Dr. Joseph Hidler, Director of the Center for Applied Biomechanics and Rehabilitation Research at the National Rehabilitation Hospital in Washington DC USA is utilizing the Codamotion (Charnwood Dynamics, UK) and Lokomat robotic gait orthosis (Hocoma AG, Volketswil Switzerland) to study gait patterns in individuals following stroke and spinal cord injury in hopes of developing better therapeutic interventions.

Over the last decade, the field of neurorehabilitation has seen the proliferation of new therapies, including robotic devices, aimed at enhancing walking ability in individuals with neurological disorders. The major limitation with these new therapies is that there are no guidelines as to how patients should be trained. For example, we know from extensive studies done in spinalized rats and cats that the influence of limb loading, walking speed, and limb kinematics all play a key role in how the animal steps on a treadmill. Without adequate hip extension, for instance, cats will stop stepping. Unfortunately similar knowledge remains unknown in human populations, where therapists are often relegated to using heuristic rules rather than quantitative evidence for selecting how patients are trained.

To solve this problem, Dr. Hidler has combined the forces of a robotic gait-orthosis called the Lokomat and the Codamotion motion analysis system. The Lokomat is an exoskeleton device that has small DC motors that actuate the hip and knee joints of the patient. Underneath the Lokomat is a split-belt treadmill (ADAL3D-COP, Techmachine, France) that has force plates under each belt. Utilizing the Lokomat to address these questions rather than simple gait analysis is necessary because many of the subjects tested cannot ambulate on their own but instead require significant assistance. To quantify this assistance, Dr. Hidler’s team modified the cuffs that couple the subject to the Lokomat so that they now contain 6-axis load cells (JR3 Inc, Woodland, CA, USA). Between the Lokomat, load cells and instrumented treadmill, it is possible to identify all of the forces acting on the subject’s legs at any point in the gait cycle. Unfortunately tracking limb motion is not as easy. As a first pass, Dr. Hidler attempted to use the potentiometers on the Lokomat to track the knee and hip angles of the subject. This turned out to be futile as misalignment of the Lokomat’s hip and knee joint axes and those of the subject is a common problem. Further, the subject is not rigidly coupled to the Lokomat so that they now contain 6-axis load cells (JR3 Inc, Woodland, CA, USA). Between the Lokomat, load cells and instrumented treadmill, it is possible to identify all of the limb motion was through motion analysis.

The problem with motion analysis within the Lokomat is two fold. First, there are significant reflections throughout the device that make reflective marker-based systems difficult if not impossible to employ. And secondly, losing markers due to obstructions of the device at various points in the gait cycle is difficult to avoid.
To overcome these issues, Dr. Hidler acquired a Codamotion motion analysis system. The advantages of the Codamotion system over passive systems are that reflections from the metallic surfaces of the Lokomat and treadmill are not a problem due to the active nature of the system. In addition, because the Codamotion is active, if a marker is lost during the gait cycle, it is easy to distinguish once back in view. Over the last 3 months of testing, Dr. Hidler has found that the Codamotion has worked brilliantly in the Lokomat and is now ready for full scale testing.

With the technological bridges crossed, Dr. Hidler and his group have now begun testing individuals with stroke and spinal cord injury where they are studying the influence of walking speed, level of body-weight support, and leg kinematics on each individual subject’s gait pattern. The goal is to identify the set of training conditions through which the subject steps with the most appropriate muscle activation patterns and joint moments throughout the gait cycle. A 3-dimensional inverse dynamics model is being developed for Visual 3D (C-Motion, Rockville MD) which takes into account the Lokomat instrumentation.

Future plans include using the Codamotion and Lokomat data to develop more rigorous bio-feedback displays in Visual 3D that subjects can use during training sessions.

See us at http://cabrr.cua.edu to monitor the progress of this research.

A comparison of normal data between two clinical gait analysis labs.

Different clinical gait analysis labs use different equipment, place markers in different locations and have different “models” for finding joint centers. To what extent are the results obtained comparable? To begin an investigation of this question we here compare two sets of normal data for children between 3 and 8 years old. One set was collected using CODA equipment and software in the Motion Analysis Laboratory of the Royal National Orthopaedic Hospital Trust in Stanmore, the other at the One Small Step Gait Laboratory at Guy’s Hospital, using Vicon equipment and software. The CODA system (Charnwood Dynamics, UK) is used to track limb segment motion during Lokomat trainings.

The Stanmore data is for 12 children, and the Guy’s data is for 17 children, each group has a mean age of 5.4 yrs. Data was not different between left and right legs, and so all legs within each group were combined. For technical reasons records for two legs from the Guy’s set were rejected. Each leg provided signals for twelve kinematic variables, rotations about three orthogonal axis of the pelvis, the hip, the knee and the ankle; however coronal plane rotation at the ankle is not yet satisfactorily analysed at the time of writing this abstract.

Each signal was divided for analysis into two components: “position” and “movement”. The position is the mean value through the gait cycle and movement = signal – position. Fig 1 illustrates this dissection. This was done for two reasons: (1) work with the Stanmore normal data set has shown that, for many variables, a large part of the variation between subjects is due to variations in position rather than movement; (2) differences between labs in modelling centers of rotation would be expected to influence position more than movement.

