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between two equilibrium positions that define the spatial boundaries in a pendulum-like manner by central destabilization of the system at one point, from which it is supported by previous studies, showing that temporal characteristic of limb endpoint appears to be related to motor planification and might be centrally encoded.

Discussion: It was surprising that arthritis and consecutive joint limitations at foot level did not affect the timing of foot trajectory. Hence, this possibility is supported by previous studies, showing that temporal characteristics of limb endpoint appears to be related to motor planification and might be centrally encoded.

Results: When perturbed, the oscillations of the arm or arms were reset around the extreme forward or backward arm position. This was especially evident in the case of bi-manual movements when the non-perturbed arm stopped moving at this position. When oscillations were renewed, the phase shifted randomly with respect to the pre-perturbation period. Such phase resetting occurred in both uni- and bi-manual movements, regardless of when or which arm was perturbed.

Discussion: Results support the hypothesis that the central nervous system produces transitions between two stable equilibrium positions of the arm(s), rather than elicits pendulum-like oscillations about a single position. The frequency and spatial boundaries of arm oscillations may be controlled by changing the rate of transitions and by adjusting the equilibrium positions, respectively. In response to perturbations, the generator may arrive at one of the equilibrium states and resume oscillations at a new phase, as observed in the present study. Our findings are relevant to locomotion and suggest that walking may also be generated by transitions between several equilibrium states of the body.

11.14 Phase resetting of uni- and bi-manual rhythmic arm movements due to perturbation

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Introduction: Rhythmic arm movements may be produced in a pendulum-like manner by central destabilization of the system at one equilibrium position. Alternatively, they may result from transitions between two equilibrium positions that define the spatial boundaries of movement.

Methods: Standing subjects swung one or both arms from the shoulder joints, in-phase at ~0.8 Hz. In randomly selected cycles, one arm was transiently arrested by an electromagnetic device while the arm was moving forward or backward.

Results: When perturbed, the oscillations of the arm or arms were reset around the extreme forward or backward arm position. This was especially evident in the case of bi-manual movements when the non-perturbed arm stopped moving at this position. When oscillations were renewed, the phase shifted randomly with respect to the pre-perturbation period. Such phase resetting occurred in both uni- and bi-manual movements, regardless of when or which arm was perturbed.

Discussion: Results support the hypothesis that the central nervous system produces transitions between two stable equilibrium positions of the arm(s), rather than elicits pendulum-like oscillations about a single position. The frequency and spatial boundaries of arm oscillations may be controlled by changing the rate of transitions and by adjusting the equilibrium positions, respectively. In response to perturbations, the generator may arrive at one of the equilibrium states and resume oscillations at a new phase, as observed in the present study. Our findings are relevant to locomotion and suggest that walking may also be generated by transitions between several equilibrium states of the body.

11.15 Paradoxical muscle movements in human standing

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Introduction: In human standing the calf muscles soleus and gastrocnemius actively prevent forward toppling about the ankles. It has been assumed that these postural muscles behave like springs with stiffness reflecting their mechanical properties, reflex gain and central control. Here we test the muscle-spring hypothesis that contractile element length increases during forward sway of the body.

Methods: We used an ultrasound scanner and automated image analysis to record the tiny muscular movements occurring in normal standing and during large voluntary sways. This new, non-invasive technique resolves changes in muscle length as small as 10 microns without disturbing the standing process [1].

Results: The contractile elements are longest when the subject is closest to the vertical and shortest as the subject sways forwards (paradoxical movements). In quiet standing, muscle length fluctuates at approximately three times the frequency of body sway: on average, shortening during forward sway and lengthening during backwards sway.

Discussion: This counter-intuitive result is consistent with the fact that calf muscles generate tension through a series elastic component (Achilles tendon and foot) which limits maximal ankle stiffness to 92±20% (±S.D.) of that required to balance the body.

Conclusion: The intrinsic length-tension relationship of the calf muscles partially stabilizes the human body in quiet standing while leaving the body mechanically unstable. Stability and balance is achieved by an impulsive process that is poorly correlated with CoM angle.

References


11.16 Somatosensory graveicision inhibits soleus H-reflex gain during walking in humans revealed by reduced gravity condition

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Introduction: The purpose of this study was to investigate how gravity related somatosensory information affects the excitability of the soleus muscle (SOL) motoneuron pool in humans while walking in water compared with on land.

Methods: SOL H-reflexes were elicited in ten healthy males walking at 2.0 km/h on a treadmill both on land and in water. To