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Clinical experience of gait analysis in the management of cerebral palsy*

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Abstract

This paper describes clinical experience of the use of gait analysis in the management of cerebral palsy. Recording procedures are outlined and the advantages of gait analysis in patient assessment are presented.

Introduction

The pathophysiology of cerebral palsy is so complex that a more detailed analysis than that obtainable by standard methods of examination is required for treatment planning.

Gait analysis provides both long lasting documentation of movement disorders and reveals phenomena which are invisible to the eye such as forces, muscle activity and bursts of rapid motion. In studying cerebral palsy, the movements of head, trunk and large body segments as well as those of the feet and hands contain valuable information. Recordings with high spatial resolution such as are obtainable by cinephotography are therefore required; stick figures are sometimes insufficient.

Experience in a busy cerebral palsy clinic has demonstrated that the long term management of these patients is greatly facilitated by gait analysis. This technique has also played a decisive role in improving treatment programmes during the past 15 years.

The instrumentation employed differs little from that of other clinical gait laboratories. It was designed primarily for children and adults with cerebral palsy and other neurogenic disorders with orthopaedic problems and consists of two transparent force platforms KISTLER model Z 4305 with a natural frequency of 500 Hz; three high speed cameras LOCAM; a six channel electromyography system using radiotelemetry; a digitizing tablet for film evaluation and a connected minicomputer with magnetic discs and a matrix printer.

To date, the gait laboratory has been used to record all ambulatory patients who needed orthopaedic surgery or functional bracing. Considerable benefits have accrued from the follow-up assessment of these patients in the gait laboratory with observation periods up to 12 years. The pre- and postoperative evaluations of patients with hip adductor transfers to the ischial tuberosity (Baumann et al, 1978), distal hamstring lengthening (Baumann et al, 1980) and intertrochanteric femoral osteotomies (Baumann, 1981) have led to an improvement in the treatment programmes by modifying some of the operative procedures and changing the timing of others. They have also provided an improved insight into the benefits and limitations of the three main treatment modalities in cerebral palsy, that is, physiotherapy, orthotics and orthopaedic surgery.

Patients with cerebral palsy suffer from brain damage acquired before, during, or shortly after birth; the basic disorder is non-progressive. Early physiotherapy within the first weeks and months of life may improve some brain functions by stimulating compensatory mechanisms in a still plastic nervous system. Later on, treatment can only help to achieve optimal use of the remaining functions and inhibit the

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development of secondary deformities. The speed of development of the latter appears to run parallel to the rate of growth. Children with cerebral palsy are born without musculo-skeletal deformity and, ideally, good treatment should fully prevent such deformity.

Gait analysis assists an evaluation of the functional effect of the primary disorders of neuromotor control by the brain such as spasticity, athetosis, ataxia and hypotonicity. In addition, it can demonstrate the practical importance of muscle contractures and secondary bone deformity. The changes in the movement patterns of these patients usually develop slowly over years, as a result the important role of gait analysis in follow-up studies is widely appreciated by clinicians and many authors have published studies in this field.

Clinical application of gait analysis

The clinical application of gait analysis in cerebral palsy has demonstrated important phenomena either caused by natural developments alone or in connection with treatment. Spastic crouch gait, particularly its variant produced by overlengthening of the Achilles tendon, was elucidated by Sutherland and Cooper (1978) who showed that the Achilles tendon lengthening is a particularly hazardous procedure with many contra-indications in spastic cerebral palsy in spite of the fact that it is still the most common operation for this condition (Sutherland 1980). Feldkamp (1979) has carefully described the correlations between the severity of spastic symptoms in cerebral palsy and gait parameters such as step length. Fleiss (1978) has used a force plate not only for evaluation and documentation in children with spastic disorders of movement of cerebral origin, but also for feed-back therapy, in order to improve gait characteristics under voluntary control by the patient.

The author's personal experience is based upon the use of standardized slow motion cinematographic recordings using short exposure times of 1 or 2 ms, an exposure rate of 50 pictures/sec and orthogonally placed cameras moving on rails that can track the patient during locomotion activity. The value of this technique for planning and evaluating natural development and treatment effects in cerebral palsy is beyond doubt (Phelps, 1967). This may be illustrated by describing a typical case whose management was monitored in this way. A patient with infantile spastic hemiplegia, was treated at the age of 7 years, by Achilles tendon lengthening for equinus foot deformity leading to an excellent result. A severe equino-cavo-varus deformity of the foot developed, however, during the growth spurt of puberty. The combination of further operative correction at the level of the foot and leg with intertrochanteric femoral osteotomy for derotation and long term physiotherapy, resulted in an almost normal walking pattern by the age of 17 years. In order to maintain the equilibrium of muscle length around the ankle joint, the patient continues to use a night splint with the ankle joint at right angle. She still shows a small deficit in active knee extension and weak propulsion by her foot on the spastic side.

