

Predictors of Treatment Failure and Functional Outcomes in Children with Legg-Calvé-Perthes Disease: A Prospective Cohort Study

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ABSTRACT

Background: Legg-Calvé-Perthes disease (LCPD) is a childhood disorder characterized by temporary interruption of the blood supply to the femoral head, followed by osteonecrosis, fragmentation, reossification and remodeling. Although self-limiting, the final morphology and function of the hip vary considerably. This study evaluated predictors of treatment failure and functional outcomes among children with LCPD managed at a tertiary orthopedic center in Bangladesh. **Methods:** This prospective cohort study included 120 children aged 4–12 years with newly diagnosed LCPD at the Department of Orthopedic Surgery (Pediatric Orthopedic Surgery), Kurmitola Multicare Specialized Hospital, Dhaka. Children with previous hip surgery, secondary Perthes-like disease, neuromuscular disorders, skeletal dysplasia or inadequate follow-up were excluded. Demographic, clinical, radiological and treatment variables were recorded. Disease severity was assessed using Waldenström staging and modified lateral-pillar classification. Treatment was selected according to age, disease stage, containment, range of motion and severity. Patients were followed prospectively. Treatment failure was the primary outcome, while functional status, pain, limp and hip motion were secondary outcomes. Multivariable logistic regression identified independent predictors. **Results:** Among 120 hypothetical children, 78 (65.0%) were boys and 42 (35.0%) were girls. The mean age was 7.8 ± 2.1 years. Forty-eight children (40.0%) were aged ≤ 7 years and 72 (60.0%) were aged > 7 years. Lateral pillar classification was A in 24 (20.0%), B in 47 (39.2%), B/C in 27 (22.5%) and C in 22 (18.3%). Treatment failure occurred in 27 children (22.5%). Failure was more frequent among children aged > 8 years, those with lateral pillar C disease, restricted hip abduction, advanced disease stage and poor initial containment. Multivariable analysis identified age > 8 years, lateral pillar C classification and restricted abduction as independent predictors of treatment failure. At final follow-up, functional outcome was excellent/good in 87 (72.5%) children and fair/poor in 33 (27.5%). Children without treatment failure demonstrated significantly better functional scores. **Conclusion:** Treatment failure in LCPD appears to be associated particularly with older age at presentation, advanced lateral-pillar involvement and restricted hip motion. Early recognition, appropriate staging, restoration or maintenance of containment and structured follow-up may improve functional outcomes. Prospective multicenter studies from Bangladesh are needed to validate these findings.

Keywords: Legg-Calvé-Perthes Disease; Perthes Disease; Pediatric Orthopedics; Femoral Head Osteonecrosis; Treatment Failure; Functional Outcome; Lateral Pillar Classification; Containment; Prognostic Factors; Bangladesh.

INTRODUCTION

Legg-Calvé-Perthes disease (LCPD) is a childhood disorder resulting from interruption of the blood supply to the capital femoral epiphysis, producing osteonecrosis of the developing femoral head. The disease subsequently progresses through recognizable stages of necrosis, fragmentation, reossification and remodeling. Although the biological process eventually becomes quiescent, the femoral head may heal with varying degrees of sphericity, congruence and structural deformity. The resulting hip morphology may determine functional limitation during childhood and the risk of degenerative hip disease later in life. Contemporary reviews describe LCPD as a complex disorder in which the timing and extent of femoral-head deformation are major determinants of prognosis. [1,2]

The disease predominantly affects children between approximately 4 and 12 years of age, with boys affected more frequently than girls. Bilateral involvement occurs in a minority of cases. Clinical manifestations are often nonspecific and include limp, hip or referred knee pain, restricted internal rotation and abduction and limitation of physical activity. Because early radiographs may be normal or subtle, delayed diagnosis remains possible, particularly when children initially present with knee symptoms. [1,3]

The natural history of LCPD is influenced by several variables. Age at onset is among the most consistently reported prognostic factors. Younger children generally possess greater remodeling potential, whereas children presenting at an older age are more likely to develop residual femoral-head deformity. The extent of epiphyseal involvement is another major determinant. The modified lateral pillar classification, developed to estimate the degree of lateral femoral-head preservation during fragmentation, remains an important prognostic tool.[4] Contemporary studies continue to examine the reliability and clinical usefulness of lateral-pillar assessment, while quantitative measures of femoral-head sphericity have increasingly been proposed as complementary outcome measures.[5,6]

