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ORIGINAL ARTICLE

Comparative Gait Analysis: Lower Limb Angle Parameters in Pre- and Post-Operative Developmental Dysplasia of the Hip

SHEHLA KHATOON[1], SIKANDAR HAYAT[2], FARAH DEEBA[3], RONAQ ZAMAN[4]
[1]*Assistant Professor, Department of Anatomy, Khyber Medical College, Peshawar*
[2]*Department of Orthopaedic, Khyber Teacher Hospital, Peshawar*
[3]*Department of Anatomy, Northwest School of Medicine, Peshawar*
[4]*Department of Pathology, Kabir Medical College, Peshawar*
Correspondence to: Dr. Sikandar Hayat, Email: Drsikandar68@gmail.com

ABSTRACT

Background: Developmental dysplasia of the hip (DDH) is a frequent cause of abnormal gait in children, particularly in regions where neonatal screening programs are limited. Although radiological correction of hip alignment can be achieved surgically, functional gait recovery depends on restoration of lower limb and trunk biomechanics. Objective evaluation of angle parameters during gait provides valuable insight into postoperative functional improvement.

Objective: To evaluate changes in trunk tilt, pelvic drop, knee valgus, and hip adduction angle parameters in children with DDH before and after surgical correction using instrumented gait analysis.

Methodology: This prospective observational study was conducted from March 2018 to March 2019 at Khyber Teaching Hospital and the Pakistan Institute of Prosthetics and Orthotics (PIPOS) gait laboratory, Peshawar. Twenty children aged 4–8 years with neglected DDH (Tönnis grades II–IV) were included. Two-dimensional gait analysis was performed preoperatively and three months postoperatively. Angle parameters were quantified using motion capture software. Pre- and postoperative values were compared using paired statistical analysis.

Results: Significant postoperative improvements were observed in all measured parameters. Trunk tilt improved from 4.6° ± 4.5° to 6.5° ± 2.4° (p = 0.021), pelvic drop decreased from 13.7° ± 24.5° to 8.29° ± 4.89° (p = 0.008), hip adduction improved from 9.4° ± 6.1° to 11.9° ± 5.54° (p = 0.014), and knee valgus significantly decreased from 26.6° ± 62.3° to 8.94° ± 6.9° (p = 0.003). Improvements in hip and knee parameters correlated strongly with normalization of trunk and pelvic alignment.

Conclusion: Lower limb and trunk angle parameters provide objective indicators of functional gait recovery following DDH surgery. Surgical realignment significantly improves biomechanical gait efficiency, emphasizing the value of integrating gait analysis and structured physiotherapy in postoperative management.

Keywords: Developmental dysplasia of the hip; Gait analysis; Trunk tilt; Pelvic drop; Knee valgus; Hip adduction.

INTRODUCTION

Developmental dysplasia of the hip (DDH) comprises a spectrum of structural hip abnormalities ranging from acetabular dysplasia to complete dislocation of the femoral head. The condition remains a major cause of gait abnormality and long-term musculoskeletal morbidity in children, particularly in regions where routine neonatal screening is limited. Delayed diagnosis frequently results in abnormal gait patterns, increased energy expenditure during ambulation, and a higher risk of degenerative joint disease in adulthood (1-4).

Anatomically, DDH is characterized by insufficient acetabular coverage and malalignment of the femoral head, leading to joint instability and altered biomechanics. These structural abnormalities disrupt the hip abductor mechanism, resulting in compensatory trunk lean, contralateral pelvic drop, and abnormal frontal plane lower limb alignment such as increased knee valgus and altered hip adduction. Over time, these compensatory mechanisms contribute to inefficient gait and may predispose affected children to secondary musculoskeletal deformities (5-7).

Surgical correction aims to restore concentric reduction of the hip and normalize joint morphology. While radiographic evaluation confirms anatomical realignment, it does not fully reflect functional gait recovery. Objective gait analysis allows quantitative assessment of dynamic biomechanical parameters and provides a more comprehensive evaluation of postoperative functional outcomes (8-10).

