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

O. J. Quittmann[1,4,5], C. Richter[1], M. Sanno[2,3] & J.-P. Goldmann[2,3]

[1] M. Sc. Exercise Science and Coaching, German Sport University Cologne [2] German Research Centre for Elite Sport Cologne (momentum) [3] Institute of Biomechanics and Orthopeadics

[4] Institute of Training Science and Sport Informatics [5] Institute of Movement and Neurosciences

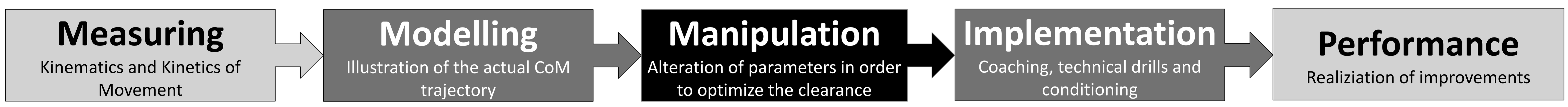
INTRODUCTION

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 for the improvement of competetion results [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.

METHODS

To determine the relevant parameters, kinematics and kinetics of a female hurdler (international level; 23 yrs; 63.4 kg) were measured using 16 high speed infrared cameras (250 Hz, MX-F40, Vicon Nexus 1.8.2, Oxford, UK) and three force plates (1250 Hz, 600x900 mm, Kistler, Winterthur, Swiss) placed in front of the first hurdle. 54 spherical retro-reflective markers were placed on anatomical landmarks according to the three-dimensional multibody human model Dynamicus 7.0® (alaska®, Institute of Mechatronics, Chemnitz, Germany). The calculations based on formulas used in mechanics (esp. the inclined launch). An assumption for the flight time calculation was an equal height of the CoM at take-off and landing. Air resistance and segment movements during the flight phase were disregarded in the simulation. Assuming that the vertical and horizontal components of GRF cannot be altered independently [6], the reduction in vertical momentum directly favored the horizontal acceleration by less braking and more propulsion. The implementation of the simulation was realized using Microsoft Excel 2016® (Microsoft Corporation®, Redmond, WA, USA).