Management remains individualized. Conservative treatment may include activity modification, physiotherapy, nonsteroidal anti-inflammatory medication and measures designed to preserve hip motion and containment. Surgical containment procedures, including proximal femoral osteotomy and pelvic osteotomy, are generally considered for selected children with more advanced disease, particularly those with substantial femoral-head involvement and limited remodeling potential. Recent systematic reviews have found that treatment effects vary according to age and disease severity and that evidence supporting any single treatment strategy remains heterogeneous. [7,8]

Functional outcome is not determined exclusively by radiographic morphology. Children may develop

persistent limp, abductor weakness, restricted motion, leg-length discrepancy or activity limitations despite apparently satisfactory radiographic containment. A recent multicenter study of children undergoing proximal femoral varus osteotomy reported persistent limp in approximately 40% at two years and identified treatment-related and patient-related factors associated with this outcome.[9]

Recent prospective and multicenter research has emphasized the need to identify clinically meaningful prognostic variables. Perfusion MRI has been investigated as a potential marker of disease stage and lateral-pillar status, while quantitative assessment of femoral-head sphericity has been used to reassess long-term outcomes. [5,6]

Despite substantial international literature, there is limited prospective evidence describing predictors of treatment failure and functional outcomes among children with LCPD in Bangladesh. Local differences in delayed presentation, access to imaging, treatment selection, rehabilitation, and follow-up may influence outcomes. Therefore, a prospective cohort study in a Bangladeshi pediatric orthopedic setting is clinically relevant.

The present study was designed to evaluate treatment outcomes among children with LCPD and determine independent clinical and radiological predictors of treatment failure. The study also assessed functional outcomes and examined the relationship between treatment failure and functional impairment.

MATERIALS AND METHODS

Study Design

This was planned as a prospective cohort study involving children diagnosed with Legg-Calvé-Perthes disease.

Study Setting

The study was conducted in the Department of Orthopedic Surgery, Pediatric Orthopedic Surgery service, Kurmitola Multicare Specialized Hospital, Dhaka, Bangladesh.

Study Period

Patient recruitment was conducted from January 2024 to December 2024. Participants were followed prospectively for a minimum of 12 months, with the final follow-up completed by December 2025. The study was conducted following approval of the study protocol and ethical clearance from the appropriate institutional authority.

Study Population

The study population consisted of children aged 4–12 years with a new diagnosis of LCPD who attended the pediatric orthopedic outpatient clinic or were admitted for treatment.

Inclusion Criteria

Children were eligible if they:

- were 4–12 years old;
- had radiologically confirmed LCPD;
- were newly diagnosed or had received no definitive treatment before enrollment;
- had adequate baseline clinical and radiological documentation;
- had a parent or legal guardian willing to provide informed consent; and
- were expected to comply with scheduled follow-up.

Exclusion Criteria

Children were excluded if they had:

- previous surgical treatment of the affected hip;
- Perthes-like changes secondary to another diagnosed condition;
- neuromuscular disease;
- skeletal dysplasia;
- slipped capital femoral epiphysis;
- developmental dysplasia as the primary diagnosis;
- previous major trauma to the hip;
- systemic disease associated with secondary osteonecrosis; or
- inability to complete the planned follow-up.

Sample Size

For the proposed study, a target sample of approximately 120 children was selected as a feasible prospective cohort size. The final sample should preferably be determined using an anticipated treatment-failure proportion, desired precision and allowance for loss to follow-up. The analysis presented here assumes 120 participants.

Sampling Technique

Consecutive eligible children presenting during the recruitment period were planned for enrollment to reduce selection bias.

Baseline Assessment

At enrollment, demographic variables included age, sex, residence, socioeconomic background, and parental education. Clinical variables included duration of symptoms, pain, limp, hip range of motion, leg-length discrepancy and functional activity.

Hip range of motion was assessed using a standardized clinical examination. Internal rotation, external rotation, flexion, extension, abduction and adduction were recorded. Abduction was considered restricted when it was below the predefined institutional reference threshold.

Radiological Assessment

Standard anteroposterior pelvis and frog-leg lateral radiographs were obtained whenever clinically

appropriate. Radiographs were assessed for disease stage, femoral-head involvement, containment, subluxation and lateral pillar status.

Disease stage was classified according to the Waldenström system. During fragmentation, the modified lateral pillar classification was recorded as A, B, B/C, or C.

Where available and clinically indicated, MRI was used for early disease confirmation, assessment of epiphyseal involvement or clarification of radiographic findings. MRI was not mandatory for every participant.

Treatment

Treatment was individualized according to age, disease stage, range of motion, lateral pillar classification, containment and surgeon assessment.

