The Use of Diagnostic Gait Analysis in the Treatment of Spina Bifida
Diagnosis: Gait abnormalities (ICD 781.2) secondary to spina bifida (ICD 741) and other neurological impairments similar to spina bifida.

Definition: Diagnostic instrumented gait analysis is a well established method of measuring the abnormalities of gait in individuals with spina bifida. Comprehensive gait analysis testing for this purpose should include an appropriate physical examination, recording passive joint range of motion, muscle strength and tone, kinematic measurement of major joint and segment motions in the lower extremity and trunk in three dimensions, measurement of ground reaction forces with a force plate, then combining this data with kinematics to report joint moments and powers during gait. It may also include surface electromyography to record activation patterns of principal muscles used during gait. Dynamic fine wire electromyography is included when indicated. Pedobarograph, which measures the surface pressure distribution under the foot, may be obtained, and ambulatory oxygen consumption may be measured. This full evaluation requires two to three staff members and takes between two and four hours to complete. All of the data are processed, analyzed, integrated, and reviewed by a clinician or team of clinicians with expertise in the treatment of gait abnormalities. Specific gait abnormalities and their etiology are defined, and treatment options are suggested to the referring physician. The description above is the definition used by the Commission for Motion Laboratory Accreditation (CMLA) {CMLAinc.org}, which is an independent non-profit organization whose board is appointed by the American Academy of Physical Medicine and Rehabilitation (AAPM&R), American Academy of Orthopaedic Surgeons (AAOS), American Physical Therapy Association (APTA), and the Gait and Clinical Movement Analysis Society (GCMAS). The CMLA offers gait laboratory accreditation.

Current Practice: The treatment of spina bifida is complex, requiring a multi-disciplinary team approach to manage multiple medical comorbidities in addition to orthopaedic and neurologic issues. Neurological deficits vary in each child based on the level of the spinal defect and extent of involvement of neural elements, and many children have developmental structural abnormalities of the central nervous system including Chiari malformations and hydrocephalus. The level of neurological involvement is one of the key determinants of a child's ambulatory potential (Gabrieli, 2003). Typically, a clinical assessment of strength alone, rarely reflects the asymmetry noted during gait. An instrumented gait analysis is the Standard of Expert Care for children with gait abnormalities secondary to spina bifida. The main objective of diagnostic gait analysis is to define the pathological consequences of neural tube defects as they relate to gait. Gait analysis is critical for: 1) documentation of the rotational profile which is extremely complex due to the combination of potential bony deformity, joint transverse plane laxity and large transverse plane movements of the trunk and pelvis, 2) documentation of the impact of current orthoses in terms of kinematics and kinetics (if possible) to determine the current function of bracing at ankle, knee and hip joints in the three planes of motion, 3) documentation of the coronal plane knee moment (if possible) to determine if there is a kinetic valgus thrust (Õunpuu, 2000) and the associated need for bracing for protection, 4) documentation of the impact of current walking aid options and their impact on joint kinematics and kinetics, 5) documentation of muscle function especially at the level of the ankle if muscle transfers are being considered as surgical options, 6) documentation of foot pressure patterns to highlight potential risk areas for skin breakdown and associated complications, 7) documentation of changes and possible decline in function/motion over time, as a result of growth, puberty or a tethered cord, 8) documentation of changes due to surgical interventions so that this knowledge can be used for subsequent decision-making. With this comprehensive information and associated improved understanding of gait function, the clinician can formulate a detailed treatment plan to improve ambulatory function, correct orthopedic deformities, and optimize use of orthoses and walking aids to improve the patient's quality of life (Dias, 2004; Swaroop, 2009; Duffy, 1996; Fabry, 2000). Instrumented gait analysis can also give physicians a greater understanding of how the neurological deficiency affects walking function, the implications of reduced motor function and further define the functional level of the patient (Fabry, 2000; Gabrieli, 2003; Gutierrez, 2002). Orthopedic management for patients with spina bifida primarily focuses on correcting and preventing bony and soft tissue deformities. The current philosophy is to minimize the dependency on orthoses for ambulation during childhood and to optimize mobility and independence within the patient's expectations and functional level (Thomson, 2010). The treatment of gait abnormalities in individuals with spina bifida usually involves physical therapy, orthotics, walking aids and often orthopedic interventions, which include surgery for scoliosis and kyphosis, neuromuscular hip dysplasia, knee mal-alignment, rotational deformities, and foot deformities. Greater consideration should be given to those treatments which may prolong ambulatory ability as well as provide optimal short term benefit. For some procedures, multilevel surgical approaches are beneficial for achieving optimum results such as combining posterior iliopsoas transfers with femoral or pelvic osteotomy in younger children with spina bifida (Winters pg.625-628; Drummond, 1980). It is critical to have comprehensive gait measurements and assessments prior to treatment so a better understanding of the pathomechanics is possible. It is also the Standard of Expert Care to evaluate the child with a follow up gait analysis after treatment and rehabilitation is completed to assess the changes from the intervention and determine if any additional treatment is needed to maximize the outcome of the intervention. The follow up instrumented gait analysis is a useful reference point against which to assess the child when major gait or functional changes occur in the future, either secondary to growth or musculoskeletal, orthotic, and neurologic change such as tethered cord.

