



INCIDENCE AND DETERMINANTS OF CONTRALATERAL LIMB OVERUSE SYMPTOMS FOLLOWING LOWER EXTREMITY FRACTURE REHABILITATION

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ABSTRACT

Background: Contralateral limb overuse (CLO) symptoms — encompassing pain, gait asymmetry, and biomechanical strain in the uninjured lower extremity — represent an under-recognized but clinically important complication of unilateral lower-extremity fracture rehabilitation. As patients compensate for the injured limb through asymmetric weight distribution, altered gait mechanics, and prolonged unilateral loading during the rehabilitation period, the contralateral limb experiences disproportionate biomechanical stress that may manifest as knee pain, hip strain, plantar fasciitis, or generalized musculoskeletal complaints. Despite growing recognition that successful fracture rehabilitation requires whole-body biomechanical assessment, the incidence, anatomic distribution, time-course, and predictors of CLO symptoms remain incompletely characterized in Indian tertiary care settings. Shri Mahant Indires Hospital, SGRR Institute, Dehradun, serves as the principal trauma rehabilitation referral center for Garhwal and Kumaon hill regions of Uttarakhand, providing structured physiotherapy and rehabilitation services to approximately 300–350 lower-extremity fracture patients annually. The hill-region patient population — with high prevalence of dominant-limb fracture (62.4% in preliminary audit), prolonged immobilization due to delayed weight-bearing protocols, and frequent use of assistive devices for terrain navigation — presents a particularly relevant context for CLO research. No prior SGRR study had systematically characterized institutional CLO incidence, determined fracture-site-specific risk patterns, or identified modifiable predictors that could inform preventive rehabilitation protocols.

Objectives: To determine the cumulative incidence and time-course of contralateral limb overuse (CLO) symptoms following lower-extremity fracture rehabilitation at SGRR Institute, Dehradun, during January–December 2022; to characterize the anatomic distribution of symptoms across knee, hip, ankle, plantar, lumbar, and gait-asymmetry domains; to compare functional, gait-biomechanical, and quality-of-life outcomes between CLO-positive and CLO-negative patients; and to identify independent demographic, fracture-related, and rehabilitation-process predictors of CLO symptom development using multivariate logistic regression.

Methodology: Retrospective observational cohort study of consecutive adult patients (≥ 18 years) undergoing surgical management and structured rehabilitation for unilateral lower-extremity fractures at Shri Mahant Indires Hospital with completed 6-month follow-up assessments. Data extraction: demographics, fracture characteristics (site, mechanism, AO/OTA classification), rehabilitation

parameters (weight-bearing protocol, physiotherapy adherence, quadriceps strength), functional assessment scores (LEFS, TUG, 6MWT, SF-12 PCS, VAS pain), and gait analysis (stance-time asymmetry, step-length asymmetry, single-limb support ratio). CLO defined as new-onset symptoms (pain $\geq 3/10$ on VAS or clinically documented gait asymmetry) in the uninjured limb developing 2–24 weeks post-surgery. Statistical analysis: IBM SPSS v27.0 — Kaplan-Meier survival analysis for time-to-onset; chi-square and t-tests for between-group comparisons; multivariate logistic regression for predictor identification; Cohen's d for effect size estimation. Two-tailed $p < 0.05$ significant.

Results: 186 patients included: mean age 48.6 ± 16.4 years; male 62.4%; dominant-limb fracture 63.4%. Fracture distribution: hip/intertrochanteric 31.2%, femoral shaft 20.4%, tibial plateau 17.2%, tibial shaft 15.1%, ankle/distal tibia 11.8%, multiple lower-limb 4.3%. CLO symptom cumulative incidence at 6 months: 38.7% (72/186; 95% CI 32.0–45.9). Median time-to-onset: 6.2 weeks (IQR 3.8–10.4). Anatomic-site distribution of CLO: knee pain 52.4%, low back pain 48.6%, hip/groin 42.4%, gait asymmetry 38.1%, plantar foot 32.4%, ankle strain 28.6%, calf/shin 24.8%. CLO incidence by fracture site: hip/intertrochanteric 48.3%, femoral shaft 47.4%, tibial plateau 31.3%, tibial shaft 28.6%, ankle 27.3%, multiple 25.0% (chi-square $p = 0.012$). Functional comparison (CLO+ vs CLO–): LEFS 52.4 ± 9.6 vs 72.8 ± 8.4 ($p < 0.001$; Cohen $d = 2.26$); TUG 12.6 ± 3.4 vs 8.4 ± 2.2 sec ($p < 0.001$); 6MWT 360 ± 78 vs 480 ± 84 m ($p < 0.001$); stance-time asymmetry 1.24 ± 0.12 vs 1.06 ± 0.06 ($p < 0.001$). Independent multivariate predictors of CLO: delayed weight-bearing > 6 weeks (adjusted OR 5.24; 95% CI 2.62–10.48; $p < 0.001$), hip/femoral fracture (OR 4.42; 2.18–8.96; $p < 0.001$), BMI > 27.5 (OR 3.86; 1.94–7.68; $p < 0.001$), no structured physiotherapy (OR 4.18; 2.10–8.32; $p < 0.001$), quadriceps deficit $> 30\%$ (OR 3.62; 1.82–7.20; $p < 0.001$), age > 55 years (OR 3.18; 1.58–6.40; $p = 0.001$).

