THE USE OF LEG RETRACTION IN OBSTACLE AVOIDANCE

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INTRODUCTION

For stable running, a proper adjustment of the leg angle of attack α_0 to the leg stiffness k_{LEG} is required (Seyfarth et al., 2002a). In a simulation study, a rotational leg control at the end of the swing phase (Figure 1) was shown to be a simple strategy to further improve running stability (Seyfarth and Geyer, 2002b). *Leg retraction* is a behaviour that has been observed in humans and animals in which the swing-leg is moved rearward towards the ground during late swing-phase. In this study we ask whether leg retraction is actually *used* to stabilise running. Therefore, we studied undisturbed and disturbed human treadmill running (Figure 2).

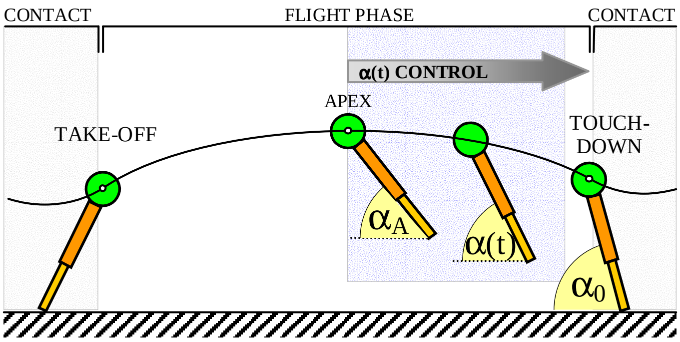

Figure 1: A rotational control of the leg prior to landing (leg retraction) is a simple strategy to stabilise running.

METHODS

An instrumented treadmill (Woodway, Germany) was equipped with an obstacle-machine consisting of a cylindrical-shaped bar (2.5 cm diameter, 12 cm above the belt). Every 9-16 seconds, the bar moved towards the human runner at a speed equivalent to the treadmill surface, forcing the runner to change his swing phase kinematics to avoid the obstacle.

A B

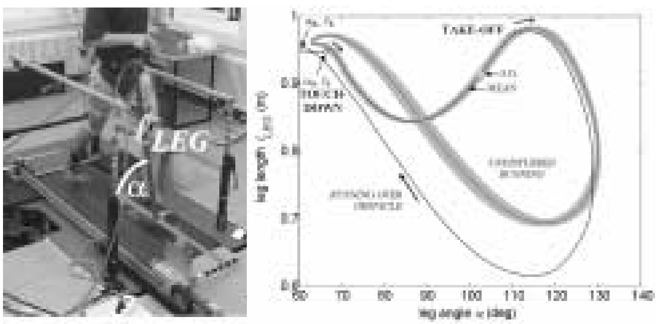

Figure 2: (A) During treadmill running, an obstacle (plastic bar) was repeatedly introduced. (B) When passing the obstacle, the swing leg is significantly more flexed. However, a similar leg angle at touch-down α_0 is reached.

Using this apparatus, we conducted experiments on five male subjects (mass 79.6 ± 5.9 kg, age 30.6 ± 3.2 yrs) performing treadmill running at 3 m/s. Leg angle α_0 and length λ_{LEG} at the onset of swing-leg retraction and at touch-down were used to characterise the kinematic leg control prior to landing (Figure 2A).

RESULTS AND DISCUSSION

During obstacle avoidance, the kinematics of the swing phase were significantly changed (Figure 2B). At the same time, the leg stiffness k_{LEG} after disturbance remained rather unchanged compared to the undisturbed condition (Table 1). Leg retraction was observed in the undisturbed condition (Table 1: α_{SHIFT} = 4.5°) and significantly enhanced ($p<0.05$) when passing over the obstacle (α_{SHIFT} = 9.1°). Hence, leg retraction is an experimentally observable strategy to cope with perturbations during human running.

	k_{LEG} (kN/m)	α_R (deg)	α_0 (deg)	α_{SHIFT} (deg)
undisturbed	25.2±6.8	64.3±2.0	68.8±2.1	4.5±0.9
disturbed	22.9±3.9	61.3±1.5	70.4±2.7	9.1±3.6
difference	**-2.3±4.4**	**-3.0±2.5**	**1.7±2.1**	**4.7±3.0**

Table 1: Comparison of leg stiffness k_{LEG}, onset angle of retraction α_R, angle of attack α_0, and the angle swept during retraction $\alpha_{SHIFT} = \alpha_0 - \alpha_R$ between undisturbed and disturbed conditions (mean ± S.D. for 5 subjects).

Leg retraction is a feedforward control scheme, and therefore, can neither avoid obstacles nor place the foot at desired foot-targets. Rather, the scheme provides a mechanical ‘background stability’ that may relax the control effort for locomotory tasks. It remains for future research to understand to what extent environmental sensory information might allow for varied kinematic trajectories and an increase in the stabilizing effects of swing-leg retraction.

REFERENCES

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