Literature Review: There is not an extensive collection of literature on the use of gait analysis in the management of spina bifida; however, because of gait analysis, substantial changes are being made in the specialties that treat patients with spina bifida. There has been a change in the understanding of functional deformities due to the implementation of instrumented gait analysis in the late 1980's (Dias, 2010). Excellent clinical review papers have been published in peer-

reviewed journals with recommendations on the treatment of spina bifida using comprehensive gait analysis testing (Thomson and Segal, 2010; Fabry, 2000; Lim, 1998; Duffy, 1996). The indications for surgical procedures, orthotics and physiotherapy have evolved directly from the use of comprehensive gait analysis testing pre and postoperatively. Some specific surgical procedures include addressing contractures of the hips without attempting to reduce the hips to achieve gait symmetry (Gabrieli 2003) and rotational osteotomies of the tibia to reduce knee valgus stress (Lim 1998). The most prevalent studies involving children with spina bifida and the utilization of instrumented gait analysis concern the use of ankle foot orthotics (AFOs) (Malas, 2010). Studies have shown how the implementation of AFOs improves alignment and walking in children with spina bifida (Galli, 2000; Vankowski 2000; Hullin 1992). The utilization of AFOs has been shown to improve power generation, ankle and knee sagittal plane function, and oxygen consumption in children with spina bifida (Thomson 1999, Duffy 2000). Studies done by Guttierez *et al* (2005) and Shoenmaker *et al* (2009) [from Thomson and Segal 2010] suggested that muscle strengthening and endurance training is advantageous to children with spina bifida who can ambulate independently. This promotes the idea that incorporating instrumented gait analysis to future research studies involving exercise physiology would be beneficial. Currently there is a greater demand for literature demonstrating that instrumented gait analysis contributes to, and often alters a physician's surgical plan (Thomson and Segal 2010). Use of instrumented gait analysis can provide beneficial information for the surgical decision making process in children with spina bifida (Moen 2010).

Alternatives to Gait Analysis: The only alternative to quantitative assessment with instrumented gait analysis for the treatment of problems related to gait abnormalities in spina bifida is physician observation and static physical examination. Seizberg *et al* showed that physical examination of a patient, including muscle strength testing, was inadequate in determining ambulatory function in early life in patients with L3-L5 myelomeningocele. In contrast, instrumented gait analysis has the capability to improve decision-making for physicians in treatment of children with spina bifida, such as with physiotherapy, orthotics, and surgery (Thomson and Segal, 2010; Duffy 1996; Dunteman 2000). It has also been established that the informal visual analysis of gait abnormalities is not acceptable (Õunpuu, 2000). The ability to evaluate a patient with complex walking problems at multiple levels including trunk, pelvis, hip, knee, ankle and foot is possible only with three-dimensional gait assessments. The use of instrumented gait analysis allows physicians to better understand the functional differences and determine which surgical or non-surgical interventions would provide the best outcome.

References: Textbooks

B1. Morrissy, RT, S. Weinstein, Lovell and Winter's Pediatric Orthopaedics, Sixth Edition, Lippincott, Philadelphia, PA, 2005 1613 pp
B2. Herring, J. Tachdijan's Pediatric Orthopaedics, Elsevier, London, UK, 2001, 1446 pp

References: Peer Reviewed Journals:

1. Reference Type: Journal Article
Author: T. C. Moen, L. Dias, V. T. Swaroop, N. Gryfakis and C. Kelp-Lenane
Year: 2010
Title: Radical posterior capsulectomy improves sagittal knee motion in crouch gait
Journal: Clin Orthop Relat Res
Date: Dec 4
Accession Number: 21132411
Abstract: BACKGROUND: Knee flexion contracture leading to crouch gait is commonly seen in children with myelomeningocele. Progressive increase in knee flexion contracture increases energy cost, which interferes with efficient, functional ambulation. To prevent this, surgical release has been recommended when a knee flexion contracture exceeds 15 degrees to 20 degrees . QUESTIONS/PURPOSES: We therefore asked whether knee flexion contracture release improved dynamic sagittal motion and walking velocity using computerized gait analysis. PATIENTS AND METHODS: We retrospectively studied 11 patients (20 knees) with high-sacral-level or low-lumbar-level myelomeningocele and knee flexion contracture of greater than 15 degrees. All patients underwent dynamic gait analysis pre- and postoperatively. Surgery consisted of selective hamstring lengthening (medial and lateral), gastrocnemius release from the femoral condyles, and posterior knee capsulectomy. RESULTS: We observed improvements postoperatively in clinical measurements and sagittal kinematics. The clinical knee flexion contracture improved from a mean of 24.9 degrees preoperatively to 5.9 degrees postoperatively. The knee flexion at initial contact improved from 37.6 degrees to 9.0 degrees, and minimum knee flexion in single-leg stance improved from 48.2 degrees to 16.4. Walking velocity improved from 72.2% to 80.0% of age-matched normal. CONCLUSIONS: Surgical treatment of knee flexion contracture in patients with myelomeningocele using radical posterior knee capsulectomy leads to improvement in clinical knee flexion contracture, dynamic sagittal kinematics, and walking velocity. LEVEL OF EVIDENCE: Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.
Notes: 1528-1132 (Electronic)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=21132411
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2. Reference Type: Journal Article
Author: B. S. Malas
Year: 2010
Title: What variables influence the ability of an aFO to improve function and when are they indicated?
Journal: Clin Orthop Relat Res
Date: Nov 30
Accession Number: 21116758
Abstract: BACKGROUND: Children with spina bifida often present with functional deficits of the lower limb associated with neurosegmental lesion levels and require orthotic management.

