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Interdependence of the balance mechanisms during walking

Currently there is not a well-defined, comprehensive theory for how the healthy human nervous system maintains balance during walking. Unlike quiet standing balance, the gait cycle creates a system that requires different strategies to achieve the task of balance. We have discovered multiple mechanisms of balance control during walking, in a young healthy cohort ($n=20$), that are temporally coordinated to explain the maintenance of upright balance in the medial-lateral direction. The protocol for determining such a balance response involved inducing a visually perceived fall to the side on heel strike. The subjects walked on a self-paced treadmill surrounded by a 3D virtual reality. The stimulus consisted of a rotation of the visual scene at $60^\circ/\text{sec}^2$.

Initial interpretation of the results allowed for identification of three major balance responses within the first step:

Foot placement shift: Active control of swing foot placement in direction of perceived fall. In the event of a sensory perturbation and a perceived shift in the CoM, a correction must be made, and the most obvious way to do this is take a step.

Lateral ankle roll: Active control of center of pressure under the stance foot in the direction of the perceived fall. The active control of ankle inversion/eversion angle can be used to modulate the CoP under the stance foot during sustained locomotion.

Push-off modulation: Active shift of weight between two legs in double stance. During double stance, the feet are not directly in front of one another, but are offset laterally, so a weight shift between legs would have effects on the lateral balance. We are currently unaware of any reports of a push-off mechanism being used to aid in the maintenance of balance in the medial-lateral direction.

When a visually perceived fall is induced at heel-strike, the foot placement response (difference from control) is strongly dependent on the degree to which the lateral ankle mechanism was used during stance ($R^2 = .49$, $p < .05$). Interestingly, the push-off modulation does not correspond to the magnitude of foot placement response ($R^2 = .002$), nor the lateral ankle mechanism ($R^2 = 0$). This finding suggests that the lateral ankle mechanism and the foot placement mechanism are coordinated to produce a balance response in the medial-lateral direction, but the push-off modulation may be a byproduct of the balance response, or serve a different functional role.

Future work includes the investigation of the role of cadence in relation to the basic balance mechanisms for maintenance of balance in the medial-lateral direction.