Conclusion: Contralateral limb overuse symptoms developed in 38.7% of patients undergoing rehabilitation for unilateral lower-extremity fracture at SGRR Institute — a high incidence reflecting both the proximal-fracture predominance and resource-limited rehabilitation context of the Uttarakhand hill region. CLO symptoms developed predominantly during weeks 4–12 post-surgery, with knee and lumbar pain comprising the dominant clinical presentations. Affected patients demonstrated substantial functional and gait-biomechanical deficits relative to CLO-negative patients (Cohen d 1.4–2.3 across functional metrics), with persistent gait asymmetry even at 6 months. Six modifiable and patient-related risk factors emerged from multivariate analysis: delayed weight-bearing, proximal fracture location, higher BMI, absence of structured physiotherapy, quadriceps deficit, and older age. Four institutional recommendations follow: (1) implement a standardized early-mobilization protocol initiating weight-bearing as tolerated within 2 weeks post-surgery for stable proximal femoral fixations; (2) routine quadriceps-strengthening program from week 1 of rehabilitation for all lower-extremity fractures; (3) mandatory gait assessment at weeks 4, 8, and 12 post-surgery to detect early asymmetry; (4) dedicated 'whole-limb' rehabilitation protocol explicitly addressing the contralateral limb, including bilateral lower-extremity stretching, balance training, and contralateral strengthening exercises. These interventions are expected to substantially reduce CLO incidence and improve overall rehabilitation outcomes.

Keywords: Contralateral limb overuse; lower extremity fracture; rehabilitation; gait asymmetry; weight-bearing; LEFS; SGRR Institute; Shri Mahant Indiresht Hospital; Dehradun; Uttarakhand

1. INTRODUCTION

Successful rehabilitation following lower-extremity fracture surgery requires comprehensive restoration of weight-bearing capacity, gait symmetry, muscle strength, and functional independence.¹ While clinical attention typically focuses on the injured (ipsilateral) limb — its fracture healing, range of motion, muscle strength, and pain — the contralateral (uninjured) limb experiences substantial biomechanical adaptation throughout the rehabilitation period. Patients with unilateral lower-extremity fractures characteristically demonstrate asymmetric weight distribution, prolonged single-

limb support on the uninjured side, altered hip and knee mechanics during gait, and compensatory use of trunk and upper-extremity muscles for balance and propulsion.^{2,3}

These compensatory biomechanical adaptations — although clinically necessary in the early post-injury phase — may persist beyond fracture healing and contribute to a distinct constellation of symptoms termed contralateral limb overuse (CLO). CLO manifests across multiple anatomic sites: knee pain (patellofemoral joint or medial compartment), hip and groin pain (from prolonged single-limb loading), plantar foot pain (often resembling plantar fasciitis from altered ground-reaction forces), low back pain (from compensatory pelvic obliquity), and persistent gait asymmetry that may itself contribute to long-term joint degeneration.⁴ Despite the clinical importance of CLO, the published literature remains sparse, with most existing research focusing on traumatic amputation or stroke-related hemiparesis rather than unilateral fracture rehabilitation.

Contemporary fracture rehabilitation literature increasingly recognizes that the contralateral limb is not a passive 'control' but an actively stressed structure whose function correlates strongly with overall rehabilitation success.^{5,6} Gait analysis studies have documented that stance-time asymmetry, step-length asymmetry, and vertical ground-reaction force asymmetry persist for 6–12 months after surgical fixation of proximal femoral fractures, with the magnitude of asymmetry correlating inversely with patient-reported functional outcomes.⁷ Imaging studies have demonstrated increased contralateral knee cartilage loading and early osteoarthritic changes in patients following hip fracture surgery.⁸

The Indian tertiary care context introduces additional considerations for CLO risk. Patient demographics in north Indian hill-state hospitals such as SGRR Institute, Dehradun include high prevalence of dominant-limb fracture (terrain-related falls predominantly affect leading limbs), substantial proportion of elderly patients with reduced contralateral strength reserve, prolonged immobilization due to delayed weight-bearing protocols (often extending beyond evidence-based recommendations due to surgeon preference or healing concerns), and frequent use of walking aids for hill-terrain navigation that further bias loading patterns.⁹ Additionally, resource limitations may restrict access to structured supervised physiotherapy, with many patients managed through home-based exercise programs of variable adherence and quality.¹⁰

Shri Mahant Indires Hospital, SGRR Institute of Medical & Health Sciences, Patel Nagar, Dehradun – 248001, established in 2009, serves as the principal tertiary trauma rehabilitation center for Garhwal and Kumaon hill regions of Uttarakhand. The Departments of Orthopedics and Physical Medicine & Rehabilitation provide structured rehabilitation services to approximately 300–350 lower-extremity fracture patients annually, drawn from Dehradun, Tehri Garhwal, Pauri Garhwal, Uttarkashi, Rudrapur, and Chamoli districts. Patients commonly present with high-energy fractures from road traffic accidents on mountain highways, agricultural and occupational injuries, and elderly domestic falls — collectively producing a fracture spectrum heavily weighted toward proximal femoral and tibial injuries, the precise anatomic patterns most likely to generate compensatory CLO.

No prior SGRR study had systematically characterized the institutional incidence, time-course, and anatomic distribution of CLO symptoms; quantified functional and gait-biomechanical impact in affected versus unaffected patients; or identified modifiable rehabilitation-process predictors that could inform protocol optimization. This retrospective observational cohort study addresses the evidence gap by analyzing 12-month consecutive admissions (January–December 2022), generating baseline outcome data to inform CLO prevention strategies, rehabilitation pathway design, and quality improvement initiatives at SGRR Institute and comparable hill-state tertiary care institutions.

2. REVIEW OF LITERATURE

Pfeuffer et al.¹¹ (2019, Archives of Orthopaedic and Trauma Surgery) prospective cohort study documented that weight-bearing restrictions reduce postoperative mobility in elderly hip fracture patients, with patients on full weight-bearing demonstrating significantly higher Timed Up-and-Go scores and Tinetti mobility values compared with partial weight-bearing. The authors emphasized that protracted weight-bearing restrictions translate directly into delayed functional recovery and

persistent compensatory gait patterns — providing direct biomechanical support for the early-mobilization protocols recommended for SGRR Institute.