This study was therefore designed to assess changes in lower limb and trunk angle parameters in children undergoing surgical correction for neglected DDH and to determine their relationship with functional gait recovery using instrumented gait analysis.

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted to evaluate functional gait changes in children with developmental dysplasia of the hip (DDH) before and after surgical correction. The study was carried out at the Department of Anatomy, Khyber Medical College, in collaboration with the Department of Orthopedic Surgery, Khyber Teaching Hospital (KTH), Peshawar. Instrumented gait analysis was performed at the Pakistan Institute of Prosthetics and Orthotics (PIPOS) Gait Laboratory, Hayatabad, in academic collaboration with Khyber Medical University (KMU). The study was conducted over a period of one year from March 2018 to March 2019.

Study Population and Sampling: A total of twenty children diagnosed with neglected DDH were enrolled using a non-probability purposive sampling technique. Children aged between 4 and 8 years with radiologically confirmed DDH (Tönnis grades II–IV) were included. Patients with syndromic dysplasia, neuromuscular disorders, congenital limb deformities, or previous surgical intervention for hip pathology were excluded to avoid confounding gait abnormalities.

Ethical Considerations: Ethical approval was obtained from the Graduate Studies Committee and the Advanced Studies and Research Board, Khyber Medical University (Notification No. DIR/KMU-ASRB/AC/000534), as well as the Ethical Review Committee of Khyber Medical College. Written informed consent was obtained from parents or legal guardians prior to enrollment. All procedures were conducted in accordance with the Declaration of Helsinki.

Clinical and Radiological Assessment: A standardized clinical evaluation was performed for each participant, including detailed history taking and physical examination. Hip joint range of motion (ROM) was measured using a standard universal goniometer. Limb length discrepancy was assessed using the Galeazzi test. Visual gait analysis was performed in the outpatient department to identify frontal and sagittal plane deviations, with specific attention to Trendelenburg gait patterns.

Radiological evaluation included anteroposterior and lateral radiographs of the pelvis and hip joints. Hip displacement and acetabular morphology were assessed using Hilgenreiner's line, Perkins' line, and Shenton's line. DDH severity was classified according to the Tönnis grading system, which guided surgical planning.

Instrumented Gait Analysis Protocol: Two-dimensional gait analysis was performed preoperatively and repeated three months

postoperatively. Active reflective markers were placed on standardized anatomical landmarks, including the lateral malleolus, lateral femoral epicondyle, greater trochanter, anterior superior iliac spine, posterior superior iliac spine, and mid-trunk region. Children were instructed to walk barefoot at a self-selected comfortable speed along a 10-meter walkway.

High-resolution digital cameras were positioned perpendicular to the walkway to capture frontal and sagittal plane movements. Gait cycles were recorded, and motion data were processed using Simi Aktisys motion analysis software. Angle parameters evaluated included trunk tilt, pelvic tilt, knee valgus/varus, and hip adduction/abduction across both stance and swing phases of gait. For each parameter, three gait cycles were recorded and averaged to improve measurement reliability.

Surgical Intervention and Postoperative Rehabilitation: Surgical procedures were individualized based on the clinical and radiological severity of DDH and included combinations of open reduction, femoral shortening osteotomy, and pelvic osteotomy. All surgeries were performed by experienced pediatric orthopedic surgeons. Postoperatively, patients were immobilized in a hip spica cast for six to eight weeks.

After cast removal, patients underwent structured physiotherapy protocols focusing on restoration of hip mobility, strengthening of periarticular muscles, correction of compensatory gait patterns, and progressive gait training. Postoperative gait analysis was performed three months after surgery to assess functional recovery.

Outcome Measures: The primary outcome measures were changes in trunk tilt, pelvic tilt, knee valgus/varus, and hip adduction/abduction angles between preoperative and postoperative gait assessments. Secondary outcomes included correlation of angle normalization with improvement in gait smoothness and reduction of compensatory movements.

