Terminology of Human Walking

From North American Society for Gait and Human Movement 1993 and AAOP Gait Society 1994

Gait Cycle: The period of time from one event (usually initial contact) of one foot to the following occurrence of the same event with the same foot. Abbreviated GC.

Gait Stride: The distance from initial contact of one foot to the following initial contact of the same foot.

Normalization of the Gait Cycle: A method used to achieve uniform representation of the gait cycle (or any part thereof) for the purposes of comparison or averaging data across subjects. The usual method is based on representation of a percentage of the complete cycle or percentage of stance or swing phase.

Stance phase (ST): The period of time when the foot is in contact with the ground. Approximately 62% of the GC.

Swing phase (SW): The period of time when the foot is not in contact with the ground. In those cases where the foot never leaves the ground (foot drag) it can be defined as the phase when all portions of the foot are in forward motion. Approximately 39%of GC.

Double support (DS): The period of time when both feet are in contact with the ground. This occurs twice in the gait cycle, at the beginning and end of stance phase. Also referred to as left and right double limb stance or LDLS and RDLS respectively. For example, LDLS refers to the DS after left initial contact.

Single support (SS): The period of time when only one foot is in contact with the ground. In walking, this is equal to the swing phase of the other limb.

Terminal contact (TC): The point in the gait cycle when the foot leaves the ground: this represents the end of the stance phase or the beginning of swing phase. Also referred to as foot off. Toe off should not be used in situations where the toe is not the last part of the foot to leave the ground. Note: For those cases of pathology where the foot never leaves the ground (foot drag), the termination of stance and the onset of swing may be somewhat arbitrary. The termination of stance and the onset of swing is defined as the point where all portions of the foot have achieved motion relative to the floor. Likewise, the termination of swing and the onset of stance may be defined as the point when the foot ends motion relative to the floor.

Toe-off: When terminal contact is made with the toe.

Foot-flat (FF): The point in time in stance phase when the foot is plantar grade.

Heel-off (HO): The point in time in stance phase when the heel leaves the ground.

Phases of the gait cycle: The gait cycle may be further divided into specific sub phases related to normal function; loading response, mid stance, terminal stance, pre-swing, initial swing, mid swing and terminal swing (Perry,1992). This terminology is very useful for referring to specific portions of the gait cycle when describing pathological gait. The percentages given apply to normal gait.

Mid stance: The first half of the single support from 10 to 30% of the gait cycle and is defined from the time the opposite limb leaves the floor until body weight is aligned over the forefoot. This period can be identified in the vertical force pattern as beginning when the force initial peak begins to diminish and ending when the force peak reaches its lowest point between the first and second peak.

Pre-swing: The final double support stance period which is defined from the time of initial contact with the contralateral limb to ipsilateral toe-off. Pre-swing begins when the vertical force reaches the apex of its second peak and ends when there is no long a vertical force.

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Mid-swing: The middle third of the swing phase from 73 to 87% of the gait cycle as defined from the time the swing foot is opposite the stance limb to when the tibia is vertical.

Initial contact: The point in the gait cycle when the foot initially makes contact with the ground; This represents the beginning of the stance phase. Heel strike is not a term applicable in the description of many pathological conditions and in clinical gait analysis as in many circumstances initial contact is not made with the heel. Alternative Term: foot strike.

Heel contact (HC): Is used when initial contact is made with the heel. Alternative Term: heel strike.

Loading response: The initial double support stance period which is defined from initial contact (0%) to 10% of the gait cycle. During this period the vertical ground reaction force line moves from 0 to its first peak.

Terminal stance: The second half of the single support from 30 to 50% of the gait cycle and is defined as the time from heel rise until the other limb makes contact with the floor. During this phase body weight moves ahead of the forefoot. At this time, just prior to mid-stance, the vertical ground reaction force moves from its lowest point which occurs following peak one and ends at the apex of the second peak.

Initial swing: The initial third of the swing phase from 60 to 73% of the gait cycle as defined from toe-off to when the swing limb foot is opposite the stance limb.

Terminal swing: The final third of the swing phase from 78 to 100% of the gait cycle as defined from the time when the tibia is vertical to initial contact.

Push off: The period in time in late stance (between 40% of stride and prior to toe-off) when there is an ankle plantar flexor moment and simultaneous power generation (see biomechanical terms) of the triceps surae to help advance the limb into swing phase. Note: There is not active plantar flexor activity at the end of stance phase.

Observational Gait Assessment: A qualitative visual description of an individual's upper and lower extremities, pelvis, and trunk motion during ambulation.

