

# SEGMENTAL INTERACTIONS DURING RUNNING OVER OBSTACLES OF INCREASING HEIGHT

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## INTRODUCTION

Much research has been produced on behavioral transitions such as the walk-to-run or the run-to-sprint. However, limited research exists on running over high enough obstacles to cause a change of the landing strategy. Previous research has indicated that during running over obstacles of increasing height, most heel-strike runners change their contact strategy to a forefoot landing pattern (Scholten et al., 1999). Recently, behavioral transitions have been examined using the Dynamical Systems Theory (DST). In DST, the interacting components are examined while scaling up a control parameter to elicit new patterns of coordination (Clark & Phillips, 1993). The purpose of this study was to examine the different landing strategies used during running over obstacles of increasing height. By using DST, we investigated the interacting segments, while scaling up a control parameter (obstacle height).

## PROCEDURES

Ten heel-strike subjects ran at a self-selected pace under seven conditions: a level surface and over obstacles of six different heights (10%, 12.5%, 15%, 17.5%, 20%, and 22.5% of their standing height). Sagittal view kinematics were collected (180 Hz) from the right lower extremity using a Peak Performance system. To examine segmental interactions, the phase portraits from segmental angular positions and velocities were used to calculate phase angles (Scholtz, 1990). Relative phase (RP) curves

were calculated for two segmental relationships [foot-shank (F-S) and shank-thigh (S-T)] by subtracting the phase angle of the proximal segment from the distal segment. Mean ensemble RP curves were calculated for all conditions. From these curves two parameters were evaluated: a) mean relative phasing (MRP), and b) deviation phasing (DP). MRP and DP were calculated by averaging the absolute values and the standard deviations, respectively, of all points of the mean ensemble RP curve. MRP and DP were calculated for two intervals, a pre-landing period (from the obstacle to ground contact) and stance. One-way repeated measures ANOVAs were performed on MRP and DP for each segmental relationship and for each interval. A Tukey test was performed in comparisons that resulted in a significant F-ratio ( $p < 0.05$ ).

## RESULTS AND DISCUSSION

Group results are presented in Table 1. The F-S MRP significantly increased in both periods, indicating that the F-S relationship becomes more out-of-phase with increases in obstacle height. An out-of-phase relationship means more independence in the actions of the two segments. No significant differences were found for the S-T MRP, indicating that the changing obstacle height did not affect the S-T segmental relationship. The DP results revealed significant differences for both F-S and S-T but only for the pre-landing period. The F-S DP increased with obstacle height, while the S-T DP decreased with the

introduction of the obstacle. Increases in DP reveal an unstable system, while decreases are associated with a fixed and rigid system. Thus, the F-S relationship is unstable because it changes to more out-of-phase. On the contrary, the S-T relationship doesn't change and becomes even more rigid and inflexible. The fact that no significant changes were observed for DP during stance indicated that the system was stable in this period. Thus, it is possible that the system conducted all the necessary accommodations prior to contact.

A further examination of Table 1 reveals that the larger differences in F-S MRP for both periods were observed from 0% to 10% and from 12.5% to 15%. That was also the case for the pre-landing F-S DP. Therefore, the introduction of the obstacle caused behavioral changes, but the 15% condition was probably the height with the greatest effect. These results are in agreement with Scholten et al. (1999). In that study, it was mentioned that the 15% height condition is the height in which the landing strategy has been shown to change from heel-strike to forefoot strike.

## SUMMARY

Introducing an obstacle and increasing the obstacle height elicited behavioral changes. These changes were different for the interacting segments at the ankle and at the knee. While the foot and the shank became more independent in their actions, the shank and the thigh strengthened even more their stable relationship. The 15% height seems to be a critical height for the observed changes.

## REFERENCES

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**Table 1:** Parameters evaluated with superscripts indicating post-hoc differences ( $p < 0.05$ ). All values are in degrees.

Variables	0%	10%	12.50%	15%	17.50%	20%	22.5%
<b>PRE MRP</b>	10.4 <sup>15%-22.5%</sup>	19.8 <sup>20%-22.5%</sup>	18.9 <sup>15%-22.5%</sup>	30.6 <sup>22.5%</sup>	30.6 <sup>22.5%</sup>	39.2	43.6
Foot-shank	+1.7	+11.1	+7.9	+13.9	+11.2	+15.6	+14.4
<b>PRE MRP</b>	88.8	93.8	91.8	92.5	90.0	87.3	85.9
Shank-thigh	+7.8	+19.6	+20.1	+19.7	+20.3	+19.8	+18.8
<b>PRE DP</b>	6.1 <sup>17.5%-22.5%</sup>	10.1	11.3	15.3	17.4	17.8	16.8
Foot-shank	+2.7	+5.9	+7.0	+6.6	+9.1	+6.2	+4.7
<b>PRE DP</b>	16.9 <sup>10%,15%</sup>	10.1	10.9	10.2	11.2	11.1	12.3
Shank-thigh	+8.7	+2.0	+4.1	+3.3	+3.3	+3.6	+4.7
<b>STANCE MRP</b>	37.8 <sup>12.5%-22.5%</sup>	44.8 <sup>20%-22.5%</sup>	45.8	50.9	51.2	52.9	53.2
Foot-shank	+5.6	+11.4	+10.6	+12.8	+11.5	+11.0	+12.3
<b>STANCE MRP</b>	48.7	48.6	47.8	46.8	48.1	45.9	43.4
Shank-thigh	8.1	7.1	6.5	10.3	10.6	10.7	12.7
<b>STANCE DP</b>	9.4	11.3	13.0	14.3	15.5	17.4	15.9
Foot-shank	+6.9	+5.3	+7.2	+4.4	+6.6	+9.5	+6.8
<b>STANCE DP</b>	10.9	11.4	12.7	14.3	15.5	17.4	15.9
Shank-thigh	+7.7	+3.6	+4.7	+5.8	+5.3	+8.1	+3.9