Corticospinal excitability during unpredictable mediolateral gait destabilizations

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Summary

We investigated corticospinal excitability during mediolateral destabilization of gait. Fifteen healthy participants underwent single-pulse TMS over the primary motor cortex during steady-state and destabilized treadmill walking, with MEPs recorded from seven leg muscles. Destabilized gait showed greater step width, variability, and dynamic instability, alongside shorter stride duration and increased foot placement errors. Muscle activity and absolute MEP amplitudes were higher in proximal muscles (RF, BF, GM, AM), with normalized MEP amplitudes elevated during destabilized gait, particularly during low muscle activity phases. In distal muscles, MEP size remained unchanged, possibly reflecting the limited effectiveness of ankle strategies under random surface shifts. These findings suggest that destabilized gait prompts a cautious walking strategy, emphasizing hip and knee muscle readiness.

Introduction

Unpredictable disturbances during gait, particularly in the mediolateral direction, challenge stability and are a common contributor to falls. Although the corticospinal tract is critical for gait and postural control, its response to such instabilities remains unknown. Thus, the aim of the current study was to quantify corticospinal excitability of proximal and distal leg muscles during unpredictable mediolateral destabilization of gait.

Methods

Single-pulse transcranial magnetic stimulation was delivered over the primary motor cortex of 15 healthy individuals at a random instant every 3-5 strides during steady-state and mediolaterally destabilized treadmill gait. Full body kinematics were recorded. Stimulations where the coil was >5 mm from the target location on the head were excluded (<3% of total). An average of 212 and 215 stimulations per participant were included in the steady-state and destabilized conditions, respectively, distributed across the gait cycle. Responsiveness of the corticospinal tract was quantified from responses to cortical stimulation (motor evoked potentials; MEPs) recorded from seven muscles using surface electromyography: tibialis anterior (TA), medial gastrocnemius, lateral gastrocnemius (LG), rectus femoris (RF), biceps femoris (BF), gluteus medius (GM), adductor magnus (AM).

Results and Discussion

Step width was greater (128 ± 2 mm vs 105 ± 3 mm) and more variable and stride duration was shorter (1.09 ± 0.03 vs 1.15 ± 0.04 s) and more variable during destabilized gait. Dynamic instability was greater (local divergence exponent (3.17 ± 0.18 vs 2.68 ± 0.30), along with greater foot placement control at midstance and greater foot placement error. Muscle activity was higher during destabilized gait for TA, LG, RF, BF, GM and AM. Absolute MEP amplitudes were higher for RF, BF, GM and AM. After normalization to the ongoing EMG, MEP amplitudes were higher during destabilized gait for these same muscles, although for a smaller portion of the gait cycle and primarily only during periods of low muscle activity (Figure). Normalized MEP in TA was also higher during destabilized gait at the transition from stance to double support.

Conclusions

Participants adopted a more cautious walking strategy when destabilized. This was accompanied by greater muscle activity and larger MEPs in proximal muscles. The unchanged MEP size in distal muscles may reflect the method of destabilization, whereby the unpredictability of constant random surface shifts limited the effectiveness of ankle strategies, leading participants to adopt a more cautious walking strategy with heightened readiness of the hip and knee muscles to maintain stability. The predominance of differences in normalized MEPs during periods of muscle quiescence may indicate that corticospinal input to motor neurons is particularly important in these periods.

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