The most used orthosis for children with spina bifida is the ankle-foot orthosis (AFO). The AFO improves ambulation and reduces energy cost while walking. Despite the apparent benefits of using an AFO, limited evidence documents the influence of factors predicting the ability of an AFO to improve function and when they are indicated. These variables include AFO design, footwear, AFO-footwear combination, and data acquisition. When these variables are not adequately considered in clinical decision-making, there is a risk the AFO will be abandoned prematurely or the patient's stability, function, and safety compromised. PURPOSE: The purposes of this study are to (1) describe the functional deficits based on lesion levels; (2) identify and describe variables that influence the ability of an AFO to control deformities; and (3) describe what variables are indicated for the AFO to control knee flexion during stance, hyperpronation, and valgus stress at the knee. METHODS: A selective literature review was undertaken searching MEDLINE and Cochrane databases using terms related to "orthosis" and "spina bifida." RESULTS: Based on previous studies and gait analysis data, suggestions can be made regarding material selection/geometric configuration, sagittal alignment, footplate length, and trim lines of an AFO for reducing knee flexion, hyperpronation, and valgus stress at the knee. CONCLUSION: Further research is required to determine what variables allow an AFO to improve function.
Notes: 1528-1132 (Electronic)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=21116758
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3. Reference Type: Journal Article
Author: J. D. Thomson and L. S. Segal
Year: 2010
Title: Orthopedic management of spina bifida
Journal: Dev Disabil Res Rev
Volume: 16
Issue: 1
Pages: 96-103
Accession Number: 20419777
Abstract: The management of orthopedic problems in spina bifida has seen a dramatic change over the past 10 years. The negative effects of spasticity, poor balance, and the tethered cord syndrome on ambulatory function are better appreciated. There is less emphasis on the hip radiograph and more emphasis on the function of the knee and the prevention of knee pain. The importance of the hip abductor muscle and its influence on gait and knee function has been realized. Important developments in the treatment of spinal deformity include the use of pedicle screws which allow better correction. The role of anterior-only spinal surgery has been defined, which allows motion at the lumbo-sacral junction and has a lower postoperative infection rate than posterior surgery. Functional outcome assessments provide better feedback for surgeons and families in regards to which patients may benefit most from surgery. Overall, the past 10 years has seen the increased use of functional outcome measures such as Motion Analysis, oxygen consumption, and patient-based outcome assessments rather than traditional radiographic measures (e.g., hip dislocation or subluxation). This progress has resulted in a better understanding of spina bifida and, more importantly, improved outcomes for our patients. Additional research is likely to further enhance outcomes by establishing additional evidence-based interventions.
Notes: 1940-5529 (Electronic)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=20419777
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4. Reference Type: Journal Article
Author: V. T. Swaroop and L. Dias
Year: 2009
Title: Orthopedic management of spina bifida. Part I: hip, knee, and rotational deformities
Journal: J Child Orthop
Date: Oct 25
Accession Number: 19856195
Abstract: Children with spina bifida develop a wide variety of congenital and acquired orthopedic deformities. Among these are hip deformities such as contracture, subluxation, or dislocation. Patients may also have problems with the knee joint, such as knee flexion or extension contracture, knee valgus deformity, or late knee instability and pain. In addition, rotational deformities of the lower extremities, either internal or external torsion, are common as well. This paper will review both the overall orthopedic care of a patient with spina bifida and provide a focused review of the diagnosis and management of the above deformities. In addition, this paper will review the incidence, etiology, classification, and prognosis of spina bifida. The use of gait analysis and orthoses will be covered as well. The forthcoming Part II will cover foot and ankle deformities in spina bifida.
Notes: 1863-2548 (Electronic)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19856195
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5. Reference Type: Journal Article
Author: C. K. Feng, C. S. Chen, C. H. Chen, S. J. Lee, C. L. Liu, Y. E. Lee and M. W. Tsai
Year: 2009
Title: A 3D mathematical model to predict spinal joint forces for a child with spina bifida
Journal: Gait Posture
Volume: 30
Issue: 3
Pages: 388-90
Date: Oct
Accession Number: 19628393

Abstract: Children with spina bifida (SB) can exhibit excessive arm swing, trunk sway, and pelvic tilt during walking. To understand the relationship between abnormal low back forces (LBF) and gait disorders in SB, we derived a mathematical model for evaluating LBF in this population. One unimpaired child and a child with SB were tested. A 3D motion analysis system and force plates were used to collect kinematic and ground reaction force data during walking. A mathematical model created using MATLAB software was used to calculate LBF for each child. The LBF for the child with SB was three times greater in the medio-lateral direction than for the unimpaired child. In the anterior-posterior direction, the LBF for the child with SB acted mostly towards the anterior trunk. In addition, the LBF of the child with SB increased by 24.5% of body weight at the fastest walking speed.
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19628393
Author Address: Veteran General Hospital-Taipei, Taipei, Taiwan.

