Gait

Objectives

1. Describe the normal gait cycle
2. Describe the motion, ground reaction vector force, and the internal moment generated by muscle force for the hip, knee, and ankle in each phase of gait
3. Describe mechanisms to lessen energy expenditure during normal gait
4. Describe the development of mature gait
5. Discuss the technology used by motion analysis labs

Discussion points

1. How much can you learn about a patient's gait without a motion analysis laboratory?
2. What effect does an equinus contracture have on gait? A knee flexion contracture?
3. Where is the center of gravity?

Discussion

While surprisingly sophisticated attempts at motion analysis have been performed for more than a century, motion analysis as a discipline has been in existence for a half century or less. Inman, in California, developed the first motion analysis laboratory; two of his residents, Jacqueline Perry and David Sutherland, largely developed the field. There are now a number of motion analysis laboratories in virtually all states.

The goal of an efficient gait is a smooth progression of the center of gravity (located just anterior to the second sacral vertebral body) with minimal displacement in any direction during the gait cycle. The gait cycle is divided into stance and swing phases, with further subdivisions of each phase. The subdivisions are intuitively sensible. Stance phase is subdivided into initial contact, loading response, mid stance, terminal stance, and preswing. The swing phase is subdivided into initial, mid, and terminal swing. Each subphase is accompanied by a change in position, ground reaction force, and/or internal muscular forces. Gait cycle analysis in this sense is essentially a sagittal plane function. At the hip, however, transverse and coronal mechanisms are critical. The hip is flexed at initial contact through loading response, neutral at midstance, and extended in terminal stance. During stance phase, the ground reaction vector force is an adduction moment, resisted by the gluteus medius. Before terminal stance, the ground reaction vector force is anterior, resisted by the gluteus maximus, when it passes posteriorly, it is resisted by the anterior ligaments. In the transverse plane, the pelvis is rotated forward at heelstrike, then rotates to a backward position over the limb at preswing. Inability of the hip joint to compensate for pelvic rotation will be evident in the gait pattern (lack of external rotation at heelstrike in a patient with femoral anteversion).

During swing phase, the pelvis rotates forward (advances) and flexes. The knee is extended at heelstrike, flexes somewhat at loading response (this transient flexion is important in smoothing the excursion path of the center of gravity) when the ground reaction force is posterior to the knee joint, then extends again at midstance, through terminal stance. The ground reaction force is anterior until preswing, and the knee passively flexes as it is unloaded. In swing phase, inertia carries the knee into further flexion to aid clearing the limb, until it actively extends in terminal swing in preparation for heelstrike. The ankle is plantarflexed 10 degrees at heelstrike, with further plantorflexion dampened by the ankle dorsiflexors, aiding with shock absorption. At midstance, ground reaction tends to dorsiflex the ankle which is held rigid by the plantarflexors, controlling forward thrust of the tibia. Ground reaction continues to push the ankle toward dorsiflexion in terminal stance, resisted by the plantarflexors. The ankle passively dorsiflexes as it is unloaded in preswing.

These actions serve to smooth the excursion of the center of gravity. The center of gravity is highest in midstance, lowest in terminal stance. The synchonous motion of hip, knee and ankle, facilitated by two joint muscles, also smooths the excursion.

Normal gait matures in a stereotyped fashion. The toddler has abducted upper limbs, with extended elbows, and reduced knee flexion, with external rotation of the hip throughout the gait cycle. Progression during swing phase is by circumduction. By age 2, reciprocal arm motion begins, and there is a knee flexion wave in early stance, as in the adult. The adult pattern is achieved by age 7.

Motion analysis laboratories use either video analysis with reflective markers on the body, or light-emitting diodes activated by a central computer. Neither system is without technical difficulties. All laboratories use a force plate located in the runway sensitve to forces in three planes. Dynamic EMG is performed with either surface or fine needle electrodes, the disadvantages of either method are obvious. Oxygen consumption measures efficiency.

Even without a formal motion analysis laboratory, much information can be gleaned. Velocity, stride length and cadence can be timed and measured without a computer. Video recordings can be slowed or stopped to assess joint position in any phase of gait. Rotation is more difficult to document, a ceiling camera does this in laboratories. The strategy of focusing on a particular phase of gait during each walking cycle down the hall can pick up subtleties that might be overlooked by trying to observe all the components of gait simultaneously. Weakness can be analyzed in the same manner.

Once the normal cycle is understood, the effects of weakness and contracture become more evident. With a fixed knee flexion contracture, the ground reaction force vector will not pass anterior to the joint during stance phase, so muscle activity must be greatly increased to prevent the knee from buckling. With an equinus contracture of the ankle, the knee will be forced into hyperextension during midstance and terminal stance, or the patient must vault over the leg, or compensate by increased knee and hip flexion, both of which increase energy consumption.

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