allocation and health policy decisions related to fracture prevention in India.

Deterministic sensitivity analysis

Deterministic sensitivity analysis demonstrated that the model results were most sensitive to variations in key cost drivers, including population size, treatment rates, fracture distribution, and direct medical costs such as hospitalization and pharmacotherapy. The tornado diagram for the PMO population is presented in Figure 7, while corresponding analyses for male osteoporosis and GIOP are provided. The tornado diagram (Figure 7) illustrate the relative impact of each parameter on total cost estimates.

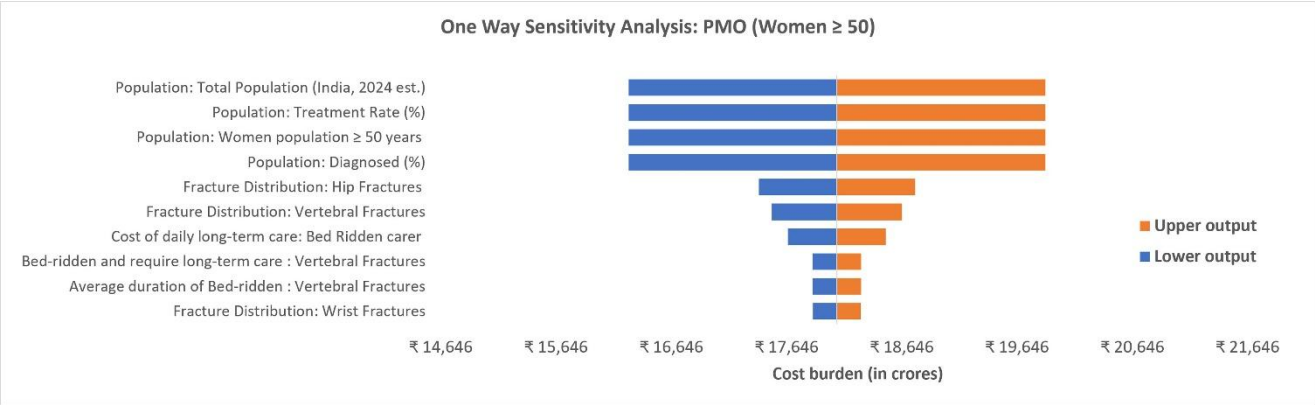


Figure 7: Tornado diagram for PMO population.

PMO: Postmenopausal osteoporosis. Note: All costs are reported in Indian Rupees (INR) and reflect 2025 price levels.

Among the PMO population, the top-ranked parameters showed similar magnitude of impact on total costs. Across all populations, similar patterns were observed. This reflects the multiplicative structure of the model, where several parameters contribute proportionally within the same cost equation. As all parameters were varied symmetrically (±10%), those influencing the same component of the cost calculation produced comparable changes in the outcome. Consequently, for some populations, multiple parameters demonstrated identical or near-identical impacts on cost outcomes.

Although detailed cost components such as hospitalization, rehabilitation, and pharmacotherapy are key contributors to total costs, these are embedded within broader cost categories and are not always represented as independent parameters in the sensitivity analysis. The tornado diagram therefore reflects the most influential drivers of cost variation, rather than all individual cost elements included in the model. Overall, the sensitivity analysis confirms that while absolute cost estimates vary within plausible ranges, the overall findings remain robust, with fracture-related costs consistently emerging as the dominant driver of economic burden across all populations. The deterministic sensitivity analysis further strengthens the credibility of the model by demonstrating that the overall conclusions remain stable across plausible variations in key parameters.

Extended one-way sensitivity analysis results are presented. Additional analyses evaluating diagnosis-treatment gaps, untreated population burden, weighted average cost calculations, and expanded sensitivity analysis results are provided.

DISCUSSION

This study provides a comprehensive estimate of the economic burden of osteoporosis among treated patients in India using a prevalence-based cost-of-illness framework. The findings demonstrate that osteoporosis imposes a substantial societal burden, with total annual costs exceeding INR 22,700 crores across postmenopausal women, older men, and patients with glucocorticoid-induced osteoporosis. Direct medical costs were the predominant driver of expenditure, largely attributable to hospitalization and follow-up care. These findings are consistent with previous international and Indian studies reporting fracture-related medical care as the major contributor to osteoporosis-related costs.[15,17,22]

A key finding of this study is the marked difference in costs between primary prevention and secondary prevention populations. Patients with osteoporotic fractures incurred approximately seven-fold higher costs than those without fractures. Hip and vertebral fractures were associated with the highest economic burden because

of hospitalization, rehabilitation, prolonged recovery, and caregiver requirements. Similar observations have been reported globally, where fracture occurrence, particularly hip fractures, is the principal determinant of osteoporosis-related healthcare expenditure.[15,23,24]

The present analysis also demonstrated that societal costs substantially exceeded payer-based estimates. Although direct medical costs represented the largest component of expenditure, direct non-medical costs and productivity losses contributed meaningfully to the overall burden. In India, where out-of-pocket healthcare expenditure and informal caregiving remain common, restricting evaluations to the payer perspective may underestimate the true impact of osteoporosis. Previous cost-of-illness studies have similarly highlighted the importance of accounting for caregiver burden, productivity loss, and long-term disability when estimating disease burden.[15,25,26]

Another important observation was the considerable diagnosis and treatment gap across all osteoporosis populations. A large proportion of individuals with osteoporosis remain undiagnosed and untreated despite the availability of effective therapies. Consistent with previous reports from India, inadequate screening and delayed treatment contribute to preventable fractures and increased healthcare utilization.[17,27] Scenario-based analyses in the present study suggested that persistent non-treatment could result in a substantially higher economic burden, emphasizing the potential value of early diagnosis and timely intervention.[22,27]

The findings have important implications for healthcare policy and clinical practice. Improving access to diagnostic services, increasing awareness among healthcare professionals, and strengthening treatment adherence may help reduce fracture incidence and the associated economic burden. In particular, prevention of hip and vertebral fractures should be prioritized, given their disproportionate contribution to overall costs. Integration of osteoporosis screening into existing non-communicable disease programs may further support early detection and management of high-risk individuals.[17,27,28]

This study has several limitations. Some model inputs were based on expert opinion due to limited India-specific real-world data. The one-year time horizon may not capture the full long-term economic consequences of osteoporosis and recurrent fractures. In addition, indirect costs were estimated using population-level economic indicators, which may not fully reflect individual-level productivity losses. Nevertheless, the use of published evidence, expert validation, and sensitivity analyses strengthens the robustness and relevance of the findings.[21] In addition, untreated osteoporosis estimates were based on scenario-based projections and should be interpreted as illustrative estimates rather than observed costs.

CONCLUSION

Osteoporosis imposes a substantial economic burden in India, particularly when complicated by fractures. Fracture-related events, especially hip and vertebral fractures, are the major drivers of healthcare and societal costs. These findings support prioritizing early diagnosis, treatment initiation, and fracture prevention strategies to reduce the growing burden of osteoporosis in India.

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