RESULTS

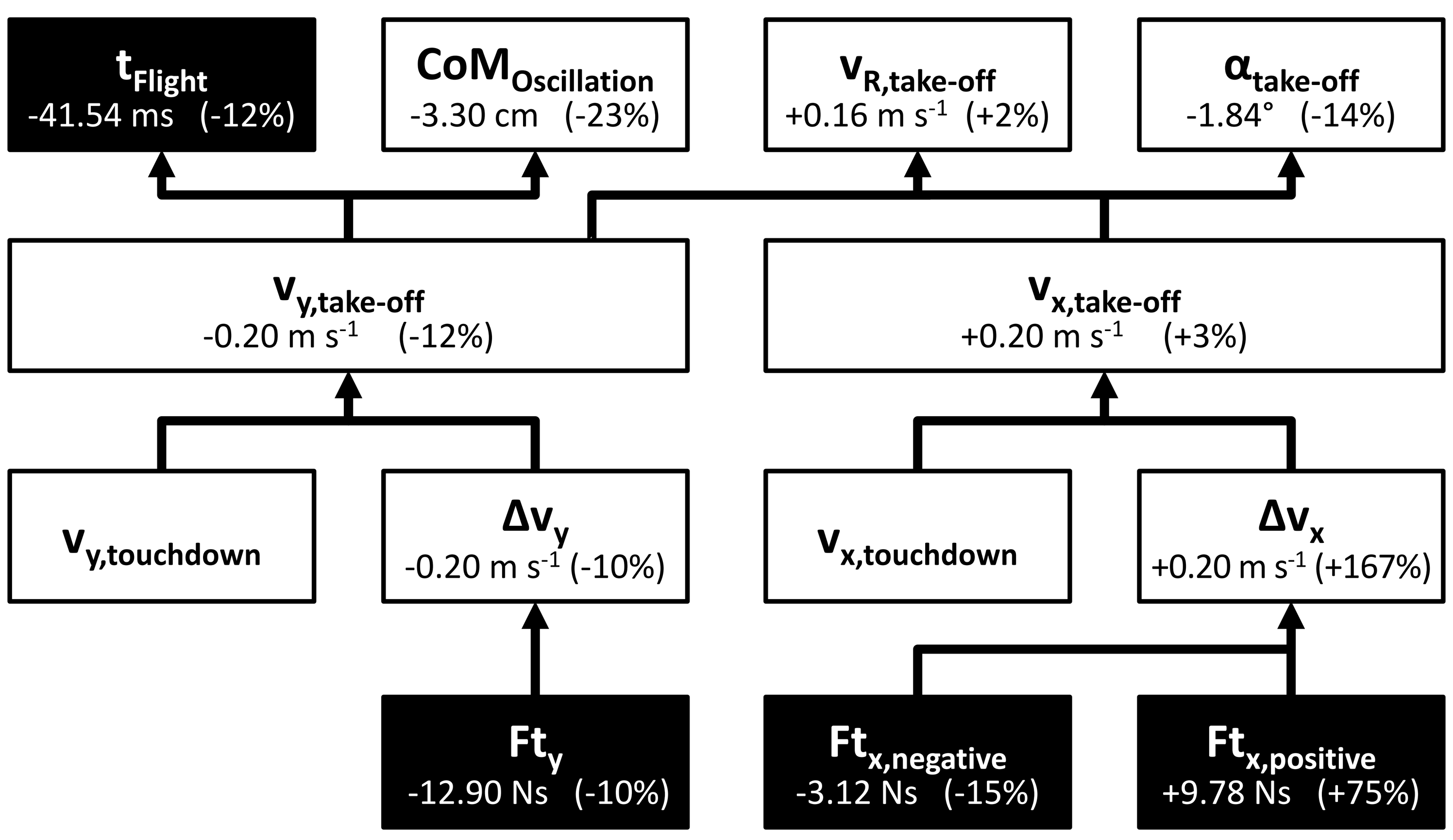


Fig. 1. **Manipulation of GRF and effects on kinematic parameters leading to a change in flight time**

Ft_y = Vertical momentum; **$Ft_{x,negative}$** = Negative horizontal momentum; **$Ft_{x,positive}$** = Positive horizontal momentum; **$v_{y,touchdown}$** = Vertical velocity at touchdown; **Δv_y** = Change in vertical velocity; **$v_{x,touchdown}$** = Horizontal velocity at touchdown; **Δv_x** = Change in horizontal velocity; **$v_{y,take\text{-}off}$** = Vertical velocity at take-off; **$v_{x,take\text{-}off}$** = Horizontal velocity at take-off; **t_{Flight}** = Flight time; **$CoM_{Oscillation}$** = Difference between the height of the CoM at take-off and maximal height; **$v_{R,take\text{-}off}$** = Velocity resultant at take-off; **$\alpha_{take\text{-}off}$** = CoM take-off angle.