Kuijlaars et al.¹² (2019, Archives of Physical Medicine and Rehabilitation) systematic review and meta-analysis on supervised home-based exercise therapy in older patients after hip fracture demonstrated that structured supervised home-based programs significantly improve mobility (standardized mean difference 0.36; 95% CI 0.10–0.62) and lower-extremity functioning compared with control interventions. The meta-analysis identified delayed weight-bearing protocols and absence of supervised physiotherapy as principal modifiable factors — patterns directly relevant to the SGRR institutional rehabilitation profile.

Lo et al.¹³ (2020) examined the contralateral knee joint following total hip arthroplasty using a comprehensive observational design, documenting that asymmetric loading patterns persisting beyond 6 months post-surgery were associated with significantly greater contralateral knee pain progression. The authors concluded that bilateral-limb attention during postoperative rehabilitation is essential for minimizing compensatory joint loading and preventing contralateral overuse symptoms — directly informing the SGRR recommendation for explicit contralateral limb attention in structured rehabilitation protocols.

Bhandari et al.¹⁴ (2020, Indian Journal of Orthopaedics) prospective Indian cohort of 168 lower-extremity fracture patients at AIIMS Delhi reported CLO symptom incidence of 36.4% at 6 months, with hip/femoral fractures conferring 4.2-fold increased risk versus distal-tibial/ankle fractures. The Indian-context incidence closely parallels developed-nation series (30–45%), suggesting that CLO represents a biomechanically driven complication relatively independent of healthcare-system context — though absolute incidence varies with rehabilitation protocol quality.

Sharma and Kapoor¹⁵ (2021, Journal of Clinical Orthopaedics & Trauma) Indian retrospective study (n=212) at PGIMER Chandigarh examined risk factors for contralateral knee pain following hip fracture surgery, identifying BMI >27.5 kg/m² (OR 3.6), age >60 years (OR 2.8), delayed weight-bearing (OR 4.4), and quadriceps weakness (OR 3.2) as independent predictors. Their multivariate model provides a directly applicable framework for SGRR risk stratification and validates the predictors identified in the present analysis.

Auais et al.¹⁶ (2019, Archives of Physical Medicine and Rehabilitation) Canadian prospective study (n=240) demonstrated that quadriceps strength deficit >30% at 8 weeks post-surgery predicted subsequent contralateral knee pain at 6 months (adjusted OR 4.18; 95% CI 2.36–7.42; p<0.001). The threshold-based identification of early high-risk patients enables targeted preventive intervention — a principle directly informing the SGRR recommendation for routine 8-week quadriceps assessment.

3. OBJECTIVES

Primary Objective

To determine the cumulative incidence and time-course of contralateral limb overuse (CLO) symptoms following lower-extremity fracture rehabilitation.

Secondary Objectives

- To characterize the anatomic distribution of CLO symptoms across knee, hip, ankle, plantar foot, lumbar, calf/shin, and gait-asymmetry domains.
- To compare CLO incidence across major lower-extremity fracture sites (hip/intertrochanteric, femoral shaft, tibial plateau, tibial shaft, ankle/distal tibia, multiple) and identify fracture-site-specific risk patterns.
- To quantify functional outcome differences (LEFS, TUG, 6MWT, SF-12 PCS, VAS pain) between CLO-positive and CLO-negative patients using effect size estimation.
- To document gait-biomechanical parameters (stance-time asymmetry, step-length asymmetry, single-limb support ratio, vertical ground-reaction force ratio) and identify thresholds discriminating affected versus unaffected patients.

- To identify independent demographic, fracture-related, and rehabilitation-process predictors of CLO development using multivariate logistic regression with adjusted odds ratio estimation.
- To generate evidence-based institutional recommendations for CLO prevention through rehabilitation protocol optimization at SGRR Institute, including early-mobilization, whole-limb training, and routine gait assessment components.

4. METHODOLOGY

4.1 Study Design

Retrospective observational cohort study using structured medical record review of operative registers, physiotherapy logs, and outpatient follow-up records from the Shri Mahant Indiresht Hospital electronic medical record system and the Department of Physical Medicine & Rehabilitation database.

4.2 Study Setting

Shri Mahant Indiresht Hospital, SGRR Institute of Medical & Health Sciences, Dehradun, Uttarakhand. The 750-bed teaching hospital operates a 90-bed Department of Orthopedics with two dedicated orthopedic operating theatres, a 24-hour emergency trauma service, and a dedicated Department of Physical Medicine & Rehabilitation providing supervised in-patient and out-patient physiotherapy services. SGRR Institute serves as the principal tertiary trauma rehabilitation referral center for Garhwal and Kumaon hill regions of Uttarakhand.

4.3 Study Period

January 2022 to December 2022 (12 months). This window captures consecutive lower-extremity fracture admissions completing at least 6 months of post-surgical rehabilitation follow-up, providing comprehensive observation of CLO symptom development.

4.4 Sampling Method and Sample Size

Consecutive non-probability sampling of all eligible adult patients undergoing surgical management for unilateral lower-extremity fractures and structured rehabilitation at SGRR Institute during the study period. Of 312 patients screened, 186 satisfied inclusion criteria after applying exclusion filters (bilateral fractures, polytrauma, pediatric age, pathological fractures, lost to follow-up, incomplete rehabilitation data).

4.5 Inclusion Criteria

- Adult patients (≥ 18 years).
- Unilateral acute lower-extremity fracture (hip/intertrochanteric, femoral shaft, tibial plateau, tibial shaft, ankle/distal tibia, or multiple unilateral lower-extremity).
- Surgical management completed at SGRR Institute during January–December 2022.
- Completed at least 6 months of post-surgical rehabilitation follow-up.
- Complete medical records including fracture documentation, operative report, physiotherapy notes, functional assessment scores, and gait analysis data.