The movements recorded by the two labs were very similar. For most variables there were no statistically significant differences between the two data sets. Only the rotations of the hip and the knee were significantly different for part of the gait cycle. These differences were largely during swing. In contrast the positions...
recorded by the two labs were statistically
different for 6 of the 11 variables
examined. It is possible to explain these
differences, at least qualitatively, as due to
the different modelling of joint centres
between the two laboratories.

It is hoped to extend this work in the future
by including:
• more age groups; so that a large
combined data base can be age stratified;
• data from other laboratories;
• kinetic variables; these may be more
model dependent than kinematic variables.

Clinical laboratories with normal data are
invited to participate in this project by
contacting
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**Fluctuations in knee angular acceleration in young and older adults during functional tasks**

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Lower limb muscle steadiness has been
shown to be greater in younger than old
people during isometric (Tracy and Enoka
2002) and isotonic (Hortobagyi et al.
2001) contractions, but no studies have
examined steadiness during functional
tasks in these two age groups.

40 young (29.3+ 0.6 (mean + SEM, range
19-41 years) and 42 older (75.9+ 0.6,
range 70-86 years) adults participated in
the study. The CODA motion analysis
system was used to track bilateral markers
placed on the ankle, knee and hip of
participants during stepping up and down
on a 20cm high box and during standing
up and sitting down on a 42cm high
armless chair. A stick figure of each leg
was created, and the angular acceleration
of the knees was measured during the
tasks. The standard deviation of angular
acceleration was calculated as the measure
of steadiness.

When analysed according to both the most
and least steady legs, the elderly were less
steady than the young when standing up on
the most steady and down on the least
steady leg. During standing and sitting
there were no differences between the two
groups (Table)

Standard deviation of knee angular
acceleration (rad.sec -2) during functional
tasks. *= significant difference between
groups (P<0.01) for the most and least
steady legs.

These CODA measurements are a useful
tool in measuring functional steadiness and
show some age related changes. Functional
steadiness may be a factor in medically
unexplained falls in older people and it
remains to be seen whether steadiness is
reduced in this group compared to people
of a similar age with a history of such falls.

<table>
<thead>
<tr>
<th>Task</th>
<th>Young</th>
<th>Older</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>Stand up</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most</td>
<td>39</td>
<td>4.14*</td>
</tr>
<tr>
<td>Least</td>
<td>39</td>
<td>5.53</td>
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<tr>
<td><strong>Sit down</strong></td>
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<td></td>
</tr>
<tr>
<td>Most</td>
<td>39</td>
<td>3.83</td>
</tr>
<tr>
<td>Least</td>
<td>39</td>
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<tr>
<td><strong>Step up</strong></td>
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<td></td>
</tr>
<tr>
<td>Most</td>
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<td>4.62</td>
</tr>
<tr>
<td>Least</td>
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<td><strong>Step down</strong></td>
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<td></td>
</tr>
<tr>
<td>Most</td>
<td>38</td>
<td>5.37</td>
</tr>
<tr>
<td>Least</td>
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<td>7.42*</td>
</tr>
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</table>
Mapping Musical Movement: The Physical Expression of Musical Individuality

Tânia Lisboa1, A. Williamon1, R. Woledge2, R. Delaney2, E. Clarke3.
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This project measures how movements made while playing a piece on the cello differ during the progression from sight reading for the first time to performing the piece from memory. Some movements (defined in this study as ‘local’) will be minimally required to execute ‘the notes’ of a given piece while others (defined as ‘global’) are associated with and enable the projection of musical expressiveness and individuality.

Our initial hypotheses are:
1. local movements become more consistent as performers become familiar with a piece and in better technical control of the instrument;
2. there is comparatively little variability between the expert performers in relation to the movements necessary for technical control;
3. global movements increase as performers work toward a performance and the individual variability between performers become greater;

Five cellists were studied; each performed four unfamiliar cello pieces on three occasions: sight-reading (SR) intermediate session (IS) memorised performance (MP). In each session each piece was recorded 4 times. Measurements were made at 50 Hz with the CODA MPX30 motion analysis system; three markers were placed on each of these eight segments: pelvis, thorax, head, right upper arm, right lower arm, right hand, the bow, and the cello.

Segment position at each time point is defined as the mean of the positions of the three markers and mean position is the average over the recording period. Segment movement at each moment (a scalar) is defined as the distance of the segment from its mean position. Mean movement is the average over the recording period. Mean speed, mean angular rotation and mean angular rotational speed were similarly defined. So far the results for only one piece have been analysed: J.S. Bach: Menuet I from ‘Seventh Suite’ (arranged and edited by D. Kadarauach).

Results for the four recordings of the piece within each session were highly repeatable. Mean movement in sight-reading is less than in any other session; there is significant increase for all segments except hand and bow in the progression from SR session to IS+MP sessions. The differences between IS and MP are individual (perhaps related to the amount of practice?). Thus, the amount of local movements (hand and bow) changes little whereas segments participating in a more global way (expressive?) change more. Bow and hand move faster than head, thorax, pelvis, upper arm, with lower arm intermediate. Speed generally increases from SR to IS and MP. Thus, speed of local movements increases (related to accuracy?) whilst that of global movements (expressive?) changes little.

For future work one may aim to examine the reasons for these trends in greater detail.

This work was supported by The British Academy