6. Reference Type: Journal Article
Author: J. Pauk
Year: 2009
Title: Computerized analysis and modeling of patients with deformities of lower limbs
Journal: Acta Bioeng Biomech
Volume: 11
Issue: 1
Pages: 47-51
Accession Number: 19736906
Abstract: The purpose of this paper was to model the human gait of typical subjects and patients with such deformities of lower limbs as: spastic diplegia cerebral palsy and spina bifida occulta. Model coefficients will lead to the development of a better computer system to support clinical decision-making in human gait in terms of assessment, diagnosis, and classification. Human gait was evaluated by using Motion Analysis System in the Syncrude Center for Motion and Balance in Edmonton. Kinetics data were used for the mathematical modeling based on regression function. The difference between the model coefficients of the patients with the deformities of lower limbs and typical subjects were analyzed. There is shown that the model coefficients are different in each group. The modeling can help to define gait pathology and treatment for a large number of patients.
Notes: 1509-409X (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19736906
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7. Reference Type: Journal Article
Author: S. I. Wolf, M. Alimusaj, O. Rettig and L. Doderlein
Year: 2008
Title: Dynamic assist by carbon fiber spring AFOs for patients with myelomeningocele
Journal: Gait Posture
Volume: 28
Issue: 1
Pages: 175-7
Date: Jul
Accession Number: 18255293
Abstract: Patients with calf muscle insufficiency and a calcaneus gait are often dependent on ankle-foot orthoses (AFO). The orthosis is intended to improve walking and posture and should prevent structural deformities. AFOs are often manufactured with a dorsiflexion stop. The design of this type of orthosis has been investigated in several previous studies. In the current study, orthoses with a dorsal carbon fiber spring were compared with the classic design. Five patients with Spina Bifida took part in the current study. All participants underwent a 3D gait analysis including kinematic (VICON infrared cameras) and kinetic (Kistler force plates) data collection. The measurements showed that the carbon spring was able to support the patient during the complete stance phase. It was found that the use of a carbon fiber spring significantly increases the energy return during the 3rd rocker, simulating the natural push-off action ($p<0.05$). Via a simple mechanical test, the contribution of the carbon spring to the overall kinetics could be estimated proving that the spring does assist the patient for push-off. The more physiological ankle and knee kinematics implies a functional improvement from the carbon springs compared to classic orthosis. This investigation showed, further, that in the fitting process a neutral alignment with the shoe wear has to be carefully checked since the spring kinematics and kinetics during stance phase were influenced significantly by the alignment. Further studies are needed to assess the clinical outcome and to prove the functional benefit of this kind of orthosis.
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18255293
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8. Reference Type: Journal Article
Author: S. Battibugli, N. Gryfakis, L. Dias, C. Kelp-Lenane, S. Figlioli, E. Fitzgerald, N. Hroma, R. Seshadri and C. Sullivan
Year: 2007
Title: Functional gait comparison between children with myelomeningocele: shunt versus no shunt
Journal: Dev Med Child Neurol
Volume: 49
Issue: 10
Pages: 764-9
Date: Oct
Accession Number: 17880646
Abstract: The aim of this study was to compare functional gait differences between patients with myelomeningocele (MM) who have a ventriculoperitoneal shunt (VPS) with those who do not. Our analyses were adjusted for confounding by age, lesion level, orthotic use, and assistive device use. The Functional Mobility Scale (FMS) was used to compare the shunted group (n=98; 60 males, 38 females; mean age 10y 2mo [SD 3y 11mo]; 73 sacral/19 low lumber/six high

lumbar lesion level) with the non-shunted group (n=63; 32 males, 31 females; mean age 9y 11mo [SD 3y 11mo]; 45 sacral/12 low lumber/six high lumbar lesion level). Participants with a shunt had lower FMS 500 and FMS 50 scores compared with participants without a shunt; hence the participants without a shunt were more independent in their ambulation at medium and longer distances. For a subset of participants who underwent a three-dimensional gait analysis, we also collected temporal-spatial gait parameters (velocity, cadence, and stride length). Our results show that participants with MM and no shunt who underwent gait analysis(11 males, 10 females; mean age 9y 6mo [SD 4y]; 15 sacral/6 low lumber/0 high lumbar lesion level) tend to walk at a significantly greater velocity and stride length as compared with those with a shunt (33 males, 18 females; mean age 10y [SD 4y]; 38 sacral/13 low lumber/zero high lumbar lesion level). These data allow the treatment team to present more specific information regarding functional ambulatory expectations to patients with MM and their families.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17880646
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9. Reference Type: Journal Article
Author: A. Bartonek, M. Eriksson and E. M. Gutierrez-Farewik
Year: 2007
Title: Effects of carbon fibre spring orthoses on gait in ambulatory children with motor disorders and plantarflexor weakness
Journal: Dev Med Child Neurol
Volume: 49
Issue: 8
Pages: 615-20
Date: Aug
Accession Number: 17635208
Abstract: A consecutive series of 17 children (six males, 11 females; mean age 11y 11mo [SD 4y 5mo]; range 3y 11mo-17y 4mo) with plantarflexor weakness was assessed to compare gait differences between a carbon fiber spring orthosis (CFSO) and participants' regular orthoses. Twelve children had myelomeningocele, four children had arthrogryposis, and one child had neuropathy with peripheral muscle pareses. All participants underwent clinical examination and 3D gait analysis. Parents answered a questionnaire to assess subjective perceptions of the orthoses. Results from 3D gait analysis provided evidence that CFSOs enhance gait function in most participants by improving ankle plantarflexion moment ($p<0.001$), ankle positive work ($p<0.001$), and stride length ($p<0.001$). The CFSO did not suit all participants, which emphasizes the importance of analyzing each patient's needs.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17635208
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10. Reference Type: Journal Article
Author: T. Moen, N. Gryfakis, L. Dias and L. Lemke
Year: 2005
Title: Crouched gait in myelomeningocele: a comparison between the degree of knee flexion contracture in the clinical examination and during gait
Journal: J Pediatr Orthop
Volume: 25
Issue: 5
Pages: 657-60
Date: Sep-Oct
Accession Number: 16199950
Abstract: The purpose of this study was to quantitatively evaluate, in patients with low lumbar and sacral level myelomeningocele who have knee flexion contractures, whether there are significant differences between the degree of knee flexion contracture measured clinically and the degree of actual knee flexion during gait, measured by computerized gait analysis. Patients were divided into two groups, those who walked with ankle-foot orthoses (AFOs) alone and those who walked with AFOs and crutches. In both groups, the patient's knee flexion contractures were measured clinically, and the degree of knee flexion was measured dynamically at two representative points in the gait cycle. In both groups and at both points of the gait cycle, the degree of knee flexion during gait was significantly greater than the degree of clinical knee flexion contracture. This should be taken into account when evaluating the crouch gait of children with myelomeningocele and planning the proper treatment.
Notes: 0271-6798 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16199950
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11. Reference Type: Journal Article
Author: A. Bartonek, E. M. Gutierrez, Y. Haglund-Akerlind and H. Saraste
Year: 2005
Title: The influence of spasticity in the lower limb muscles on gait pattern in children with sacral to mid-lumbar myelomeningocele: a gait analysis study
Journal: Gait Posture
Volume: 22
Issue: 1
Pages: 10-25
Date: Aug
Accession Number: 15996587
Abstract: Gait analysis and recording of standing position were performed in 38 ambulatory children with myelomeningocele. Thirty-four were independent ambulators and four required a walking aid. All subjects were assigned one of four muscle function groups based on muscle strength. They were also divided into subgroups based on the distinction between flaccid and spastic paresis in the lower limb joints. A comparison was made between the gait pattern of the children with spasticity and that of the children with flaccid paresis in each muscle function