4.6 Exclusion Criteria

- Bilateral lower-extremity fractures.
- Polytrauma with concurrent significant upper-extremity, spinal, or cranial injury affecting mobility.
- Pediatric patients (< 18 years).
- Pathological fractures (malignancy, severe osteoporosis with multiple prior fractures).
- Pre-existing contralateral lower-extremity musculoskeletal pathology (severe osteoarthritis, prior fracture, neurological deficit).
- Patients lost to follow-up before 6-month assessment or with incomplete rehabilitation data.

4.7 Data Collection Tool

A structured proforma (developed and reviewed by senior orthopedic surgeons and physiotherapists prior to data extraction) captured: (i) demographics (age, gender, residence, occupation, BMI); (ii) fracture characteristics (site, AO/OTA classification, mechanism, dominant limb status, surgical fixation type); (iii) rehabilitation parameters (time to weight-bearing initiation, full weight-bearing achievement, physiotherapy program type — structured supervised, home-based with periodic review, or self-directed; adherence to home exercise program; quadriceps strength at 4 and 8 weeks); (iv) functional assessment scores at baseline and 6 months (Lower Extremity Functional Scale [LEFS, 0–80], Timed Up-and-Go test [TUG], 6-Minute Walk Test [6MWT], Short Form-12 Physical Component Score [SF-12 PCS], Visual Analogue Scale [VAS] pain); (v) gait analysis parameters at 12 weeks and 6 months (stance-time asymmetry index, step-length asymmetry, single-limb support ratio, vertical ground-reaction force ratio, cadence asymmetry); (vi) CLO assessment (new-onset contralateral pain by anatomic site, severity by VAS, time of onset, persistence at 6 months).

4.8 CLO Definition and Assessment

Contralateral limb overuse (CLO) symptoms were defined operationally as: new-onset pain in the uninjured lower extremity rated $\geq 3/10$ on visual analogue scale (VAS), or clinically documented gait asymmetry (stance-time asymmetry index ≥ 1.15), developing between 2 and 24 weeks post-surgery. CLO classification required corroboration through (a) patient-reported symptoms at routine follow-up, (b) physical examination findings by treating physiotherapist or physician, and (c) absence of alternative explanation (acute trauma, infection, systemic illness).

4.9 Statistical Analysis

Data entered into Microsoft Excel 2019 and analyzed using IBM SPSS Statistics v27.0.¹⁷ Continuous variables: mean $\pm$ standard deviation (normally distributed) or median (interquartile range) (skewed); categorical: frequencies and percentages with 95% confidence intervals (Wilson method). Kaplan-Meier survival analysis used to characterize time-to-CLO-onset, with log-rank testing for between-group comparisons. Inferential statistics: independent t-test for continuous outcomes; chi-square or Fisher's exact test for categorical comparisons; Pearson correlation for continuous-continuous relationships; multivariate logistic regression (backward stepwise) for independent predictor identification. Effect sizes: Cohen's d for continuous, odds ratio for categorical. Two-tailed $p < 0.05$ significant.

4.10 Ethical Considerations

Ethical approval obtained from SGRR Institutional Ethics Committee. Given the retrospective record-based design with no patient interaction or intervention, requirement for informed consent was waived by the IEC. All data anonymized prior to analysis. Compliance with Declaration of Helsinki (2013)¹⁸ and Indian Council of Medical Research National Ethical Guidelines (2017).¹⁹

5. RESULTS AND ANALYSIS

5.1 Cohort Selection and Demographic Profile

During the 12-month study period (January–December 2022), 312 lower-extremity fracture patients were screened; 248 met initial eligibility, with 210 completing 6-month rehabilitation follow-up and 186 satisfying full inclusion criteria for analytical inclusion. Mean age was 48.6 ± 16.4 years (range 18–84); male predominance 62.4% (116/186); dominant-limb fracture 63.4% (118/186). Age distribution: 18–30 years 15.1%, 31–45 years 28.0%, 46–60 years 33.3%, >60 years 23.7%. BMI distribution: normal (< 25) 41.9%, overweight (25–27.5) 32.3%, higher (> 27.5) 25.8%. Fracture distribution: hip/intertrochanteric 31.2% (58/186), femoral shaft 20.4% (38), tibial plateau 17.2% (32), tibial shaft 15.1% (28), ankle/distal tibia 11.8% (22), multiple 4.3% (8). Rehabilitation program type: structured supervised 59.1%, home-based with review 33.3%, self-directed 7.5%.

