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Gait Analysis in Low Lumbar Myelomeningocele Patients With Unilateral Hip Dislocation or Subluxation

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Summary: The surgical indications for the treatment of unilateral hip dislocations or subluxations in patients with low lumbar myelomeningocele remain highly debatable. This study examines the influence of unilateral hip dislocation or subluxation on the gait of these patients using three-dimensional gait analysis. Twenty patients with a diagnosis of low lumbar myelomeningocele underwent three-dimensional gait analysis. All patients were community ambulators with solid ankle-foot orthoses and crutches who presented with unilateral hip dislocation or subluxation and no scoliosis. The patients were divided in two groups. Group 1 comprised 10 patients who demonstrated either no evidence of hip flexion or adduction contractures or symmetric hip contractures. Group 2 comprised 10 patients with unilateral hip flexion and/or adduction contractures. Pelvic and hip kinematics were assessed to determine the symmetry of motion between the involved and the noninvolved side during walking. Seven patients from group 1 walked with a symmetric gait pattern; only two patients from group 2 walked with a symmetric pattern. Gait symmetry corresponded to the absence of hip contractures or bilateral symmetrical hip contractures and had no relation to the presence of hip dislocation. The authors concluded that reduction of the hip is unnecessary. **Key Words:** Gait—Hip dislocation—Myelomeningocele.

In myelomeningocele, the level of the lesion generally correlates with the magnitude of neurologic impairment. Patients can be classified according to their neurologic level as thoracic/high lumbar, low lumbar, and sacral levels (29). Low lumbar level patients typically show quadriceps and medial hamstring strength but no functional gluteal, ankle plantar flexor, or ankle dorsiflexor strength. For walking they require ankle-foot orthosis (AFO) braces and crutches. The neurologic level is the most important factor in determining ambulatory ability (1,2,14,15,17,27,29,32,33,36). In our experience, 80% of children with low lumbar lesions should retain community ambulator status, as classified by Hoffer et al. (17), during adult life. Other factors that affect walking ability and the quality of gait are tethered cord, shunt malfunction, and deformities of the lower extremities and spine (8).

Nearly half of the children with myelomeningocele show some degree of hip instability during the first 10 years of life (23,24). Muscle imbalance between the hip flexors and extensors and hip abductors and adductors accounts for this tendency (18). Previous authors have espoused differing views regarding the correlation between hip dislocation and subluxation and the decrease or loss of walking ability in patients with myelomeningocele. Some studies failed to demonstrate a relationship between the hip status and ambulatory ability (3,7,9,12, 13,24,30–33); therefore, the authors concluded these patients would not benefit from surgical relocation of the hip. However, others have supported surgical relocation of the hip, particularly unilateral cases, to improve the ambulatory level for these patients and to avoid possible development of leg length discrepancy, pelvic obliquity, and scoliosis (2,4,8,16,19,21,22,25,28,35,36). None of these studies based their conclusions on objective measures such as those provided by three-dimensional gait analysis. Surgical relocation of the hip for these patients remains controversial, because the benefits of relocation have not been clearly substantiated and the incidence of postsurgical complications around the hip, such as stiffness, pathologic fractures, and failure to keep the hip reduced, is high (10,13).

Gait analysis in myelomeningocele has primarily focused on the description of gait patterns (11,34,35) and the effectiveness of orthoses. More recently, some authors have demonstrated clinical applications of gait analysis in the treatment of musculoskeletal deformities such as external tibial torsion (20).

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TABLE 1. *Radiological, physical examination, and gait information with specific asymmetrical gait parameters in group 1*

Patient	% Migration index	Contractures	Leg length discrepancy (cm)	Gait (asymmetries)
1	38.7	None	0	S
2	88.3	None	0	S
*3	58.3	None	0.9	S
4	100	None	2	S
*5	66.6	Moderate flexion	0.5	S
6	48.5	Mild flexion	0	S
*7	41.3	Moderate flexion	1	S
*8	62.5	Mild flexion Moderate adduction	2.7	A (PO)
†9	62	Mild flexion Moderate adduction	5.2	A (PO,HA)
10	58.9	Severe flexion Moderate adduction	0	A (HA)
Mean	62.60		1.2	

* Patients showing instability (telescoping) of the affected hip on physical examination.