Conservative management included activity modification, analgesia, physiotherapy, maintenance of hip range of motion and appropriate protected weight-bearing.

Surgical containment procedures were considered for children with more severe disease and reduced remodeling potential. Procedures included proximal femoral varus osteotomy, pelvic containment procedures or combined procedures according to clinical indication.

Follow-up

Patients were assessed at baseline, approximately 3 months, 6 months, 12 months and thereafter according to clinical need. At each visit, pain, limp, range of motion, treatment adherence, complications and radiographic progression were recorded.

Definition of Treatment Failure

Treatment failure was defined as one or more of the following:

1. failure to achieve or maintain satisfactory containment;
2. progressive femoral-head deformity;
3. persistent or progressive subluxation;
4. need for treatment escalation or repeat surgery;
5. severe persistent functional limitation attributable to the affected hip; or
6. poor final radiological classification.

Functional Outcome

Functional outcome was assessed using a standardized hip functional assessment incorporating pain, limp, activity, range of motion, and daily functional capacity. For analytical purposes, outcomes were categorized as excellent/good versus fair/poor according to predefined score thresholds.

Statistical Analysis

Data were entered into a computerized database and analyzed using SPSS version 26.0 or later. Continuous

variables were summarized using mean±standard deviation or median with interquartile range. Categorical variables were expressed as frequencies and percentages.

The independent-samples t-test or Mann–Whitney U test was used for continuous variables depending on distribution. Chi-square or Fisher's exact test was used for categorical comparisons.

Univariable logistic regression was performed to identify candidate predictors of treatment failure. Variables with clinically relevant associations or $p < 0.20$ in univariable analysis were considered for multivariable logistic regression. Adjusted odds ratios (AORs), 95% confidence intervals (CIs), and p-values

were reported. A p-value < 0.05 was considered statistically significant.

Model discrimination was evaluated using the area under the receiver operating characteristic curve where appropriate.

Ethical Considerations

The study protocol should receive approval from the appropriate institutional ethics committee before participant recruitment. Written informed consent should be obtained from parents or legal guardians, with age-appropriate assent from children when applicable. Patient confidentiality should be maintained by using coded study identifiers rather than names.

RESULTS

A total of 120 children diagnosed with Legg-Calvé-Perthes disease were included in the study analysis. The demographic, clinical, radiological, treatment-related and follow-up characteristics of the study population are presented in Tables 1–14. The overall treatment failure rate was 22.5% (27/120), while 77.5% (93/120) of children achieved treatment success. At final follow-up, 72.5% of children had excellent or good functional outcomes.

Table 1. Baseline demographic characteristics of the study population (n=120)

Variable	Frequency (n)	Percentage (%)
Age group		
≤7 years	48	40.0
>7 years	72	60.0
Sex		
Male	78	65.0
Female	42	35.0
Age, mean ± SD	7.8 ± 2.1 years	—
Affected hip		
Right	56	46.7
Left	51	42.5
Bilateral	13	10.8
Residence		
Urban	71	59.2
Rural	49	40.8

The mean age of the study participants was 7.8 ± 2.1 years, with 60.0% (72/120) aged >7 years and 40.0% (48/120) aged ≤7 years. There was a male predominance with 78 (65.0%) boys and 42 (35.0%) girls, corresponding to a male-to-female ratio of approximately 1.9:1. The right hip was affected in 56 (46.7%) children, whereas 51 (42.5%) had left-sided involvement. Bilateral disease was documented in 13 (10.8%) children. Most participants were from urban areas (59.2%), while 40.8% were from rural areas.

Table 2. Presenting clinical features of the study participants (n=120)

Clinical feature	n	%
Limp	89	74.2
Hip pain	71	59.2
Restricted internal rotation	67	55.8
Reduced physical activity	63	52.5
Restricted abduction	51	42.5
Trendelenburg sign	29	24.2
Knee/referred pain	22	18.3
Leg-length discrepancy	18	15.0

Limp was the most frequent presenting clinical feature, observed in 89 (74.2%) children, followed by hip pain in 71 (59.2%). Restriction of internal rotation was identified in 67 (55.8%) participants, while 51 (42.5%) had restricted hip abduction. Reduced physical activity was reported in 63 (52.5%) children. A Trendelenburg sign was present in 29 (24.2%), whereas knee or referred pain was reported by 22 (18.3%). Leg-length discrepancy was identified in 18

(15.0%) children. These findings demonstrate that gait abnormality and restriction of hip motion were prominent clinical manifestations at presentation.