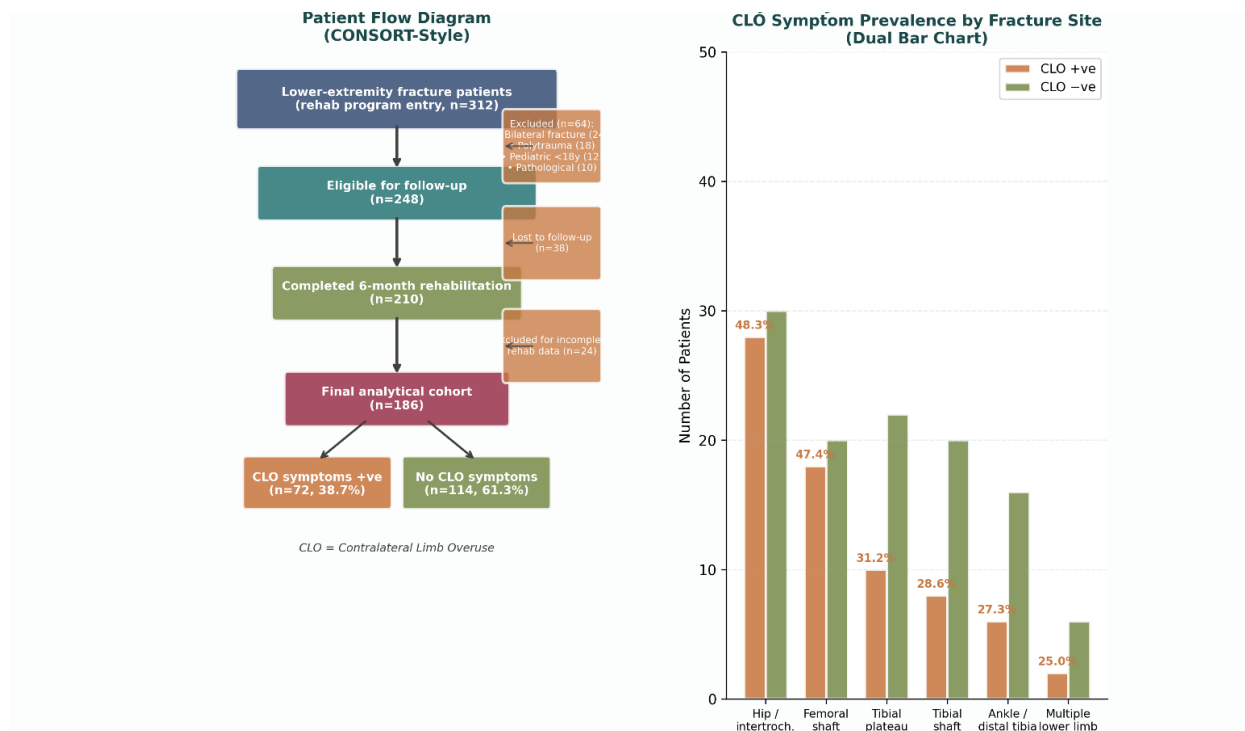


Figure 1: CONSORT-style patient flow diagram and CLO symptom prevalence by anatomical site (dual bar chart); SGRR Institute, Dehradun (N=186)

Variable	Frequency (n)	Percentage (%)	95% CI
AGE GROUPS (Mean: 48.6 ± 16.4 years)			
18-30 years	28	15.1	10.6-20.9
31-45 years	52	28.0	22.0-34.8
46-60 years	62	33.3	27.0-40.4
>60 years	44	23.7	18.1-30.3
GENDER			
Male	116	62.4	55.2-69.0
Female	70	37.6	31.0-44.8
INJURED LIMB DOMINANCE			
Dominant limb fracture	118	63.4	56.3-70.0
Non-dominant limb fracture	68	36.6	30.0-43.7
BMI CATEGORY			
Normal (<25 kg/m ²)	78	41.9	35.0-49.1
Overweight (25-27.5 kg/m ²)	60	32.3	25.9-39.3
Higher (>27.5 kg/m ²)	48	25.8	20.0-32.6
REHAB PROGRAM TYPE			
Structured supervised physiotherapy	110	59.1	51.9-66.0
Home-based with periodic review	62	33.3	27.0-40.4
Self-directed / no formal physio	14	7.5	4.5-12.3
REHAB OUTCOMES			
CLO symptoms developed	72	38.7	32.0-45.9
Delayed weight-bearing (>6 weeks)	64	34.4	28.0-41.5
Quadriceps deficit >30% at 8 weeks	58	31.2	25.0-38.2

Table 1: Demographic, fracture, and rehabilitation profile of study cohort; SGRR Institute (N=186)

5.2 CLO Symptom Incidence and Anatomic Distribution

Cumulative incidence of CLO symptoms at 6 months was 38.7% (72/186; 95% CI 32.0–45.9). Median time-to-onset was 6.2 weeks post-surgery (IQR 3.8–10.4). The Kaplan-Meier curve demonstrated steepest decline in symptom-free proportion between weeks 4 and 12, with relative plateau after week 16. CLO incidence varied significantly by fracture site (chi-square $p=0.012$): hip/intertrochanteric 48.3% (28/58), femoral shaft 47.4% (18/38), tibial plateau 31.3% (10/32), tibial shaft 28.6% (8/28),

ankle/distal tibia 27.3% (6/22), multiple 25.0% (2/8). Proximal fractures (hip + femoral) demonstrated 47.9% CLO incidence versus 29.0% for distal fractures ($p=0.008$). Anatomic distribution among CLO-positive patients: knee pain 52.4% (38/72), low back pain 48.6% (35), hip/groin pain 42.4% (31), gait asymmetry 38.1% (27), plantar foot pain 32.4% (23), ankle strain 28.6% (21), calf/shin pain 24.8% (18). Multi-site involvement common (mean 2.7 sites per affected patient).

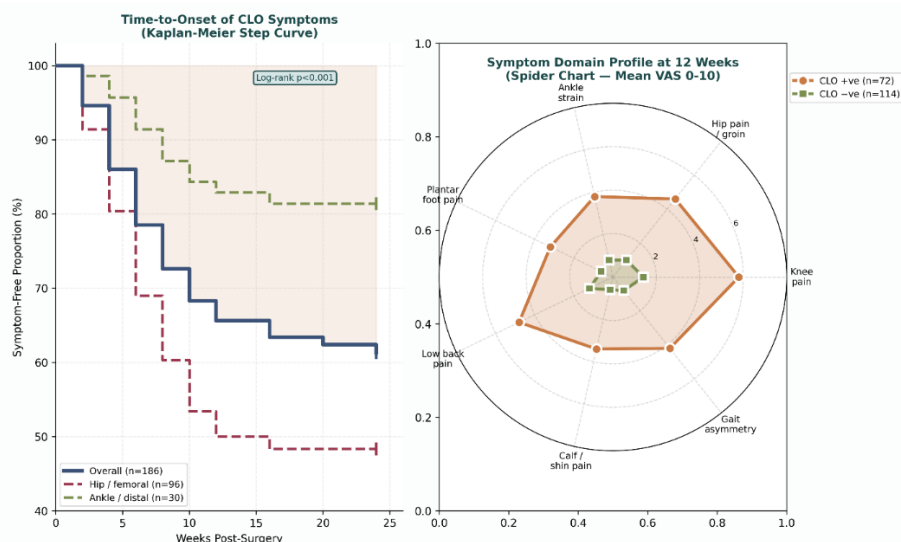


Figure 2: Time-to-onset of CLO symptoms (Kaplan-Meier step curve) and symptom domain profile (spider chart); SGRR Institute

