

MODELING THE GYMNAST-MAT INTERACTION DURING VAULT LANDINGS

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INTRODUCTION

Landings are an essential element in gymnastics and are a time when injuries may occur. Most injuries to gymnasts affect the lower extremity [1]. The landing surface and the landing control strategy adopted by the gymnast contribute to the dissipation of forces at landing.

The aim was to design a model of the landing surface and gymnast's body in order to obtain reasonable estimates of the landing forces experienced by the gymnast. Modeling the gymnast-mat interaction may help to reduce the forces experienced by the gymnast at landing and improve performance.

METHODS

A subject-specific 6 link wobbling mass model of a gymnast was developed using Visual Nastran4D. Torque-angle-angular velocity functions for the model's joint torque generators were derived from isokinetic dynamometer measurements of the gymnast. A landing mat model based on independent mat testing [2] was also developed in Visual Nastran 4D. These two model were used to simulate the gymnast landing.

Landings from four vaults were recorded: a backward somersault, a forward somersault, a handspring vault and a tsukahara vault. Sixteen Vicon cameras (250Hz), a Phantom (v5) high-speed camera (1000Hz), a Kistler force plate (1000Hz) and a Biovision surface EMG system (250Hz) were used to collect data.

Simulation inputs for model evaluation were the body orientation, centre of mass velocity, joint angles and angular velocities of the gymnast during landing. Torque activation histories were optimized using a Simplex algorithm to minimize the difference between simulated and experimental ground reaction forces, joint angle and body orientation time histories.

RESULTS AND DISCUSSION

The landing mat model matched the experimental material tests to within 1.4 % of the peak force and had an RMS difference of 1014.2 N. The majority of the RMS error arose from the latter half of the simulation. In the experiment the mat could lift from the force plate during the rebound phase

Table 1: Evaluation of the mat-gymnast model against the actual performance.

Gymnastic Skill	RMS (all joints)	RMS (body orientation)	RMS (Vert GRF)	RMS (Hor GRF)	Peak (VGRF)
Front Somersault	8 %	4 %	21 %	15 %	3 %
Back Somersault	15 %	1 %	15 %	36 %	23 %
Handspring	11 %	1 %	25 %	31 %	33 %
Tsukahara	35 %	8 %	20 %	21 %	2 %

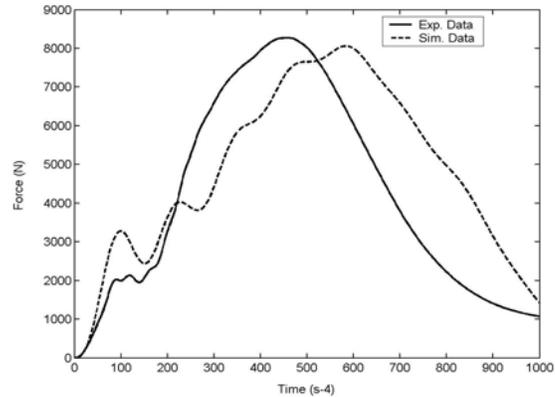


Figure 1: A comparison of the vertical ground reaction forces for the gymnast-mat model and equivalent experimental data during the landing of a front somersault.

which could not occur in the simulation. The simulation of the gymnast only included a small part of the rebound phase.

The model of the gymnast and mat matched the actual performances with overall scores between 12 % and 21 %. The best match was obtained for the forward somersault skill (Table 1). This produced a difference between simulated and actual vertical peak force of 3 % with an RMS of 21 % (Figure 1). The computational run time limited the number of simulations and the complexity of the optimization routine. Manual variations in activation time histories produced better ground reaction force fits but slightly worse scores overall.

CONCLUSIONS

The gymnast-mat model was able to reproduce the key elements of the landing dynamics. Optimization of the mat parameters and / or the torque activation patterns may provide an insight into equipment modifications or landing strategy changes that may reduce injuries in gymnastics.

REFERENCES

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