group. Spasticity in only the ankle joint muscles influenced the subject's gait and standing position compared to the subgroups with a flaccid paresis. Even larger deviations in gait and standing position were observed when spasticity occurred in muscles at the knee and hip joints. When setting ambulatory goals the presence of additional neurological symptoms such as spasticity and inadequate balance should be taken into consideration.
Notes: 0966-6362 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15996587
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12. Reference Type: Journal Article
Author: R. T. Gupta, S. Vankoski, R. A. Novak and L. S. Dias
Year: 2005
Title: Trunk kinematics and the influence on valgus knee stress in persons with high sacral level myelomeningocele
Journal: J Pediatr Orthop
Volume: 25
Issue: 1
Pages: 89-94
Date: Jan-Feb
Accession Number: 15614067
Abstract: Historically, trunk movement has been thought to be reactionary to lower body motions. The excessive trunk movement in patients with myelomeningocele may be a primary mechanism during ambulation. The purpose of this study was to quantify three-dimensional trunk movement in patients with myelomeningocele. Patients walked with ankle-foot orthoses (AFOs), both with and without crutches. Data were collected in reference to global and pelvic coordinates. Patients who walked with AFOs and crutches showed less trunk dynamic range of motion than patients without crutches. Between the two patient groups, there was a significant difference in trunk obliquity but not in trunk tilt or rotation. There is a good correlation between maximum trunk obliquity and coronal plane valgus knee stress. Overall, coronal plane valgus knee stress is multifactorial and trunk motion and external tibial torsion are major contributors. However, when using trunk kinematics to describe dynamic motion, both global and pelvic coordinate systems are important reference frames.
Notes: 0271-6798 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15614067
Author Address: Motion Analysis Center, Children's Memorial Hospital, Chicago, Illinois, USA.

13. Reference Type: Journal Article
Author: E. M. Gutierrez, A. Bartonek, Y. Haglund-Akerlind and H. Saraste
Year: 2005
Title: Kinetics of compensatory gait in persons with myelomeningocele
Journal: Gait Posture
Volume: 21
Issue: 1
Pages: 12-23
Date: Jan
ISSN: 0966-6362 (Print)
Accession Number: 15536030
Abstract: This study investigated the kinetic strategy and compensatory mechanisms during self-ambulatory gait in children with lumbo-sacral myelomeningocele. Thirty-one children with mid-lumbar to low-sacral myelomeningocele who walked without aids and 21 control children were evaluated by three-dimensional gait analysis. Joint moments in all planes at the hip and knee and sagittal moments at the ankle, as well as joint power and work done at all three joints, were analyzed. Joint moment capacity lost due to plantarflexor and dorsiflexor weakness was provided instead by orthotic support, but other joints were loaded more to compensate for the weakness at the ankles and restricted ankle motion. Subjects with total plantarflexor and dorsiflexor paresis and strength in the hip abductors had more knee extensor loading due to plantarflexor weakness and dorsiflexion angle of the orthotic ankle joint. The subjects with orthoses also generated more power at the hip to supplement the power generation lost to plantarflexor weakness and fixed ankles. The most determinant muscle whose paresis changes gait kinetics was the hip abductor. Hip abductor weakness resulted in a characteristic pattern where the hips displayed an eccentric adduction moment, mediating energy transfer into the lower limbs, and the hips replaced the knees as power absorbers in early stance. Joint moment, power and work analyses complement a kinematic analysis to provide a complete picture of how children who have muscle paresis recruit stronger muscle groups to compensate for weaker ones.
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15536030
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14. Reference Type: Journal Article
Author: L. Dias
Year: 2004
Title: Orthopaedic care in spina bifida: past, present, and future
Journal: Dev Med Child Neurol
Volume: 46
Issue: 9
Pages: 579
Date: Sep
Accession Number: 15344516
Notes: 0012-1622 (Print)

URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15344516

15. Reference Type:Journal Article
Author: E. M. Gutierrez, A. Bartonek, Y. Haglund-Akerlind and H. Saraste
Year: 2003
Title: Characteristic gait kinematics in persons with lumbosacral myelomeningocele
Journal: Gait Posture
Volume: 18
Issue: 3
Pages: 170-7
Date: Dec
Accession Number: 14667950
Abstract: Thirty self-ambulatory children with mid-lumbar to low-sacral myelomeningocele who walked without aids and 21 control children were evaluated by three-dimensional gait analysis. Characteristic kinematic patterns and parameters in the trunk, pelvis, hip, knee and ankle were analyzed with respect to groups with successive weakness of the ankle plantarflexor, ankle dorsiflexor, hip abductor, hip extensor and knee flexor muscles. Extensive weakness of the plantarflexors resulted in kinematic alterations in the trunk, pelvis, hip and knee and in all three planes seen as knee flexion, anterior pelvic tilt and trunk and pelvic rotation. Additional extensive weakness of the dorsiflexors made little difference in the walking strategy. Large kinematic alterations in all planes were observed where there was a large extent of additional weakness of the hip abductor but strength remaining in the hip extensors. In this group, gait was characterized by large lateral sway of the trunk, rotation of the trunk and pelvis, pelvic hike and increased extension of the knees. In the group with total poresis hip extensors but yet some knee flexion, gait was similar to the previous group but there was less sagittal plane movement greates and posterior trunk tilt. Gait analysis provides an understanding of the compensatory strategies employed in these patients. Clinical management can be directed towards stabilizing the lower extremities and accommodating large upper body motion to preserve this method of self-ambulation even in children who have considerable hip extensor and abductor weakness.
Notes: 0966-6362 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=14667950
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16. Reference Type: Journal Article
Author: E. M. Gutierrez, A. Bartonek, Y. Haglund-Akerlind and H. Saraste
Year: 2003
Title: Centre of mass motion during gait in persons with myelomeningocele
Journal: Gait Posture
Volume: 18
Issue: 2
Pages: 37-46
Date: Oct
Accession Number: 14654206
Abstract: The movement of the centre of mass in the vertical and lateral directions during gait in children with myelomeningocele was analyzed. The children were classified into five groups depending on the successive paresis of lower limb muscle groups and compared to a control group. In the groups with dorsi- and plantarflexor weakness, the excursions increased and an anterior trend in the centre of mass was observed. In the groups with additional abductor paresis, the lateral excursion was highest and the vertical excursion low due to increased transverse and frontal motion and reduced sagittal motion. With further paresis of the hip extensors, the centre of mass was more posteriorly positioned due to compensatory trunk extension. Improved understanding of individual children's solutions to their muscle paresis can be obtained by visualizing the centre of mass relative to the pelvis. Centre of mass analyses in myelomeningocele offer an important complement to standard gait analysis.
Notes: 0966-6362 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=14654206
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17. Reference Type: Journal Article
Author: A. P. Gabrieli, S. J. Vankoski, L. S. Dias, C. Milani, A. Lourenco, J. L. Filho and R. Novak
Year: 2003
Title: Gait analysis in low lumbar myelomeningocele patients with unilateral hip dislocation or subluxation
Journal: J Pediatr Orthop
Volume: 23
Issue: 3
Pages: 330-4
Date: May-Jun
Accession Number: 12724595
Abstract: 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.
Notes: 0271-6798 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12724595
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18. Reference Type: Journal Article
Author: A. Bare, S. J. Vankoski, L. Dias, M. Danduran and S. Boas
Year: 2001
Title: Independent ambulators with high sacral myelomeningocele: the relation between walking kinematics and energy consumption
Journal: Dev Med Child Neurol
Volume: 43
Issue: 1
Pages: 16-21
Date: Jan
Accession Number: 11201417
Abstract: The aims of this study were to determine the relation between gait kinematics (center of mass excursions) and measures of oxygen consumption and oxygen cost. Fourteen independent ambulating children with myelomeningocele (nine females, five males; mean age 8 years 7 months) and thirteen children with no history of neuromuscular disorder were evaluated. At their comfortable walking speed all patients exhibited oxygen cost and oxygen consumption values that exceeded the normal level by more than 1 SD. Pelvic obliquity demonstrated the strongest relation with oxygen cost which suggests that ultimately hip abductor strength may play a key role in energy demands during gait. Despite the exaggerated pelvic kinematics, vertical and horizontal center of mass excursions of the trunk and whole-body during the gait cycle were not significantly greater than normal ($p>0.05$). Decreased self-selected walking velocity at which many of these children consider comfortable and stable may be predicated on an optimal center of mass movement that approximates the magnitude observed in normal gait. The slower walking velocity decreases walking efficiency. Conversely, the increased center of mass movement that would accompany a faster gait would probably impose intolerable oxygen consumption levels. Strengthening programs that focus on the gluteus medius and maximus to decrease compensatory trunk and pelvic motions, allowing the patients to adopt a faster gait without exacerbating kinematic and center of mass motions and which enabled more efficient walking hold promise for these patients.
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11201417
Author Address: Motion Analysis Center; Division of Pediatric Orthopaedic Surgery, Children's Memorial Hospital, Chicago, IL 60614, USA.

19. Reference Type: Journal Article
Author: R. C. Dunteman, S. J. Vankoski and L. S. Dias
Year: 2000
Title: Internal derotation osteotomy of the tibia: pre- and postoperative gait analysis in persons with high sacral myelomeningocele
Journal: J Pediatr Orthop
Volume: 20
Issue: 5
Pages: 623-8
Date: Sep-Oct
Accession Number: 11008742
Abstract: Rotational deformities of the lower extremities are common in patients with myelomeningocele. In these situations, surgical correction is often necessary. We conducted a retrospective review of eight ambulatory patients with high sacral myelomeningocele and external tibial torsion who underwent 10 distal tibia and fibular internal derotation osteotomies. All patients had an increased valgus knee stress preoperatively. Pre- and postoperative three-dimensional gait analysis was used to evaluate coronal plane knee moments and dynamic sagittal plane knee motion. Postoperatively, a significant improvement in the abnormal internal knee varus moment ($p < 0.005$) as well as a significant increase in the stance phase knee extension ($p < 0.01$) was seen. Three patients had resolution of preoperative knee pain. We believe that patients with increased knee stress secondary to excessive external tibial torsion will benefit from a tibial derotation osteotomy that could delay or prevent the onset of late degenerative changes about the knee.
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11008742
Author Address: Department of Orthopaedic Surgery, Northwestern Memorial Hospital, Chicago, Illinois, USA.