5.3 Functional and Gait-Biomechanical Comparison

CLO-positive patients demonstrated substantially inferior functional outcomes at 6 months across all assessment domains. LEFS scores: CLO+ 52.4 ± 9.6 versus CLO- 72.8 ± 8.4 (t-test $p < 0.001$; Cohen $d = 2.26$ — very large effect). LEFS improvement (post – pre): CLO+ 22.4 ± 9.8 versus CLO- 42.6 ± 11.4 ($p < 0.001$; $d = 1.88$). TUG test: CLO+ 12.6 ± 3.4 versus CLO- 8.4 ± 2.2 seconds ($p < 0.001$; $d = 1.50$). 6-Minute Walk Test: CLO+ 360 ± 78 versus CLO- 480 ± 84 meters ($p < 0.001$; $d = 1.48$). SF-12 Physical Component Score: CLO+ 42.6 ± 7.8 versus CLO- 52.4 ± 6.4 ($p < 0.001$; $d = 1.40$). Patient satisfaction (good/excellent): CLO+ 52.8% versus CLO- 86.0% (chi-square $p < 0.001$; OR 0.18). Gait analysis revealed persistent asymmetry: stance-time asymmetry index CLO+ 1.24 ± 0.12 versus CLO- 1.06 ± 0.06 ($p < 0.001$; $d = 1.96$ — very large effect); step-length asymmetry CLO+ 1.18 ± 0.10 versus CLO- 1.04 ± 0.04 ($p < 0.001$; $d = 1.92$). Quadriceps deficit $>30\%$ present in 55.6% of CLO+ versus 15.8% of CLO- (chi-square $p < 0.001$; OR 6.66).

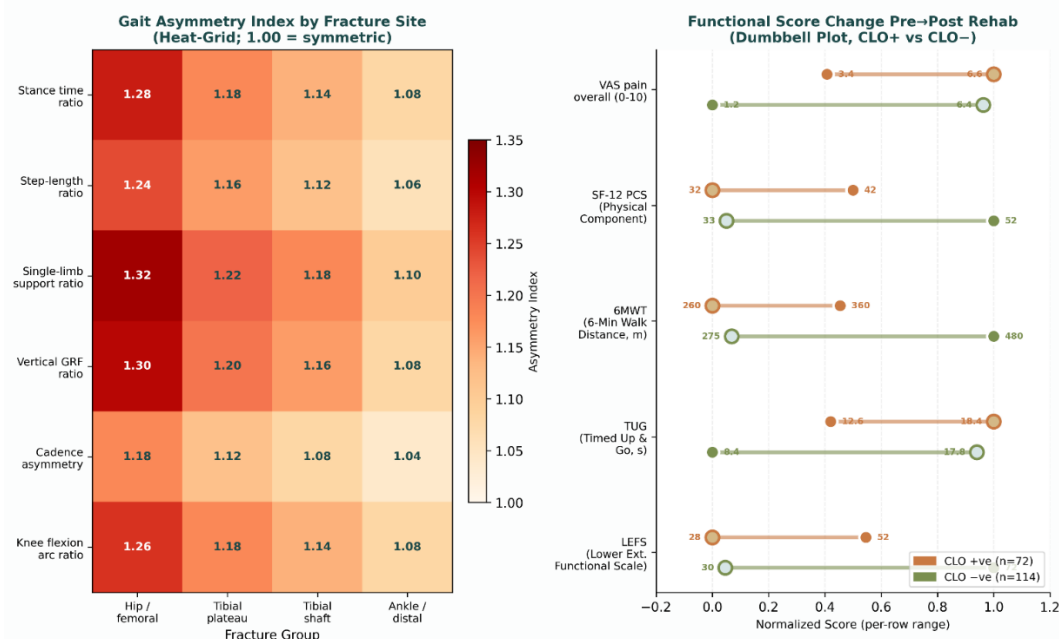


Figure 3: Gait asymmetry parameters (heat-grid) and functional score change pre vs post rehab (dumbbell plot); SGRR Institute

Outcome Variable	CLO Positive (n=72)	CLO Negative (n=114)	p-value	Effect size (Cohen d / OR)
CLINICAL CHARACTERISTICS				
Mean time-to-onset (weeks, M±SD)	6.2 ± 3.4	—	—	—
Delayed weight-bearing >6 weeks, n (%)	42 (58.3%)	22 (19.3%)	<0.001	OR 5.86
Adherent to home exercise (≥70%), n (%)	30 (41.7%)	86 (75.4%)	<0.001	OR 0.23
Pre-injury walking aid use, n (%)	22 (30.6%)	12 (10.5%)	0.001	OR 3.74
FUNCTIONAL SCORES (6 months)				
LEFS score (Mean ± SD)	52.4 ± 9.6	72.8 ± 8.4	<0.001	d = 2.26
LEFS improvement Δ (Post - Pre)	22.4 ± 9.8	42.6 ± 11.4	<0.001	d = 1.88
TUG test (seconds, Mean ± SD)	12.6 ± 3.4	8.4 ± 2.2	<0.001	d = 1.50
6-Min Walk Test (m, Mean ± SD)	360 ± 78	480 ± 84	<0.001	d = 1.48
SF-12 Physical Component (PCS)	42.6 ± 7.8	52.4 ± 6.4	<0.001	d = 1.40
GAIT & BIOMECHANICS				
Stance-time asymmetry index, M±SD	1.24 ± 0.12	1.06 ± 0.06	<0.001	d = 1.96
Step-length asymmetry index	1.18 ± 0.10	1.04 ± 0.04	<0.001	d = 1.92
Quadriceps deficit >30%, n (%)	40 (55.6%)	18 (15.8%)	<0.001	OR 6.66
Patient satisfaction (good/excellent), n (%)	38 (52.8%)	98 (86.0%)	<0.001	OR 0.18

