INERTIA TENSOR DURING HIGH BAR GIANT SWINGS

[1] Philipp Huber, [1]Claus Cagran and [1]Wolfram Müller

[1]Human Performance Research Graz, Max-Mell-Allee 11, 8010 Graz, Austria;

email: philipp.huber@uni-graz.at, web: hpr.uni-graz.at

INTRODUCTION

Giant swing exercises in artistic gymnastics have been extensively studied in the past using motion tracking techniques as well as simulation approaches [1,2].

In this work the whole-body inertia tensor during different giant swing exercises measured with a Vicon motion capture system is presented.

METHODS

An elite athlete (m = 65.4 kg; h = 1.70 m) performed a series of giant swings (GS) and giant swings before dismounting (GSD). Anthropometric measurements according to [3] were performed for determination of segmental properties.

A Vicon V612 motion capturing system (with 8 M2 near-infrared cameras) at 100 Hz was used to acquire 3D marker coordinates.

The athlete was equipped with 38 retro-reflective markers positioned according to the Cleveland clinical marker set with modifications to avoid interference with the athlete's movement. In addition 6 markers were attached to the bar in order to utilize it as a dynamometer [4].

A global optimization (GO) approach [5] was used to find generalized variables of a functional model with 36 degrees of freedom adjusted to the athlete's body.

Combining the GO approach with subject specific mass and inertia properties we are able to determine the athlete's center of mass (CM) and whole-body inertia tensor during the exercise.

RESULTS AND DISCUSSION

In Figure 1 measured trajectories of the attached body markers are plotted. Additionally, the computed CM trajectory and reconstructed postures at φ = 0°, 90°, 180° and 270° are displayed, where φ is the angle defined by z-axis and the vector from the bar center to the CM.

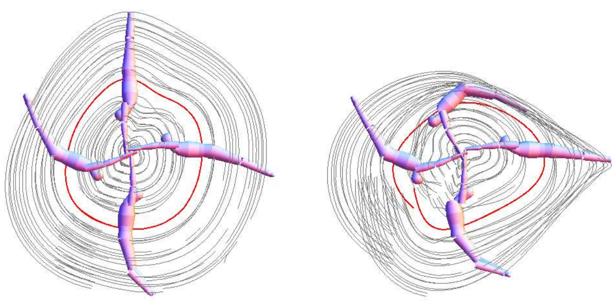

Figure 1: Measured marker trajectories (gray), the center of mass trajectory (red) and the body posture at φ = 0°, 90°, 180° and 270° during backward GS (left) and GSD (right); movement in clockwise direction.

In Figure 2 we present the projection of the inertia tensor to the axis of rotation (bar axis without load) computed for the subject's center of mass (I_{CM}) for a GS and a GSD. I_{CM} values range from 12.2 kg·m^2 at φ = 259° to 13.8 kg·m^2 at φ = 136° for the GS (13% increase) and from 9.9 kg·m^2 at φ = 354° to 13.8 kg·m^2 at φ = 92° for the GSD (increase of 39%); a local maximum of 13.7 kg·m^2 at φ = 197° is observed for the latter. It is interesting to note that the peak forces on the bar (displayed in [4]) occur roughly 60-70 ms after the peaks in the total moment of inertia.

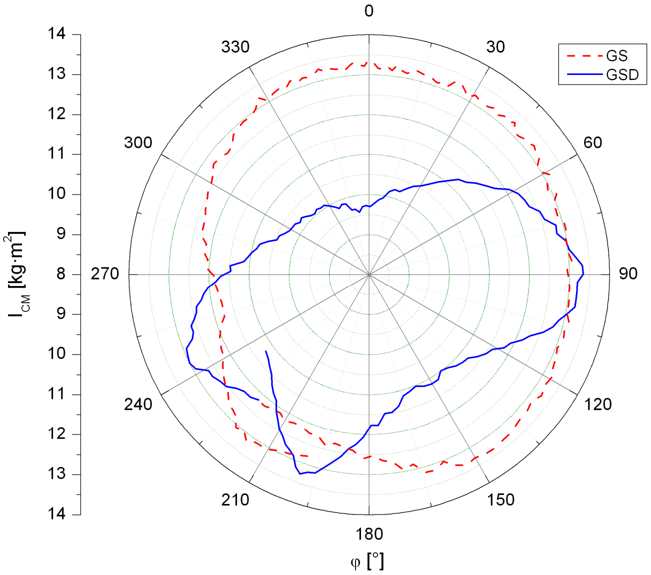

Figure 2: I_{CM} during backward GS (dashed line) and GSD (solid line); movement in clockwise direction.

The knowledge of the inertia tensor allows the computation of moments of inertia projected on arbitrary axes of rotation. As an example the moment of inertia with respect to the axis of rotation during a GSD changes from 41.1 kg·m^2 (φ = 0°) to 98.5 kg·m^2 (φ = 90°) yielding an increase of 140% within 300 ms.

CONCLUSIONS

The presented approach allows us to address inertia tensors, angular momenta, and rotation energies for both, body segments and the whole body. Kinetic and elastic energies are accessible through forces obtained from marker displacements on the calibrated bar.

Consequently we are able to study all relevant contribution to the total energy of giant swings as well as other elements of high bar performances or other disciplines with similar requirements (parallel or uneven bars, tightrope, slackline).

REFERENCES

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