Motion Analysis: Interpretation of computerized data that documents an individual's lower and upper extremities, pelvis, trunk, and head motion during ambulation.

Markers: Active or passive objects (balls, hemispheres, or discs - see below) aligned with respect to specific bony landmarks used to help determine segment and joint position in motion analysis.

Active Markers: Joint and segment markers used during motion analysis that emit a signal.

Passive Markers: Joint and segment markers used during motion analysis that reflect visible or infrared light.

Electrogoniometer: An electrical transducer that can be attached to adjacent segments to measure a joint angle. Different designs accommodate changes in joint center of rotation location and three dimensional motion.

Line of progression: The patients direction (of progression) during the data collection.

Contralateral: The opposite side of the body, i.e., the opposite limb.

Ipsilateral: On the same side of the body, i.e., the same limb.

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Locomotor apparatus: The lower extremities and pelvis that provide the mechanics of walking.

Coronal plane: The plane that divides the body or body segment into anterior and posterior parts.

Sagittal plane: The plane that divides the body or body segment into the right and left parts.

Transverse plane: The plane that divides the body or body segment into superior and inferior parts.

TEMPORAL AND STRIDE PARAMETERS

Step length: The distance from a point of contact with the ground of one foot to the following occurrence of the same point of contact with the other foot. The right step length is the distance from the left heel to the right heel when both feet are in contact with the ground, expressed in meters (m).

Step Period: The period of time taken for one step is measured from an event of one foot to the following occurrence of the same event with the other foot, expressed in seconds (s).

Stride length: The distance from initial contact of one foot to the following initial contact of the same foot. Sometimes referred to as cycle length, expressed in meters (m).

Stride period or cycle time: The period of time from initial contact of one foot to the following initial contact of the same foot, expressed in seconds (s).

Velocity: The rate of change of linear displacement along the direction of progression measured over one or more strides, expressed in meters per second (m/s).

Cadence: Rate at which a person walks, expressed in steps per minute.

Stance/Swing ratio: The ratio of the stance period to the swing period.

Walking base (or stride width): The side-to-side distance between the feet, which is typically measured from the ankle joint center.

Natural cadence/velocity: The rate of walking that is voluntarily assumed.

Foot switch: A device that measures the duration of foot contact of a designated part of the foot.

Instrumented walkway: A pathway that either contains sensors in the floor or sensors around the walkway that monitor gait.

Dorsiflexion recovery: Movement from plantar flexion toward dorsiflexion during the swing phase.

Dynamic range of motion: Indicates joint motion excursion from the maximum angle to the minimum angle during a particular phase(s) in the gait cycle.

ANGLE DEFINITIONS

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In order to interpret gait analysis data, joint angle definitions must be defined. This is important for routine clinical use of gait data for treatment decision-making and for the presentation of research data in publications. The joint angle definitions are system dependent and ultimately depend on the marker alignment and underlying mathematical models. Interpretation of joint kinematic and kinetic data involves a knowledge of marker placement and an appreciation of the joint models used. It must be clearly stated whether angles are relative (relating the position of one body segment to another) or absolute (segment orientation in terms of a laboratory coordinate system). Labels used in data output should reflect whether angles are relative or absolute. For example, referring to the thigh segment orientation in the sagittal plane as the "hip angle" is incorrect. Joint angle information should be obtained using three-dimensional techniques and relate to body segment axes, or coordinate systems, as determined by the appropriate anatomy.

Ultimately, there is a need to work toward standardization of angle definitions independent of our body segment marker set placement and gait model (for example, the use of Euler angles for kinematics). This will improve the ability to communicate data between different laboratories.

The descriptions given below are based on the perspective of an observer placed at a certain location in relation to the joint or segment of interest. For example, absolute angles (as defined above) are seen by an observer standing in the laboratory with a particular instantaneous view.

Upper Trunk Motion: The position of the upper trunk as defined by a marker set (for example, the plane formed by the markers on the second rib and lateral to the sternum and C7) relative to a laboratory coordinate system.

Sagittal Plane Upper Trunk Anterior/Posterior Tilt: Motion of the long axis of the trunk as seen by an observer positioned along a medial-lateral axis of the trunk.

Coronal Plane Upper Trunk Elevation (Rise) Depression (Drop): Motion of the medial-lateral axis of the trunk as seen by an observer positioned along an anterior-posterior axis of the trunk.

Transverse Plane Upper Trunk Internal (Protraction)/ External (Retraction) Rotation: Motion of the medial-lateral or anterior-posterior axis of the trunk as seen by an observer positioned along a longitudinal axis of the trunk. (Comment: It is unclear whether the angles are relative to the room or to other body segments.)

