Use of Gait Analysis in the Treatment Decision-Making Process of Patients with Spastic Cerebral Palsy

Spastik Serebral Palsili Hastalarda Tedaviye Karar Verme Sürecinde Yürüme Analizi Kullanımı

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Summary

The aim of this study was to evaluate the gait deviations of patients with spastic cerebral palsy (CP) with computerized gait analysis and to allow objective criteria to physicians for clinical decision making.
Medical charts and gait analysis reports of the 43 patients with spastic CP were reviewed, retrospectively. The mean±SD age was 9.5±5.2 years. Seventy-six percent had diplegia and 24% had hemiplegia pattern. A five-camera VICON 370 system and Vicon Clinical Manager software was used for gait analysis.
Kinematic gait analysis revealed excessive pelvic excursion in three of the planes; excessive hip flexion, adduction and internal rotation angles in sagittal, coronal planes and transverse plane, respectively. Twenty-five percent of the children with spastic CP had crouch and 35% had stiff-knee gait pattern. Eighty percent of the analysis (n=34) were resulted in recommendations of a change in patient care. Ninety-five of these recommendations were specific physical therapy regimens, 46% botulinum toxin Type A injections, 49% bracing, and 7% were surgery.
In conclusion, gait analysis is a tool that enables the clinicians to differentiate gait deviations, objectively. It serves not only as a measure of treatment outcome, but also as a useful tool in planning ongoing care. *Turk J Phys Med Rehab 2005; 51 (1): 1-5*
Key Words: Cerebral palsy, gait analysis, rehabilitation

Özet

Bu çalışmanın amacı spastik serebral palsili (SP) hastaların yürüme bozukluklarını değerlendirmek ve hekimlere, klinik uygulamalarında kullanmaları için objektif kriterler sunmaktır. Spastik SP'li 43 hastanın hastane dosyaları ve yürüme analizi raporları retrospektif olarak incelendi. Yaş ortalaması 9,5±5,2 yıldı. Hastaların %76'sı spastik diplejik tip, %24'ü ise hemiplejik tip olarak değerlendirildi. Yürüme analizleri beş kameralı "Vicon 370" sistemi ve "Vicon Clinical Manager" yazılım programı kullanılarak yapıldı.
Kinematik analizlerde pelvis hareketlerinde her üç planda da artış olduğu; kalça fleksiyon, addüksiyon ve iç rotasyon açılarının sırasıyla, sagital, koronal ve transvers planlarda artmış olduğu gözlendi. Spastik SP'li çocukların %25'inde bükük diz yürüyüşü, %35'inde tutuk diz paterni tespit edildi. Yürüme analizi yapılan çocukların %80'inde (n=34), mevcut tedavilerinde bir değişiklik önerildi. Bu önerilerin %95'ini özgün fiziksel tedavi programları oluşturmaktaydı. Çocukların %46'sına botulinum toksin Tip A enjeksiyonları, %49'una ortezleme ve %7'sine ise cerrahi yaklaşımlar önerildi.
Sonuç olarak yürüme analizi, klinisyenlerin yürüme bozukluklarını objektif olarak tanımlamalarında kullanabilecekleri bir yöntemdir. Yürüme analizi tedavinin başarısını değerlendirmede kullanılabileceği gibi, tedavinin planlanması aşamasında da yararlı olabilir. *Türk Fiz Tıp Rehab Derg 2005; 51 (1): 1-5*
Anahtar Kelimeler: Serebral palsi, yürüme analizi, rehabilitasyon

Introduction

Cerebral palsy (CP), "the disorder of movement and posture due to defect or lesion of the immature brain" (1), is the most common motor disability originating in childhood (2). The major neuromuscular problems in CP that may necessitate medical, neurosurgical and/or orthopedic intervention can be divided into four categories (3): 1) Loss of selective motor control and dependence on primitive reflex patterns for ambulation; 2) Abnormal muscle tone (spasticity or dystonia) that is strongly influenced by body posture, position and /or movement; 3) Relative imbalance between muscle agonists and antagonists

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which, with time and growth, leads to fixed muscle contracture and bony deformity; 4) Impaired body balance mechanisms. Although CP is defined primarily as a motor disorder, because of the associated problems, the interdisciplinary, multidisciplinary, or transdisciplinary team approach is current standart of practice for assessment and treatment of CP.

