

Motion Times

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The World's first mobile gait laboratory

The Gait Laboratory at the Central Remedial Clinic is unique within the Irish Health Care System. For the past fifteen years CRC has offered this specialised service nationally, providing comprehensive assessment, diagnosis and management solutions for children and adults with walking disability. The objective information provided by gait analysis enables clinicians to differentiate between a number of conditions, to make recommendations for surgical, medical and conservative interventions with confidence, to monitor the progress of each client following intervention and to objectively evaluate the different treatments. The laboratory and team are recognised internationally as leaders in their field, resulting in numerous visits from abroad each year by medical teams wishing to replicate CRC's service in their own countries.

Almost 40% of gait laboratory clients are from outside Dublin, resulting in families often having to travel long distances to gain the benefit of this specialised service. In general, a gait assessment can last anywhere between 1.5 and 2.5 hours and children are often tired and tight in their muscles by the time they begin their analysis which can lead to difficulties with compliance and in capturing representative data. For some families the procedure can mean a very tiring fourteen hours round trip or an expensive overnight stay.

Part of the Irish government's Health Strategy is to ensure that treatment or care is provided in the most appropriate setting and that patients should receive a clear benefit from their contact with the health system. Additionally the report *"Towards an Independent Future"* on provision for people

with disabilities states amongst the main recommendations that *"Regional child assessment teams should be established in each health board area"*, and suggests that *"Centralisation may result in rural clients being unable to avail of services"* and pinpoints the need for *"a co-ordinated service...introducing a team approach to reduce the sense of isolation of therapists"*. Additionally, the National Children's strategy recommends that children with a physical disability are entitled to the services they require to fulfil their potential and emphasises the need to improve the point at which services are accessed by children and their families. In recent years CRC has embraced this caring philosophy by providing regional assessment teams to various parts of the country and more recently in establishing permanent services in Waterford and in Limerick. *Up to now it has not been possible to offer gait analysis as part of these regional services.*

Mobile Gait Laboratory

Gait analysis is a laboratory-based service located in a purpose-built facility at Dublin. Until recently technology was not advanced enough for such a service to be anything other than laboratory-based. However, due to recent developments in the *Codamotion* analysis system used at CRC, which is manufactured by Charnwood Dynamics, this situation has dramatically changed. As a result of developing a new system for use in the International Space Station through a contract with MIT and NASA, Charnwood Dynamics have developed a new system called CX1, which is very small, easily transportable and can work from a laptop.

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Gait Analysis goes on the road



Rory O'Sullivan and Mike Walsh.

On route to Limerick is what is believed to be the world's first truly portable gait analysis lab. Mike Walsh is the CRC gait lab manager (right).

"Working with Coda has given us the chance to develop our outreach services. For the first time we can quickly set up our portable gait lab, we don't need a dedicated building and all our essential equipment can travel in an estate vehicle.

This is important work as both our non surgical and surgical strategies can make the difference to a child walking independently or being confined to a wheelchair, with all the implications that brings throughout the child's life. Our new ability to transport the technologies that will deliver real time analysis can and will extend the opportunities of our work."

At the beginning of 2004 CRC purchased three CX1 motion analysers, two AMTI portable force plates and a 16-channel wireless Noraxon EMG system. Charnwood Dynamics facilitated the hardware and software integration of these three systems effectively providing a "turn key" package for setting up as a mobile unit. CRC designed and commissioned the building of a fibre glass walkway which measures 15 metres in length and 1.5 metres in width when fully assembled, and, which allows the force plates to remain flush with the walkway. This walkway has been developed with fifteen single and transportable pieces which clip firmly together with a special side clip. A Panasonic video camera with Dolly wheels as well as a DVD recorder and LCD monitor were also purchased to allow quality video capture of clients walking.

An additional part of the mobile project was in the area of telemedicine. Videoconferencing (VC) facilities were installed in the gait laboratory with projection to a large wall-mounted screen in the lab. A second mobile VC unit was purchased to go on the road with the mobile lab. While the data acquisition capabilities can now be moved out of the laboratory, the core expertise remains in CRC. Exploitation of modern telecommunications facilities allows for medical recommendations



Figure 1: Kate Hanley seen here with Judith her mother was our first client for gait analysis with the new mobile system.

to be made centrally by an expert team based on data captured remotely.

