Gait stability through ankle moment control: compensating or steering foot placement?

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***Abstract*— Foot placement control, accounting for variations in the center of mass kinematic state, is important in maintaining mediolateral steady-state gait stability in humans. The location of the center of pressure with respect to the center of mass defines the lever arm for the moment accelerating the center of mass away from the lateral border of the base of support. Errors in foot placement may hence lead to instability. We show that, during steady-state walking, ankle moment control partially corrects for foot placement errors. The resulting center of pressure shift underneath the stance foot is associated with ankle muscle activity. As such we identify ankle moment control as a muscle-driven stability mechanism. However, constraining variations in foot placement does not yield an increase in compensatory ankle moment control. We argue that foot placement and ankle moment control are circularly dependent on one another.**

***Keywords*— gait stability, ankle moment control, foot placement control**

I. Introduction

During human steady-state walking, coupling between the center of mass (CoM) kinematic state during swing and subsequent foot placement [1, 2] arises from passive dynamics [3] and active control [4-6]. When predicting foot placement based on the CoM kinematic state, a prediction error remains [1]. We interpret this error as "inaccurate" foot placement because of motor noise or relaxed control [5]. Here, we tested whether ankle moment control, following foot placement, compensates for foot placement errors.

II. Methods

Thirty healthy adults walked on a treadmill, with and without foot placement constraints. Projections on the treadmill served to constrain foot placement to a fixed step width. Stride-frequency was metronome-controlled and walking speed was set at 1.25 · √(leg length) m/s. We used (multiple-)linear regression to identify associations between (1) foot placement error and the subsequent single stance center of pressure (CoP) shift (compensatory ankle moment control) and between (2) peroneus longus, tibialis anterior and soleus activity and this CoP shift (active stability control).

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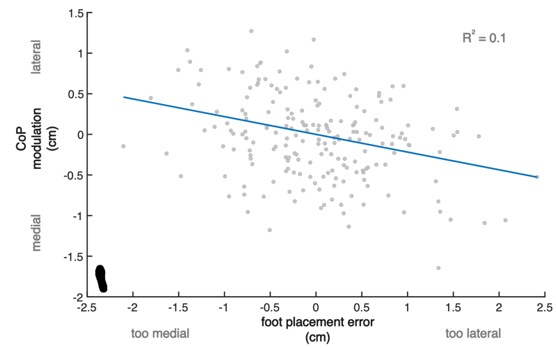

Fig. 1. Example: Regression for one participant. During steady-state walking too medial foot placement was compensated for by a lateral CoP shift and too lateral foot placement was compensated for by a medial CoP shift.

III. Results

In the normal walking condition, we found (1) a relationship between foot placement error and the subsequent single stance CoP shift (Fig. 1) and (2) associated ankle muscle activity. In the foot placement constraint condition, the absolute explained variance of the first relationship did not increase. Thus, active ankle moment control accounted for variations in foot placement accuracy but did not serve an additional compensatory function when foot placement was constrained.

IV. Discussion

Ankle moment control attenuates foot placement errors. Previous studies suggest that ankle moment control preceding foot placement can steer foot placement [7, 8]. Such circularity may explain why ankle moment control did/could not compensate for foot placement constraints in our experiment. Foot placement and ankle moment control should not be considered independently, nor in a specific temporal order.

References

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