Ambulation is the most important skill for CP patients. One of the most frequently asked questions from parents and caregivers upon being told their child has CP is "When my child will walk?". The maturation of the normal gait pattern is blocked at the stage of early development. The child with CP has a walking pattern that may include scissoring of the legs, internal rotation of the thighs, and an equinus ankle at foot contact, and frequently there is exaggerated knee flexion in stance (4).

Physical therapy is the inevitable step of CP. Besides traditional approach of range of motion, stretch, and strengthening, neurodevelopmental treatment for motor learning and tone normalization, and sensory integration for a variety of motor and arousal features are also important steps of rehabilitation. Therapy should prepare a child for independent adult life. To achieve this goal, adaptive equipment to aid positioning, assistive devices to aid ambulation, various equipments for mobility (ankle-foot orthoses) are used. Team approach is highly mandatory to decide the intervention and to follow-up the results. The physician needs objective criteria for analyzing problems of locomotion, to make rational decisions about physical therapy, drug therapy, orthotics, and surgery. It must be remembered that in CP, gait abnormalities rarely occur in isolation. Rather they are multiple and consist of primary anomalies (directly due to damage to central nervous system) and secondary anomalies (these compensations which the individual uses to circumvent the primary problems of gait). Thus the secondary compensations can be thought as "coping responses". Much of the difficulty encountered in studying pathological gait is the separation of the primary and coping responses. Since normal gait is the most efficient, any deviation from the normal, whether primary or secondary, results in excessive energy consumption. Good treatment demands their separation, because to optimize the efficiency of gait we need to correct former and not interfere with latter which will disappear spontaneously when no longer required (5). Moreover, gait analysis brings the benefits of objective analysis which aids in the decision process for treatment and post-treatment assessment (6,7). Gait analysis may be used to evaluate the effectiveness of orthoses (8-12), assistive devices (13,14), and antispastic drugs (15,16) in children with CP. Gait analysis may also be used to follow long term results of surgical interventions (17-20).

The aim of this study was to evaluate the gait deviations of children with spastic CP and to allow objective criteria to physicians for clinical decision making.

Materials and Methods

Subjects were 43 patients with CP who were referred to the Gait Analysis Laboratory of Ankara University Medical School for clinical decision-making process. In order to investigate the impact of gait analysis on current treatment, gait analysis reports and medical charts of the children with spastic CP were reviewed, retrospectively. The gait patterns and the reports used in clinical decision-making were classified.

Anthropometric data including height, weight, leg length and joint width of the knee and ankle of each child was measured. Fifteen passively reflective markers were taped to bony landmarks on the sacrum, bilateral anterior superior iliac spine, middle thigh, lateral knee (directly lateral to axis of rotation), middle shank (the middle point between the knee marker and the lateral malleolous), lateral malleolous, heel and forefoot between 2nd and 3rd metatarsal head, thus modelling the lower limbs as a four-segment link system (21). After the children were instrumented with retro-reflective markers, they were instructed to walk at a self-selected speed over a 10-meter walkway over which the data capture completed. A five-camera VICON 370a system was used to record translational and angular kinematics of the lower limb segments in the sagittal, frontal and transvers planes. All kinematic data were processed using Vicon Clinical Manager software. Calibration of the motion analysis system was performed daily. Three trials were recorded in each gait analysis.

Demographic and clinical characteristics, as well as suggested interventions after gait analysis were presented in percentages of frequency, which were calculated using descriptive analysis of SPSS version 9.0. No further statistical analysis was performed.

Results

The mean±SD age of the patients was 9.5±5.2 years (between 3-22). Twenty (47%) were female. The mean±SD weight and height of the patients were 26.5±5.9kg and 131±6cm, respectively. Seventy-six percent had spastic diplegia and 24% had spastic hemiplegia. Twelve child (28%) had one or more previous operation history. The most leading gait patterns were jump gait, scissoring, crouch (Figure 1) and stiff knee (Figure 2) gait patterns. Ninety-percent of the patients were walking with either toe strike or flat foot contact.