Pelvic Motion: The position of the pelvis as defined by marker set (for example, the plane formed by the markers on the right and left anterior superior iliac spine (ASIS) and the midpoint between the right and left posterior superior iliac spine (PSIS) relative to a laboratory coordinate system.

Sagittal Plane Pelvic Anterior/Posterior Tilt: Motion of the long axis of the pelvis as seen by an observer positioned along a medial-lateral axis of the pelvis.

Coronal Plane Upper Pelvic Elevation (Rise) Depression (Drop): Motion of the medial-lateral axis of the pelvis as seen by an observer positioned along an anterior-posterior axis of the pelvis.

Transverse Plane Internal (Protraction)/ External (Retraction) Rotation: Motion of the medial-lateral or anterior-posterior axis of the trunk as seen by an observer positioned along a longitudinal axis of the trunk. (Comment: It is unclear whether the angles are relative to the room or to other body segments.)

Hip Motion: The hip angles reflect the motion of the thigh segment relative to the pelvis.

Sagittal Plane Hip Flexion/Extension: Motion of the long axis of the thigh as seen by an observer positioned along the medial-lateral axis of the pelvis.

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Coronal Plane Hip Abduction/Adduction: Motion of the long axis of the thigh as seen by an observer positioned along an anterior-posterior axis of the pelvis.

Transverse Plane Hip Internal/External Rotation: The relative motion between a distal medial-lateral axis of the thigh and a medial-lateral axis of the pelvis as viewed by an observer (on the pelvis) looking down the long axis of the thigh. This measure as defined above will provide the relationship between the pelvis and the distal aspect of the femur. This does not necessarily correlate with femoral anteversion.

Knee Motion: The knee angles reflect the motion of the shank segment relative to the thigh segment. A straight knee measures 0 degrees.

Sagittal Plane Knee Flexion/Extension: Motion of the long axis of the shank as seen by an observer positioned along the medial-lateral axis of the knee.

Coronal Plane Knee Abduction/Adduction: Motion of the long axis of the shank as seen by an observer positioned along an anterior-posterior axis of the thigh.

Transverse Plane Knee Internal/External Rotation: The relative motion between a distal medial-lateral axis of the shank and a medial-lateral axis of the thigh as viewed by an observer (on the thigh) looking down the long axis of the shank.

Ankle Motion: The ankle angles reflect the motion of the foot segment relative to the shank segment in most circumstances (sagittal and transverse plane) but there are some exceptions to this, for example, in the transverse plane foot progression (see below). The ankle in the neutral position or 0 degrees refers to no plantar flexion or dorsiflexion.

Sagittal Plane Ankle Plantar Flexion/Dorsiflexion: Motion of the plantar aspect of the foot as seen by an observer positioned along the medial-lateral axis of the ankle.

Coronal Plane (hindfoot inversion/eversion): Motion of a long axis of the hindfoot as seen by an observer positioned along an anterior-posterior axis of the shank.

Coronal Plane Forefoot Supination/Pronation: Motion of a long axis of the forefoot as seen by an observer positioned along an anterior-posterior axis of the shank.

Transverse Plane Foot Progression: This is an absolute angle of the relationship between the long axis of the foot as defined by the foot marker placement and model and the direction of progression. This measure does not give any information about tibial torsion.

Transverse Plane Foot Rotation: The relative motion between a long axis of the foot and a medial-lateral axis of the distal shank (line from the medial epicondyle of the tibia to the lateral head of the fibula) as viewed by an observer (on the shank) looking down the long axis of the foot. This measure will not give any information about tibial torsion but would suggest the presence of a forefoot abduction or adduction problem.

BIOMECHANICAL TERMS

Kinematics: Those parameters that are used in the description of movement without consideration for the cause of movement abnormalities. These typically include parameters such as linear and angular displacements, velocities and accelerations.

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Segment and Joint Angular Velocities: First derivative with respect to time of the segment or joint angles.

Segment and Joint Angular Accelerations: Second time-derivatives of the segment of joint angles.

Deceleration: A decrease in velocity.

Acceleration: An increase in velocity.

Kinetics: General term given to the forces that cause movement. Both internal (muscle activity, ligaments or friction in muscles and joints) and external (ground or external loads) forces are included. The moment of force produced by muscles crossing a joint, the mechanical power flowing to and from those same muscles, and the energy changes of the body that result from this power flow are the most common kinetic parameters used.