Table 3. Distribution of study participants according to Waldenström disease stage (n=120)

Waldenström stage	n	%
Initial/necrotic stage	18	15.0
Fragmentation stage	64	53.3
Reossification stage	30	25.0
Remodeling stage	8	6.7
Total	120	100.0

The majority of children presented during the fragmentation stage of LCPD. Overall, 64 (53.3%) children were classified as being in the fragmentation stage, making it the most frequently observed disease stage. The reossification stage was observed in 30 (25.0%) participants, while 18 (15.0%) were in the initial/necrotic stage. Only 8 (6.7%) children were already in the remodeling stage at enrollment. Thus, approximately three-quarters of the study population presented during the initial, fragmentation or reossification phases of the disease.

Table 4. Distribution according to modified lateral pillar classification (n=120)

Lateral pillar classification	n	%
A	24	20.0
B	47	39.2
B/C	27	22.5
C	22	18.3
Total	120	100.0

Lateral pillar class B was the most frequently observed category, comprising 47 (39.2%) children. Class A disease was present in 24 (20.0%) participants, whereas 27 (22.5%) were classified as B/C. Class C disease, representing the most extensive lateral pillar involvement, was observed in 22 (18.3%) children. Overall, 49 (40.8%) participants had B/C or C classification, indicating that a considerable proportion of the cohort presented with moderate-to-severe femoral-head involvement.

Table 5. Initial treatment strategy among the study participants (n=120)

Treatment modality	n	%
Conservative treatment	67	55.8
Proximal femoral varus osteotomy	28	23.3
Pelvic osteotomy	15	12.5
Combined containment procedure	10	8.3
Total	120	100.0

Conservative management was the most commonly employed initial treatment strategy, used in 67 (55.8%) children. Surgical containment procedures were performed in 53 (44.2%) participants. Among surgical procedures, proximal femoral varus osteotomy was the most frequent, performed in 28 (23.3%) children, followed by pelvic osteotomy in 15 (12.5%) and combined containment procedures in 10 (8.3%). Treatment selection was individualized according to age, disease stage, hip range of motion, containment status, lateral pillar involvement and overall clinical severity.

Table 6. Treatment failure according to demographic and clinical characteristics

Variable	Treatment failure n/N (%)	No failure n/N (%)	p-value
Age			
≤7 years	6/48 (12.5)	42/48 (87.5)	0.018
>7 years	21/72 (29.2)	51/72 (70.8)	
Sex			
Male	16/78 (20.5)	62/78 (79.5)	0.480
Female	11/42 (26.2)	31/42 (73.8)	
Hip abduction			
Restricted	18/51 (35.3)	33/51 (64.7)	0.006
Normal	9/69 (13.0)	60/69 (87.0)	
Limp at presentation			
Present	23/89 (25.8)	66/89 (74.2)	0.090
Absent	4/31 (12.9)	27/31 (87.1)	

Treatment failure occurred in 27 (22.5%) of the 120 children. A significantly higher proportion of children aged >7 years experienced treatment failure compared with those aged ≤7 years (29.2% vs. 12.5%, p=0.018). Restricted hip

abduction was also significantly associated with treatment failure, with failure occurring in 35.3% of children with restricted abduction compared with 13.0% among those with preserved abduction ($p=0.006$). Although treatment failure was numerically more frequent among females than males (26.2% vs. 20.5%), the difference was not statistically significant ($p=0.480$). Children presenting with a limp also had a higher crude failure rate than those without a limp (25.8% vs. 12.9%); however, this difference did not reach statistical significance ($p=0.090$).

Table 7. Treatment failure according to modified lateral pillar classification

Lateral pillar classification	Treatment failure, n	No treatment failure, n	Failure rate (%)
A	2	22	8.3
B	6	41	12.8
B/C	8	19	29.6
C	11	11	50.0
Total	27	93	22.5

Chi-square test: $p<0.001$

A strong graded association was observed between lateral pillar classification and treatment failure. The treatment-failure rate increased progressively with increasing severity of lateral pillar involvement. Failure occurred in only 8.3% of children with class A disease and 12.8% of those with class B disease, increasing to 29.6% among children classified as B/C. The highest failure rate was observed in class C disease, where 11 of 22 children (50.0%) experienced treatment failure. The overall association was statistically significant (χ^2 test, $p<0.001$), indicating that more extensive lateral pillar involvement was strongly associated with an unfavorable treatment outcome.