A first pilot of the mobile gait laboratory was run in early Summer 04 in CRC's centre in Limerick. Limerick was chosen because CRC own a large building in that city from where they provide specialised seating and client



Figure 2: The mobile gait analysis lab "fast and easy to set up for reliable real time data capture".

technical services. Pilot testing was carried out on an actual patient (figure 1) and was very successful with the acquisition of a full and clean 3-D kinematic, kinetic and EMG data set. The first official outreach clinic was conducted a few weeks later and a live clinical reporting session was done from Limerick to Prof. O'Brien's clinic in Clontarf. Effectively, three sources of data were communicated live over the videoconference, namely, laptop data for the kinematic, kinetic and EMG graphs etc., video data to allow the team to actually see a client walk, and data from a docucamera which allowed Prof. O'Brien to read clinical examination measures and see doctors' referral letters, etc. This real time reporting session was also very successful and Prof. O'Brien dictated his medical and surgical recommendations via VC.

Effectively, these children received their specialised assessment with full medical recommendations from an expert team without having to travel out of the local region. The feedback which has come from the parents of these children is overwhelming and very gratifying so far. They are absolutely delighted with not having to travel the long and costly distances to Dublin for this assessment. Additionally, local therapists can attend the reporting sessions and become more closely involved with the decision making process in the clients whom they treat. The outreach service also provides them with direct access to a large and specialised knowledge base which the very experienced gait laboratory team possesses. This will be

A New Coda Laboratory in Israel

Uri Givon MD, Medical Director • Motion Analysis Laboratory and Human Performance Center, Sheba Medical Center, Tel Hashomer, Israel.

"The Sheba Medical Center is the largest medical facility in the state of Israel. The general and rehabilitation hospitals on the Sheba campus have more than 1,000 beds, and provide services to all ages and all pathologic conditions. After we have identified the need for a modern motion analysis system in the hospital, a search committee was created to search for the best system available.

The committee was headed by the director of the rehabilitation hospital, and included physicians and therapists involved in the treatment of adults and children, amputees, paraplegics, orthopaedic and neurological conditions. All of these professionals met and defined the necessary abilities of the system to be installed in the hospital. After reviewing the needs, the committee decided that only an active marker system is versatile enough to answer our needs. The next step in the process was to review the available systems, and the Coda CX-1 system was chosen."

The Laboratory at the Sheba Medical Centre will be featured in the next issue of Motion Times.

further enhanced with a series of regular workshops and educational lectures which will form part of the outreach service. One large and immediate benefit to the Irish Health Service and local Health Boards is that the mobile clinic provides a low cost solution for providing gait analysis services in local Health Board areas. Each Health Board, whilst they might have a desire to provide specialised services locally, would find it impossible to finance and develop gait laboratories in each area. Likewise the size of the population requiring the service locally would not justify the investment. By providing a mobile laboratory CRC has effectively provided a low cost solution which Health Boards can contract out (figure 2).

The mobile lab was piloted successfully in Waterford city in October and the first official outreach clinic commenced in early November.

The importance of a Clinical Gait Analysis Lab

Prof. Timothy M O'Brien, MCh, FRCSI - Born in 1951 at Loughrea, County Galway, Ireland. He is married to classmate Dr Mary Jennings who he describes as his lifelong friend, they have three children. His qualifications are: - Undergraduate training at University College Galway 69-75. MB, BCh, BAO June 75. FRCSI 79. MCh 83. Fellowships in Paediatric Orthopaedics at the Hospital for Sick Children University of Toronto Canada 83-84 with Prof. Robert B Salter and the Children's Hospital, Harvard University, Boston 84-85 with Prof. John E Hall. Prof. O'Brien was the Abraham Colles Professor of Orthopaedic Surgery at the Royal College of Surgeons, this being the first chair of Orthopaedic Surgery in Ireland. Director of Postgraduate Training in Orthopaedics in Ireland 91-01 and Chief of Department of Orthopaedic Surgery, Mater Misericordiae Hospital from 90 through 94.

In 1990, Prof. O'Brien established the clinical Gait Analysis Lab at the Central Remedial Clinic at Dublin and has remained its Director since this time.



Prof. Tim O'Brien (second from right) with Joe Gallagher, Ann Jenkinson and Mike Walsh.

"Gait analysis has come a long way since I first met David Mitchelson over twenty years ago at a conference. I realised that his automatic identification by Coda of individual markers was a major advance at the time. I had spent many days in Boston trying to track markers manually and the automatic identification even of superficial markers was a great improvement. Now we have progressed to models using Euler's mathematics, and the data is consistent and reproducible. The Central Remedial Clinic has been committed to a Gait Analysis Laboratory to provide the best care for its patients for 15 years. During this time we have shared our knowledge and exchanged ideas with a large number of international visitors to the Laboratory and we have hosted the British Paediatric Orthopaedic Society and the British Cerebral Palsy Society at our Laboratory as well as the Swedish Paediatric Orthopaedic Society. ESMAC was hosted by the Laboratory in 1996. We are still working with Coda and breaking new ground with what I believe is the world's first truly portable gait analysis system. We hope that the next fifteen years will be as fruitful and as beneficial to our patients as the last".

