

STEPPING FROM A NARROW SUPPORT

¹Yun Wang, ²Elena Yu. Shapkova, ¹Siripan Siwasakunrat,
¹Vladimir M. Zatsiorsky, and ¹Mark L. Latash

¹Department of Kinesiology, The Pennsylvania State University, University Park, PA 16802

²Children's Surgery Clinic, Institute of Phthisiopulmonology, St. Petersburg, Russia

email: ml111@psu.edu

INTRODUCTION

When a standing person initiates a step, the center of pressure (COP) shifts in the medio-lateral (ML) direction towards the supporting foot and in the anterior-posterior (AP) direction backwards [1,2]. Apparently, COP cannot be shifted beyond the available dimensions of the support area. However, humans can initiate a step forward after balancing for a short time on a support that is very narrow in the AP direction. One possibility is that people use horizontal forces to move the body forward; this would violate the balance and initiate a fall of the body in the required step direction.

We investigated mechanical and electromyographic (EMG) events prior to making a step and their changes associated with changes in the AP dimension of the support area. We hypothesized that a constraint on possible COP shifts will be associated with increased changes in the horizontal force and with changed neural strategies reflected in changes in EMG signals from the leg muscles.

METHODS

Eight healthy subjects participated in the experiment. A force platform recorded the reactive forces and moments. Disposable electrodes were used to record the surface EMG of the following muscles from both sides of the body: tibialis anterior (TA), soleus (SOL), rectus femoris (RF), and biceps femoris (BF), and of the rectus abdominis (RA) and erector spinae (ES) on the left side of the body.

The subjects stood barefoot on the force plate or on one of two specially constructed wooden boards with the same horizontal dimensions as the force plate. One of the boards was fitted with a narrow beam on the undersurface (3.3 cm wide, 5.3 cm high). This board was placed over the force plate such that its narrow dimension was in the AP direction. In other trials, a similar wooden board was placed on the top ridge of a triangular metal wedge (4.9 cm in height, 91.4 cm in length). The wedge was placed on the force plate such that its upper ridge ran horizontally in the ML direction. The subjects performed self-paced steps from quiet stance while standing on either the force plate, or the board fitted with the narrow beam ("narrow support"), or the board resting on the upper ridge of the wedge ("ridge support").

All trials were aligned by the first visible shift of the moment about the vertical axis (time zero, t_0). After alignment, sets of trials performed by the same subject, with the same leg, in the same condition were averaged. Changes in the background EMG were quantified using rectified signals integrated over 100 ms intervals starting 300 ms prior to t_0 and ending 300 ms after t_0 . COP shifts and changes in the force in the AP

direction (F_x) were quantified within the interval $\{-300 \text{ ms}; +300 \text{ ms}\}$ with respect to t_0 .

RESULTS

Stepping from the force plate was associated with COP shifts towards the support foot and backwards and an increase in F_x acting forward on the subject. Stepping from the "narrow support" led to smaller AP COP shifts. Stepping from the "ridge support" was associated with very small COP shift in AP direction, smaller COP shifts in ML direction, and larger F_x changes (Fig. 1). There was a general increase in the level of activation of leg and trunk muscles during stepping from the "narrow support" and "ridge support". Such differences in the activity of ankle extensors were seen in the stepping leg only at the beginning of the preparation period and in the supporting leg over the whole time interval of analysis.

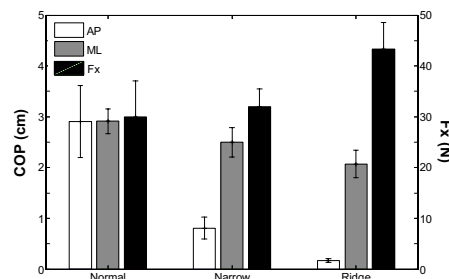


Fig. 1 Shifts of the COP (AP-white bars; ML-grey bars) and F_x (black bars) averaged across the subjects.

DISCUSSION AND CONCLUSIONS

Our observations demonstrate the existence of alternative mechanical strategies that can be used in a task-specific manner to initiate a step. We suggest a hypothesis that a subjectively perceived postural instability may prevent the subjects from using the most common method of step initiation, namely a COP shift backwards. Then, an alternative strategy of an increased F_x change is discovered. If this is correct, training of persons who show an impaired ability to initiate a step may benefit from providing feedback on the horizontal force and practicing on a surface with high friction.

REFERENCES

- Halliday S, et al. The initiation of gait in young, elderly, and Parkinson's disease subjects. *Gait Posture* **8**, 8–14, 1998.
- Couillandre A, et al. Is human gait initiation program affected by a reduction of the postural basis? *Neurosci Lett* **285**, 150–154, 2000.

ACKNOWLEDGEMENTS

This research was supported in part by NIH grants AG-018751, NS-35032, and AR-048563.