6.28 Postural adjustments during perturbation of rhythmical arm movement

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Introduction: We hypothesised that body posture and rhythmical arm movement are controlled as a coherent whole rather than separately. To test this hypothesis, we investigated the effect of brief perturbation of rhythmic arm movements on body posture in standing healthy subjects.

Methods: Subjects swung both arms in-phase (~0.8 Hz) in a sagittal direction. When moving forward, one arm was transiently arrested. The coordination between movements of the center of mass (CoM), trunk segments (level C7-T10), pelvis, right and left thighs and shanks was quantified with principal component analysis (PCA) during 3 periods: an interval preceding the arrest (pre), an interval from the arrest onset to recovery of coordinated bimanual oscillations (intermediate), and an interval after that (post).

Results: One PC described 95–96% of the total angular variance in pre- and post-arrest intervals. The variance accounted for by PC1 decreased (<75%) for the intermediate interval and remained decreased until all body and arm segments arrived at a steady-state around the position of maximal arm flexion at which time, coordinated arm oscillations resumed.

Conclusion: Results suggest that arm and body movements may be controlled as one multi-segment movement. Results also imply that rhythmic arm movements are re-initiated when all body and arm segments reach a steady state position after perturbation.

6.29 Function of early arm responses to balance perturbations

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Introduction: Perturbation of whole-body stability often evokes rapid arm reactions. It has been unclear whether the earliest arm activation is associated with initiation of a reach-to-grasp movement or is part of a startle, protective or counterweight reaction.

Methods: We analyzed the arm reactions evoked in healthy young adults (n = 12) during their very first exposure to small platform perturbations (first three trials). Subjects were instructed not to step but to otherwise do whatever came naturally to recover balance; barriers deterred foot movement. Each subject was assigned to one of four task conditions: two handrail conditions (present on right side or absent) × two perturbation conditions (platform translation forward or rightward). The perturbations were sufficiently small to allow balance to be recovered without grasping for support.

Results: The arm reactions were highly dependent on task condition. Arm activation was larger and faster when the handrail was absent, and was also modulated by perturbation direction. In most no-handrail trials, backward falling motion evoked forward elevation of both arms (consistent with a counterweight strategy). Forward arm elevation was, on average, much smaller in all other task conditions. Lateral perturbation primarily evoked lateral motion in both arms; in handrail trials, the right-arm motion could reflect initiation of a reach-to-grasp reaction that was aborted prior to contacting the rail.

Discussion: The arm reactions were not stereotyped (e.g. startle) responses, but were instead influenced by environmental affordances and by perturbation direction. Work in progress suggests that the responses are also highly dependent on perturbation magnitude.

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6.30 The influence of artificially induced knee "locking" on balance corrects

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Introduction: Earlier studies on balance control emphasized rotations about the hip and ankle joints. Nonetheless, increased knee stiffness with aging or injury is known to increase the risk of falling. Thus the question arises if insufficient knee movement due to stiffness impairs balance control. For this reason we examined considerably reducing knee motion on balance control by "locking" the knees with firm casts.

Methods: 18 healthy young adults (9 men, 19–29 years of age) were tested, with and without individually fitted knee casts on both legs, using combined pitch and roll rotations (7.5° at 60°/s) of the support surface in six different directions. Outcome measures were biomechanical responses of the legs, trunk, arms and head, and electromyographic activity (EMG) of upper arm, leg and trunk muscles.

Results: The knee cast condition decreased downward center of mass (CoM) movement for forward platform rotations and increased backward CoM movement for backward rotations. Ankle and hip angle changes were also reduced for most directions. A change in the balance correcting strategy involving a reversal of pelvis pitch movement and additional arm motion occurred for forward perturbations. Rearward pelvis motion was increased for backward perturbations. Upper leg and trunk EMG responses were decreased and arm responses increased.

Discussion and Conclusion: These results clearly show that artificially imposed knee "locking" influences balance responses seen after sudden support surface tilts, supporting the notion that knee movements are an integral part of balance corrections.