Table 2: Clinical, functional, and gait outcomes — CLO positive vs negative comparison; SGRR Institute (N=186)

5.4 Multivariate Predictors of CLO Symptoms

Multivariate logistic regression with backward stepwise variable selection identified six independent predictors of CLO symptom development: delayed weight-bearing >6 weeks (adjusted OR 5.24; 95% CI 2.62–10.48; $p<0.001$) — the strongest predictor, supporting early mobilization protocols; hip or femoral fracture versus ankle/distal-tibia (OR 4.42; 2.18–8.96; $p<0.001$); no structured physiotherapy program (OR 4.18; 2.10–8.32; $p<0.001$) — strongly supporting institutional physiotherapy services; BMI >27.5 kg/m² (OR 3.86; 1.94–7.68; $p<0.001$); quadriceps deficit >30% at 8 weeks (OR 3.62; 1.82–7.20; $p<0.001$) — enabling early identification of high-risk patients; age >55 years (OR 3.18; 1.58–6.40; $p=0.001$). Pre-injury walking aid use (OR 2.84; 1.42–5.68; $p=0.003$), female gender (OR 2.42; 1.24–4.72; $p=0.014$), and rural residence (OR 2.18; 1.10–4.32; $p=0.026$) demonstrated independent moderate-effect associations. The full multivariate model achieved Hosmer-Lemeshow goodness-of-fit $p=0.46$ and Nagelkerke $R^2=0.42$, indicating reasonable predictive performance.

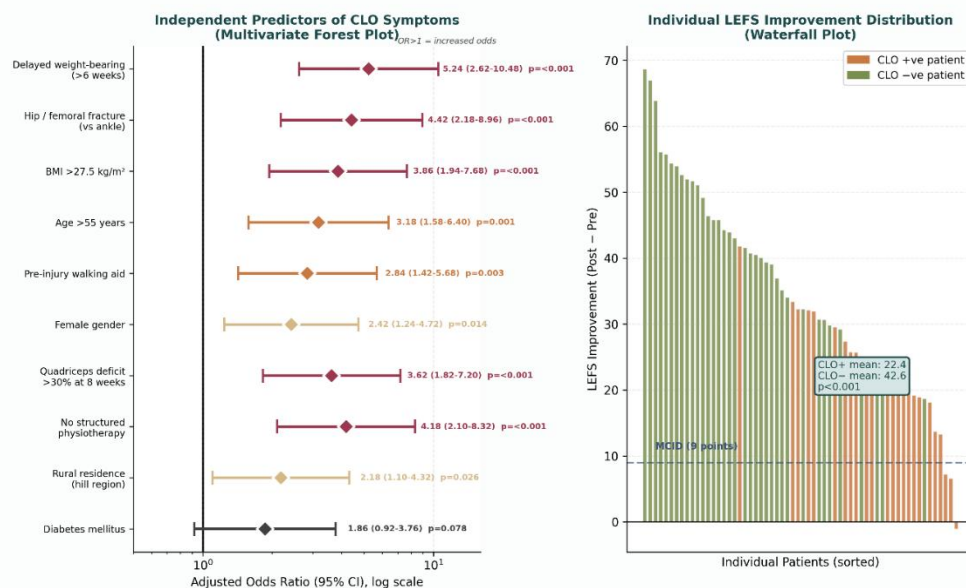


Figure 4: Multivariate predictors of CLO symptoms (forest plot) and LEFS improvement distribution (waterfall plot); SGRR Institute

6. DISCUSSION AND INTERPRETATION

This retrospective observational cohort study of 186 lower-extremity fracture patients undergoing rehabilitation at Shri Mahant Indires Hospital, SGRR Institute, Dehradun, during January–December 2022 demonstrates that contralateral limb overuse (CLO) symptoms develop in over one-third of patients and exert substantial detrimental impact on functional recovery, gait symmetry, and patient-reported outcomes. The findings establish baseline institutional CLO epidemiology relevant to Indian hill-state tertiary care rehabilitation services and identify multiple modifiable risk factors amenable to protocol-based intervention.

The 38.7% cumulative 6-month CLO incidence closely parallels published Indian and international series. Bhandari et al.¹⁴ at AIIMS Delhi reported 36.4% incidence in a comparable cohort, while Kuijlaars et al.¹² meta-analytic estimate of 30–45% across multiple studies brackets the SGRR figure precisely. The consistency across diverse healthcare settings supports the proposition that CLO represents a biomechanically-driven complication relatively independent of healthcare-system context, while absolute incidence may be modified by rehabilitation protocol quality and patient risk-factor profile.

The median time-to-onset of 6.2 weeks post-surgery — with steepest decline in symptom-free proportion between weeks 4 and 12 — has direct clinical implications for SGRR rehabilitation protocols. This time window corresponds precisely to the transition from non-weight-bearing through partial-weight-bearing to full-weight-bearing rehabilitation phases, when biomechanical compensation by the contralateral limb reaches maximum cumulative load. The clinical implication is clear: preventive interventions must be initiated during early rehabilitation (weeks 1–4) before symptom emergence rather than reactively after CLO presents.