† Patient uses a 3-cm shoe lift

PO, pelvic tilt; PO, pelvic obliquity; PR, pelvic rotation; HF, hip flexion; HA, hip abduction/adduction.

The purpose of this study was to determine the influence of unilateral hip instability on the gait pattern in patients with low lumbar myelomeningocele. The premise that unilateral hip subluxation/dislocation affects the gait pattern will be investigated by assessing the gait pattern of patients with this deformity and then further elucidated by comparing those with symmetric hip contractures to those with asymmetric contractures.

MATERIALS AND METHODS

Twenty patients with low lumbar myelomeningocele and unilateral hip subluxation or dislocation were eligible for inclusion. There were 13 girls and 7 boys ranging in age from 5 to 18 years (mean 10.2). All patients were community ambulators, as described by Hoffer et al. (17), and walked with bilateral solid AFOs and crutches. All patients presented with unilateral hip dislocation or subluxation as determined by the percentage of migration of Reimers (26). We considered hip subluxation to occur when the migration percentage exceeded 33%. None of the patients showed scoliosis greater than 20° or neurologic complications related to the myelomeningocele at the time of the gait analysis, and none had undergone previous bone surgeries at the hip before this study.

Patients were divided in two groups according to the nature of hip contractures. Group 1 (Table 1) included 10 patients either with no hip contractures or with symmetric flexion or adduction contractures. Hip flexion contractures were considered severe when greater than 30°, moderate when 20° to 30°, and mild when less than 20°. Hip adduction contractures were classified as severe for abduction range of motion of less than 10°, moderate between 10° and 30°, and mild for greater than 30°. The mean age for group 1 was 9.8 years (range 5–15). Group 1 comprised eight girls and two boys. In group 2, there were 10 patients with unilateral hip flexion or adduction contractures (Table 2). Mean age was 10.5 years (range 7–18). There were five boys and five girls. Eight patients showed hip instability on the right. Two patients had a leg length discrepancy greater than 3 cm and wore a shoe lift at the time of the gait analysis.

All patients underwent a lower extremity manual muscle test and physical examination before the gait analysis. After the clinical examination the patients were assessed using a three-dimensional motion measurement system (Vicon Motion Systems, Oxford Metric, Tustin, CA, U.S.A.). Retro-reflective markers were applied to anatomic landmarks and the patients were instructed to ambulate at a self-selected pace through the data collection area. Three-dimensional lower extremity joint motion was calculated from the conventional marker protocol. At least three walking trials were performed to assess intrasubject variability. A representative walking trial for each patient was selected for subsequent data analysis. Complete kinematic, kinetic, and electromyographic data were collected, but for this study only the kinematic data were used. Specifically, pelvic obliquity, pelvic tilt, pelvic rotation, hip rotation, hip abduction/adduction, and hip flexion/extension were classified as symmetric or asymmetric. The kinematic parameter was categorized as asymmetric when discrepancies of greater than 10° between the unstable hip and the stable side occurred for more than 50% of the gait cycle. The temporal gait parameters of velocity, cadence, and stride length were also examined using analysis of variance (ANOVA) procedures.

RESULTS

In group 1, 7 of the 10 patients walked symmetrically based on the criteria of less than 10° difference between the subluxed/dislocated hip and the contralateral side

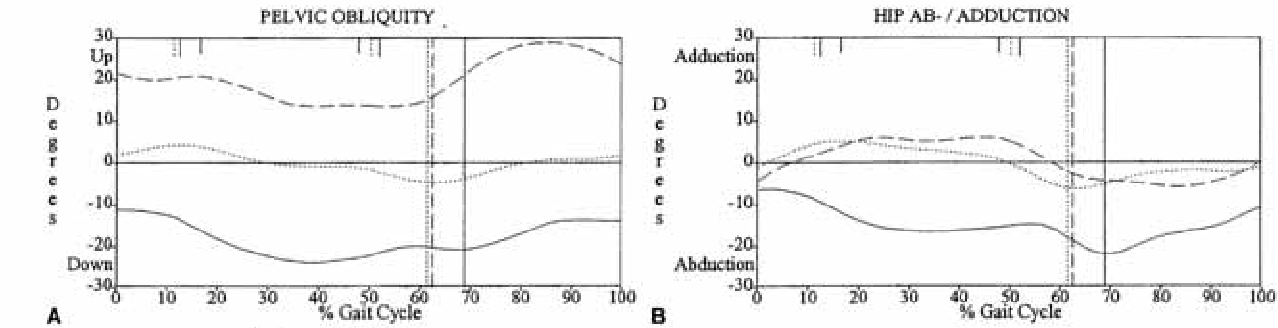
TABLE 2. *Radiological, physical examination, and gait information with specific asymmetrical gait parameters in group 2*

