BIOMECHANICS LABORATORY

Measurement of Gait Kinematics

Object:

To illustrate how to extract a useful kinematic information and how to analyze it

Introduction

The term kinematics simply means a description of the movement in terms of the angles, positions (displacements), velocities and accelerations of the body segments and joints. Several techniques are available for the measurement of gait kinematics. Electrogoniometers (sometimes called elgons) are probably the simplest method, being just an electronic version of an ordinary clinical goniometer. Although such systems are relatively cheap and give immediate (real-time) results, their fundamental limitation lies in the need for accurate alignment of the potentiometer spindle with the joint axis of rotation. This is not always constant and may change with the joint angle. Electrogoniometer is also fundamentally limited in that while they can record ***relative*** motion between adjacent body segments (joint angles), they cannot measure the ***absolute*** motion of body segments in space.

In order to measure absolute motion of body segments, measurements must be taken with respect to a ***fixed global reference system***. Basically the optical methods are presently the most popular for clinical gait analysis. Although originally cine film was used (Sutherland & Hagy 1972), these days the most popular measurement systems are based on video-based photogrammetry. To do this, it's worth carrying out a simple 2D (sagittal plane) analysis of gait using one camera.
The simplest kinematic measurements are made using a single camera, in an uncalibrated system. Such measurements are fairly inaccurate but they may be useful for some purposes. Without calibration, it is impossible to measure distances accurately and such a system is normally used only to measure joint angles in the sagittal plane. The camera is positioned at right angles to the plane of motion (Fig.1) and as far away as possible, to minimize the distortions introduced by perspective.

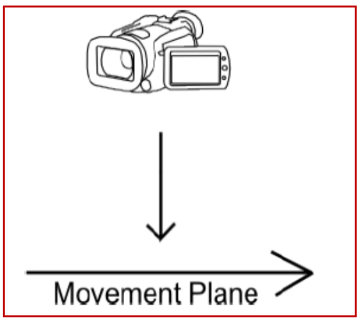

Figure.1 position of the camera with 2D analysis

To give a reasonable size image, with a long camera-to-subject distance, a 'telephoto' (long focal length) lens is used. The angles measured from the image are projections of three-dimensional angles onto a two-dimensional plane and any part of the angulation which occurs out of that plane is ignored. To achieve reasonable accuracy in kinematic measurement, it is necessary to use a calibrated three-dimensional system, which involves making measurements from more than one viewpoint. When a subject walks in front of the camera, the calibration process is reversed and two-dimensional positions are calculated for the markers fixed to the subject's limbs, so long as they are visible to the camera.

Data are collected at a series of time intervals known as 'frames'. Most systems have an interval between frames of either 20 ms, 16.7 ms or 5 ms, Thus, kinematic systems are good at measuring position but poor at determining acceleration, because of the problems of differentiating even slightly noisy data, therefore, filtration must be done. It is impossible to be perfectly accurate in digitizing the position of the markers. These small inaccuracies in each coordinate lead to what is called digitization noise in the results. Luckily this noise tends to be high frequency whereas the signal (the marker trajectories) is relatively low frequency as shown in Fig.2. So the noise can be reduced by low-pass filtering. The most common type of filter used in gait analysis is a critically damped 2nd order Butterworth low-pass filter with cut off frequency of 6 Hz.

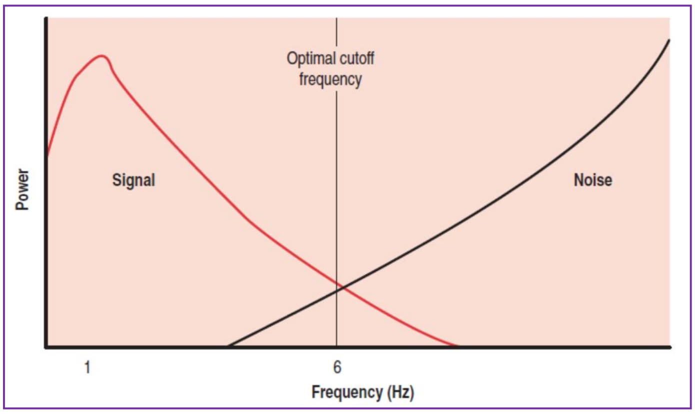

Figure.2 Frequency spectrum of the marker trajectory data.

Calculation of Segment Angles

The next job is to convert the marker trajectories into segment angles (Fig. 3). This is done by trigonometry, specifically the tangent function (opposite over adjacent):

$$\tan \theta = (y_d - y_p)/(x_d - x_p)$$

Where d and p stands for distal and proximal, respectively

Each joint (ankle, knee, hip) angle is calculated as shown in Figure 4. The angle must then be transformed to the clinical convention, based on the anatomical position. For the ankle, this means subtracting 90°.