Kinematic gait analysis revealed excessive pelvic excursion in three of the planes. Excessive hip flexion, adduction and internal rotation angles were observed in sagittal, coronal planes and transverse plane, respectively. Twenty-five per-

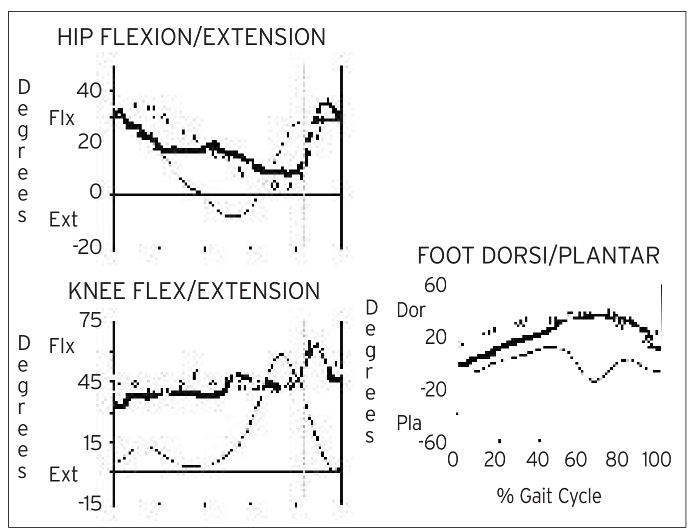

Figure 1: Joint rotation angles of hip, knee and ankle in sagittal plane indicating crouch gait pattern, with excessive hip, knee flexion and ankle dorsiflexion angles.
(The vertical axis is degrees of motion (flexion is positive). The horizontal axis is the percent of the gait cycle. The vertical line divides stance and swing (toe-off). Bold line stands for left side data, dotted line for right side and fine line for the data of age-matched normal child).

cent of the patients with spastic CP had crouch and thirty-five percent had stiff-knee gait pattern. Recurvatum was observed in the knees of 3 patients (7%) (Figure 3).

Excessive plantarflexion (PF) (37%) (Figure 4), dorsoflexion (DF) (33%) angles (Figure 1) and bony deformities (equinus, valgus-varus, invertion-evertion) (67%) were observed in the foot and ankle. "Double bump" pattern was observed in sagittal joint rotation angles of the ankle of 5 patients (12%) (Figure 4). Eighty percent of the analysis (n=34) were resulted in recommendations of a change in patient care. Ninety-five of these recommendations were specific physical therapy regimens (range of motion, stretch, and strengthening exercises, neurodevelopmental treatment for motor learning and tone normalization, and sensory integration for a variety of motor and arousal features), 49% bracing (solid ankle foot orthoses) , 46% botulinum toxin injections (10-15IU/kg-body weight to iliopsoas, hamstring and gastrosoleus muscles in multilevel injection technique) and 7% were surgery (corrections for foot deformities and lengthening operations for iliopsoas, hamstring and gastrosoleus muscles).

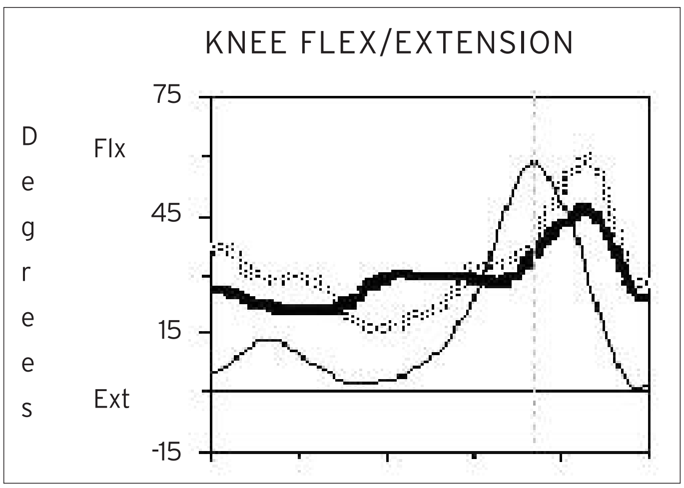

Figure 2: Joint rotation angles of knee in sagittal plane with stiff-knee gait pattern
(The vertical axis is degrees of motion (flexion is positive). The horizontal axis is the percent of the gait cycle. The vertical line divides stance and swing (toe-off). Bold line stands for left side data, dotted line for right side and fine line for the data of age-matched normal child).