Impulse: Integration with respect to time of a force or moment curve (area under the curve), and is usually employed in ballistic movements to reflect changes in momentum of the associated limbs. Linear impulse is expressed in N-s, angular impulses in N-m-s.

Force: May be defined as a push or a pull and is produced when one object acts on another. The units are Newtons (N).

Reaction Force: The force a body A exerts on a second body B in response to a force exerted by body B on the body A. The reaction force has equal magnitude but opposite direction relative to the force exerted on the body A by body B. The units are Newtons (N).

Resultant Ground Reaction Force (GRF): The vector summation of the three reaction forces resulting from the interaction between the foot and ground. The resultant ground reaction force has three vector components, i.e., the vertical, lateral and fore-aft.

Force Plate: A transducer that is set in the floor to measure, about some specified point, the force and torque applied by the foot to the ground. These devices provide measures of the three components of the resultant ground reaction force vector and the three components of the resultant torque vector.

Center of Pressure: A point on the ground where the resultant ground reaction force can be assumed to act. The center of pressure is typically calculated from the force and torque measured by a force plate. In a two-dimensional case, the center of pressure is the point where the resultant ground reaction force alone (with no torque) can act and have an effect equivalent to the measured ground reaction force and torque. In three-dimensions, however, there is generally no point where the force and torque can be replaced by just an equivalent force. Thus, the center of pressure is taken to be the point where either 1) the resultant ground reaction force and a vertical torque, or 2) the resultant ground reaction force and a torque parallel to the resultant ground reaction (i.e., the torque with minimum magnitude), can act and have an effect equivalent to the measured ground reaction force and torque.

Mass Moment of Inertia: The measure of a body segment's resistance to angular motion about a given axis. The units are kg.m2.

Moment of Force (torque): The moment of force is calculated about a point and is the cross product of a position vector from the point to the line of action for the force r and the force F (i.e., r x F). In two-dimensions, the moment of force about a point is the product of a force and the perpendicular distance from the line of action of the force to the point. Typically, the moments of force are calculated about the center of rotation of a joint. The units are

Newton-meters (N-m).

Internal Joint Moments: The net result of all the internal forces acting about the joint which include moments due to muscles, ligaments, joint friction and structural constraints. The joint moment is usually calculated around a joint center. A net knee extensor moment, for example, means that the knee extensors (quadriceps) are dominant at the knee joint and the knee extensors are creating a greater moment than the knee flexors (hamstrings and gastrocnemius). Units are Newton-meters (N-m) and usually normalized to the subject's body mass, i.e., N-m/kg.

External Moment: The load applied to the human body due to the ground reaction forces, gravity and external forces (not common in clinical gait analysis applications).

Kinetic Energy: The component of a body's mechanical energy that is due to its motion. When a body is at rest the kinetic energy is zero, and kinetic energy reaches a maximum at maximum velocity.

Potential Energy: The component of a body's mechanical energy associated with its position relative to other bodies (including the ground). For example, gravitation potential energy of a body is proportional to the height of the center of mass of a body above the ground. Potential energy can also be developed through stretch of a muscle or tendon and this type of potential energy is sometimes referred to as elastic potential. Potential energy is sometimes also referred to as stored energy.

Mechanical Energy: Energy state (potential and kinetic) of any limb segment or total body system at an instant in time. It is expressed in Joules (J).

Mechanical Power: Rate of change of mechanical energy at an instant in time. Also, rate of doing work. It is expressed in Watts (W).

Mechanical Work: The product of a displacement and the component of force that is collinear with the displacement (i.e., the dot product of the force and the displacement). Mechanical work can also be calculated as the dot product of a moment and an angular displacement. The work done on a system is equal to the change in energy in a system (segment or total body) over that same period of time. It is expressed in Joules (J).

Positive Work: Work done by a force or torque when the force or torque and the resulting displacement (linear or angular) have components in the same direction. Concentrically contracting muscles are often said to do positive work.

Negative Work: Work done by a force or torque when the force or torque and the resulting displacement (linear or angular) have components in the opposite direction. Eccentrically contracting muscles are often said to do negative work.

Couple: A set of force vectors whose resultant is equal to zero. Two force vectors with equal magnitude and opposite direction are an example of a force couple.

Joint Power: The product of a joint moment and the joint angular velocity. Joint power is said to be generated when the moment and the angular velocity are in the same direction and said to be absorbed when they are in opposite directions. The units are Watts (W).

Center of Gravity: A single force formed by the convening of all forces of gravity acting on the body. In static standing this occurs at the level of the hips slightly anterior to the ankles.

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Pressure: Force per unit area measured in N/cm2.