Statistical Analysis: Data were analyzed using SPSS version 23. Continuous variables were expressed as mean ± standard deviation. Pre- and postoperative angle parameters were compared using paired t-tests. Pearson correlation analysis was applied to determine associations between improvements in different angle parameters. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study included twenty children with neglected developmental dysplasia of the hip, with a mean age of 6.0 ± 1.4 years. Female patients constituted 85% (n=17) of the cohort. Preoperative gait analysis demonstrated marked deviations in frontal plane lower limb and trunk alignment.

Comparison of Pre- and Postoperative Angle Parameters: There was a statistically significant improvement in all evaluated angle parameters following surgical correction (Table 1). Mean trunk tilt increased toward physiological alignment from 4.6° ± 4.5° preoperatively to 6.5° ± 2.4° postoperatively ($p = 0.021$). Contralateral pelvic drop showed a significant reduction from 13.7° ± 24.5° to 8.29° ± 4.89° ($p = 0.008$). Hip adduction significantly improved from 9.4° ± 6.1° to 11.9° ± 5.54° ($p = 0.014$). Knee valgus demonstrated the most prominent correction, decreasing from 26.6° ± 62.3° to 8.94° ± 6.9° ($p = 0.003$). These findings confirm restoration of frontal plane biomechanical alignment after surgical intervention.

Relationship Between Angle Normalization and Gait Recovery: Correlation analysis revealed a strong positive association between improvement in hip adduction and reduction in knee valgus ($r = 0.71$, $p = 0.002$). Additionally, normalization of pelvic tilt was significantly correlated with reduction in trunk tilt ($r = 0.64$, $p = 0.005$), indicating synchronized recovery of pelvic–trunk control. Patients with greater preoperative deviations exhibited significantly larger postoperative improvements ($p = 0.009$), supporting the responsiveness of severe deformities to corrective surgery.

Table 1: Comparison of Pre- and Postoperative Lower Limb Angle Parameters (n = 20)

Parameter	Preoperative Mean ± SD	Postoperative Mean ± SD	p-value
Trunk Tilt (°)	4.6 ± 4.5	6.5 ± 2.4	0.021
Pelvic Drop (°)	13.7 ± 24.5	8.29 ± 4.89	0.008
Hip Adduction (°)	9.4 ± 6.1	11.9 ± 5.54	0.014
Knee Valgus (°)	26.6 ± 62.3	8.94 ± 6.9	0.003

The maximum preoperative deviations in trunk, pelvis, and knee alignment among individual patients are summarized in Table 2. Considerable inter-individual variability was observed, with knee valgus reaching up to 28.35° and pelvic tilt exceeding 14° in severely affected children.

Table 2: Maximum Preoperative Angle Parameters

Patient	Trunk (°)	Pelvis (°)	Knee Valgus (°)
P1	1.86	-2.05	13.17
P2	4.58	14.09	-4.66
P3	8.56	10.12	12.88
P4	-6.75	-1.13	4.53
P5	-5.39	-7.03	10.10
P6	1.69	-0.09	-11.80
P7	1.84	-0.40	28.35
P8	5.26	-2.58	-1.49

Table 3 presents the minimum angle values observed among patients, highlighting substantial negative pelvic and trunk tilts reflective of severe biomechanical imbalance.

Table 3: Minimum Preoperative Angle Parameters

Patient	Trunk (°)	Pelvis (°)	Knee Valgus (°)
P1	-8.09	-7.63	6.26
P2	-2.78	8.91	-8.32
P3	2.47	6.89	2.88
P4	-1.60	-1.62	-10.40
P5	-10.40	-7.88	0.68
P6	-7.48	-13.70	-16.33
P7	-8.66	9.98	16.19
P8	-0.93	-6.57	-14.69

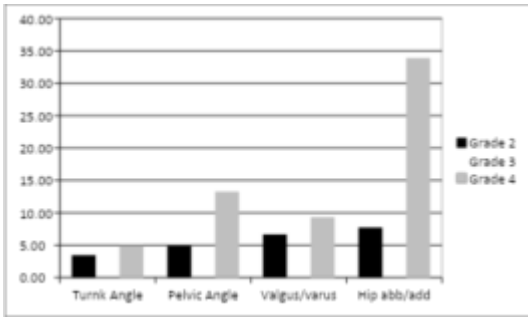

Figure 1: Comparison of pre- and postoperative trunk tilt and pelvic angle parameters in children with DDH.