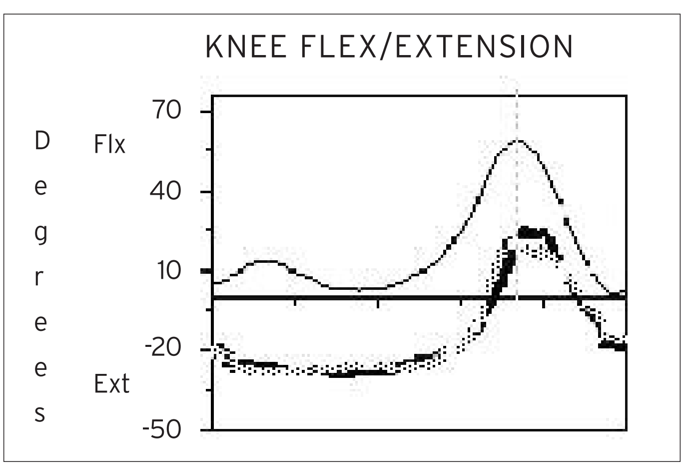

Figure 3: Joint rotation angles of knee in sagittal plane with genu recurvatum gait pattern (The vertical axis is degrees of motion (flexion is positive). The horizontal axis is the percent of the gait cycle. The vertical line divides stance and swing (toe-off). Bold line stands for left side data, dotted line for right side and fine line for the data of age-matched normal child)

Discussion

Gait Laboratory of Ankara University Medical School has started performing gait analysis and data interpretations in 1997. For the last two years, all ambulatory patients with CP, with or without a walking aid, has been evaluated and data interpretations have been discussed with the referring physicians. Spastic CP can cause significant deviations in gait pattern either primary or adaptive due to coping mechanism. By evaluating the primary gait deviations with the help of gait analysis, treatment strategies can be planned more precisely.

In this study, kinematic analysis revealed excessive pelvic excursion in three of the planes in almost all of the patients with CP, which showed the higher energy consumption during walking. In general, the hip flexors, adductors and internal rotators are dominant over their antagonists, so hip flexion, adduction and internal rotation deformity is the rule. Since this puts the hip extensors, abductors and external rotators at a disadvantage, the individual is forced to use weight shifts of the upper body to compensate which results in excessive pelvic excursions.

Excessive hip flexion and adduction were observed in sagittal and coronal planes, respectively. Excessive hip flexion was primarily due to spasticity and/or contracture of hip flexor and weakness of hip extensor muscles. Secondarily, it was together with excessive knee flexion and ankle dorsiflexion as a part of crouch gait pattern. In the coronal plane, excessive hip adduction was primarily because of spasticity of hip adductor and weakness of hip abductor muscles. Pseudo-adduction secondary to excessive internal rotation of the hips in transverse plane, especially in the first half of the stance, was remarkable. Overactivity of the hip adductors on the swing side often causes "scissoring gait" with the result that the individual catches the swinging limb on the stance limb. Hip deviations in transverse plane

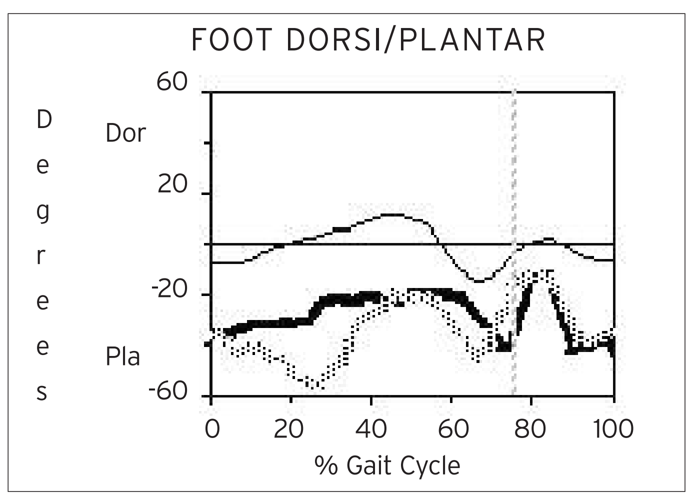

Figure 4: Joint rotation angles of ankle in sagittal plane with excessive ankle plantarflexion of both ankles and double bump pattern at the left side (The vertical axis is degrees of motion (dorsiflexion is positive). The horizontal axis is the percent of the gait cycle. The vertical line divides stance and swing (toe-off). Bold line stands for left side data, dotted line for right side and fine line for the data of age-matched normal child)

were mainly secondary to bony deformities and malrotation which were the results of hyperactivity and inbalance of hip flexor, internal rotator and adductor muscles. This excessive internal rotation of the hips limited adequate step length and was compensated with trunk movements.