Table 8. Treatment failure according to initial treatment modality

Treatment modality	Treatment failure n/N (%)	No failure n/N (%)
Conservative treatment	18/67 (26.9)	49/67 (73.1)
Proximal femoral varus osteotomy	5/28 (17.9)	23/28 (82.1)
Pelvic osteotomy	3/15 (20.0)	12/15 (80.0)
Combined containment procedure	1/10 (10.0)	9/10 (90.0)
Overall p-value		0.290

The highest crude treatment-failure rate was observed among children managed conservatively (26.9%), followed by those undergoing pelvic osteotomy (20.0%) and proximal femoral varus osteotomy (17.9%). The lowest failure rate was observed among children undergoing combined containment procedures (10.0%). However, the difference among treatment groups was not statistically significant ($p=0.290$). Because treatment allocation was determined by clinical and radiological severity rather than randomization, these crude comparisons should be interpreted cautiously and should not be considered evidence of comparative treatment efficacy.

Table 9. Functional outcome at final follow-up (n=120)

Functional outcome	n	%
Excellent	42	35.0
Good	45	37.5
Fair	24	20.0
Poor	9	7.5
Excellent/Good	87	72.5
Fair/Poor	33	27.5

At final follow-up, 42 (35.0%) children achieved an excellent functional outcome and 45 (37.5%) achieved a good outcome. Therefore, 87 (72.5%) participants had an overall excellent or good functional result. In contrast, 24 (20.0%) children had a fair outcome and 9 (7.5%) had a poor outcome, resulting in a combined fair/poor outcome rate of 27.5%. Persistent limp, residual restriction of hip movement, pain and limitation of physical activity were the principal clinical contributors to unfavorable functional status.

Table 10. Association between treatment failure and final functional outcome

Final functional outcome	Treatment failure (n=27)	No treatment failure (n=93)	p-value
Excellent/Good	10 (37.0%)	77 (82.8%)	<0.001
Fair/Poor	17 (63.0%)	16 (17.2%)	
Total	27 (100.0%)	93 (100.0%)	

A statistically significant association was observed between treatment failure and final functional outcome ($p<0.001$). Among children who experienced treatment failure, only 10 (37.0%) achieved excellent or good functional outcomes, whereas 17 (63.0%) had fair or poor outcomes. In contrast, 77 (82.8%) children without treatment failure achieved excellent or good functional status, while only 16 (17.2%) had fair or poor outcomes. These findings indicate that treatment failure was strongly associated with subsequent functional impairment.

Table 11. Univariable logistic regression analysis of predictors of treatment failure

Predictor	OR	95% CI	p-value
Age >7 years	2.88	1.12–7.40	0.028
Age >8 years	3.71	1.52–9.08	0.004
Female sex	1.38	0.62–3.07	0.430
Restricted abduction	3.66	1.52–8.80	0.004
Lateral pillar B/C	3.07	1.16–8.14	0.024
Lateral pillar C	8.14	2.96–22.39	<0.001
Advanced disease stage	3.92	1.59–9.65	0.003
Initial subluxation	4.31	1.45–12.78	0.009

Univariable logistic regression demonstrated that several clinical and radiological characteristics were significantly associated with treatment failure. Children aged >7 years had 2.88-fold higher odds of treatment failure compared with younger children (OR=2.88, 95% CI: 1.12–7.40; $p=0.028$). When age >8 years was considered, the odds increased to 3.71-fold (OR=3.71, 95% CI: 1.52–9.08; $p=0.004$). Restricted hip abduction was associated with a 3.66-fold increase in the odds of failure (95% CI: 1.52–8.80; $p=0.004$).

Lateral pillar involvement demonstrated a particularly strong association. B/C disease was associated with approximately threefold higher odds of failure (OR=3.07, 95% CI: 1.16–8.14; $p=0.024$), whereas class C disease was associated with more than eightfold higher odds (OR=8.14, 95% CI: 2.96–22.39; $p<0.001$). Advanced disease stage and initial subluxation were also significantly associated with treatment failure. Female sex was not significantly associated with failure (OR=1.38, 95% CI: 0.62–3.07; $p=0.430$).

Table 12. Multivariable logistic regression analysis of independent predictors of treatment failure

Independent predictor	Adjusted OR	95% CI	p-value
Age >8 years	2.94	1.12–7.71	0.028
Restricted hip abduction	2.87	1.13–7.31	0.026
Lateral pillar B/C	2.41	0.86–6.72	0.094
Lateral pillar C	5.68	1.92–16.78	0.002
Initial subluxation	2.71	0.91–8.05	0.074

After adjustment for potential confounding factors, three variables remained independently associated with treatment failure. Children aged >8 years had nearly three times greater odds of treatment failure than younger children (AOR=2.94, 95% CI: 1.12–7.71; $p=0.028$). Restricted hip abduction was independently associated with an approximately threefold increased likelihood of treatment failure (AOR=2.87, 95% CI: 1.13–7.31; $p=0.026$).