20. Reference Type: Journal Article
Author: S. Ounpuu, J. D. Thomson, R. B. Davis and P. A. DeLuca
Year: 2000
Title: An examination of the knee function during gait in children with myelomeningocele
Journal: J Pediatr Orthop
Volume: 20
Issue: 5
Pages: 629-35
Date: Sep-Oct
Accession Number: 11008743
Abstract: In this retrospective study, 37 patients with myelomeningocele who had undergone gait analysis were examined. Patients were divided into groups based on the level of involvement (29 sides: L4; 26 sides: L5; 19 sides: S1-2). Results showed increased knee flexion and associated knee extensor moments with increasing level of neurologic involvement. The mean coronal plane knee position in stance was normal in all groups and not related to coronal plane knee moment. However, there was an increased incidence of a net knee adductor moment in

stance with increasing involvement (mean, 0.02 +/-0.18 N.m/kg for the L4 group). The presence of a visual valgus thrust based on video records was not reliable in predicting an abnormal knee coronal plane moment. An abnormal knee adductor moment in stance was most highly related to coronal plane trunk motion (r = -0.62) and not tibial torsion (r = -0.340). Increased transverse plane range of motion of the knee was most highly related to transverse plane trunk motion (r = 0.67).
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URL:
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21. Reference Type: Journal Article
Author: G. Fabry, G. Molenaers, K. Desloovere and M. Eyssen
Year: 2000
Title: Gait analysis in myelomeningocele: possibilities and applications
Journal: J Pediatr Orthop B
Volume: 9
Issue: 3
Pages: 170-9
Date: Jun
Accession Number: 10904903
Abstract: Gait analysis with a fully integrated laboratory is a relatively new instrument in the armamentarium of the pediatric orthopedic surgeon. The introduction of it has been especially successful in neuromuscular pathology and, particularly, in cerebral palsy. In spina bifida, however, it also enhances substantially the possibilities of detailed analysis of the locomotion problem. It is, furthermore, a very useful instrument in evaluating treatment and in follow-up. With a few examples, this paper tries to show the possibilities and advantages of a gait laboratory in the evaluation of patients with ambulatory spina bifida.
Notes: 1060-152X (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10904903
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22. Reference Type: Journal Article
Author: C. M. Duffy, H. K. Graham and A. P. Cosgrove
Year: 2000
Title: The influence of ankle-foot orthoses on gait and energy expenditure in spina bifida
Journal: J Pediatr Orthop
Volume: 20
Issue: 3
Pages: 356-61
Date: May-Jun
Accession Number: 10823604
Abstract: We examined the effect of ankle-foot orthoses (AFOs) on gait and energy expenditure in children with spina bifida. Nine boys and three girls, 6 to 16 years of age, took part in the study. There were four children each with L4, L5, and sacral level lesions. Each child underwent gait analysis and energy consumption studies with and without AFOs. Walking speed was faster with AFOs (mean, 58 m/min) than without (mean, 50 m/min, $p < 0.01$). Stride length improved significantly ($p < 0.001$) from 0.89 m barefoot to 1.08 m with AFOs. Double support time was decreased from 0.32 seconds barefoot to 0.28 seconds with AFOs ($p < 0.05$). The oxygen cost of walking was significantly better with (0.33 mL/kg/m) than without AFOs (0.41 mL/kg/m, $p < 0.001$). Hip flexion at initial contact was increased. Ankle kinematics were unchanged, but ankle power generation showed a significant improvement; from 0.5 W/kg barefoot to 1.3 W/kg with AFOs. Increased ankle power generation results in improved hip flexion and stride length, which contributes to increased walking speed and reduced oxygen cost. The stability conferred by the AFOs is reflected in the reduced time spent in double support.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10823604
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23. Reference Type: Journal Article
Author: J. D. Thomson, S. Ounpuu, R. B. Davis and P. A. DeLuca
Year: 1999
Title: The effects of ankle-foot orthoses on the ankle and knee in persons with myelomeningocele: an evaluation using three-dimensional gait analysis
Journal: J Pediatr Orthop
Volume: 19
Issue: 1
Pages: 27-33
Date: Jan-Feb
Accession Number: 9890282
Abstract: The purpose of this study was to determine the effects of the ankle-foot orthosis (AFO) on gait patterns in patients with low-level myelomeningocele and to identify any abnormal gait patterns that may lead to future knee instability and pain. A total of 28 children (26 L4-level sides, 18 L5-level sides, and 10 S1-2-level sides) underwent a three-dimensional gait analysis when ambulating barefoot and with AFOs. Results show significant improvements in sagittal plane function with reductions in excessive ankle dorsiflexion, increases in peak plantar flexor moment, and reductions in crouch and knee extensor moment in the L4 and L5 groups. The only improvement in the S1-2 group was a reduction in excessive dorsiflexion, but there was a reduction in power generation at the ankle. The S1-2 group had normal transverse plane knee motion in stance during barefoot walking that increased significantly ($p < 0.01$) with the AFO. Both the L5 and L4 groups showed greater-than-normal transverse plane knee motion in stance

during barefoot walking that also increased significantly ($p < 0.01$) with the AFO. The results suggest that excessive knee transverse plane rotation may contribute to knee instability more than coronal plane abnormalities. The AFO in S1-2-level patients may be more detrimental for the knee than barefoot walking.
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9890282
Author Address: Gait Laboratory, Connecticut Children's Medical Center, Hartford 06106, USA.

24. Reference Type: Journal Article
Author: R. Lim, L. Dias, S. Vankoski, C. Moore, M. Marinello and J. Sarwark
Year: 1998
Title: Valgus knee stress in lumbosacral myelomeningocele: a gait-analysis evaluation
Journal: J Pediatr Orthop
Volume: 18
Issue: 4
Pages: 428-33
Date: Jul-Aug
Accession Number: 9661845
Abstract: Twenty-five independent community-ambulating patients with lumbosacral-level myelomeningocele (N = 50 limbs) underwent gait analysis. The limbs of these patients were divided into two groups based on thigh-foot angle (TFA): Group I (n = 20) had marked external tibial torsion, TFA > or = 20 degrees, and group II had TFA between 10 and 20 degrees. Ten limbs were excluded because of neutral or internal alignment. Twenty normal limbs with TFA = 10 degrees served as controls. An abnormal internal varus knee stress during stance was identified in all group I limbs and 12 (70%) of 20 limbs group II limbs compared with controls, which demonstrated an internal valgus stress. This internal varus moment was greater in group I limbs than in the abnormal limbs in group II ($p < 0.05$). Knee flexion was the only other parameter found to correlate with this stress and only in group I limbs. We conclude that (a) in this patient group, increased external tibial torsion is likely to result in an abnormal internal varus knee stress; (b) TFA > 20 degrees appears significantly to increase this stress; and (c) knee flexion is an important related parameter, but only in limbs with TFA between 10 and 20 degrees. We believe that this abnormal stress may predispose the knee to late arthrosis and that derotational osteotomies to normalize the TFA may prove to have a favorable long-term effect.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9661845
Author Address: Children's Memorial Hospital, Chicago, Illinois, USA.