The most common gait abnormalities of the knee in patients with CP occur in the sagittal plane. Rotational problems were mainly secondary to femoral anteversion. Based on the experience gained from performing gait analysis on more than 588 patients with spastic CP, Sutherland and Davids described four primary gait abnormalities of the knee: jump knee, crouch knee, stiff knee, and recurvatum knee (22). In stance, the usual problem is abnormal position (usually a static or dynamic flexion contracture), whereas in swing the common difficulty is an inadequate range of motion. In swing, the usual causes of inadequate motion are inadequate acceleration forces of the hip flexors and triceps surae, and co-spasticity of the hamstring and rectus femoris. Co-spasticity of the rectus femoris and hamstrings commonly produces a stiff-knee gait, leading problems with foot clearance in swing. This is frequently compensated by hip abduction to circumduct the swinging limb.

In this study, genu recurvatum was observed in 3 patients. In one of the diplegic patients, genu recurvatum was due to weakness of hamstring muscles, after hamstring release operation. And the other two spastic diplegics had excessive ankle plantarflexion-knee extension couple. In midstance, the knee moves into hyperextension with a premature heel rise accompanied by excessive ankle plantar flexion. "Double bump" pattern was observed in sagittal joint rotation angles of the ankle. Knee recurvatum results from excessive and premature action of a highly spastic soleus and quadriceps.

Abnormal pre-position of the foot at initial contact, premature heel rise in stance and inadequate foot clearance in swing were the most common gait deviations in CP. In this study excessive PF, excessive DF and bony deformities (equinus, valgus-varus, invertion-evertion) were observed in foot and ankle. Excessive PF was due to weakness in tibialis anterior muscle (slap gait pattern) and spasticity or tightness in gastro-soleus muscle. Excessive DF of the ankle was either secondary to bony deformities or iatrogenic to staged operations starting with achilles tendon release, although hip flexor and hamstring muscles were overactive, too (a component of crouch gait). In spastic hemiplegic patients, because of the spasticity at gastrosoleus and tibialis posterior muscles, adduction of forefoot, and inversion and equinovarus deformities were observed at foot and ankle. However, in spastic diplegic patients spasticity at gastrosoleus and peroneus brevis muscles leaded to supination and abduction of forefoot and equinovalgus deformity of foot and ankle. At swing phase drop foot and foot drag were the most prominent findings. A child with spastic diplegia will commonly have internal rotation of the leg and foot secondary to pes valgus with forefoot abduction and/or external tibial torsion.

Eighty percent of the analysis (n=34) were resulted in recommendations of a change in patient care. Ninety-five of these recommendations were specific physical therapy regimens, 49% bracing, 46% botulinum toxin injections and 7% were surgery. Patients who were recommended surgery and botulinum toxin injections were also received physical therapy and bracing interventions. Gait analysis is highly recommended in determining the effect of botulinum toxin injections in CP patients (15,16,23).

In this study, 12 patients (28%) had one or more previous operation history. All of the operations had been done on staged, single joint procedures. The most leading pattern after operations was crouch gait which was mainly due to the weakness of gastrocnemius muscle. One girl had an excessive knee hyperextension because of hamstring weakness after hamstring release operation. Surgical treatment of children with CP has changed from staged, single joint procedures to comprehensive simultaneous bony and soft-tissue corrections. This regimen of treating multiple joint levels and planes of abnormality is subject to error when based solely on the clinical examination. A more scientific evaluation can be provided by the use of clinical gait analysis (24).

Johnson et al. suggested that many patients with spastic diplegia, despite having a static brain lesion, will have progressive deterioration of their walking ability in childhood and adolescense. Serial gait assessment provides an objective means of following the direction of change over time and also of comparing the changes resulting from therapeutic interventions (25).

In conclusion, gait analysis is a tool that enables the clinicians to differentiate gait deviations objectively. It serves not only as a measure of treatment outcome, but also as a useful tool in planning ongoing care. When used together with traditional clinical assessments, computerized gait analysis is a useful technology in the management of patients with CP.