Patient	% Migration index	Contractures	Leg length discrepancy (cm)	Gait (asymmetries)
*11	100.0	Mild flex left	0.4	A (PR,HF,HA)
12	65.0	Moderate flex right	0.5	A (HF,HA)
*13	57.1	Moderate flex right	0.8	A (PO,PR,HA)
14	63.6	Moderate adduc right	1.5	S
*15	34.6	Moderate adduc left	2.0	S
†16	100.0	Severe adduc right	6.7	A (HA)
*17	36.3	Moderate flex bilat Moderate adduc right	0.0	A (HA)
18	50.0	Moderate flex right Moderate adduc right	1.1	A (PT,HA)
19	50.0	Moderate flex right Moderate adduc right	1.8	A (PO,PR,HA)
20	72.9	Moderate flex right Severe flex left Severe adduc right Moderate adduc left	0.8	A (HA)
Mean	63.0		1.6	

* Patients showing instability of the affected hip on physical examination.

† Patient uses a 3-cm shoe lift.

PO, pelvic tilt; PO, pelvic obliquity; PR, pelvic rotation; HF, hip flexion; HA, hip abduction/adduction.



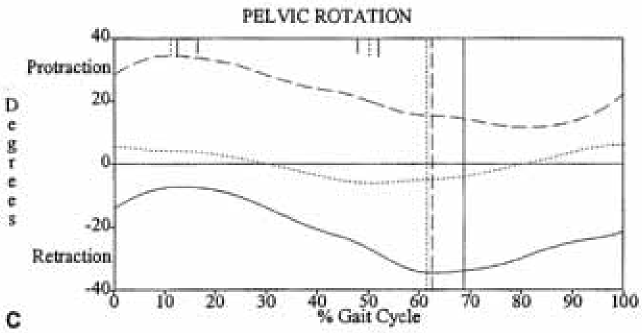
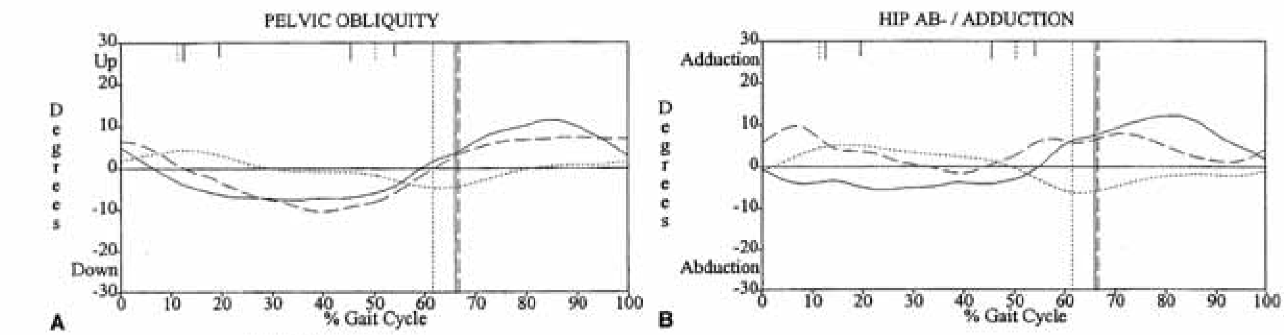


FIG. 1. A. Asymmetric pelvic obliquity. Note the extreme asymmetry in pelvic obliquity with the elevated, subluxed right side (*dashed line*) and the lowered, reduced left side (*solid line*) compared with the normal pattern (*dotted line*). **B.** Asymmetric hip abduction/adduction. Note the asymmetry in the coronal plane hip motion with the adducted, subluxed right side (*dashed line*) and the abducted, reduced left side (*solid line*) compared with the normal pattern (*dotted line*). **C.** Asymmetric pelvic rotation. Note the extreme asymmetry in pelvic rotation with the protracted, reduced left side (*solid line*) compared with the normal pattern (*dotted line*).