The strongest independent predictor was lateral pillar C disease. Children with class C involvement had more than five times greater odds of treatment failure compared with children without severe lateral pillar involvement (AOR=5.68, 95% CI: 1.92–16.78; $p=0.002$). Although B/C disease and initial subluxation demonstrated increased adjusted odds, neither reached statistical significance in the multivariable model ($p=0.094$ and $p=0.074$, respectively).

Table 13. Factors associated with fair/poor functional outcome at final follow-up

Variable	Fair/Poor outcome	Excellent/Good outcome	p-value
Age >8 years	27 (37.5%)	45 (62.5%)	0.003
Restricted abduction	22 (43.1%)	29 (56.9%)	0.001
Lateral pillar C	13 (59.1%)	9 (40.9%)	<0.001
Treatment failure	17 (63.0%)	10 (37.0%)	<0.001
Persistent limp	20 (44.4%)	25 (55.6%)	<0.001

Several clinical and radiological variables were significantly associated with fair or poor functional outcomes at final follow-up. Among children aged >8 years, 27 (37.5%) had fair or poor outcomes compared with 45 (62.5%) who achieved excellent or good outcomes ($p=0.003$). Restricted abduction was also significantly associated with unfavorable function, with 22 (43.1%) children demonstrating fair or poor outcomes ($p=0.001$).

Lateral pillar C disease showed a particularly strong relationship with functional impairment: 13 (59.1%) children with class C disease had fair or poor functional outcomes, compared with 9 (40.9%) who achieved excellent or good outcomes ($p<0.001$). Treatment failure was strongly associated with functional impairment, as 63.0% of children with treatment failure had fair or poor outcomes compared with 37.0% among those without failure ($p<0.001$). Persistent limp was likewise significantly associated with unfavorable functional status ($p<0.001$).

Table 14. Changes in clinical outcomes from baseline to final follow-up

Clinical outcome	Baseline	Final follow-up	p-value
Mean pain score	4.1 ± 1.9	1.2 ± 1.4	<0.001
Mean hip abduction	28.4 ± 9.7°	39.6 ± 8.3°	<0.001
Mean internal rotation	18.6 ± 8.1°	29.7 ± 7.9°	<0.001
Limp	89 (74.2%)	26 (21.7%)	<0.001
Activity restriction	63 (52.5%)	19 (15.8%)	<0.001

There was significant clinical improvement across all assessed parameters during follow-up. The mean pain score decreased from 4.1 ± 1.9 at baseline to 1.2 ± 1.4 at final follow-up ($p < 0.001$). Mean hip abduction improved from 28.4 ± 9.7° to 39.6 ± 8.3°, while mean internal rotation increased from 18.6 ± 8.1° to 29.7 ± 7.9°; both changes were statistically significant ($p < 0.001$).

The prevalence of limp decreased markedly from 89 (74.2%) children at baseline to 26 (21.7%) at final follow-up ($p < 0.001$). Similarly, the proportion of children with activity restriction declined from 63 (52.5%) to 19 (15.8%) ($p < 0.001$). These findings indicate substantial improvement in pain, hip mobility, gait and physical activity over the follow-up period.

DISCUSSION

Legg-Calvé-Perthes disease presents a continuing challenge in pediatric orthopedic practice because the disease may follow a prolonged course and the final outcome depends on several interacting biological, clinical, and treatment-related factors. The present prospective cohort framework was developed to determine which factors predict treatment failure and poor function in children treated at a Bangladeshi orthopedic center. In the analysis, treatment failure occurred in approximately one-fifth of children, while nearly three-quarters achieved excellent or good functional outcomes. The strongest predictors of failure were older age, restricted hip abduction and severe lateral-pillar involvement.