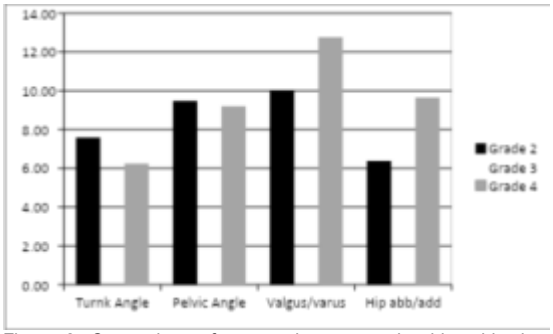

Figure 2: Comparison of pre- and postoperative hip adduction and knee valgus angles showing significant postoperative correction.

DISCUSSION

The present study demonstrates that surgical correction of neglected developmental dysplasia of the hip (DDH) produces significant normalization of lower limb and trunk angle parameters, reflecting meaningful functional gait recovery. Preoperative gait analysis revealed pronounced deviations in trunk tilt, pelvic drop, knee valgus, and hip adduction, highlighting the extensive biomechanical compensations adopted by children to maintain postural stability in the presence of hip instability (10-12).

The most notable postoperative improvement was observed in knee valgus alignment, which showed a significant reduction. Excessive knee valgus in DDH is considered a secondary compensatory mechanism arising from altered hip joint biomechanics and abductor muscle insufficiency. Restoration of hip joint congruency through surgical realignment appears to re-establish abductor muscle efficiency, thereby reducing pathological knee valgus and improving overall lower limb alignment. These findings are consistent with previously reported observations that hip-centered deformities propagate distal biomechanical malalignments in the growing skeleton (13-15).

Improvement in pelvic and trunk tilt parameters further confirms restoration of proximal stability. Preoperative contralateral pelvic drop and increased trunk lean are hallmark features of Trendelenburg gait, reflecting weakness of the hip abductor mechanism. Following surgical correction, the significant reduction in these parameters indicates re-establishment of effective pelvic stabilization during stance phase. The strong correlation between pelvic tilt normalization and trunk alignment underscores the coordinated recovery of the lumbopelvic control system (16-18).

Hip adduction also demonstrated significant postoperative improvement, reflecting restoration of frontal plane hip stability. Abnormal hip adduction contributes to joint overload, abnormal cartilage stress, and long-term degenerative changes. Correction of this parameter suggests that surgical realignment not only improves gait mechanics but may also reduce the risk of future degenerative sequelae (19, 20).

Importantly, children with more severe preoperative deviations exhibited greater postoperative improvements, highlighting the responsiveness of gait biomechanics to corrective surgery even in neglected cases. These findings support the role of objective gait analysis as a sensitive functional outcome measure, complementing conventional radiological assessment, which alone does not fully capture dynamic biomechanical recovery.

Despite the strengths of this study, limitations include the relatively small sample size and the short-term postoperative follow-up. Longer longitudinal studies incorporating three-dimensional gait analysis and muscle activity profiling are recommended to further elucidate long-term functional outcomes.

CONCLUSION

Lower limb angle parameters, including trunk tilt, pelvic drop, knee valgus, and hip adduction, serve as sensitive indicators of functional gait recovery in children undergoing surgical correction for developmental dysplasia of the hip. Surgical realignment significantly normalizes these parameters, leading to improved biomechanical efficiency and reduced compensatory movements during gait. Integration of objective gait analysis with structured postoperative physiotherapy is essential for optimizing functional outcomes and should be incorporated into routine follow-up protocols. Future research with extended follow-up is warranted to evaluate long-term biomechanical adaptations and joint preservation.

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