Using ADAMS/VIEW and IDL for optimisation of long jumping techniques

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Abstract

The jumpers objective in the long jump is to obtain a maximum jumping distance with given geometrical and physiological constrains. Therefore the running speed and the preparing of the touch down are very important for a maximum jumping distance. Elite jumpers can achieve good results by different ways of preparing the jump and with different antropometric conditions (Fukashiro 1993). At present the influence of various parameter is estimated by statistical methods but required a large number of trails (Hay 1993, Lees 1994). Furthermore the athlete has a number of system parameters like stiffness, swing mass, damping properties of the foot and the leg lengthening which can not be described very well by statistical analysis.

The goal of the present study is a) to find out correlation between kinematic and dynamic parameters of the long jump by using a simple spring mass model (Blickhan 1989) b) to predict the jumping distance with a dynamic model based on algorithms from ADAMS/VIEW and IDL. c) to describe the trajectory of the centre of gravity and the ground reaction force. The proposed model should support athletes to improve her performance during the training and to help the jumper and the coach for a better understanding his jumping techniques.

Introduction

The long jump is a classical track and field event which consists of two primary parts the approach phase and the jump phase. The major task at the approach phase is to achieve a maximum running speed and a good preparation of the last ground contact. In the jumping phase the jumper uses the geometrical and physiological properties of his leg to achieve a maximum distance. The last ground contact is characterised by a specific ground reaction force pattern with an early passive peak, a second active peak and a asymmetric trajectory of the c.g.. The purpose of the present paper is to show the development of a series of models from very simple models to more complex multi-body-systems with ADAMS/VIEW and IDL. Our research should contribute to the understanding of the dynamic and kinematic properties of a jumpers leg.

Measurement Methods

30 long jumps were filmed during two competitions in Jena (1994 and 1995). The jumps were recorded with a VHS video system (50 Frames per second) for a later kinematic analysis. The vertical and horizontal ground reaction force were measured with a 3D force plate (IAT Leipzig) at sampling rate of 1KHz. The video was digitised with a 12 segment human model (APAS, Ariel) and the position, velocity and c.g. were computed according to the Hannavan-model. We use a dynamic model for the prediction of the jumping distances. The model was described by ADAMS/View and IDL (Creaso).

Simple Spring mass model

Running and jumping consists of a series from arial and ground contact phases. A simple spring mass model can roughly describe the kinematics and dynamic of a long jump (Blickhan et al. 1993). Our simplest ADAMS/View model is based on this spring mass model (Blickhan 1989) for running and jumping. A point mass is coupled via a massless spring to the ground. The kinematic input parameters of the system are the vertical and horizontal velocity, the initial leg length, the angle of attack and the mass of the athlete. The only dynamic input parameter is the stiffness of the contacting leg. Stiffness of the leg is defined as the ratio of the force at the maximal knee flexion (active force peak) to the maximal deflection of the leg. The initial length of the contacting leg is equal to the unloaded spring length at the beginning of the last ground contact. Due to the properties and the lack of distal masses the model can only describe the active part of the vertical and horizontal ground reaction force with a sinusoidal function.

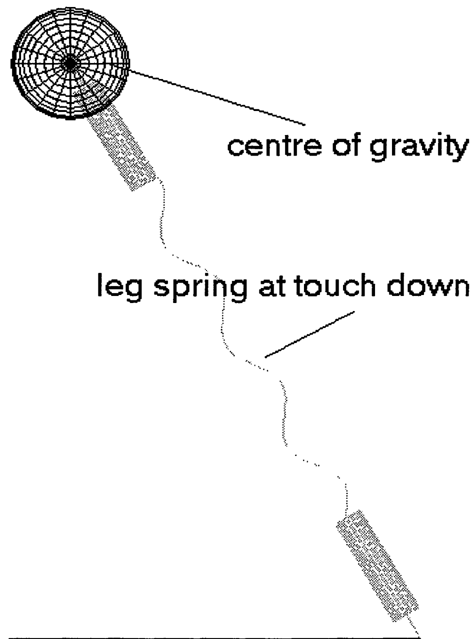

Fig1. Simple spring mass model at touch down.

