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PHYSIOLOGY AND BIOMECHANICS OF LOCOMOTION

The field of research of our lab is the physiology and the biomechanics of terrestrial locomotion and analysis of movements in sports (particularly in gymnastics and in track and field). At first glance, there are many different modes of terrestrial locomotion: some vertebrates move on Earth on two legs while others use four: They walk, amble, trot, pace, canter, gallop, hop, etc. Intrinsic factors (morphology, development, pathologies...) or extrinsic factors (slope or softness of the terrain, carrying a load, obstacles, gravity ...) may modify the pattern of locomotion (stride length, step frequency, muscular activity, ...). The aim of our research is to understand how the human system adapts to these particular situations.

THE EFFECT OF GRAVITY ON THE MUSCULAR CONTROL OF LANDING FROM A JUMP

C. Gambelli (Supervision: B. Schepps and P.A. Willems)

The aim of this study is to understand how gravity affects the mechanisms of jumping. When a subject jumps on Earth, the lower limb muscles are activated before landing, allowing for a smooth touchdown. The sensory inputs from the proprioceptive, otolithic and visual systems provide critical information to estimate the duration of the aerial phase (and thus the timing of muscular pre-activation) and the magnitude of the impact (and thus the amplitude of the muscular activity). Controversy still exists about the role of each of these sensory input systems in the modulation of pre-landing muscle activation. The general purpose of this study is to assess the relative contribution of the sensory inputs, by measuring the ground reaction forces, the limb movements and the electrical activity of the lower limb muscles during a squat jump. The role of these sensory input systems in the muscular pre-programming of the landing phase is studied by modifying the gravity field in which the jump is performed (using parabolic flights with different gravity levels), and by adding a pull-down force (using a subject loading system).

The subject is asked to perform a squat jump. The following variables are recorded: -1- the ground reaction force during the push and the reception (by means of a 3-D force plate), -2- the amplitude and direction of the pull-down force (by means of force and displacement transducers), -3- the movements of the limb segments (by means of a digital camera) and -4- the lower limb muscles activity (by means of surface electromyography).

Left: Fig.1. Subject jumping (squat jump) in micro-gravity during the 55th ESA campaign flight.
Right: Fig. 2. Subject landing after the opening of the trap door mechanism during the 59th ESA campaign flight. Subject Loading System incl. harness, EMG surface electrodes and several markers can be seen.
BIOMECHANICAL AND PHYSIOLOGICAL ASPECTS OF JUMPING OVER AN OBSTACLE WHILE RUNNING IN HUMAN

G. Mauroy (Supervision: B. Schepens and P.A. Willems)

When leaping a barrier, the runner increases the vertical velocity of its centre of mass (COM) at take off to augment the amplitude and duration of the aerial phase over the obstacle. The purpose of the project is to determine whether and how the bouncing mechanism of running and the stiffness of the lower-limb muscles are adjusted, while running to and jumping over an obstacle.

In the first part of the study, the modification of the bouncing mechanism of running are analysed during the running steps preceding the jump over a barrier. The approaching speed varies between 9 and 21 km h\(^{-1}\). The forces exerted by the feet on the ground are measured by a 13 m-long force platform. The movements of the COM are evaluated by time-integration of the forces and the overall stiffness of the bouncing system by computer simulation. The running mechanism is modified during the two steps preceding the hurdle. During the contact period before last, the overall leg-spring stiffness decreases; consequently, the COM is lowered and accelerated forwards. Then during the contact period preceding the obstacle, the overall leg-spring stiffness increases and the COM is raised and accelerated upwards, whereas its forward velocity is reduced. During this phase, the leg-spring acts like a pole, which stores elastic energy and changes the direction of the velocity vector to release this energy in a vertical direction. This mechanism allows saving mechanical energy during the step preceding the jump.

In a second part of the study, the muscular power and the stiffness generated separately at each lower-limb joint are measured. The leg-spring’s stiffness and the net muscular moment and power, generated at each joint are calculated from the force exerted on the ground and the movements of the lower limb segments. The effect of the barrier height and the approaching speed is studied.

