13ème Congrès International de l'ACAPS

Approche Pluridisciplinaire de la Motricité Humaine

Editeurs scientifiques :

- Christian Collet
- Emma Guillet
- Florent Lebon
- Jean Saint-Martin
- Isabelle Rogowski

ACAPS

CRIS

UCB Lyon 1

UNIVERSITÉ DE LYON

Lyon, 28 au 30 Octobre 2009

Sommaire

Informations concernant la proposition de communication

(1) Titre de la communication : **Model of joint angle displacement: application to vertical jumping**

(2) Nom des auteurs : **Thomas Creveaux, Jérôme Bastien & Pierre Legreneur**

(3) Affiliation des auteurs : **Centre de Recherche et d'Innovation sur le Sport, EA 647 Université de Lyon, Université Claude Bernard, Lyon 1.**

(4) Adresse et coordonnées complètes du premier auteur : **Université de Lyon – Université Claude Bernard Centre de Recherches et d'Innovation sur le Sport – Bâtiment Raphaël Dubois. 8, Rue Raphaël Dubois. 69 622 Villeurbanne Cedex. France.**

Tel. : +33 (0)472 432 837 - Fax : +33 (0)472 438 010. Mèl : thomas.creveaux@gmail.com

(5) Forme de communication souhaitée : **Oral**

(6) Participation au prix Jeune Chercheur : **Oui**

(7) Thème de recherche : **Biomécanique**

(8) Mots clés : **vertical jumping, modeling, optimization, joint displacement, sigmoid, kinematics**

Model of joint angle displacement: application to vertical jumping

Thomas Creveaux, Jérôme Bastien & Pierre Legreneur
Centre de Recherche et d'Innovation sur le Sport, Université de Lyon – Lyon 1.
thomas.creveaux@gmail.com

Despite many authors suggest that movement control may be kinematic based, there is actually no such model able to reproduce the features of open-loop dynamic movements. This research focused on both the development of a mathematical model of joints angles displacements and the confrontation of this model to experimental data obtained in vertical jumping. Through an optimization procedure, the parameters of the model were set to fit experimental data using sigmoid function. Differences between modeled and experimental CoM positions were greater on the vertical than horizontal axis (p<0.001). Proximal joints angles displacements were best reproduced. The results could be explained by the distribution of the limbs masses and the necessity to fit closely the experimental take-off conditions. This research showed that a kinematic based model using a small set of kinematic parameters was able to reproduce the experimental vertical jumping.
Keywords: vertical jumping, modeling, optimization, joint displacement, sigmoid, kinematics

INTRODUCTION

The displacement of a human body in the gravity field has to take into account two constraints (Ingen Schenau, 1989). The anatomical one implies zero angular velocities when maximal amplitudes are reached whereas the geometrical one represents the conversion of the rotational kinetic energy of joints into translational kinetic energy of the Centre of Mass (CoM). Although there are evidences that these constraints are taken into account in movement planning, the question concerning the controlled parameters by the central nervous system remains open.

Results of dynamical movements' simulation using muscles activations optimization procedure are consistent with experimental data and provided original results (Bobbert & van Soest, 1994). However, many studies suggest that the movement may be controlled through kinematic parameters (Wolpert et al., 1995, Moran & Schwartz, 1999). To date, there is no kinematic based model able to reproduce the dynamical movement features. Thus, the aim of this study was to develop and validate a kinematic based model of the vertical jump.

METHODS

The skeletal model was defined as a 4 rigid bodies system, *i.e.* the foot, the shank, the thigh and the Head-Arms-Trunk system (HAT). The time history of each joint angle during the movement was defined as a sigmoid: $\forall t \le t_i,\ \theta(t) = \theta_i$; $\forall t \ge t_f,\ \theta(t) = \theta_f$;

$$\forall t \in \left]t_i, t_f\right[,\ \theta(t) = \theta_i + \left(\theta_f - \theta_i\right)\sigma(\tilde{t}) \text{ where } \tilde{t} = \frac{t-t_i}{t_f-t_i}$$

$$\forall \tilde{t} \in]0,1[,\ \sigma(\tilde{t}) = \phi[G(\tilde{t})] = \frac{1}{2}\operatorname{erf}\left(\frac{G(\tilde{t})-\mu}{\sqrt{2}s}\right) + \frac{1}{2},\ G(\tilde{t}) = \ln\left(\frac{\tilde{t}_p}{1-\tilde{t}_p}\right) \text{ and } a = G^{-1}(\mu)$$

