

This article was downloaded by:[Sheffield Hallam University]  
On: 14 September 2007  
Access Details: [subscription number 773565535]  
Publisher: Routledge  
Informa Ltd Registered in England and Wales Registered Number: 1072954  
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Sports Biomechanics

Publication details, including instructions for authors and subscription information:  
<http://www.informaworld.com/smpp/title~content=t776628940>

### Runners do not push off the ground but fall forwards via a gravitational torque

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Online Publication Date: 01 September 2007

To cite this Article: Romanov, Nicholas and Fletcher, Graham (2007) 'Runners do not push off the ground but fall forwards via a gravitational torque', Sports Biomechanics, 6:3, 434 - 452

To link to this article: DOI: 10.1080/14763140701491625

URL: <http://dx.doi.org/10.1080/14763140701491625>

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## NEW METHODS AND THEORETICAL PERSPECTIVES

# Runners do not push off the ground but fall forwards via a gravitational torque

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### Abstract

The relationship between the affect and timing of the four forces involved in running (gravity, ground reaction force, muscle force, and potential strain energy) is presented. These forces only increase horizontal acceleration of the centre of mass during stance but not flight. The current hierarchical models of running are critiqued because they do not show gravity, a constant force, in affect during stance. A new gravitational model of running is developed, which shows gravity as the motive force. Gravity is shown to cause a torque as the runner's centre of mass moves forward of the support foot. Ground reaction force is not a motive force but operates according to Newton's third law; therefore, the ground can only propel a runner forward in combination with muscle activity. However, leg and hip extensor muscles have consistently proven to be silent during leg extension (mid-terminal stance). Instead, high muscle–tendon forces at terminal stance suggest elastic recoil regains most of the centre of mass's height. Therefore, the only external motive force from mid-terminal stance is gravity via a gravitational torque, which causes a horizontal displacement. The aim of this paper is to establish a definitive biomechanical technique (Pose<sup>®</sup> method) that is easily taught to runners (Romanov, 2002): falling forwards via a gravitational torque while pulling the support foot rapidly from the ground using the hamstring muscles.

**Keywords:** *Biomechanics, gravity, hierarchical model, Pose<sup>®</sup> method, running, technique*

### Introduction

Running has interested people throughout history from a theoretical and practical standpoint. Many previous observations and measurements were attempts to develop or understand a clear biomechanical model of efficient running. For example, Leonardo Da Vinci (1452–1519) wrote the following about motion, balance, and foot contact:

Motion is created by the destruction of balance, that is, of equality of weight, for nothing can move by itself which does not leave its state of balance, and that thing moves most rapidly which is furthest from its balance. (McMahon, 1956, pp. 133–134)

Graham Brown (1912, p. 875) wrote the following about the gait cycle:

The cycle of progression may be supposed to commence at a point at which one of the limbs is perpendicular to the ground. The “initial velocity” then carries the body past this

point, and it then falls forwards along the circumference of a circle the radius of which is the limb in contact with the ground.

However, from a biomechanical perspective, running is simply the horizontal displacement of a runner's centre of mass, but scientists, coaches, and athletes have a disparity of views on this activity. Some scientists insist that "there is no commonly accepted running model which will suit everyone" (Nytro, 1987). Similarly, the common view of coaches and athletes is: "No, there is no correct running form, and you couldn't learn it. Form is God-given. If you systematise it, you destroy it" (Wallack, 2004).

Certain known forces exist in running: external forces include gravity (Fenn, 1930; Graham-Brown, 1912) and ground reaction force (Cavanagh and LaFortune, 1980). Internal forces include muscle force (Heise, Morgan, Hough, and Craib, 1996) and the force due to muscle elasticity (Cavagna, Saibene, and Margaria, 1964). Air resistance is neglected in line with most other gait research (Anderson, 1996). These forces only increase horizontal acceleration of the centre of mass during stance but not flight. The horizontal displacement of the centre of mass during flight is, therefore, a consequence of the action of these forces throughout stance. The hierarchical order of these forces involved in running and their relationship to each other are currently unclear.

Several attempts to model running hierarchically (Hay and Reid, 1988; McGinnis, 2005; Paradisis and Cooke, 2001) lack a clear integration of the forces involved in running. For example, in their models, gravity is neither effective during stance nor does it relate to forces exerted, and time forces act despite gravity being a constant force.

In this paper, we hope to establish theoretically that gravity is the motive force in running using current running research. A brief review of the current models is given highlighting incorrect assumptions on the motive force in running by reviewing all the internal and external forces. A new gravitational model is then developed to represent gravity as the motive force. The new model is based upon a theoretical method of running called Pose<sup>®</sup> running (Romanov, 2002). The Pose<sup>®</sup> method is explained and practical application of the method is given.

### **Internal force: Muscle activity**

Coordinated muscle activity plays a significant role in running (Elliott and Blanksby, 1979). Beginning with muscle activation before impact, there are accelerations of body segments from muscle contractions via the swing leg (Montgomery, Pink, and Perry, 1994). Lowering body weight from impact until maximum vertical ground reaction force requires the muscle system to support the runner at the knee and hip as the quadriceps and hamstring muscle groups co-contract during early support and knee flexion (Elliott and Blanksby, 1979; Heise et al., 1996; Mann, Moran, and Dougherty, 1986; Montgomery et al., 1994). These muscles, therefore, resist the work of gravity, as the body lowers from impact to mid-stance (maximum vertical ground reaction force and maximum knee flexion). Maximum quadriceps muscle activity occurs at the transition between knee flexion and extension coinciding with maximum vertical ground reaction force (Brandell, 1973; Nilsson and Thorstensson, 1985). After this, hip and knee extensor muscle activity begins to decrease and ends just as leg extension begins (Brandell, 1973; Mann and Hagy, 1980; Montgomery et al., 1994; Nilsson and Thorstensson, 1985; Paré, Stern, and Schwartz, 1981; Schwab, Moynes, Jobe, and Perry, 1983; Wank, Frick, and Schmidtbleicher, 1998). Therefore, as the leg is rapidly extending during the propulsive phase, the leg and hip extensor muscles are silent; this has become known as the "extensor paradox"