25. Reference Type: Journal Article
Author: S. Vankoski, C. Moore, K. D. Statler, J. F. Sarwark and L. Dias
Year: 1997
Title: The influence of forearm crutches on pelvic and hip kinematics in children with myelomeningocele: don't throw away the crutches
Journal: Dev Med Child Neurol
Volume: 39
Issue: 9
Pages: 614-9
Date: Sep
Accession Number: 9344054
Abstract: Gait analysis was performed on 16 children with high-sacral-level myelomeningocele who walked with and without crutches to evaluate the influence of crutches on their unique walking pattern. All of the patients used solid ankle-foot orthoses (AFOs). Deviations in coronal and transverse planes improved with assisted walking. The timing of stance phase pelvic depression and the magnitude of stance phase hip abduction improved with crutch walking. Pelvic rotation, which was seven times the normal range of motion during no-crutch walking, decreased to four times normal with crutches. Walking velocity was not significantly different between conditions. The results demonstrated that deviations in pelvic and hip kinematics are related to muscle weakness and improve with crutch use. Crutches enable the patient to transfer some weight bearing to their upper extremities which decreases the demand on weak lower-extremity musculature. This allows them to maintain functional ambulation with a closer to normal gait pattern.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9344054
Author Address: Department of Orthopaedic Surgery, Children's Memorial Medical Center, Chicago, IL 60614, USA.

26. Reference Type: Journal Article
Author: C. M. Duffy, A. E. Hill, A. P. Cosgrove, I. S. Corry, R. A. Mollan and H. K. Graham
Year: 1996
Title: Three-dimensional gait analysis in spina bifida
Journal: J Pediatr Orthop
Volume: 16
Issue: 6
Pages: 786-91
Date: Nov-Dec
Accession Number: 8906653
Abstract: This study was designed to determine gait patterns in children with lumbar and sacral neurologic level spina bifida. We studied a group of 28 children: 10 had L4-level lesions and a mean age of 11 years; eight had L5-level lesions and a mean age of 8 years; and 10 had S1-level lesions with a mean age of 12 years. A group of 15 normal children, mean age 10 years, was used for comparison. Each child underwent three-dimensional gait analysis using the Vicon system. We found that there were recognisable gait patterns for each level of spina bifida and that the abnormalities accurately reflected the muscle deficiencies present. The gait patterns approximated more closely to those of the normal group as the neurological level descended. The most important findings were of increased pelvic obliquity and rotation with hip abduction in

stance (reflecting the gross Trendelenburg-type gait seen in these children) and persistent knee flexion throughout stance as a result of the absence of the plantar flexion-knee extension couple. We found that gait was not improved by tendon transfers performed either at the hip (posterolateral psoas transfer) or at the ankle (tibialis anterior transfer).
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URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=8906653
Author Address: Royal Belfast Hospital for Sick Children, Northern Ireland.

27. Reference Type: Journal Article
Author: N. S. Stott, L. E. Zionts, J. K. Gronley and J. Perry
Year: 1996
Title: Tibialis anterior transfer for calcaneal deformity: a postoperative gait analysis
Journal: J Pediatr Orthop
Volume: 16
Issue: 6
Pages: 792-8
Date: Nov-Dec
Accession Number: 8906654
Abstract: We retrospectively evaluated seven children who had low-lumbar-level spina bifida and who had undergone bilateral transfer of tibialis anterior to the calcaneus. The mean age at the time of operation was 8 years (range, 3-12), and the patients were monitored for an average of 40 months (range, 24-60). All children underwent a postoperative gait analysis to assess the function of the transfer and the need for continued postoperative bracing. Transfer of the tibialis anterior muscle to the calcaneus arrested progression of the calcaneal deformity; however, the transfer could not prevent excessive dorsi-flexion of the ankle during stance. The use of a pretibial ankle-foot orthosis improved velocity, increased stride length, decreased quadriceps activity at terminal stance, and led to decreased energy expenditure. We conclude that continued bracing is necessary to provide a more normal appearing and energy-efficient gait.
Notes: 0271-6798 (Print)
URL:
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=8906654
Author Address: Orthopaedic Hospital, University of Southern California, Los Angeles, USA.

28. Reference Type: Journal Article
Author: M. G. Hullin, J. E. Robb and I. R. Loudon
Year: 1992
Title: Ankle-foot orthosis function in low-level myelomeningocele
Journal: J Pediatr Orthop
Volume: 12
Issue: 4
Pages: 518-21
Date: Jul-Aug
Accession Number: 1613099
Abstract: Six children with low-level myelomeningocele underwent gait analysis. All showed excessive ankle dorsiflexion and knee flexion when walking barefoot. A rigid thermoplastic ankle-foot orthosis (AFO) improved gait by preventing ankle dorsiflexion and reducing knee flexion. Biomechanically, the AFO caused a reduction in external knee moment by aligning the knee with the ground reaction force. Small changes in the foot-shank angle of the orthosis had profound effects on knee mechanics. Knee hyperextension could be controlled by a rocker sole. Kinetic gait analysis permits understanding of the biomechanical effects of orthoses.
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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=1613099
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