This is an example of the possible prevalence of secondary effects within the musculo-skeletal system over those of the primary neurological disorder and the importance of optimal orthopaedic management in spite of a persisting neurological deficit.

On the basis of the long term results observed following Achilles tendon lengthening and in some cases of gastrocnemius recession in different gait laboratories, a policy was adopted which has almost completely succeded in preventing such operations by a combination of physiotherapy and the use of ankle-foot orthoses for positioning at night. In some instances these had to be supplemented by functional ankle-foot-orthoses with a solid ankle made from polypropylene.

Another advantage of gait analysis in cerebral palsy is represented by improved techniques in treating hamstring contractures of patients with spastic diplegia and tetraplegia. Comparison of pre-operative recordings of knee flexion/extension during walking with recordings made at an average interval of 32 months following distal hamstring lengthening, showed satisfactory improvement in knee extension during late swing and early stance phase. Concern remains regarding the regular loss of knee flexion occurring around mid-swing following these operations (Baumann et al, 1980). So far, increased use of so-called fractional lengthening of muscles, instead of tendon-elongation, applying multiple transactions of the aponeurotic tendinous sheets on and within the muscle appears to provide a better equilibrium between the gain in knee extension while the hip is flexed and the conservation of sufficient contractility of the hamstrings for bending the knee and thus functionally shortening the leg during its forward swing.

In spite of successful operations the preferred policy is to prevent hamstring contractures or treat them with a daily programme of exercises by very slow stretching.

Valuable documents on specific phases of movement are obtainable from stroboscopic photographs, multiple exposures on photographic film, serial drawings of body contours with superimposed force vectors (Sutherland and Cooper, 1978) or by stick figures obtained from computer assisted print-outs of body marker positions. Multiple exposures are informative, easy to obtain and relatively economical when obtained using a series of electronic flash units and a suitable camera. A commercial timer permits recording up to 10 pictures (Fig. 1).

In cerebral palsy, the coordination of force generation by different muscles is disturbed. The measurement of ground reaction forces using force plates must logically reflect the most important functional impairment in locomotion produced by this part of the disorder. A prominent feature in force plate recordings from patients with spasticity of cerebral origin is the contrast between high but short peak forces connected with loading of the foot, breaking and supporting, and both low and slowly developing sagittal shear forces during the phase of propulsion in the second half of stance phase (Fig. 2). This can be explained by the natural contraction of many muscles, both flexors and extensors during the period of limb loading (positive supporting reaction), while the rapid, forceful activity of the extensors for propulsion is made less effective by the pathological co-contraction of the flexors in connection with their rapid stretching due to extensor activity.

Fig. 1. Multiple exposure photograph showing a typical pattern of gait in a 10 year old boy with cerebral spasticity and moderate hamstring contractures.

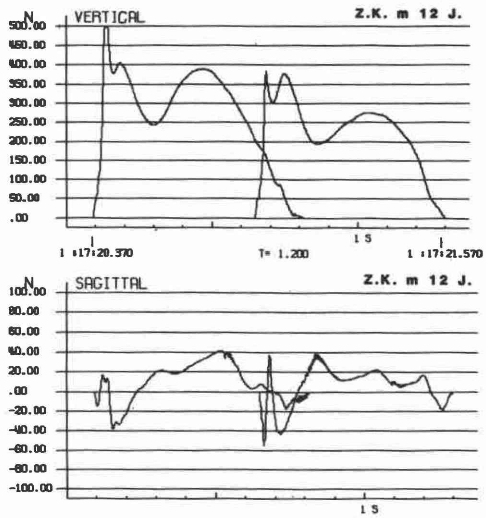

Fig. 2. Typical force platform recordings for left and right foot in spastic diplegia from a boy age 12 years. High initial vertical force peaks, slowly developing propulsive force in the sagittal direction.

The vector of floor reaction forces can be used to calculate approximate moments produced by these forces at the major joints. In addition, force plates may be used to calculate the energy output for walking (Cavagna, 1975). Normally, the vectors of floor reaction forces tend to pass very near the centres of rotation of the major joints. In patients with spasticity, the distance of these force vectors from the joint centres is often markedly increased, leading to much larger passive moments.

Summary

A number of procedures for gait analysis have proved useful for the management of patients with cerebral palsy. They have provided deeper insight into the pathophysiology of locomotion in the presence of spasticity, resulting in better methods of treatment. In addition, both kinematic and kinetic recordings have yielded otherwise unobtainable documents for monitoring the progress of the patients and their walking ability, as well as offering possibilities for the evaluation of the short and long term effects of physiotherapy, orthotics and operative procedures. There are technical inadequacies in gait recording and measuring techniques which still have to be resolved. A high spatial and temporal resolution would increase its value for practical purposes.

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