

SWING PHASE INTERRUPTION IN A SLIP: ACTIVE OR PASSIVE RESPONSE?

Rakié Cham, PhD

Department of Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA

E-mail: rcham@pitt.edu

INTRODUCTION

Prevention of slip-precipitated falls requires an understanding of postural reactions to such perturbations. Prior slips/falls gait research has, to a large extent, focused on the leading/slipping leg, while the dynamics of the trailing leg have not been often examined. In Moyer *et al.* (2007), four types of trailing leg response, termed *minimum*, *foot-flat* (FF), *mid-flight* (MID), and *toe-down* (TD) were identified. Trailing foot toe off occurs in all four patterns. The swing phase is interrupted in FF, MID and TD responses, the focus of this analysis (Fig 1).

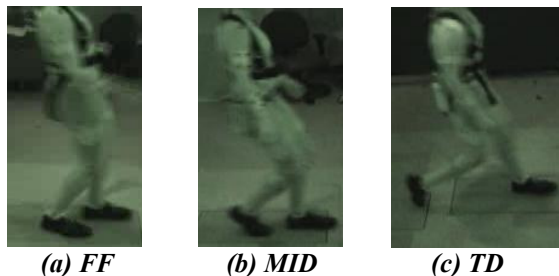


Figure 1: Trailing leg responses to a slip involving a swing phase interruption. (a) FF: entire foot sole contacts ground near leading/slipping foot. (b) MID: forefoot contacts ground behind leading/slipping foot. (c) TD: most severe slips; tip of forefoot contacts ground immediately (~50 ms) after toe off. Adapted from (Moyer *et al.*, 2007).

It may be argued that the swing phase interruption is not an active postural strategy but rather a consequence of the passive dynamics of the fall. Indeed, Tripp *et al.* (2004) suggested that the direction of the step cannot be modulated after foot lift-off. Thus, the goal of this analysis is to compare the latency of the muscles in the trailing leg with foot floor contact time to determine if the swing phase interruption is an active or

passive response. Net joint moments computations revealed that simultaneous hip extension and knee flexion reactions in the trailing limb cause the interruption of the swing phase, lowering the leg onto the ground and decelerating knee extension (Moyer *et al.*, 2007). Thus, compared to normal gait, it is expected that during the slip the magnitude of the hamstring will be greater than that of the vastus lateralis, but that the knee extensors activity will be non-negligible to prevent limb collapse as body weight is transferred from the leading/slipping leg to the trailing leg.

METHODS

Ten healthy adults walked at a self-selected pace, while ground reaction forces and whole body motion were sampled at 1080 and 120 Hz, respectively. EMGs were also collected from major muscle groups in both legs at 1080 Hz. Subjects were informed that the first few trials would be dry to ensure normal walking (dry condition). Then, without the subjects' knowledge, glycerol was applied on the floor to initiate a slip at heel contact of the leading/left leg. Only EMG data collected from the medial hamstring and vastus lateralis in the trailing/right leg were analyzed here.

All EMGs (dry and slip) were rectified, low-pass filtered at 50 Hz using a zero-phase filter, time normalized to stance duration (leading leg) of normal walking and magnitude normalized to the peak value collected during normal walking. EMG data collected in the dry trial prior to the slip were subtracted from the EMGs recorded

during the slip. The resulting time series was used to determine muscle latency post slip initiation using a threshold of two standard deviations above the (slip – dry) difference prior to slip initiation. In addition, this threshold was exceeded for a minimum of 30 ms for a point to be picked as the latency. Latency data were visually confirmed.

RESULTS

The latency of the hamstring and vastus lateralis ranged from 140 to 200 ms (Fig 2). For the most severe slips, e.g. TDs and few MIDs, the muscle response in the trailing leg started prior to toe off. As expected, in general, the relative magnitude of the hamstring activity was greater than that of the vastus lateralis.

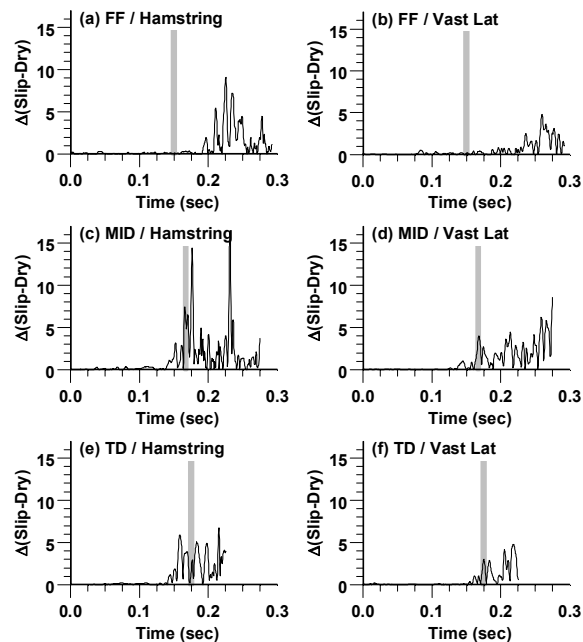


Figure 2: Typical difference in hamstring (left) and vastus lateralis (right) activity between dry and FF (a-b) /MID (c-d) /TD (e-f) slip. All EMGs are divided by the peak value recorded during normal gait before the (slip–dry) difference is computed. Time “0” = heel contact of leading leg onto slippery floor. Vertical gray line = time of trailing leg toe off. Data are chopped at time of trailing foot floor contact.

The hamstring and vastus lateralis activity was initiated prior to foot contact in all

MID/FF slip patterns (Fig 2 a-d, Table 1). In contrast, the latency of these muscles were detected prior to foot floor contact time in only one of two TD slip patterns (Fig 2e-f, greater variability is reflected in Table 1).

Table 1: Mean (SD) of within-subject difference between latency of trailing leg muscle response and trailing foot floor contact time. A negative number indicates the muscle response occurred prior to foot floor contact time in the trailing leg.

Latency – contact time (ms)	Hamstring	Vastus lateralis
FF (N=4)	-108 (14)	-90 (16)
MID (N=4)	-129 (8)	-126 (7)
TD (N=2)	52 (196)	31 (144)

DISCUSSION AND CONCLUSIONS

In summary, the latency of the muscles in the upper trailing leg is detected prior to trailing foot floor contact in FF/MID slip patterns. These findings suggest that the swing phase interruption is an active reaction in FF/MID responses. The findings also confirmed that the activity of the trailing leg’s hamstring and vastus lateralis plays a role in slip-initiated recovery efforts.

The argument of an active swing phase interruption strategy may not hold in TD slip patterns. While the muscular response in the trailing leg may be initiated early, it is likely that the severity of the slip may not allow time for effective active responses, resulting in the fall driving the dynamics of limb collapse.

REFERENCES

- Moyer, B.E. et al. (2007). *J of Biomech*, submitted.
 Tripp, B.P. et al. (2004). *IEEE Trans Neural Syst Rehabil Eng* **12**, 140-152.

ACKNOWLEDGEMENTS

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