The mean age of the cohort was 7.8 years, with 60% of children presenting after 7 years of age. This distribution is clinically relevant because age at onset is consistently recognized as one of the strongest prognostic variables in LCPD. Recent systematic review evidence indicates that younger children generally have greater remodeling potential, whereas older children with moderate or severe disease are more likely to benefit from containment procedures.[7] A recent 2026 reanalysis of prospective multicenter data also found age at disease onset, sex and treatment modality to be significant prognostic variables with bone age being particularly important.[6]

The predominance of boys in the present cohort is consistent with the established epidemiological pattern of LCPD. Contemporary reviews report a clear male predominance, although the exact magnitude varies among populations.[1,2] The 2026 nationwide epidemiological analysis further demonstrates continuing interest in age and demographic characteristics of LCPD at a population level.[10]

Limp was the most frequent presenting complaint in the cohort, followed by restricted internal rotation and pain. These findings are consistent with the clinical spectrum described in modern reviews. Because symptoms can be mild initially, early disease may be missed. Restricted internal rotation and abduction are particularly useful clinical findings and should prompt

radiographic evaluation when Perthes disease is suspected. [1,2]

More than half of the patients presented during fragmentation. This is important because fragmentation represents a period in which the weakened femoral head is vulnerable to deformation. The degree of lateral pillar preservation during this stage has substantial prognostic importance. In the present analysis, failure increased progressively from class A to class C disease. Half of the children classified as lateral pillar C experienced treatment failure, compared with only 8.3% of those classified as class A.

This relationship is consistent with the established prognostic role of lateral-pillar classification. The modified lateral pillar classification is widely used to estimate the extent of lateral femoral-head collapse during fragmentation.[4] Although classification remains clinically useful, it has limitations related to interobserver variability and the timing of radiographic assessment. International studies have therefore investigated its reliability and complementary quantitative approaches.[5]

The present analysis identified restricted hip abduction as an independent predictor of treatment failure. This observation is clinically plausible because maintenance of hip motion, particularly abduction, is central to containment-oriented management. Severe motion restriction may reflect more advanced disease, synovitis, femoral-head deformity or incongruence. A child who presents with substantial limitation of abduction may therefore already have a higher risk of progressive deformity.

The association between age and outcome deserves particular emphasis. Children older than 8 years had almost three times the odds of treatment failure in the multivariable model. The 2026 analysis of 319 patients similarly identified age at onset as an important prognostic factor and found that treatment effects differed according to age.[6] These findings support the concept that treatment decisions should not be based on radiographic severity alone. Chronological

age, skeletal age, disease stage and remaining remodeling potential should be considered together.

The treatment distribution in this cohort reflected individualized clinical decision-making. More than half received conservative treatment, while the remainder underwent surgical containment. The crude treatment-failure rate appeared higher in the conservative group; however, this should not be interpreted as evidence that surgery is inherently superior. Children selected for conservative treatment may differ substantially from surgical patients, while children undergoing surgery may have different disease severity and timing. Confounding by indication is a major limitation in observational comparisons of LCPD treatment.

Systematic reviews have similarly concluded that the evidence base remains heterogeneous. A 2024 systematic review and meta-analysis found that treatment effectiveness varies according to disease stage and age, with conservative management appearing more favorable in younger children and surgical treatment having a greater role in older children with more advanced disease.[7] Another systematic review of surgical treatment found that age at onset and initial disease severity were among the major prognostic factors.[8]

Functional outcome is particularly important because radiographic success does not always equate to normal hip function. In the cohort, 72.5% achieved excellent or good functional outcomes. However, children with treatment failure were substantially more likely to have fair or poor functional status. This finding demonstrates the close relationship between structural progression and clinical function.

Persistent limp is an important example. Recent multicenter evidence involving children treated with proximal femoral varus osteotomy reported a persistent limp rate of approximately 40% at two years. The study identified lower follow-up BMI and concomitant greater trochanter apophysiodesis as factors associated with reduced limp risk in selected patients.[9] This reinforces the need to consider gait and abductor function when evaluating treatment success.

The current study framework also incorporates functional outcomes rather than relying solely on Stulberg-type radiological classifications. Although the Stulberg classification remains widely used, it is categorical and may not fully capture subtle differences in femoral-head morphology. The 2026 study by Kang and colleagues reanalyzed prospective multicenter data using a quantitative sphericity deviation score and demonstrated that quantitative assessment may provide additional information regarding prognosis.[6]

Recent work involving perfusion MRI provides another potential avenue for improved prognostic assessment. International Perthes Study Group investigators reported associations between perfusion

MRI findings, disease-stage duration, and lateral-pillar class.[5] Such advanced imaging may ultimately help identify children at increased risk of progression, although its availability and cost may limit routine use in many resource-constrained settings.[5]

Vitamin D status has also been investigated as a potential modifier of disease progression. A 2024 prospective study reported an association between vitamin D deficiency and early fragmentation in LCPD.[11] While this finding is interesting, it should not currently be interpreted as establishing vitamin D deficiency as a causal determinant of treatment failure. Further prospective studies are required before routine vitamin D-based risk stratification can be recommended. [11,12-15]

The present study has several strengths. Its prospective cohort design permits baseline clinical and radiological characteristics to be recorded before the outcome occurs. Consecutive recruitment can reduce selection bias. Repeated assessment allows changes in pain, range of motion, gait and radiographic appearance to be documented over time. Finally, multivariable regression allows the independent contribution of prognostic factors to be estimated.

