BIOMECHANICS LABROTORY

Dynamic Measurement of the Human Center of Mass

1. Object

To demonstrate how the center of mass of the human body can be measured during walking.

2. Introduction

The center of mass, COM, (or the center of gravity "CoG") is an imaginary point at which the total body mass can be assumed to be concentrated. Several methods exist for the estimation of CoM movement that differ in the underlying assumptions. The segmental kinematics method is based on the definition of the CoM and models the body as a kinematic chain of rigid segments. By measuring the position and orientation of each segment and approximating the mass fractions as well as the locations of the CoM of each segment, an estimation of the overall CoM movement is obtained. Another method is the double integration of GRF method based on Newton's second law which states that the net external force acting upon a body is equal to its mass multiplied by its acceleration. Since the external force and body mass can be measured accurately by a force plate, an estimation of the acceleration of the CoM is obtained. The displacement of the CoM can be calculated through double integration of acceleration after subtracting gravitational acceleration, with proper consideration of initial constants of integration, i.e., initial velocity and position.

During walking, many anatomical features of the lower limbs contribute to minimizing fluctuations in the body's center of gravity and so reduce the amount of energy needed to maintain locomotion and produce a smooth, efficient gait (Fig.1 & 2). They include pelvic tilt in the coronal plane, pelvic rotation in the transverse plane, movement of the knees toward the midline, flexion of the knees, and complex interactions between the hip, knee, and ankle. As a result, during walking, the body's center of gravity normally fluctuates only about 4 cm in both vertical and lateral directions.

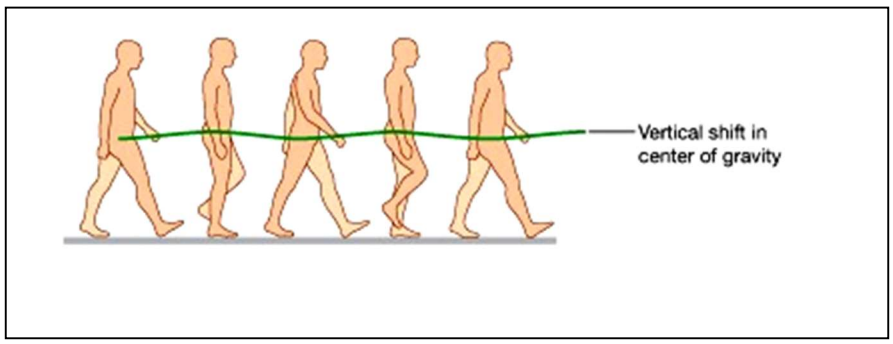

Fig.1 Vertical shift in the COM during human walking.

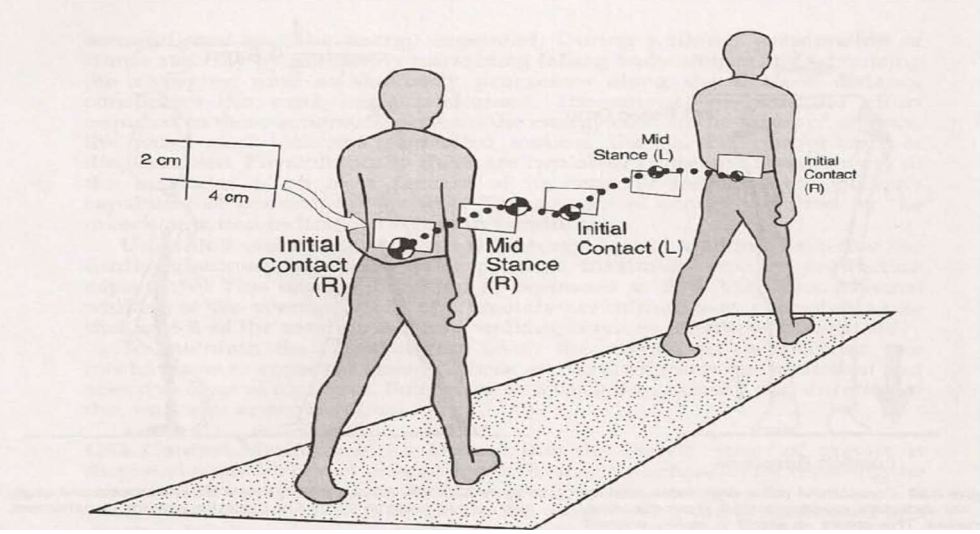

Fig.2 The normal path of the body center of gravity (black/white circle) illustrated by a stride beginning with the right toot, From the low, central point in double limb support (right initial contact), the COG moves upward and laterally (right mid stance), drops to a second central low point (left initial contact), rises to a peak again (left mid stance) and drops once more (second right initial contact). Each deviation is approximately 2cm (up and to each side).

3. Procedure:

a) Prepare the force plates (keeping in mind the warm up time for the amplifier "about 1 hr").

b) Prepare normal subjects to be walked normally and barefoot.

c) Record the weight of the subject.

d) Record the vertical GRF.

e) Compute the vertical acceleration by subtracting Mg from the force wave form. Then the resulted vector was approximated and slightly smoothed by fitting a sixth-order polynomial.

f) Perform double integration of the fitted equation in step (e).

g) Substitute the stance time in the equation resulted in step (f) to obtain COM displacement.

h) Plot the displacement of the COM against time.

4. Discussion:

1. Does the vertical shifts of the body COM have a clinical meaning? Why?
2. Enumerate the factors that the body used to minimize energy used for locomotion?