Spring mass model with leg lengthening

In a real long jump the stance leg is slightly flexed at the instant of touch down and is straightened over the foot at the instant of take-off. A linear spring does not describe this asymmetric process. Therefore a simple spring mass model (model 1) leads to a higher stiffness and to a shorter ground contact time. Considering the increase of leg lengthening during the ground contact a specific spring is needed. So the unloaded spring length is allowed to increase during the angle of rotation and is equal to the leg length at the end of take-off. The initial conditions are the same as in model 1. Because of the properties and the lack of distal masses the model can only describe the active peak (like model 1) of the vertical and horizontal ground reaction force.

Spring mass model with a second swing mass

The first vertical peak in the long jump plays an important role for preparation of the take-off and the vertical component of the velocity at the end of the contact phase. For accurate describtion of the force time histories it is necessary to extend the simple spring mass model by a second mass (Seyfarth, 1995). Therefore the body mass is coupled via a massless spring to the ground and attached to a rigid rod. This rod represents the skeletal system of the lower limb. The body mass is able to slide along the stick via a translational joint. A second swing mass is fixed more distal to the "virtual skeletal system“ via a non-linear planar spring-dash-pot element. This mass represents the compliantly coupled masses of the leg (muscles, fat, tissue) and is about 20 - 25% of the total body mass. With this distal mass the model is able to describe the active and the passive peak of the vertical and horizontal ground reaction force. The supplementary initial conditions are the initial position and velocity of the second mass. This individual parameters of the extended spring mass system were estimated by fitting the modelled forces to the measured data.

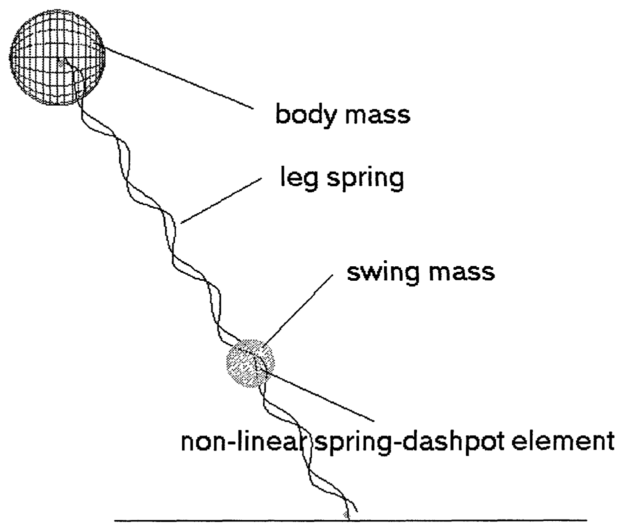

Fig. 2 Extended spring mass model with body mass and swing mass at touch down.

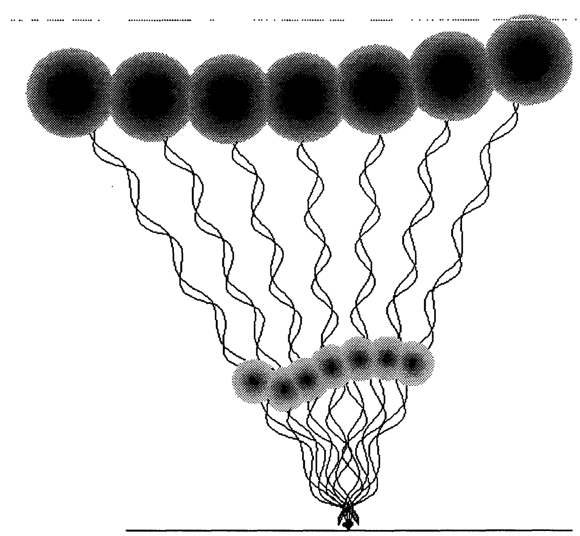

Fig. 3 Contact phase in long jump with the extended spring mass system.

Design studies

With the various possibilities at the ADAMS/VIEW simulation tool it is easy to show relations between kinematic and dynamic parameters through the design studies.