Gait analysis is the scientific method of recording and analysing gait in normal and abnormal conditions. Just like patients who undergo treatment to correct bony abnormality have X-rays taken to define the deformity, patients with walking abnormalities should have these properly defined before undergoing treatment. The subjective visual assessment of gait and the static measurement of joint motion are no longer adequate as indicators of the success of treatment undertaken to improve walking. For example, lengthening of the Achilles tendon may result in the loss of an equinus contracture on static clinical

examination and an apparent visual improvement with the patient making initial ground contact with the heel. However, closer analysis often demonstrated a disimprovement in walking after this procedure with the development of a crouch gait and lack of "push off". As a result, lengthening of the Achilles tendon, once the most common surgical procedure in Orthopaedic Surgery is seldom performed nowadays to improve gait in children with Cerebral Palsy.

In our laboratory we define normal walking as "walking at a comfortable pace where both lower limbs are in contact with the ground together (double support) for 20% of the time". When people wish to walk at a faster pace the period of double support is reduced. In contrast, when patients have a painful lower limb the stance time of that lower limb tends to be reduced while the stance time of the normal limb is increased. These subtle differences mean that, even though "normal gait" is so standard, it is easy to recognise a friend's walk on hearing them approach. One can even more readily recognise abnormal patterns such as a dropped foot or an antalgic gait.

To understand abnormal gait it is first necessary to study normal gait as this provides the standard reference to which the gait of any patient is judged. The term "normal", in relation to gait analysis, refers to the average pattern of walking in both sexes and includes a wide range of individuals of varying age and body shape. While we produce mean and standard deviation data for the objective data collected in the laboratory, we also recognise that certain normal individuals walk with different "normal" patterns. For example, a rolling pattern is common in heavier individuals while other normal people walk with an occasional skip. We are particularly careful to compare an individual patient's pattern with an age and weight related normal. This is especially important in older patients where double support tends to be prolonged with increasing age.

It is also important to realise that while a patient's gait may differ in some way from normal, this does not necessarily mean that this deviation is undesirable. Many gait abnormalities are a compensation for some problem experienced by the patient, and while they may be considered abnormal they are nonetheless useful. For example in an individual patient the abnormal pattern of walking may indeed be the most efficient way of walking for that particular person. In our

experience, patients with hemiplegic cerebral palsy who have a leg length discrepancy may initially be helped by the development of an equinus contracture which equalises their leg lengths. In other circumstances, contractures and the development of deformities may lead to a very inefficient pattern of walking. For example, a recurvatum deformity of the knee serves no useful purpose.

The role of gait analysis is to identify characteristic individual patterns of walking to allow diagnoses to be made and confirmed, to identify inefficient and abnormal patterns and to predict the outcome of surgical or other interventions designed to improve both the pattern and efficiency of walking.

In the management of walking disorders, gait analysis has allowed us to replace empirical treatments, such as elongation of the Tendo Achilles, with surgical recommendations based on objective data. Gait analysis is an example of how technological advance has re-defined our scientific knowledge. Historically there have been many difficulties in interpreting motion.



Figure 3: Horse-Racing at Epsom by Theodore Gericault (1821) Louvre, Paris.

Artists in the 19th century depicted the galloping horse with its four hooves off the ground and its legs extended (**figure 3**). Today the image of these "flying" horses looks very strange indeed but in the 19th century this was the accepted depiction of racing horses. The photographic developments pioneered by Muybridge demonstrated that this was incorrect and the galloping horse only left the ground in the flexed position. Technology can indeed alter our accepted concepts and this is what gait analysis has done. We use our clinical gait analysis laboratory as a cost-effective monitor of our patients with cerebral palsy and other neuromuscular and orthopaedic conditions. In relation to how children walk, gait analysis has allowed us to identify the role of the rectus femoris in stiff knees and the development of a crouch gait due to subacute or chronic rupture of the knee extensor mechanism. It is particularly helpful in differentiating idiopathic toe walking from mild diplegia.

Using Coda to assess spinal movement

True skeletal movement at the low back is difficult to measure non-invasively as this region is enclosed in a mobile soft tissue envelope.

Mr. John Rice, Consultant Orthopaedic Surgeon, joined our team for a period of two years to see if an adaptation of motion analysis could be used to assess spinal movement. In a preliminary study we demonstrated that sagittal movement of the lower spine involves not only movement of the lumbar region but also movement of the lower part of the thoracic spine (Rice et al. 2002). In that study we proposed that the "functional low back" extends from the sacrum to the mid thoracic spine and that movement of this region can be regarded as the movement between the immobile section of the thoracic spine and the sacro-pelvis. We then designed surface mounts that we fitted to the sacro-pelvis and the proximal thoracic spine.