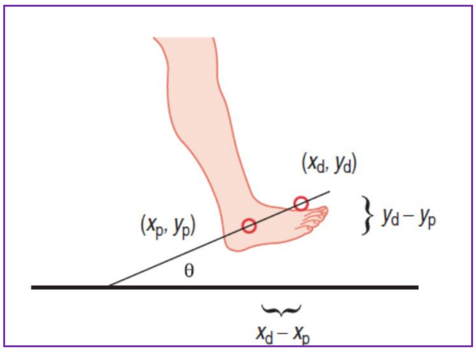

Figure.3 Segment angles are calculated by trigonometry.

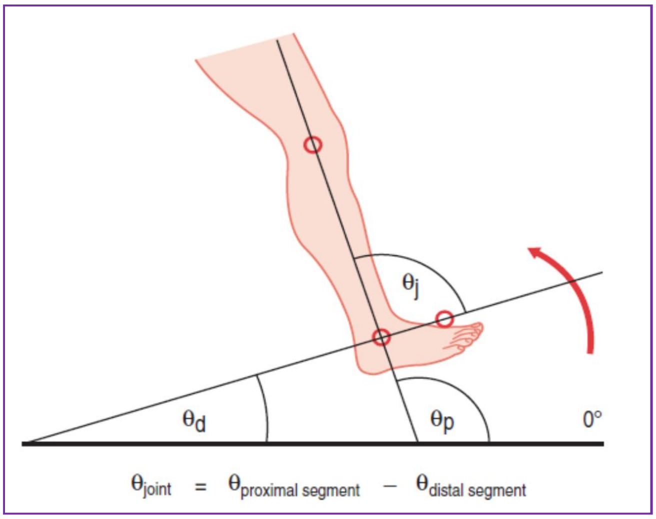

Figure.4 Joint angles are calculated from the difference between adjacent segment angles.

Procedure:

1. Use seven markers (red round stickers) to identify the location of joints' center of rotation (Fig. 5). Attached the markers at the hip (right greater trochanter), right knee (lateral femoral condyle), left knee (medial femoral condyle), right ankle (lateral malleolus), left ankle (medial malleolus), right foot (fifth metatarsal head), and left foot (left first metatarsal head).

2. Fix the camera on the tripod place the camera perpendicular to the movement plane as illustrated in Fig.1.

3. Record the movement.

4. Import the video in to the motion analysis software "tracker".

5. Determine the beginning of the movement "let it to be the initial contact frame" and the end of the movement "must be the second initial contact of the same side".

6. From the create command, select: ***Point Mass***, another window will appear, select: ***Autotracker***, choose the hip marker then follow the information appeared.

7. Take the data for the hip marker, and then export it to an Excel sheet.

8. Perform step 5, 6 and 7 for the other markers.

9. Import the data to the MATLAB software.

10. Filter the data using second order, zero phase low pass filter using the following commands:

```
[b,a]=butter(2,6/25,'low');

Output_vector=filtfilt(b,a,Input _vector);
```

11. Compute the absolute angles, then the relative angles.

12. Plot the relative hip, knee and ankle angles during gait cycle.

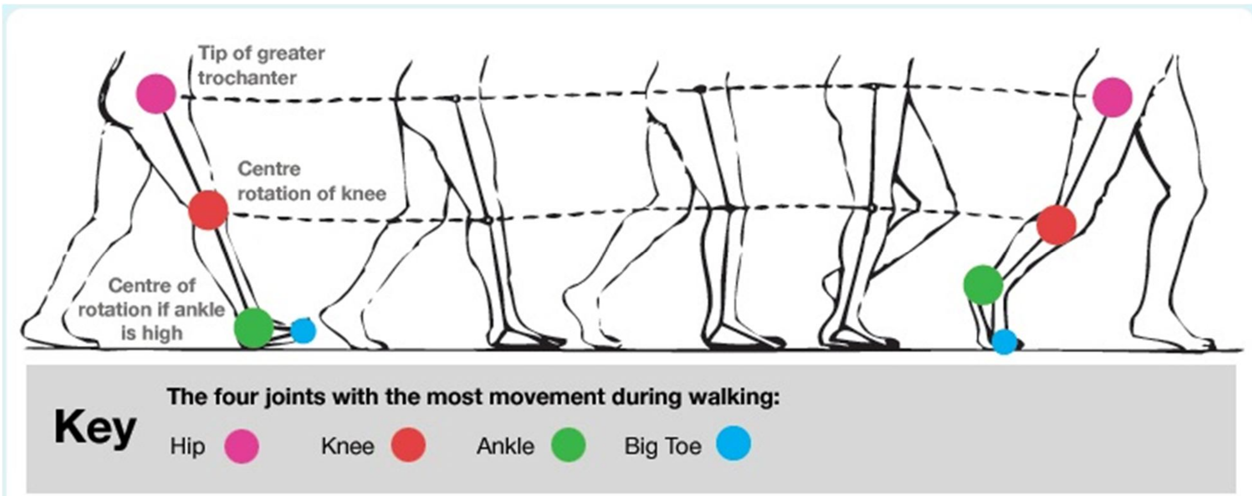

Figure.5 Marker configurations.

Discussion

1. If the cut off frequency is changed to 10 Hz and 3 Hz, is this affect the results, and why?

2. Discuss the sources of errors in the experiment.