Physiology of Posture and Gait

**Biophysics of posture and gait**

Movement is either ‘ballistic’, eg delivering a rapid punch which once released is determined and irrevocable, or under continuous control, eg tracking a moving target requiring continuous corrections of trajectory.

Control of human posture and gait must solve the problem of balancing and moving a bipedal multi-jointed ‘jointed rod’ system of masses with overall characteristics of an ‘inverted pendulum’. The main masses are heavy, articulated and some distance from the ground. The overall centre of mass may be outside the body during more gymnastic manoeuvres.

Control may be ***reflex:***  involving ‘feedback’ and ‘feed forward’ mechanisms or ***predictive:*** involvingcognitive appraisal of the environmental demands and prediction of challenges for motion. Control of movement requires prior knowledge, through experience, of how the body will respond to a given pattern of muscle forces exerted. Ultimately all forces and body reactions must refer to appropriate ‘support surfaces’; if reference is lost eg walking on ice, control becomes difficult or impossible.

Fundamental mass-energy limitations restrict the type of body movements that may be possible in given situations. Eg, when taking a wide corner at speed the whole body tilts into the curve. When cornering rapidly the legs lateropulse pushing the trunk into the curve whilst the head and trunk are maintained upright or tilt out of the curve. There is not sufficient time or energy to effect whole body tilt during rapid cornering (see ski slalom vs grand slalom).

**Simplified scheme of motor mechanisms**

**Cortex (‘pyramidal system’)**

The cortex is the source of goal directed including ‘voluntary’ movement and associates sensory signals with motor output. Primary motor cortex provides the primary motor output. *Lesion, typically stroke, leads to paralysis.* Frontal cortex provides selection and inhibition of appropriate-inappropriate actions. *Lesion, typically stroke or tumour leads to disinhibition of sensory triggered responses.*

**Basal Ganglia (part of ‘extra-pyramidal system’)**

The basal ganglia support motor programming.*Lesion, typically Parkinsons disease -> slowing of movement (‘Bradykinesia’),freezing, failure of repetitive movement.. Loss of facial expression.*

**Cerebellum (part of ‘extra-pyramidal system’)**

The cerebellum processes sensory feedback control of movement. *Lesions, typically degeneration, stroke or tumour, cause dysmetria, tremor, failure of rapid alternation, tremulous bouncing movements of whole body and exaggerated sway Patients walk with ‘broad based gait’.*

**Spinal Cord (parts of ‘extra-pyramidal system’)**

Although motor cortex neurone axons descend in the cord as the ‘primary’ motor pathway neuronal assemblies in the spinal cord also provide reflex mechanisms that assist posture and gait, eg stretch reflex, and support rhythmical activity that can drive gait although this is more effectively developed in lower species. *Spinal lesions, typically trauma, transverse myelitis, abolish movement.*

**Sensory control of movement *emphasis on posture and gait***

**Vision –** Teloceptive and panoramic; provides position, speed, direction, relative motion of self and other objects to guide movement. Cognitive interpretation facilitates planning and predictive movement. Route is mainly cortical with latencies >100ms but limited evidence for rapid sub-cortical pathways providing latencies 70-100ms. *Lesions, typically retinal blindness, anophthalmia, cortical stroke, cause loss of navigation ability and loss of fine control during challenging balance situations (ballet dancer on points). Blind people can ski, play drums, play acoustic football.*

**Vestibular signals –** The vestibular system of the inner ear comprises: the otoliths, which signal linear acceleration and tilt with respect to gravity in all 3xD of head movement and the semi-circular canals which signal rotational head velocity in all 3xD° of rotation. Vestibular signals assist balance providing rapid reactions to sudden jerks of the head (eg tripping up) and stabilise vision via ‘vestibular ocular reflex eye movements which maintain gaze on earth stationary targets during passive and active head movement. Eg, a sudden sideways tilt will provoke a reflex adjustment of posture by extensor activation of appropriate muscles for body righting. Lesions, typically through degenerative disease, ototoxicity or infection lead to clumsiness of walking in unpredictable terrain or in darkness.

Control is adaptive and there is some degree of redundancy, therefore people lacking information from vision or the vestibular system can perform remarkably well if the motor task is not too difficult, standing or walking with eyes closed for example.Patients may walk with ‘broad based gait’ to widen the base of support.

Theory that vestibular signals give an absolute reference of the position and motion of the head in space – all other sensory systems are relativistic – therefore, vestibular signals are used to help interpret the implication of other sense data for spatial orientation.

**Somatosensory signals**

*Proprioception, muscle stretch, joint rotation and touch-pressure sensation***.** Afferent feedback, particularly from the feet and ankles, knees and hips is ***essential for posture and gait*** serving to calibrate and regularise movement, triggering reflexes and control feedback, providing ascending sensory information to the cortex for movement planning and guidance and to the cerebellum for control feedback of smooth, fine control of action. Lesions of the afferent system, eg from tabes dorsalis, seriously impede the ability for co-ordinated movement and the deafferented man may not even be able to stand.

**Voluntary vs automatic control**

**Automatic reactions** are triggered by particular combinations of sensory stimuli and are appropriate for particular situations. Most primitive sensory-motor loop- ‘reflexes’ eg stretch and withdrawal from painful stimuli. Voluntary compensation may be required if automatic reactions are inappropriate.

**Voluntary movements** are determined by intention and cognitive interpretation of environmental features. Conscious anticipation produces a *postural set*, i.e. a tendency to respond in a specific way, appropriate to an expected perturbation. Unexpected perturbations can be disturbing even in unchallenging environments, eg odd sensation when stepping on a stationary escalator.

**Some further reading….**

Rothwell, J. (1994) *Control of human voluntary movement.* (Second edn). Chapman and Hall, London.

Brooks, V. B. (1986) *The neural basis of motor control.* (First edn). Oxford University Press, Oxford.

Roberts, T. D. M. (1995) *Understanding balance: The mechanics of posture and locomotion.* (First edn). Chapman and Hall, London.