The scale parameters θ_i, θ_f, t_i, t_f, are respectively the initial and final positions of the joints angles and the instants defining the beginning and end of the displacement. a, p and s define the shape of the joint angle time history from t_i, to t_f. This model holds the following properties: $(t_i) = \theta_i$; $\theta(t_f) = \theta_f$; $\dot{\theta}(t_i) = \dot{\theta}(t_f) = \ddot{\theta}(t_i) = \ddot{\theta}(t_f) = 0$ so that the dynamic parameters, *i.e.* velocity and acceleration, are continuous and the anatomical constraint is satisfied. Furthermore, $\sigma(\tilde{t})$is non-decreasing on [0,1] and holds an unique velocity peak K at $t=t_0$. At last, acceleration is successively positive and negative before and after the velocity peak.

The segmental angle of the foot and the joints angles of the ankle, knee and hip were modeled using $\theta(t)$ functions. Take-off was defined as the first instant where the CoM vertical acceleration reaches -9.81 m.s^{-2}. Using a least square minimization procedure, the parameters of the model were set to fit best experimental kinematics of 33 vertical jumps. Optimization was performed on CoM and joints linear positions from the beginning of the impulse to the instant where the CoM reaches its highest position. The consistence of modeled and experimental data was then quantified.

RESULTS

The maximal differences observed between the CoM coordinates of both experimental and modeled data were greater on the horizontal axis (0.9 cm) than the vertical one (0,3 cm, $p<0.001$). Concerning joints angles, maximal differences measured from t_i to t_f for the ankle (6.9°) were higher ($p<0.001$) than the values obtained at the knee (3.4°) and hip (2.7°) (Fig.1).

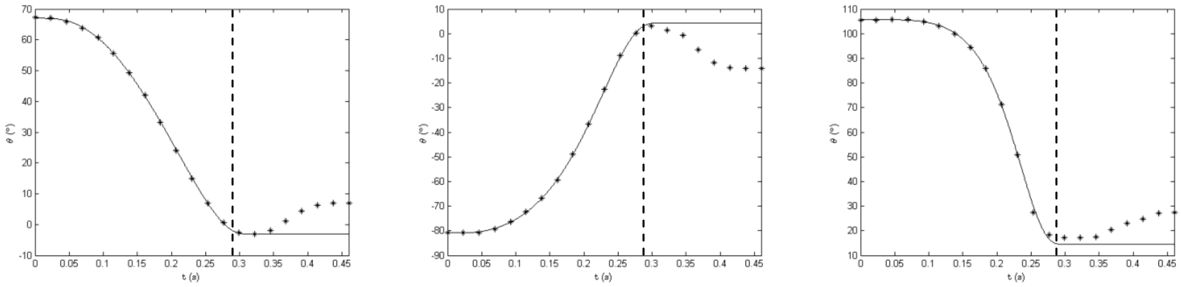

Figure 1. Left to right : experimental (stars) and theoretical (lines) time histories of hip, knee and ankle joints' displacement. The vertical dashed line indicates the take-off instant.

DISCUSSION

The results of the model were consistent with the experimental data during the impulse. After take-off, hip and knee presented oscillatory phases before attaining the top of the CoM flight. The model was not able to reproduce these variations, because of the nature of the equation of the joints' time history. However, these variations do not affect the trajectory of the CoM as it's completely defined at take-off instant by the characteristics of its velocity vector and its position.

In conclusion, this theoretical study showed that dynamic multi-joints movements could be successfully reproduced with a kinematic based model defined by a small set of parameters. Moreover, the general model of joint's displacement presented in this paper should be used successfully to fit experimental data of animal displacement.

On the hand, this study allowed to consider the joint's displacement model as valid for further kinematic based model simulation of dynamic movement like vertical jumping in humans.

REFERENCES

Bobbert, M. F. & van Soest, A. J. (1994). Effects of muscle strengthening on vertical jump height: a simulation study. *Medicine and Science in Sports and Exercice, 26(8)*:1012-1020.

Ingen Schenau van, G. J. (1989). From rotation to translation: constraints on multi-joint movements and the unique action of bi-articular muscles. *Human Movement Science 8*, 301-337.

Moran, D. W. & Schwartz, A. B. (1999). Motor cortical representation of speed and direction during reaching. *Journal of* Neurophysiology, *82(5)*:2676–2692.

Wolpert, D. M., Ghahramani, Z. & Jordan, M. I. (1995). Are arm trajectories planned in kinematic or dynamic coordinates? an adaptation study. *Experimental Brain Research*, *103(3)*:460–470