Student's full name:

MODULE BIOMECHANICS OF GAIT

Didactic Unit D: Instrumented analysis of gait

D.3 How do I interpret a biomechanics instrumented analysis' report in a case of gait pathology?

ACTIVITY ONE: clinical case

The kinematics of the lower limbs during the gait of a patient after suffering a stroke and a control subject matched in age, sex, height, length of lower limbs and weight were evaluated. The participant with stroke was measured three times (T1, T2, T3) during the same session. At each measurement time, three repetitions were carried out. In the movement curves we can see the performance of the patient in times 1, 2 and 3 (black line) and of the healthy subject (gray line). From the images, answer the questions that are posed below.

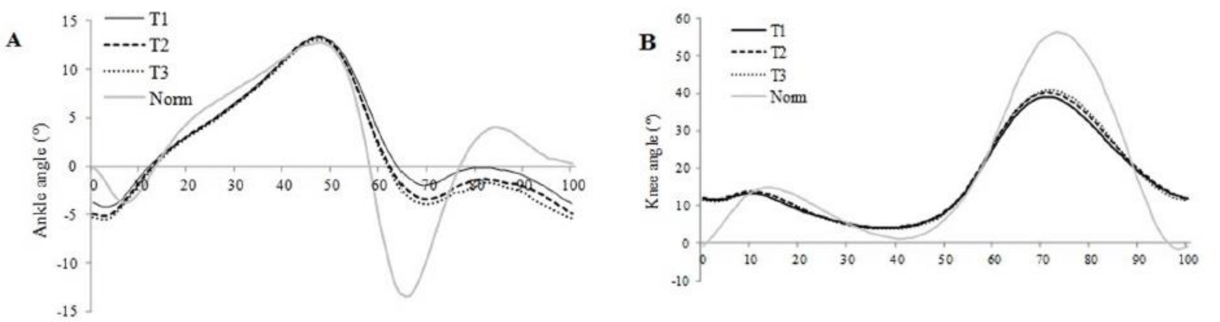

Figure 1: Kinematic assessment of lower limb during gait. Images from Boudarham J. et al. 2013.

Answer the following questions:

1) Indicate to which joint corresponds the movement curve of graph A and B.
2) In what plane of movement and what movement represents curves A and B?
3) Mention what characteristics you are going to analyze of the movement curves.
4) What frame of reference would you use to explain the gait disturbances represented in the movement curves?
5) What you can observe of the performance in the stance phase and what clinical repercussions they can cause?

6) What you can observe of the performance in the swing phase and what clinical repercussions they can cause?
7) What related or secondary variables could you obtain from the kinematic curves?
8) What other biomechanical measures would you ask to be evaluated in this patient and why?

ACTIVITY TWO: clinical case

Ground reaction forces were evaluated in a group of patients with total hip replacement and in healthy subjects. One of the most frequent complications after joint replacement surgery is the asymmetry between the length of the lower limbs that can be observed after surgical treatment. This could have serious sequelae in the rest of the joints of the lower limb since it could cause joint inflammation and end up causing a new joint osteoarthritis in another area or in the contralateral limb to the operated side.

In the graph on the left you can see curves that correspond to: subjects with a normal pattern, subjects with total hip replacement and lower limb symmetry (THR), and subjects with total hip replacement and limb length inequality (LLI). In the graph on the right, you can see, in addition, the separate measurements for the non-operated limb and the operated limb.

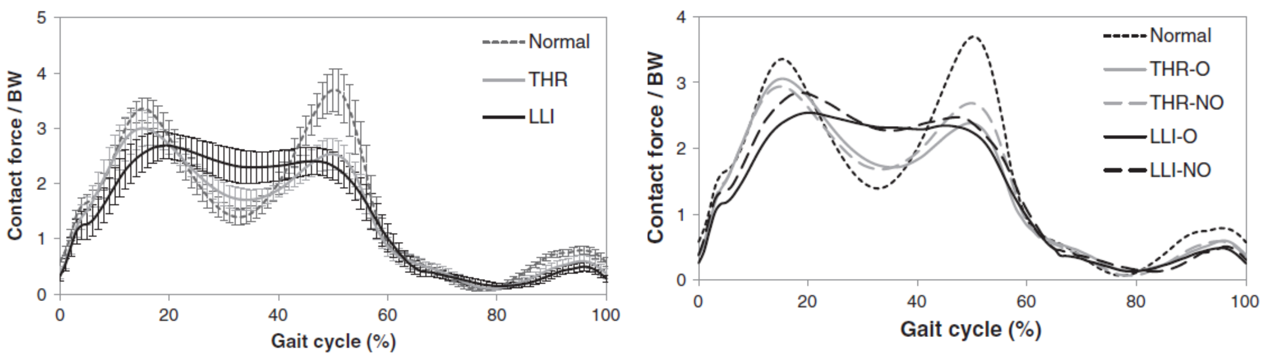

Figure 2: Ground reaction force assessment during gait. Images from Li J. et al 2015.