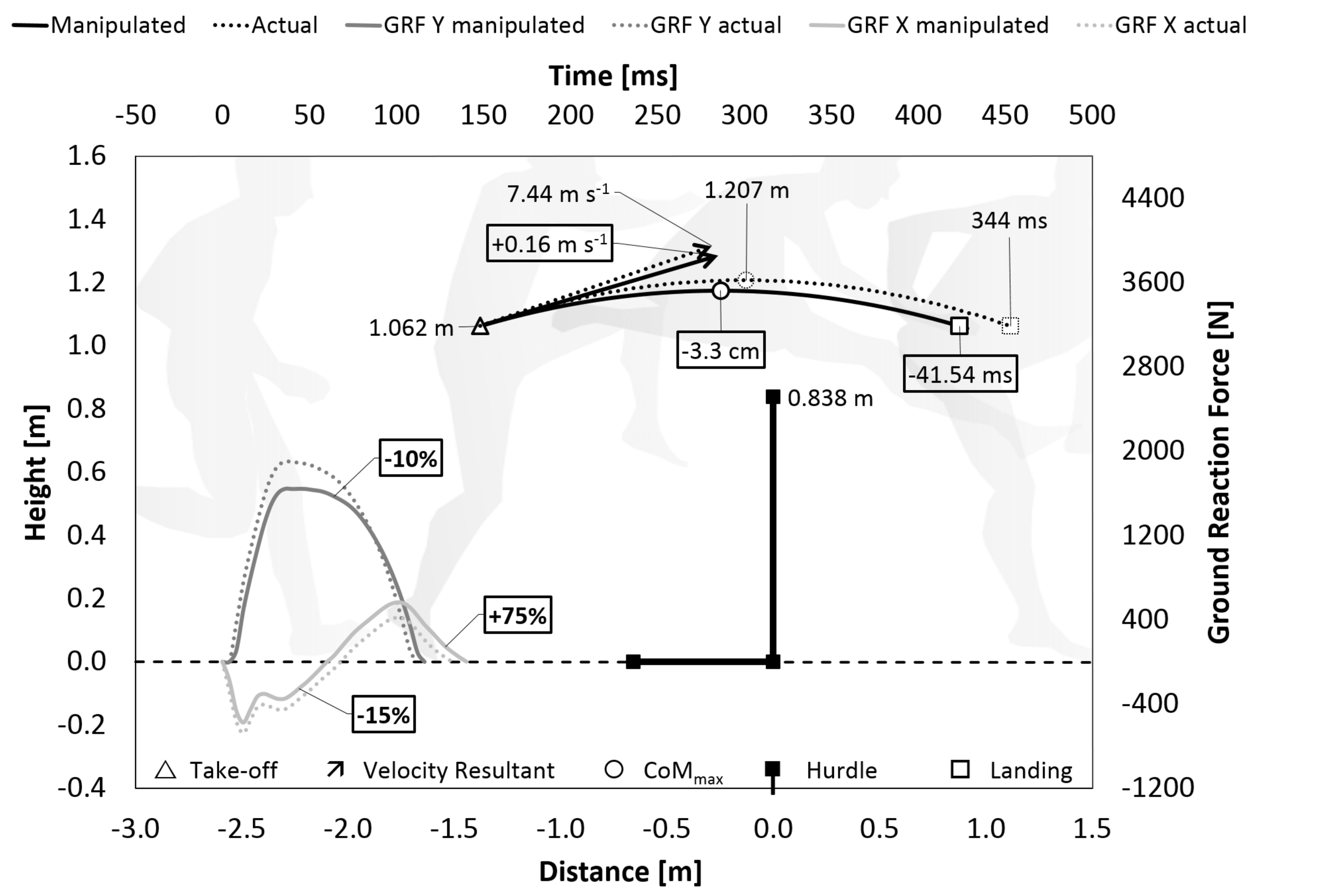


Fig. 2. **Manipulation of GRF and the corresponding change in the CoM trajectory and flight time**

The **dotted lines** show the actual trajectory of the CoM and GRF. The **solid lines** illustrate the manipulated GRF and corresponding alterations of the CoM trajectory and flight time. For **Ft_y**, the GRF caused by body weight are substracted.

DISCUSSION

A decrease in Ft_y (-12.90 Ns) in favor of horizontal acceleration, resulted in a reduction of flight time (-41.54 ms) and landing distance (-18.60 cm). An extrapolation of this benefit is hindered by the facts 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 most power [6, 10]. Exercises to improve the propulsion ability include sledge 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.

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Forschung

Beratung und Betreuung

Fort- und Weiterbildung

Kontakt: O.Quittmann@dshs-koeln.de