In a third part of this study, we analyse how trained hurdle athletes modify the strategy described in normal subjects. Two questions arise from the results on the normal subjects. First, do athletes optimize the trajectory of the COM to reduce its vertical excursion and limit the loss in the speed of progression? Second, are trained athletes able to maintain the magnitude of the velocity vector during the last contact before the jump?

THE EFFECT OF A PERTURBATION WHEN RUNNING AND ITS MOTOR CONTROL

M. Schijfier
(Supervision: B. Schepens and D. De Jaeger)

The goal of this project is to investigate the adaptations made by the running subject after a dorsiflexion of unexpected timing.

Running is one of the most popular recreational activities. In the real world runners must negotiate various perturbations and little is known about the way they do it. In our protocol, the subject is asked to run on a treadmill at a speed of 2.8 m.s\(^{-1}\) while wearing regular running shoes and equipped with a powered exoskeleton on his right leg. This exoskeleton allows only dorsi-plantar movements and is designed to deliver a defined perturbation to the right ankle joint while the subject is running on the treadmill. The perturbation is evoked at different phases of the running cycle to test whether the adjustments are modulated as a function of the perturbation timing.

To investigate the adjustments made by the subject to maintain his stability, the angular position of the ankle, the ground reaction forces and the muscular activity of lower limb muscles are measured.
THE DOUBLE CONTACT PHASE IN WALKING

G. Meurisse (Supervision: G. Bastien & B. Schepens)

The aim of this study is to understand how the double contact influences walking. Human walking is characterized by the occurrence of a double contact phase (DC), when both feet are on the ground, separating periods of single contact when a lower limb is swung forward. The DC is the step-to-step transition with the transfer of body weight from the rear foot to the front foot.

The quantification of the components of ground reaction force under each foot is necessary to study the mechanics of the double contact when walking, especially the muscular mechanical work done by one foot against the other. However, it requires either sophisticated apparatus such as a split-belt treadmill or to place each foot on separate plates when using fixed force platform. Moreover, the subject walks unnaturally with these devices.

In the first part of the study, a method for detecting the limits of the double contact and calculating the 3-D forces under each foot from simple equipment such as a force platform (a measure of the sum of forces) will be developed. This method may have a general utility in gait laboratory. In the second part of the study, we will examine various parameters of double contact, such as mechanical work and the stability of the walking pattern, in healthy adults and subsequently in the elderly.

Fig. 6 and 7. Typical trace of the reconstruction of the vertical GRFs.

Top : Vertical ground reaction forces (GRFs) as a function of time. The bold continuous lines present the real GRFs measured under the front and back legs (respectively Frfront and Frback) when using two force platforms, whereas the dashed lines present the reconstructed GRFs. Note that the dashed line is sometimes hidden the continuous line. The thin continuous line presents the sum of front and back legs for the vertical GRF (Fvtotal). Bottom: Corresponding time evolution of the relative error calculated as:

\[ \text{Relative Error} = \frac{|\text{Reconstructed Force} - \text{Real Force}|}{\text{Real Force}} \times 100\% \]

In order to quantify the quality of the reconstruction, the reconstructed vertical GRFs is compared with the forces measured with individual force plates. An absolute mean difference of 1.76% (±0.77%, max=4.72%, n=374, walking speeds from 0,83 to 1,94 m s⁻¹) is observed.

EQUIPMENT

- A force platform made of 16 plates (size of each plate: 1m x 1m) measures the ground reaction forces in the three directions of the space. It has a resolution of 3 N and a full scale of 50.000 N.
- A force platform made of 10 plates (total length: 6 m) measures the vertical and forward components of the ground reaction force during several continuous walking or running steps.
- A piezo-electric force platform (KISTLER®) measures the ground reaction forces in the three directions of the space.
- A motion analysis system with two color digital cameras (Basler®) measures the movements of the body segments at a maximal frequency of 210 frames/s.
- A motion analysis system with one B-W digital camera (Basler®) records the movements of the body segments at a maximal frequency of 100 frames/s.
- An electromyographic system (FreeEMG, BTS®) records the electrical activity of up to 16 muscles.
- An electromyographic system (Myosystem, Noraxon®) records the electrical activity of up to 8 muscles.

SELECTED PUBLICATIONS


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