(Fig. 1). Four of these seven patients presented with no hip flexion or adduction contractures, and three had symmetric contractures. Three patients showed pelvic or hip kinematic differentials between the sides and were judged as asymmetric. All three patients had flexion or adduction symmetric hip contractures (Table 1). The asymmetric parameters were confined to pelvic obliquity or hip abduction/adduction.

In group 2, two patients demonstrated a symmetric gait based on the pelvic and hip kinematic data. Both of these patients had a moderate adduction contracture on the affected side. The other eight patients were judged as having an asymmetric gait (Fig. 2). Hip abduction/adduction most frequently differed between the sides with a severe or moderate adduction contracture present on the affected side (Table 2).

Analysis of the frequency of an asymmetric gait using a 2 × 2 table yielded a chi-square value of 5.05, which exceeds the critical level of significance at a 95% confidence level for this one degree of freedom analysis. There was an association between asymmetric passive range of motion and an asymmetric gait pattern (Table 3). There was no significant difference in stride length, cadence, walking velocity, or leg length discrepancy be-



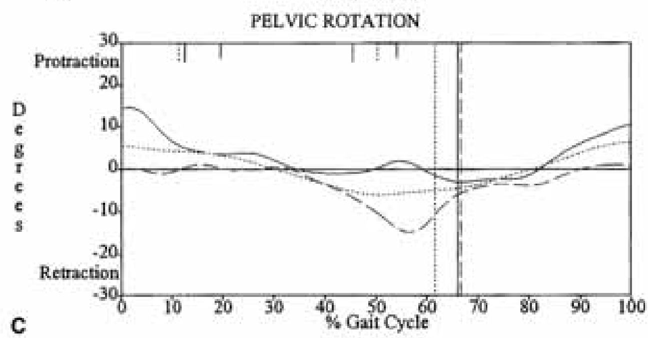


FIG. 2. A. Symmetric pelvic obliquity. Note the symmetric dynamic motion of the subluxed right side (*dashed line*) and the reduced left side (*solid line*) compared with the normal pattern (*dotted line*). **B.** Symmetric hip abduction/adduction. Note the symmetric dynamic motion of the subluxed right side (*dashed line*) and the reduced left side (*solid line*) compared with the normal pattern (*dotted line*). **C.** Symmetric pelvic rotation. Note the symmetric dynamic motion of the subluxed right side (*dashed line*) and the reduced left side (*solid line*) compared with the normal pattern (*dotted line*).

TABLE 3. *Symmetrical/asymmetrical gait*

	Symmetrical	Asymmetrical
Group 1	7	3
Group 2	2	8

$\chi^2 = 5.05$.

tween groups 1 and 2 (Table 4). Intragroup comparison revealed no significant difference in migration percentage, leg length discrepancy, velocity, cadence, and stride length between the symmetric and asymmetric patients for both groups. Comparison of the patients with symmetric and symmetric gaits, regardless of the type of contractures, showed no significant difference in walking velocity, stride length, or cadence.

DISCUSSION

The patients, taken in their entirety, walked with a similar velocity that has been reported previously for the crutch-walking population (34). Therefore, the unilateral hip instability does not influence walking velocity. Both groups showed a similar walking velocity, and it was determined that asymmetric contractures do not limit walking velocity. It is important that asymmetry does not appear to adversely affect walking velocity, because oxygen cost is a function of walking velocity. Although asymmetry may not overtly limit walking velocity, consideration should be given to the notion that asymmetry may disrupt the center of mass excursion and muscle recruitment patterns, which could have a detrimental effect on gait efficiency.

When the patients were grouped based on the symmetry of the passive range of motion, the relationship between unilateral hip stability and gait asymmetry becomes clearer. Seven of the 10 patients in group 1 presented with a symmetric gait pattern despite the presence of unilateral hip instability. Conversely, 8 of the 10 patients with an asymmetric range of motion walked asymmetrically. The asymmetry manifested primarily because of differences in the hip abduction/adduction motion. It appears that the difference in the magnitude of contracture between the unstable hip and the contralateral limb has greater influence on the gait pattern than simply the presence of unilateral hip instability.