References

1. Bax MCO. Terminology and classification of cerebral palsy. Dev Med Child Neurol 1964;6:295-7.
2. Molnar GE. Rehabilitation in cerebral palsy. West J Med 1991; 154: 569-72.
3. Russman BS. Rehabilitation of the pediatric patient with a neuromuscular disease. Neurol Clin 1990; 8: 727-40.
4. Binder H, Eng GD. Rehabilitation management of children with spastic diplegic cerebral palsy. Arch Phys Med Rehab 1989; 70: 482-9.
5. Gage JR. Gait analysis in cerebral palsy. Oxford: Mac Keith Press, 1991.
6. Sutherland DH. Disorders of motor control. In: Gait disorders in childhood and adolescence Williams &Wilkins Baltimore 1984: 128-51.
7. Lee EH, Goh JC, Bose K. Value of gait analysis in the assessment of surgery in cerebral palsy. Arch Phys Med Rehabil 1992; 73: 642-6.
8. Radtka SA, Skinner SR, Dixon DM, Johanson ME. A comparison of gait with solid, dynamic, and no ankle-foot orthoses in children with spastic cerebral palsy. Phys Ther 1997; 77: 395-409.
9. Abel MF, Juhl GA, Vaughan CL, Damino DL. Gait assessment of fixed ankle-foot orthoses in children with spastic diplegia. Arch Phys Med Rehabil 1998; 79: 126-33.
10. Carlson WE, Vaughan CL, Damiano DL, Abel MF. Orthotic management of gait in spastic diplegia. Am J Phys Med Rehabil 1997; 76: 219-25.
11. Wilson H, Haideri N, Song K, Telford D. Ankle-foot orthoses for pre ambulatory children with spastic diplegia. J Ped Orthop 1997; 17: 370-6.
12. Rethlefsen S, Kay R, Dennis S, Forstein M, et al. The effects of fixed and articulated ankle-foot orthoses on gait patterns in subjects with cerebral palsy. J Pediatr Orthop 1999; 19: 470-4.
13. Logan L, Byers-Hinkley K, Ciccone CD. Anterior versus posterior walkers: a gait analysis study. Dev Med Child Neurol 1990; 32: 1044-8.
14. Greiner BM, Czerniecki JM, Deitz JC. Gait parameters of children with spastic diplegia: a comparison of effects of posterior and anterior walkers. Arch Phys Med Rehabil 1993; 74: 381-5.
15. Sutherland DH, Kaufman KR, Wyatt MP, Chambers HG et al. Double-blind study of botulinum A toxin injections into the gastroc-

nemius muscle in patients with cerebral palsy. Gait Posture 1999; 10:1-9.

16. Wissel J, Heinen F, Schenkel A, Doll B, et al. Botulinum Toxin A in the management of spastic gait disorders in children and young adults with cerebral palsy:a randomized, double-blind study of "high dose" versus "low-dose" treatment. Neuropediatrics 1999; 30: 120-4.
17. Vaughan CL, Berman B, Peacock WJ. Cerebral palsy and rhizotomy: A 3-year follow-up evaluation with gait analysis. J Neurosurg 1991; 74: 178-84.
18. Subramanian N, Vaughan CL, Peter JC, Arens LJ. Gait before and 10 years after rhizotomy in children with cerebral palsy spasticity. J Neurosurg 1998; 88: 1014-19.
19. Scott AC, Chambers C, Cain TE. Adductor transfers in cerebral palsy: long-term results studied by gait analysis. J Pediatr Orthop 1996; 16: 741-6.
20. DeLuca PA. Gait analysis in the treatment of the ambulatory child with cerebral palsy. Clin Orthop 1991; 264: 66-75.
21. Apkarian J, Naumann S, Cairns B. A three-dimensional kinematic and dynamic model of the lower limb. J Biomec 1989; 22: 143-55.
22. SutherlandDH, Davids JR. Common gait abnormalities of the knee in cerebral palsy. Clin Orthop 1993; 288: 139-47.
23. Thompson NS, Baker RJ, Cosgrove AP, Corry IS et al. Musculoskeletal modelling in determining the effects of botulinum toxin on the hamstrings of patients with crouch gait. Dev Med Child Neurol 1998; 40: 622-5.
24. DeLuca PA, Davis RB, Ounpuu S, Rose S, et al. Alterations in surgical decision making in patients with cerebral palsy based on three-dimensional gait analysis. J Pediatr Orthop 1997; 17: 608-14.
25. Johnson DC, Damiano DL, Abel MF. The evolution of gait in childhood and adolescent cerebral palsy. J Pediatr Orthop 1997; 17: 392-6.