These mounts retained a constant relationship to the underlying skeleton, unaffected by skin movement, and allowed us to accurately measure movement of the "functional low back". Our Coda MPX system then allowed us to isolate and record motion of both the low back and the lower limbs joints simultaneously (figure 4). We performed two investigations using this set up. The first one was to investigate the toe touching test and the second to look at spinal movement during normal walking. Each subject had four surface mounts, each of which had three LED markers, attached to the following sites:

1. the upper thorax
2. the sacro-pelvis
3. the femur and
4. the leg.

The upper thoracic mount was stuck to the skin 5 - 10 cm inferior to the vertebra prominens at the base of the neck. We have previously demonstrated that the skin at this site maintains a constant relationship with the underlying skeleton (Rice et al, 2002). The pelvic construct was attached to the pelvis at the anterior and posterior iliac spines and the femoral mount was attached to an encircling strap that was applied between the lateral and medial epicondyles of the distal femur. In a similar fashion the leg mount was attached to a strap encircling the lateral and medial malleoli. All four mounts were aligned vertically and parallel

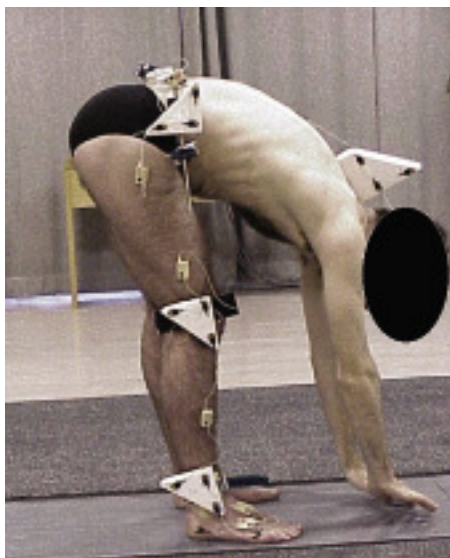


Figure 4: Volunteer with mounts attached performing the toe-touching manoeuvre.

to each other when viewed in the anatomical transverse plane before the manoeuvres were carried out.

A group of eight volunteers were enrolled to perform a series of toe touching manoeuvres with the mounts attached as described. Clinicians commonly use the "toe touching" manoeuvre to assess low back function. This involves asking patients to bend forward and attempt to touch their toes. We found that flexion during the toe touching manoeuvre involves not only low back and hip movement but also ankle plantar flexion and a varying degree of knee movement. The low back and ankle movements were highly correlated within each subject to an extent that suggests a functional connection between the lower limb and low back movements (figure 5).

The significance of our work is two-fold.

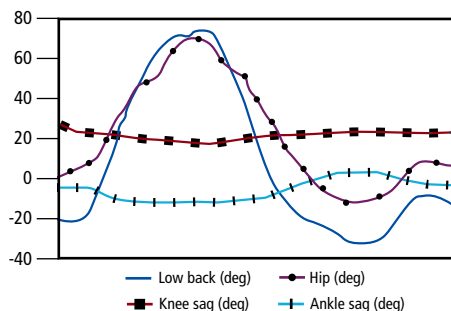


Figure 5: Dynamic movement at the low back, hip, knee and ankle is represented graphically for a toe touching and recovery to a position of trunk extension. In this graph flexion is represented as an upward deflection.

Firstly, we emphasise that the toe touching test represents a combined movement of the low back, the hips, the knees and the ankles and it is reasonable to suggest that abnormalities of these joints may affect the clinical relevance of the test as an indicator of back movement.

Secondly, we point out that the guidelines of the American Medical Association in using the test to determine hip movement are incorrect as they do not take into account the effect that knee and ankle movements make on the estimation of hip movement.

In the second investigation Mr. Rice used the same setup to measure the kinematics of the "functional low back" during normal gait. A number of volunteers when asked to walk by the Coda MPX systems in our Gait Lab with the markers attached as in Fig. 1. In this study we made no attempt to model the spine. We noted that movements at the low back were biphasic. The greatest low back movements were found to occur in the transverse plane (mean 23 degrees) while a mean of 17 degrees of movement occurred in the coronal plane and only 5 degrees of movement in the sagittal plane. These findings confirm, while using a non-invasive technique, that there are significant ranges of movement at the low back during walking. This lends some support to the theory that rotational movement at the low back is a major component of human locomotion.

In summary we found that adapting the gait analysis system was very useful for investigating motion of the spine. We have since developed a more rigid model of the spine and hope to publish it in the near future. Fifteen children and ten adults have been tested using this model and some normal reference data has been established.

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