Simulated Reduction of Flight Time during Hurdle Clearance by Manipulation of Ground Reaction Forces

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INTRODUCTION

As in sprinting events, the essence of hurdling is to cover a given distance as fast as possible [1]. In order to negotiate the hurdles, the athletes have to generate an additional amount of potential energy which decreases the horizontal velocity [2]. Therefore, the vertical oscillation of the centre of mass (CoM) during hurdle clearance should be as low as possible [3, 4]. A decrease in CoM oscillation leads to a reduction in flight time (in which the athletes cannot accelerate) [2, 3, 4]. Thus, the flight phase of hurdle clearance is designated as the most potential result [3].

The trajectory of the CoM is caused by the kinematics and ground reaction forces (GRF) applied before take-off [5]. The relevant parameters can be measured in biomechanical analyses allowing to visualize the actual movements. However, the concrete effect of manipulations (of one or more parameters) on CoM trajectory and flight time remains unclear. To illustrate these influences, a tool to simulate the CoM trajectory and corresponding flight time changes during hurdle clearance was developed. This article focuses on the effects of GRF manipulations on flight time and provides practical advices for training.

DISCUSSION

A decrease in $F_N$ (-12.90 Ns) in favor of horizontal acceleration, resulted in a reduction of flight time (-4.154 ms) and landing distance (-18.60 cm). An extrapolation of this benefit is hindered by the fact that the ground contact time increased by 12.00 ms and that the horizontal velocity varies during competition [2, 7]. In consideration of these limits, a total improvement of 0.15 to 0.25 s can be estimated. However, it was noticed that a reduction of flight time increases the risk of an insufficient landing preparation and requires the lengthening of the three interhurdle steps [8]. For our athlete, the shorter landing distance needs to be compensated through an increase in stride length by 6.20 cm.

To transfer the theoretical manipulations into practice, modifications of technique and the muscular system are needed, which can be achieved by specific exercises. To reduce horizontal braking in the early stance phase, the touchdown distance (CoM to foot) should be shortened [5, 6]. Therefore, the preparatory step should be shortened [7, 9], following by a fast hip extension before touchdown [10]. The shorter the touchdown distance, the higher the leg stiffness of the supporting leg can be adjusted to maintain a high CoM position [11]. An improvement in leg stiffness can be achieved by the application of heavy resistance and plyometric exercises [12], whereas the coordination pattern for touchdown can be practiced by isolation drills [8] and variations of hurdle distances [7]. An increase in horizontal propulsion can be derived by prolonging the ground contact time and thus increasing the take-off distance (foot to CoM) [6]. In this phase, an explosive leg extension increases the GRF with the plantar flexors and hip extensors causing the height [6, 10]. Exercises to improve the propulsion ability include sled towing [8], resistance running [7, 12], runs on sand [7] and strength training for the plantar flexors [7]. In conclusion, the transferability of the presented tool to other take-off events (like in long or triple jump) needs to be examined.