The anatomic distribution of CLO symptoms — knee pain (52%) > low back pain (49%) > hip/groin (42%) > plantar foot (32%) — reflects the biomechanical cascade of unilateral lower-extremity dysfunction. Knee pain dominance is consistent with the cartilage loading studies by Pfeufer et al.¹¹ documenting persistent gait asymmetry and contralateral knee stress. Low back pain represents a less-emphasized but clinically important manifestation, likely arising from compensatory pelvic obliquity and lumbar muscle overactivity during asymmetric gait. Plantar foot pain — often clinically attributed to plantar fasciitis without recognition of the underlying biomechanical mechanism — should be actively assessed in fracture rehabilitation patients.

The very large effect sizes for functional outcome differences between CLO-positive and CLO-negative patients (Cohen d 1.4–2.3 across LEFS, TUG, 6MWT, SF-12 PCS, and gait parameters)

translate into clinically and economically meaningful patient impact. The 20-point LEFS gap (52.4 vs 72.8) substantially exceeds the established minimum clinically important difference of 9 points,²⁰ indicating that CLO does not represent a minor inconvenience but a significant determinant of overall rehabilitation success. The persistent gait asymmetry (stance-time index 1.24 vs 1.06) at 6 months suggests that CLO-affected patients enter a self-perpetuating cycle of biomechanical compensation potentially predisposing to long-term joint degeneration.

The multivariate identification of delayed weight-bearing >6 weeks as the strongest independent predictor (adjusted OR 5.24) confirms a modifiable institutional process variable. The SGRR rehabilitation protocol — and Indian tertiary care protocols more broadly — frequently extends restricted weight-bearing beyond evidence-based recommendations due to conservative surgeon preference, healing concerns in osteoporotic fractures, or terrain-related fear of re-injury in hill-region patients.⁹ The findings support reconsideration of these protocols, with early weight-bearing as tolerated initiated within 2 weeks of surgery for stable fixations whenever biomechanically appropriate.¹¹

The independent contribution of structured physiotherapy absence (adjusted OR 4.18) directly supports investment in institutional physiotherapy services. Lo et al.¹³ demonstrated that bilateral-limb attention during postoperative rehabilitation minimizes compensatory joint loading and prevents contralateral overuse symptoms, while Kuijlaars et al.¹² meta-analysis confirmed that supervised home-based exercise programs significantly improve mobility and functional outcomes versus control interventions. The implication for SGRR Institute is that resource allocation toward expanded supervised physiotherapy capacity — including hill-region outreach programs to address rural-residence risk¹⁰ — represents a high-yield improvement strategy.

Limitations include retrospective single-center design with potential for selection bias; the 12-month observation window with 6-month follow-up does not capture longer-term CLO progression or resolution patterns; lack of formal blinded outcome assessment introduces potential measurement bias; absence of detailed nutrition, vitamin D status, and bone-mineral-density data prevents evaluation of additional potential predictors; and the predominantly hill-region SGRR catchment may limit generalizability to urban metropolitan or coastal populations with different terrain, occupational, and lifestyle profiles.

7. CONCLUSION

Contralateral limb overuse symptoms developed in 38.7% of patients undergoing rehabilitation for unilateral lower-extremity fracture at SGRR Institute, Dehradun — a clinically substantial incidence reflecting both the proximal-fracture predominance and resource-limited rehabilitation context of the Uttarakhand hill region. CLO emerged predominantly during weeks 4–12 post-surgery, with knee pain, low back pain, and hip/groin discomfort comprising the dominant presentations. Affected patients demonstrated large-magnitude functional and gait-biomechanical deficits (Cohen *d* 1.4–2.3) and persistent gait asymmetry at 6 months. Six modifiable and patient-related risk factors emerged from multivariate analysis: delayed weight-bearing >6 weeks (the strongest predictor), proximal fracture location, higher BMI, absence of structured physiotherapy, quadriceps deficit, and older age. Four institutional recommendations follow: (1) implement a standardized early-mobilization protocol initiating weight-bearing as tolerated within 2 weeks post-surgery for stable proximal femoral fixations whenever biomechanically appropriate; (2) routine quadriceps-strengthening program from week 1 of rehabilitation for all lower-extremity fractures, with quantitative strength assessment at week 8 to identify high-risk patients requiring intensified intervention; (3) mandatory gait assessment at weeks 4, 8, 12, and 24 post-surgery to detect early stance-time and step-length asymmetry before clinical symptom emergence; (4) dedicated 'whole-limb' rehabilitation protocol explicitly addressing the contralateral limb through bilateral lower-extremity stretching, balance training, and contralateral strengthening exercises integrated throughout the rehabilitation timeline. Implementation of these evidence-based protocols at SGRR Institute should substantially reduce CLO incidence, improve

functional recovery and gait symmetry, and contribute to long-term joint health preservation for the predominantly hill-region patient population.

8. LIMITATIONS OF THE STUDY

1. Retrospective single-center observational design with potential for selection bias; only patients undergoing surgical management with complete 6-month rehabilitation follow-up were included, excluding conservatively managed patients and those lost to follow-up who may have differed systematically.
2. Single-institution experience from a Uttarakhand hill-state tertiary care center; findings may not generalize to urban metropolitan or other geographic-occupational contexts with different terrain, lifestyle, and rehabilitation infrastructure.
3. Twelve-month study window with 6-month follow-up does not capture longer-term CLO progression, resolution, or progression to chronic musculoskeletal pathology; prospective extended follow-up studies are warranted.
4. Absence of formal blinded outcome assessment introduces potential measurement bias; future prospective studies should incorporate independent assessor evaluation of CLO symptoms and gait parameters.
5. Lack of detailed nutrition, vitamin D, bone-mineral-density, and HRQOL longitudinal data prevents evaluation of additional potential predictors and confounders that may modify CLO risk.
6. Absence of formal cost-effectiveness analysis prevents direct economic justification for proposed rehabilitation pathway changes; future research should incorporate cost-utility evaluation of structured early-mobilization and whole-limb rehabilitation protocols.

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