Patients with low lumbar level myelomeningocele adopt exaggerated pelvic and hip motions to facilitate forward progression in lieu of decreased or absent hip extensor, ankle plantar flexor, and hip abductor strength (11,35). With crutches, these dynamic ranges decrease but remain significantly high (34). Despite the increased range of motion, the motion should remain symmetric with no substantial discrepancy in the depression/elevation or protraction/retraction between the sides. Since these patients depend on elevated dynamic range of motion for effective ambulation, adequate pelvic and hip passive range of motion is crucial. Hence, these patients may be more affected by limitations in passive range of motion, particularly in the coronal and transverse planes. Crutches have been shown to decrease the compensatory motions of the pelvis and hip in these patients but not alter the gait asymmetry (34).

TABLE 4. *Comparison of mean magnitudes for specific anatomical measures and temporal parameters*

	Group 1	Group 2
% migration index	62.6	63.0
LLD	1.2	1.6
Velocity	62.8	60.1
Cadence	73.6	72.7
Stride length	81.4	76.5

* $p < 0.05$.

The efficacy of hip relocation surgery can be challenged because the hip instability in these patients has either minimal effect on gait symmetry or an effect that can be countered with crutch use. If contractures are causing gait asymmetry and the contractures are addressed, gait symmetry for these crutch walkers would likely be restored.

Patients who have an opportunity to walk without crutches may be good candidates for surgical relocation. These sacral level patients have functional hip abductor strength that would be compromised with hip subluxation or dislocation. The prospect for independent ambulation throughout adulthood, the magnitude of asymmetry during gait, and the joint integrity would require careful consideration for these children. Hip subluxation or dislocation theoretically displaces the center of hip rotation laterally and superiorly. This lateral deviation effectively decreases the lever arm of the hip abductors and increases the lever arm of body weight. Consequently, the moment-generating capacity of these muscles would be compromised.

Patients with low lumbar myelomeningocele have negligible hip abductor strength (3,5–7); therefore, hip subluxation or dislocation imposes little effect on the moment-generating capacity despite a shortened lever arm, because the active force generated by this muscle group already is negligible. Because the hip instability has little effect on the moment-generating capacity of the weak ipsilateral hip abductors, there would be no discrepancy with the contralateral side, and the typical symmetric compensatory motions should persist.

CONCLUSION

Nearly 80% of low lumbar level patients should be community ambulators into adulthood. Clinicians should focus not only on maintaining the general level of ambulation but also on the quality of gait. For the low lumbar level patients, crutches improve two major attributes of walking: stability on stance and energy conservation. Asymmetry can detrimentally affect center of mass excursion and alter muscle recruitment and energy efficiency. Therefore, a symmetric gait is an important goal to maintain gait quality. For patients with unilateral hip instability, a symmetric gait pattern was much more common in patients with no hip contractures or equivalent range of motion on both sides. Patients with no contractures, or symmetric contractures and hip instability will likely walk symmetrically. Asymmetric hip abduction/adduction, pelvic rotation, and pelvic obliquity were more dependent on the presence of unilateral hip adduction contracture rather than a function of an unstable hip. This leads us to conclude that correction of the contractures should be the treatment of choice to restore gait symmetry in these patients, as proposed by previous authors (12,13,30,31).

We confirmed with three-dimensional gait analysis that the hip status is not responsible for gait asymmetry. A symmetric gait is attainable and likely through treatment of the contractures despite unilateral hip dislocation or subluxation in crutch-walking patients with low lumbar level myelomeningocele. We conclude that there is no indication for surgical relocation of the unilaterally unstable hip to restore gait symmetry. Our study supports efforts directed at correcting unilateral soft tissue contractures, especially hip adduction and flexion contractures.

Frequently, for patients with unilateral hip dislocation and an asymmetric gait, the unstable side cannot be detected by simple observation. We conclude that simpler, more effective treatments such as adductor myotomy, hip flexor lengthening, or in severe cases a valgus osteotomy of the proximal femur should be performed instead of extensive hip relocation surgeries.

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