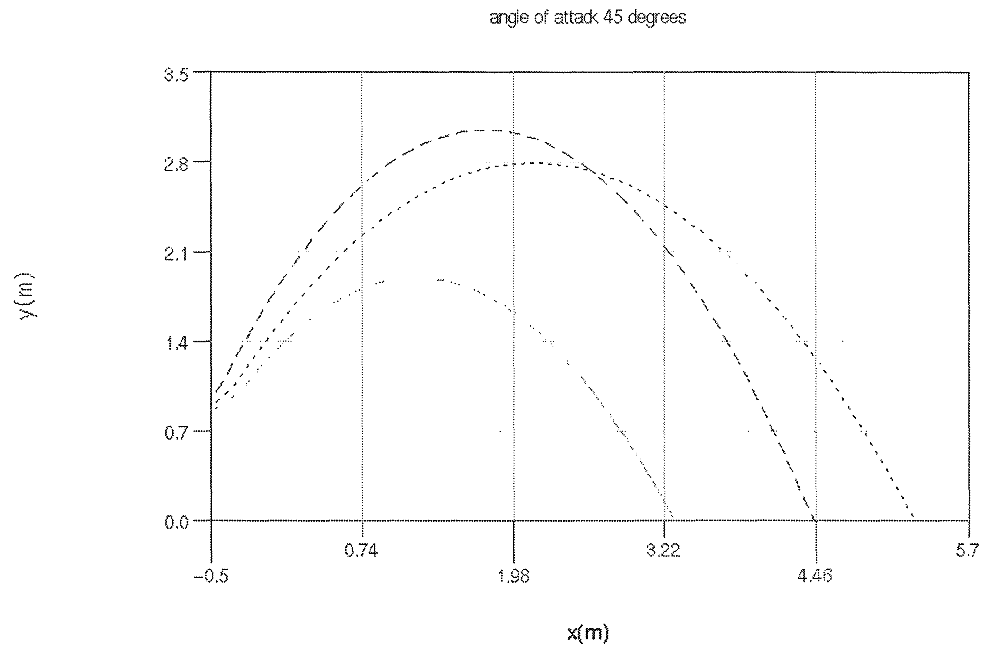

Fig. 4 Influence of leg stiffness on jumping distance, solid line 11 kN/m, dot line 22 kN/m, dot dash line 68 kN/m.

Results

As a first approach the take off phase in the long jump is described by a simple spring mass system. This reveals basic interdependencies between kinematic and dynamic parameters. In contrast to the experimental data the force time histories calculated from the model have no first peak. The implementation of a leg lengthening function in the model similar to the action of a human leg during ground contact leads to a more realistic prediction of the ground contact time and to lower leg stiffnesses. With the introduction of the swing mass the model is capable to describe the whole ground reaction force and the correct path of the c.g.. Our simple model without muscle properties is able to predict jumping distances for real jumps. Differences between the measured and calculated data are among 10 % SD. Furthermore the model development proves that we need a distal swing mass with approximately 20 - 25% of the whole body mass for the generation of the first passive peak and that it is necessary to couple this mass by a critical damped spring-dashpot element with the skeleton. The experimentally estimated stiffnesses are between 11 -26 kN/m. By using a smaller angle of attack with a more compliant leg it is possible to achieve the same distances with a stiffer leg at a steeper angle of attack (fig. 4).

Discussion

Dynamic and kinematic simulations can be a great advantage in the understanding of biomechanical systems. With the pre-set elements in ADAMS/VIEW it is very simple to build up a model which represents the complexity of the take-off phase with a model. A single ADAMS model can be used to analyse various combinations of parameters at different levels of complexity. According to the section three (design studies) it can be stated that the model shows good agreements with the experimental data. For the simulation of impacts the ADAMS/ANDROID is to be extend by non-linearly coupled swing masses otherwise the model generates to high joint torques and ground reaction forces. The proposed model should support coaches and athletes to get detailed information's about the last ground contact in the long jump and to understand the mechanism of the relation between kinematic and dynamic parameters.

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