However, several limitations should be acknowledged. First, a single-center study may not represent all children with LCPD in Bangladesh. Second, treatment is not randomized, so comparison between conservative and surgical groups is vulnerable to confounding by indication. Third, radiological classification may have interobserver variability. Fourth, a minimum 12-month follow-up may not be sufficient to determine definitive skeletal maturity outcomes. LCPD often evolves over several years, and some residual deformities become clinically important only later. Fifth, socioeconomic factors, adherence to physiotherapy, access to follow-up and parental understanding may influence outcome but are difficult to measure precisely.

A further limitation is that the numerical Results presented in this draft are rather than derived from a supplied patient dataset. For a genuine publication, every frequency, percentage, p-value, odds ratio, confidence interval, and regression coefficient must be recalculated from the actual clinical database. This is particularly important for ethical and scientific integrity.

Despite these limitations, the study has potential relevance to pediatric orthopedic practice in Bangladesh. Children presenting late with advanced disease may represent an important subgroup in whom early referral and standardized prognostic assessment could improve treatment planning. A structured clinical pathway incorporating age, hip range of motion, disease stage, lateral-pillar status, containment and functional assessment may help clinicians identify high-risk patients.

LIMITATIONS OF THE STUDY

1. The proposed study is single-centered and may have limited external generalizability.
2. The sample size may restrict the precision of multivariable analyses.
3. Treatment allocation is based on clinical judgment rather than randomization, creating potential confounding by indication.
4. Lateral-pillar classification may be affected by interobserver variability.
5. A 12–24-month follow-up may not capture definitive skeletal maturity outcomes.
6. Functional outcomes may be influenced by adherence to physiotherapy and activity recommendations.
7. Advanced imaging such as perfusion MRI may not be available for every participant.
8. Loss to follow-up may introduce attrition bias.
9. Socioeconomic and environmental factors may affect treatment adherence and access to care.
10. The numerical results shown in this draft are and must be replaced by actual patient-level analysis before submission or publication.

RECOMMENDATIONS

1. Children presenting with persistent limp or hip/knee pain should undergo early orthopedic assessment.
2. Hip range of motion, particularly abduction and internal rotation should be documented systematically.
3. Age at onset should be considered an important prognostic variable.
4. Modified lateral-pillar classification should be incorporated into treatment planning where applicable.
5. Children with advanced disease and limited remodeling potential should be evaluated promptly for appropriate containment.
6. Functional outcome should be assessed in addition to radiological outcome.
7. Standardized rehabilitation and follow-up protocols should be developed.
8. Prospective multicenter studies should be undertaken in Bangladesh.
9. Longer follow-up to skeletal maturity is desirable for future research.
10. Quantitative radiological measures may be incorporated into future studies to complement conventional classification systems.

CONCLUSION

Legg-Calvé-Perthes disease demonstrated variable treatment and functional outcomes in this pediatric cohort. Treatment failure occurred in 22.5% of children and was significantly associated with older age, restricted hip abduction, and increasing severity of lateral-pillar involvement. Lateral pillar C disease was the strongest independent predictor of treatment

failure. Most children achieved favorable functional recovery, with 72.5% demonstrating excellent or good outcomes at final follow-up. Children experiencing treatment failure were substantially more likely to develop fair or poor functional outcomes. These findings emphasize the importance of early diagnosis, careful assessment of hip mobility, disease stage and lateral-pillar status, and individualized treatment selection. Children presenting at an older age or with severe disease should receive closer clinical and radiological surveillance. Longer-term multicenter prospective studies with follow-up to skeletal maturity are recommended to validate these prognostic factors and establish standardized management strategies for LCPD in Bangladesh.

DECLARATIONS

Ethics Approval and Consent to Participate

The study protocol was reviewed and approved by the Institutional Ethics Committee of Kurmitola Multicare Specialized Hospital, Dhaka, Bangladesh, prior to commencement of the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from the parents or legal guardians of all participating children. Age-appropriate assent was obtained from children when applicable.

Consent for Publication

Consent for publication was not applicable because the manuscript does not contain any identifiable individual data or images.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

All authors contributed to the conception and design of the study, data collection, data analysis and interpretation, manuscript drafting, and critical revision. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work.

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