Answer the following questions:

1) What component or axis of ground reaction force is represented in the graphs and what does it meagning?
2) What other force components can be analyzed from ground reaction forces?
3) Mention what characteristics you are going to analyze of the kinetic curves.
4) What frame of reference would you use to explain the gait disturbances represented in the ground reaction force curves?
5) What you can observe of the performance of patients and why could it be provoked?

6) Do you notice something strange in the graphs that may be caused by the measurement methodology? What could it be?

7) What related or secondary variables could you obtain from the ground reaction force curves?
8) What other biomechanical measures would you ask to be evaluated in this patient and why?

Answers:

Clinical case 1

1) A, ankle joint. B, knee joint.

2) Sagittal plane. Both curves represent the flexion-extension movement.

3) From a kinematic curve it is possible to analyze: curve morphology, range of motion (º), maximum and minimum graduation of movement achieved in the milstones of the curve (º), angular velocity (º/s), and angular aceleration (º/s^2).

4) Gait cycle (stance and swing phase).

5) From the ankle flexion-extensión it is possible to observe in the stance phase:
   - At heel contact, the patient maintains a plantar flexion position instead of the neutral position observed in healthy subjects, which could imply a flat foot strike on the ground.
   - At the end of the stance phase, patients have limited plantar flexion, while healthy subjects perform wide plantar flexion. Patients could take off the foot en bloc instead of taking off the heel first and then the toes, which will have an impact on the reaction forces generated.

   From the knee flexion-extensión it is possible to observe in the stance phase:
   - At initial heel contact, patients have greater knee flexion than healthy subjects, probably to allow correct foot position on the ground.
   - Between the mid and terminal stance phase, patients have limited knee extension compared to the control subject.

6) From the ankle flexion-extensión it is possible to observe in the swing phase:
   - In the mid swing, patients do not perform the active dorsiflexion of the foot that we see in healthy subjects, this could cause patients to drag their foot along the ground and have a greater probability of falling.

   From the knee flexion-extensión it is possible to observe in the swing phase:
   - In the mid swing, patients do not reach the knee flexion that we see in the healthy subject. This, coupled with increased plantar flexion, increases the chances of stumbling and falling while walking.

7) Symmetry index (raw and absolute) to observe the asymmetry between hemibodies. Coeficient of variation to analyse gait parameter variability.

8) The patient's kinetic pattern could be analyzed to observe how the movement alteration affects the ground reaction forces or the excursion of the centre of pressure during walking.
   It would also be interesting to analyze the patient's electromyographic pattern to locate the movement deficiency during gait.

Clinical case 2

1) Vertical ground reaction force (z-axis). The curve in the z-axis has three milestones:
    - The first peak or maximum vertical loading force relates to the amount of loading the person is putting onto the front foot after the foot strikes on the ground. This peak should be in the order of 1.2 times the person's body weight.
    - The dip trough, after the first peak on the vertical vector, the knee extends, raising the centre of mass. As the centre of mass approaches its highest point it is slowing down or decelerating its upwards motion. This deceleration of the body upwards produces a trough in the vertical force pattern. The normal value being in the order of 0.7 times the person's body weight.
    - The second peak or maximum vertical thrusting force. When the heel lifts and the foot is pushed down and back into the ground, the centre of mass falls again. Both, the deceleration downward and propulsion from the foot and ankle complex, cause the second peak. In other words, the second peak relates to the amount of vertical propulsive force, which drives the person upwards. The value of these outcomes should be in the order of 1.2 times the person's body weight.

2) Anterior-posterior force (y-axis) and medial-lateral force (x-axis).

3) a) Morphology of the curves, b) magnitude of the force, c) time to reach the milestones of the force curve, d) total contact time.

4) Stance phase (only).

5) From the force curves we can observe the following:
    - Patients with total hip replacement who preserve symmetry in the length of the lower limbs present a morphology similar to the curve of healthy subjects, that is, the curve preserves the force milestones that we expect in a normal curve, although the magnitudes of forces are below the norm.
    - On the other hand, patients with total hip replacement who present asymmetry in the length of the legs alter the morphology of the forces recorded on the z axis, presenting a flat curve compared to that of healthy subjects. At the same time, the magnitude of the forces registered is also below the performance of the control subjects without pathology, especially in the vertical propulsive force (second peak).
    - When the forces for each leg are analyzed, differentiating between the operated and non-operated limb, we can see that the pattern described above is more severe in the in the extremity that has been operated. However, the non-treatment leg performs a similar behaviour.

6) The curves show values between 3 and 4% BW, when the normative values approach 1.2 of% BW. It may be due to a bad calibration of the dynamometric platform or an error in the post-treatment of the data when normalizing the forces (newton) by the weight of the subjects.

7) Symmetry index (raw and absolute) to observe the asymmetry between hemibodies. Coeficient of variation to analyse gait parameter variability.

9) The patient's kinematic pattern could be analyzed to observe whats is the influence of the joint movement on the ground reaction forces. If the kinematics are relatively normal, patients may not be carrying their body-weight on the leg being evaluated due to pain, fear, or other reasons. It would also be interesting to analyze the patient's electromyographic pattern during gait, specially on the hip muscle. Also the plantar pressure assessment could report abnormal pressures if the patients have altered the ground reaction forces.